NatureCheck:

Understanding Wildlife Health

on East Bay Lands in

Alameda and Contra Costa Counties

APRIL 2022

The first ecological health assessment of its kind for the East Bay region, this NatureCheck report is a science-based, landscape-scale assessment of the ecological health of native wildlife within East Bay Stewardship Network partner agency lands, which are located primarily in Alameda and Contra Costa Counties.

East Bay Stewardship Network

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When citing an individual chapter, please include the chapter author(s) and the chapter name, followed by the citation for the full report.

East Bay Stewardship Network Partner Agencies: California State Parks, Contra Costa Water District, East Bay Municipal Utility District, East Bay Regional Park District, and San Francisco Public Utilities Commission. Please contact the East Bay Regional Park District, Stewardship Department, at stewardship@ebparks.org for more information.

Cover art by Ink Dwell

ACKNOWLEDGEMENTS

We acknowledge that the East Bay Stewardship Network lands in Alameda and Contra Costa Counites are the ancestral homeland of the Ohlone, Bay Miwok, and Delta Yoku. The ancestors of this diverse and resilient group of people prospered in the places we now know as the Bay Area, where they used land management methods such as coppicing, weeding, selective harvesting, and perhaps most importantly, landscape burning. These practices purposefully shaped the region's flora and fauna. Today, Ohlone, Bay Miwok, and Delta Yokut people are thriving members of the greater Bay Area community, who advocate for environmental protection, restore Native land management practices, and work to preserve and protect their heritage.

The East Bay Stewardship Network would like to thank the leadership and staff of its five agency partners for their ongoing project support. Each contributed extensive time and expertise to review and assemble data, identify ecological health indicators and metrics, conduct analyses for each indicator, and develop this final report.

We also acknowledge the crucial role provided by each NatureCheck chapter lead author. Without their dedication, this ecological health assessment would not have been possible. Each chapter includes a complete list of authors and contributors. Appendix E lists those who participated in the East Bay ecological health assessment expert workshops (January 29–30, 2020), which helped establish the foundation for the chapters included here. These individuals also generously donated their time to peer-review a draft of this report.

Finally, we would like to acknowledge funding support provided by:

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EXECUTIVE SUMMARY

NatureCheck is a report on a landscape-scale ecological assessment of wildlife within East Bay Stewardship Network (Network) lands in Alameda and Contra Costa Counties, California (for the project's area of focus, see Figure 1.1 at the end of Chapter 1).

A science-based snapshot, this report looks at the condition and trend of select wildlife species deemed to be good indicators of the region's ecological health and for which we either have or are in the process of collecting data. As the first such ecological health assessment for the East Bay region, the project establishes a baseline against which we can use the quantitative metrics developed for each indicator to measure change over time. Understanding and tracking these changes will help us better manage these lands to support their ecological integrity and resiliency.

This report crosses jurisdictional boundaries and pools data from across the area of focus. This includes publicly owned Network partner lands managed by California State Parks (CSP), Contra Costa Water District (CCWD), East Bay Municipal Utility District (EBMUD), East Bay Regional Park District (EBRPD), and San Francisco Public Utilities Commission (SFPUC).

Together, these Network partner agencies oversee and care for more than 225,000 acres, or almost 25% of the land in Alameda and Contra Costa Counties. Their parks, open spaces, conservation areas, and reservoirs are home to the watersheds that provide clean drinking water, habitats that preserve the biodiversity and ecosystem functions the world depends upon, and expansive outdoor spaces for public enjoyment.

The extent and importance of the undeveloped, protected lands we manage are significant. When considered together, they are crucial to the landscape connectivity essential for maintaining viable plant and animal populations. They buffer a wide range of species from the impacts of genetic, recreational, and environmental variability and provide migration routes that species can use as climate conditions change. They also offer refuges for California's rare plants and wildlife, something that has become more and more precious as the vast majority of open space that was once present here has been developed.

Collectively, it is the responsibility of Network partner agencies to determine how best to manage these remaining ecosystems, given current realities and the 7,000,000-strong Bay Area population, which is projected to grow even larger. Therefore, we intentionally chose to establish this ecological baseline on existing conditions inclusive of modern anthropogenic stressors rather than use historical conditions to which we cannot realistically expect to return.

WHAT WE HAVE LEARNED ABOUT OUR WILDLIFE'S ECOLOGICAL HEALTH

We identified and analyzed NatureCheck indicators for fishes, amphibians and reptiles, birds, and mammals. Data used in these surveys were primarily from existing sources (2009–2020). These data were pulled from a variety of efforts, including publicly available datasets such as iNaturalist and eBird; land-manager monitoring surveys, which often used disparate methods; and various research projects. This evaluation also identifies instances in which not enough is known to draw meaningful conclusions and opportunities for future research and collaboration between land managers.

Brief summaries of the indicator analyses follow.

Fishes

Native fishes and rainbow trout/steelhead (*Oncorhynchus mykiss*) were evaluated across four watersheds in the area of focus: Pinole Creek, Wildcat Creek, San Leandro Creek, and Alameda Creek. While non-native fish species are present in all four, they are primarily found in their lower reaches, due primarily to intrusions from human-made reservoirs. Alameda Creek retains the most diverse and productive native fish assemblage, likely because of its greater flow, multiple reaches, and relatively undisturbed upper watershed riparian habitat. Evidence from all four watersheds suggests that they support self-sustaining populations of rainbow trout/steelhead, a critical factor for their resiliency. Many salmonid populations are no longer able to move between the San Francisco Bay and these watersheds due to stream channelization, impoundments, diversions, and other in-channel barriers that have dramatically altered both hydrology and habitats. These conditions leave our isolated rainbow trout populations at a much greater risk of extirpation in the face of extensive drought. Ongoing efforts to restore the native ecosystem and provide connections to the bay will greatly improve the ecological health of our of salmonid-bearing streams.

Amphibians and Reptiles

NatureCheck looked at two indicator species, the federally listed California red-legged frog (*Rana draytonii*) and the California tiger salamander (*Ambystoma californiense*), and evaluated amphibian and reptile diversity for multiple species. Amphibians are experiencing an unprecedented global decline and are the most threatened class of vertebrates as a result of anthropogenic changes. It is heartening, then, to see some good news regarding local amphibian populations.

Using data collected between 2009 and 2019, we found that our amphibian indicator species are in good condition, and that the area of focus has good habitat for them. For example, a California red-legged frog study comparing coastal Bay Area populations to those in other parts of their range found that those in the Bay Area are genetically diverse and gene flow is high (Richmond et al. 2014). A recent paper (Moss et al. 2021) also showed that many of our native amphibian populations are resilient to drought and are able to recover to pre-drought occupancy levels during normal or above-average precipitation years. It appears that extreme drought helps reduce available habitat for invasive species such as the American bullfrog (*Lithobates catesbeianus*) and non-native fish. However, the data, which only went to 2019, did not reflect the effects of the extreme drought of 2020/2021. Future efforts to continue to support these species will include improved monitoring using a coordinated methodology across Network partner lands and continued pond restoration efforts to help increase drought resiliency.

Birds

Since 1970, North America has lost nearly three billion—or more than one in four—of its birds. This is due to a combination of factors, including climate change, invasive species, pesticide use, disease, altered fire regimes, noise, light and air pollution, human presence, and habitat degradation and fragmentation. Additionally, introduced squirrels, rats, and free-roaming cats can act as stressors through predation and usurpation of nest sites, especially where urban and suburban areas border the area of focus. Wind and solar energy production are also major sources of bird mortality. Nevertheless, an analysis conducted by Point Blue Conservation Science of 14 common riparian bird species in protected areas of Marin County showed that protected areas do effectively conserve populations of many bird species even in proximity to urbanization (Dettling et al. 2021).

One NatureCheck indicator focused on 28 bird species that were split into four guilds based upon habitat association (grassland, riparian, oak woodland, shrubland). Most bird species analyzed were present and abundant across the area of focus. Using 2010–2020 breeding-season data, the riparian, oak woodland, and shrubland birds showed a stable trend. However, grassland birds showed a declining trend, which is cause for significant concern.

The golden eagle (*Aquila chrysaetos*) is a fully protected species in California and was chosen as an indicator because it relies on multiple habitat types for foraging and nesting. The area of focus encompasses one of the densest golden eagle nesting populations in North America. Data show this species has maintained a consistent reproductive rate and territory occupancy, even with large-scale drought. However, data also suggest that this success is due to an increasing proportion of sub-adult birds entering the breeding population due to high adult mortality and therefore caution is warranted.

Mammals

Mammal habitat loss in the area of focus has been significant, primarily due to human encroachment and development. Other historical and ongoing factors, such as predator control, climate change, and pollution/contaminants, also affect mammals here. Existing data were used to look at a cross-section of species in different trophic levels as bellwethers of ecological health: the puma (*Puma concolor*), seven species of mesocarnivores, the dusky-footed woodrat (*Neotoma fuscipes*), the California ground squirrel (*Otospermophilus beecheyi*), and bats. While we have limited data on mammals, and therefore low confidence in our assessment, we believe the overall health of our mammal community is good.

However, we are cautious looking forward. Wide-ranging species with low population densities that are indicators of habitat quality and connectivity—such as the puma and the American badger (*Taxidea taxus*)—can be difficult to detect. In addition, this assessment lacks the key analyses of habitat connectivity and linkages essential to maintaining overall ecosystem stability and resiliency to habitat change. Finally, we have insufficient information to identify the trend for a historically widespread keystone species, the California ground squirrel.

DATA GAPS

While we believe NatureCheck provides a good baseline for understanding the ecological health of our wildlife indicators, we also acknowledge critical data gaps. For example, we did not directly assess the health of vegetation communities; this will take place as part of the fine-scale vegetation mapping effort that should be completed by 2024. We also did not assess invertebrates such as insects, which are very good health indicators thanks to their fast reproduction, diversity (generalists and extreme habitat specialists), and responsiveness to climatic change. We also need to improve our understanding of abiotic systems such as streams and wetlands. However, coming together as a Network to identify these critical missing pieces will allow us to focus our collective resources on priority areas. Indeed, we are already working to fill some of these data gaps, and will continue to develop other indicators and metrics as we work toward future updates of this report.

WHERE DO WE GO FROM HERE?

This health assessment was an essential first step in understanding how our wildlife resources are faring and to track changes in their health over time. Once we fill the more critical data gaps (e.g., by collecting and analyzing vegetation and invertebrate data), we can use this information for a more comprehensive look at major East Bay habitat communities (grasslands, oak woodlands, riparian areas, and shrublands). However, even at this point, Network partners are better prepared to make appropriate decisions when responding to climate change, identifying and implementing restoration efforts, and improving the overall resiliency and health of our natural resources. We also hope to build additional partnerships with the public, our research community, and other local stakeholder groups and organizations. Together, we will do our best to steward and restore our precious wildlife resources and habitats.

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GLOSSARY OF TERMS

Term	Acronym	Definition
area of focus		The geographic region included this analysis, which encompasses only properties owned or managed by Network partner agencies (see Figure 1.1). The area of focus was determined by using criteria to rank each property for suitability for inclusion in this assessment (Appendix A). Note that not all lands owned and/or managed by partner agencies are included in the area of focus.
California State Parks	CSP	One of the East Bay Stewardship Network partner agencies.
condition		The current state of the indicator or metric relative to its desired condition, described as **Good, Caution**, **Significant Concern,** or **Unknown** if not enough information is available to determine condition.
condition goal		The desired and measurable state for each metric against which monitoring data are compared.
confidence		The amount of certainty in the data or method for which the condition and trend are assessed. • **High:** Measurements are based on recent, reliable, and suitably comprehensive monitoring. • **Moderate:** Monitoring data lacks some aspect of being recent, reliable, or comprehensive; however, measurements are also based on current expert or scientific judgement and observation. • **Low:** Data are not sufficiently recent, reliable, or comprehensive, but either some supporting data exist or measurements are also based on expert or scientific opinion.
Contra Costa Water District	CCWD	One of the East Bay Stewardship Network partner agencies.
current condition and trend		The combined current state of the indicator, based on the totality of its metrics. (For NatureCheck 2022, the initial condition assessment is also the current overall baseline condition.)
data gap		Missing data or other information needed to assess the condition or trend of a metric or indicator.
desired condition		The qualitative goal for the overall indicator; the threshold or state it should be in to be considered healthy (e.g., a recovery target for rare/listed species).
East Bay Municipal Utility District	EBMUD	One of the East Bay Stewardship Network partner agencies.
East Bay Regional Park District	EBRPD	One of the East Bay Stewardship Network partner agencies.
East Bay Stewardship Network	Network	The group of partner agencies that pooled their data and worked collaboratively to do this ecological health assessment. For NatureCheck 2022, the Network includes California State Parks, Contra

		Costa Water District, East Bay Municipal Utility District, East Bay Regional Park District, and San Francisco Public Utilities Commission.
ecological health assessment		An analysis of the condition and trend of a suite of natural resources and/or processes (i.e., this project).
East Bay ecological health assessment expert workshops	expert workshops	A two-day workshop held January 29–30, 2020. Invitees were selected based on a combination of extensive local knowledge, experience, and research monitoring and/or data collection related to wildlife species and habitats within the area of focus. Workshop discussions helped determine the metrics, thresholds, and analyses used in each of this report's indicator chapters.
indicator		A species, community, or physical process (e.g., streams) that provides an essential ecological function or is suggestive of essential habitat conditions and is measured as an indication of health. Indicators are akin to human vital signs, such as blood pressure and pulse: easily measured and strongly correlated with an overall condition, sensitive to stressors, and early warnings of potential problems.
metric		The quantitative aspect of an indicator that is assessed or measured.
Network partner agency		One of five agencies participating in the East Bay Stewardship Network
Network partner (agency) lands		The individual parks, open spaces, reservoirs, habitat management units, and other discrete locations managed by Network partner agencies and included in this analysis.
San Francisco Public Utilities Commission	SFPUC	One of the East Bay Stewardship Network partner agencies.
stressor		A factor that challenges ecosystem integrity and/or the quality of the environment for each indicator; it may be a natural environmental issue or the result of human activity. Some stressors exert a relatively local influence, while others are regional or global in scope.
subregion(s)		**East Bay Hills, Mt. Diablo Range, and Mt. Hamilton.** Where it makes sense ecologically, analyses of indicator species and vegetation communities were done at the subregion level in an attempt to capture some of the variation across this large geographic area (Figure 1.1).
threshold		The point at which a metric changes from one condition to another (e.g., Good to Caution) or one trend to another (e.g., Unchanging to Declining).
trend		The change in condition, determined by comparing current versus previous measures; trend is independent of current condition (e.g., a resource may be Declining but still be in Good condition). • **Improving:** The condition is getting better. • **Unchanging:** The condition is unchanging. • **Declining:** The condition is deteriorating/getting worse. • **Unknown:** Not enough information is available to determine trend.

CHAPTER 1. INTRODUCTION

WHY AN ECOLOGICAL HEALTH ASSESSMENT FOR WILDLIFE?

Collectively known as the “East Bay,” the eastern flank of the San Francisco Bay Area offers a remarkable abundance of protected open spaces in an otherwise highly developed region. These biodiversity hotspots support habitats that are critical for a multitude of federally and state-listed species and species of special concern, as well as rare plant communities. They also provide vital refuges for the more common species that people enjoying seeing. These lands provide drinking water for area residents; habitat to preserve biodiversity and ecosystem functions the animal kingdom depends upon; and opportunities for stewardship, recreation, and inspiration for people from many places and walks of life.

However, the extensive development that followed 18th-century European colonization of northern California has led to tremendous habitat loss, leaving fragmented remnants of what once was. The East Bay has lost more than 98% of its freshwater wetlands, 95% of its riparian areas, and 80% of its native grassland habitats. What remains is truly precious.

Five public agencies—California State Parks (CSP), Contra Costa Water District (CCWD), East Bay Municipal Utility District (EBMUD), East Bay Regional Park District (EBRPD), and San Francisco Public Utilities Commission (SFPUC)—steward more than 225,000 acres of these open spaces (Figure 1.1). As the East Bay Stewardship Network (Network), these agencies are collaborating to improve the management of these protected areas, which account for almost 25% of the land in Alameda and Contra Costa Counties.

Network partner lands range from small islands of remnant habitat to large, well-connected areas that create linkages and habitat mosaics across the landscape. This connectivity is key to maintaining viable populations of plant and animal species and provides a buffer against the impacts of genetic, recreational, and environmental variability (CLN 1.0). It also provides essential migration routes that plants and animals can use as climatic conditions change. These last remaining intact ecosystems are essential to maintaining our region’s biodiversity and ecological processes.

As land managers, our collective responsibility is to steward these habitats and the vegetation and wildlife that depend upon them. However, we must do so in the context of multiple and often overlapping threats–among them, altered fire regimes, invasive species, habitat fragmentation, diseases, infrastructure and recreational impacts, and pollution—many of which are beyond our control. These habitats and wildlife are also facing accelerating climate change, which is, in large part, driving an alarming global event termed “the sixth mass extinction.”

This threat transcends all organizational and land-use boundaries. The five Network land managers came together to conduct this ecological health assessment in order to better understand the implications of these threats and to assess the health of key resources across jurisdictional boundaries. The partners have collaborated across agency lines in the past on projects that included invasive species control, amphibian surveys, and habitat enhancement projects. However, this joint, science-based ecological health assessment represents our first effort to broadly understand and support ecosystem management at a landscape scale.

The Network agencies recognize how critical this kind of health assessment is to developing a baseline for current conditions against which to measure change over time and helping understand and better manage resource health. This process also revealed key gaps in our understanding, which we can now more efficiently leverage our collective resources to fill. Having common benchmarks and terminology to communicate to the public, funders, and decision-makers about the health of these special places and their inhabitants facilitates this process.

The advantages of a landscape-level ecological health assessment include:

Enhanced resource management

- Provides a better analysis of ecological health than considering individual species or projects in isolation.
- Offers an important baseline by which managers can measure change across jurisdictional boundaries (e.g., vegetation community shifts, species movement, disease impacts).

Improved data management and coordination

- Identifies key data gaps so that future research efforts can be coordinated.
- Creates shared data and tracking systems that can be used to more efficiently manage information, as well as valuable tools (e.g., shared key-resource maps).

Increased fundraising potential

- Helps articulate a clear, shared case for funder support of identified ecological priorities.
- Aligns with funders looking for collaborative, cross-jurisdictional projects.

More effective public engagement

- Contributes to public messaging on why open space is so important.
- Provides an ecological baseline to demonstrate the appropriateness and efficacy of agency actions.

THE NATURECHECK AREA OF FOCUS

GEOGRAPHIC SCOPE

The lands included in this project's area of focus encompass approximately 80% or the land owned or managed by the five Network partner agencies, primarily in Alameda and Contra Costa Counties (Figure 1.1 at the end of this chapter). This area of focus was determined through the use of an evaluative tool that ranked each partner property's suitability based on nine specific land unit characteristic criteria (AECOM 2018). These characteristics include the land unit's proximity to other partner lands, vegetation communities present, and location within the Conservation Lands Network (CLN) critical linkages dataset. Note that while CLN Landscape Units are more comprehensive and include privately held lands, data used in the indicator analyses in this report are from lands owned or managed by Network partner agencies. The evaluation tool and associated criteria are provided in Appendix A.

Land units excluded from the area of focus were primarily East Bay Regional Park District properties on or near the San Francisco Bay or delta shorelines. These properties are generally isolated from other Network agency lands and contain dissimilar vegetation communities, which makes them less appropriate for cross-jurisdictional collaboration and land management. Coastal regions were also excluded because they have a unique ecology, only a few of the Network partners manage coastal lands, and there are other ongoing regional health assessment efforts for these areas.

Lands that were included fell within five CLN Landscape Units: North East Bay Hills, Middle East Bay Hills, South East Bay Hills, Mt. Diablo Range, and Mt. Hamilton (CLN 2.0), which were sorted into three subregions that better encompass the dynamic and varied ecosystems that span the East Bay. (One parcel that scored highly –Corral Hollow [CCWD]–was included although it is outside of a mapped CLN Landscape Unit.)

- The **East Bay Hills Subregion** encompasses the North-, Middle-, and South East Bay Hills CLN units.
- The **Mt. Diablo Range Subregion** remains the same as the Mt. Diablo Range CLN unit.
- The **Mt. Hamilton Subregion** remains the same as the Mt. Hamilton CLN unit, though only the northern portion is included in the area of focus. For simplicity, the Corral Hollow property is included within this subregion.

These three subregions were used for the herpetological, mammal, and golden eagle analyses. For fishes, we grouped surveyed streams by watershed (Alameda Creek, Pinole Creek, San Leandro Creek, and Wildcat Creek). The bird analysis focused on species assemblages for riparian, grassland, oak woodland, and shrubland habitat throughout the entire area of focus, as there were insufficient data to draw meaningful conclusions by subregion. The analysis for a given indicator may have further grouped or divided the land units within a subregion. So, while the subregions and total land acreage for this project are fixed, some chapters may include maps or tables with nomenclature specific to an individual park, open space, or other land unit.

ECOLOGICAL CONTEXT

Several landscape-scale factors affect the wildlife species and guilds included as NatureCheck ecological health indicators. While each chapter provides specifics on why an indicator is unique and the specific threats it faces, the factors listed below define and affect overall resource health and provide important context for the challenges facing Network agency resource managers.

Biological Resources

The San Francisco Bay Area is one of the world's 35 recognized biodiversity hotspots—areas that are both rich in endemic species and have lost a significant amount of their native vegetation. Network partner lands protect a variety of remaining plant communities: streams and their associated riparian habitat, wetlands, redwood forests in coastally influenced East Bay Hills, extensive oak savannas in the Mt. Diablo Range and Mt. Hamilton, and grasslands throughout the interior regions. These habitats support a wide variety of special-status plants and wildlife species (Appendix B).

Pending the development of a fine-scale map, for this project, plant communities were grouped into broad categories, based on CLN definitions (Figure 1.2).

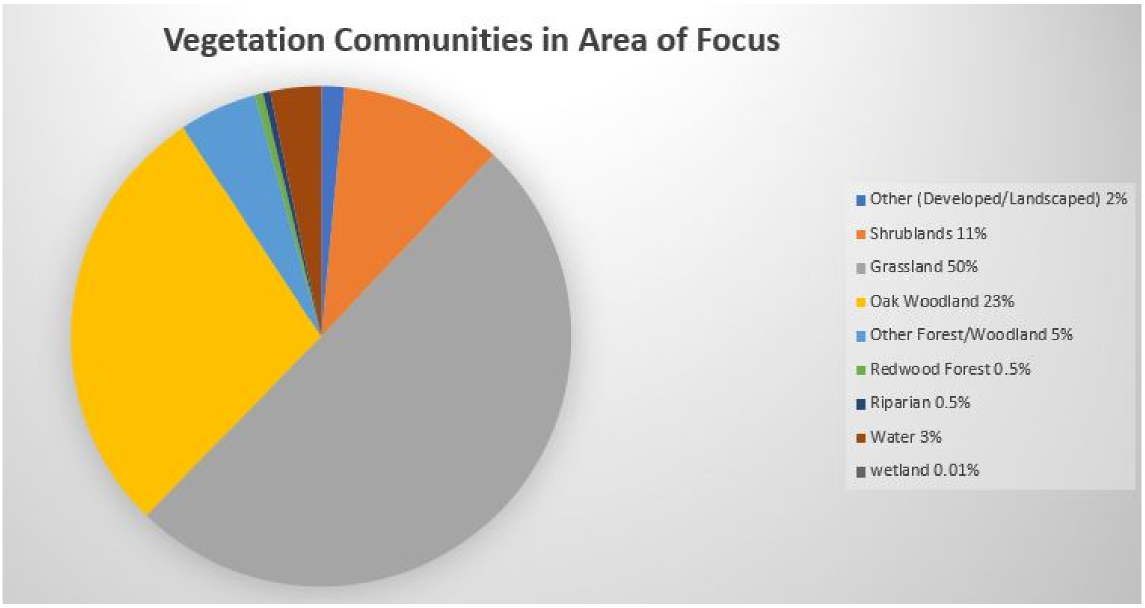

Figure 1.2. The percentage of each vegetation community within the NatureCheck area of focus (based on CLN 2.0 data).

Climate Change

The accelerating effects of climate change are transforming the planet. Models show that if greenhouse gas emissions continue unabated, Earth's average temperature may rise by as much as 11 degrees by the end of the century. In the Bay Area, the mean temperature has risen by 1.7 degrees Fahrenheit since the early 1900s. Five of the years between 2009 and 2019 also saw severe-to-exceptional regional drought (USDM 2021). Precipitation models predict even more extreme year-to-year variation and an increasing number of dry years (CDNR 2016).

Together, warmer temperatures and less rain will result in aridification and amplify drought stress. This will likely lead to species declines as well as shifts in their geographic distributions. In addition, the more rapidly the climate changes, the less able plants and animals are to respond, putting them in even greater peril. While there is little land managers can do to stop the global effects of climate change, protecting habitat connectivity and migration corridors within the area of focus and taking action to increase drought resilience will be especially critical.

Invasive Species and Disease

Once introduced, invasive plants and animals—those not native to the environment—establish, quickly reproduce, spread, and cause harm to the environment, economy, and/or human health. Nationally, invasive species are the second greatest threat to endangered species, after habitat destruction. In the East Bay, non-native animals can out compete native amphibians and spread disease, while invasive plants can create monocultures across the landscape.

Plant and animal pathogens can also cause significant disease outbreaks and contribute to native species decline. Most notably, the phytophthora pathogen that causes Sudden Oak Death has the potential to kill up to 50% of the coast live oaks it infects. A long-term study in a portion of the East Bay shows that as of 2017, 7.6% of coast live oaks were infected, a number that is likely increasing (McPherson et al. 2017).

Habitat Loss and Change

The most significant impact on wildlife's ability to survive and be resilient to change is human-caused habitat loss. Dramatic shifts in the Bay Area's population, land use, economic base, extent and types of vegetation, and species of plants and animals have occurred since the first permanent Spanish settlement was established in the region almost 250 years ago. Pre-European contact, landscape ecosystems were organized both structurally and functionally in patterns distinct from today (Allen 1989). Now, upwards of 2.8 million people live in Alameda and Contra Costa Counties, and ecosystems are fragmented, often isolated islands within the broader urban framework. These remaining grasslands, woodlands, and shrublands are a small-scale reminder of what the larger Bay Area landscape once was. However, while many aspects of our flora and fauna have changed, numerous native plants and animals remain, making the fragments of habitat that persevere even more critical to preserving the region's biodiversity.

Fire and Grazing Regime Change

Landscapes in the East Bay developed under the dynamic influences of fire and grazing wildlife over millions of years. Fire is part of the natural cycle of the region's ecological succession, and many plants and animals have adapted to and depend upon its effects. Fire suppression and the loss of large grazing animals such as elk have fundamentally changed its plant communities. For example, without these disturbances, shrubs and trees invade grasslands, converting them to a different type of habitat and increasing the risk of catastrophic wildfire to nearby development. In many areas throughout the East Bay, meeting fire-safety objectives and maintaining the health of our natural areas sometimes requires aggressive vegetation management. Periodic, well-managed fires can control vegetation and stimulate the natural cycle of ecological succession. And today across the area of focus, grazing is also often used to achieve a variety of goals, including increasing habitat quality, reducing fire hazards, and improving aesthetics.

Recent analysis of the 2020 Santa Clara Unit Lightning Complex wildfire within the NatureCheck area of focus showed that our native wildlife can recover and even improve after fire (Hamilton and Hamilton 2022). Specifically, data show that 36 out of 37 nesting golden eagle pairs returned after the fire, and that wildlife diversity and occupancy for the bobcat (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*), and black-tailed deer (*Odocoileus hemionus columbianus*) are higher in burned than in unburned areas of monitored EBRPD lands. This may not be the case under future climate change scenarios, however, as dry soil conditions and extreme drought can hinder post-fire plant recovery.

Human Activity

Despite being largely protected open space, the area of focus was and is affected by human activities. Its plant communities have been substantially altered by development, livestock grazing, logging, quarrying, road and trail construction, introduction of non-native species (most notably eucalyptus), and wildfire suppression. Wind turbines and a history of hunting and poisoning have also had impacts on many bird and mammal species.

The relationship between people and these lands is complex. We know that access to large open spaces with their biodiversity and views of nature has benefits for human health, including refuge from noise and air pollution, increased physical activity, and a sense of well-being (Panlasigui and Spotswood 2021). However, these benefits must be balanced with the impact that recreation has on the land. Even “passive recreation,” such as hiking, biking, or wildlife-viewing, has known negative effects on protected areas, among them, invasive species introduction and spread, trampled vegetation, rare plant poaching, illegal trail creation, and litter. Indeed, the sheer acreage of open space lands that humans use for recreation or to maintain power lines, radio towers, and reservoirs means there is less for wildlife to occupy. This has led to shifts in when animals will hunt or forage for food and physiological stress from increased disturbance events.

HEALTH ASSESSMENT METHODS AND PROCESS

This assessment is consistent with and supports Network partner agency master plan goals and management objectives. Though these partners have different missions and mandates, they are all responsible for and entrusted with management and stewardship of the natural resources under their care. Each Network partner agency has specific language in their mission(s) and plans that support an ecological health assessment, which is provided in Appendix C. A synopsis of key points follows.

California State Parks (CSP): The departmental operations manual specifies that resource health will be monitored to detect trends in baseline data and provide documentation of natural resource change to guide resource management.

Contra Costa Water District (CCWD): Management plans lay out actions designed to protect and enhance, and, where appropriate, restore native habitats for native species, including practicing environmental stewardship by protecting natural resources and minimizing environmental impacts.

East Bay Municipal Utility District (EBMUD): Program goals and master plans commit to the maintenance and enhancement of biological resource values on district lands through active management, Habitat Conservation Plan compliance, and careful coordination with other resource management programs.

East Bay Regional Park District (EBRPD): The master plan and management goals specify that the district will coordinate with other agencies and organizations in a concerted effort to inventory, evaluate, and manage natural resources and to maintain and enhance the biodiversity of the region.

San Francisco Public Utilities Commission (SFPUC): Through its policies and management plans, the San Francisco Public Utilities Commission articulates its commitment to proactively managing the watersheds in a manner that maintains the integrity of the natural resources, restores habitats for native species, and enhances ecosystem function. It also commits to actively monitoring the health of the terrestrial and aquatic habitats both under its ownership and affected by its operations in order to continually improve ecosystem health and refers to the use of relevant indicators for meeting these commitments.

DEFINING ECOLOGICAL HEALTH

The goal of the NatureCheck project is to measure wildlife health by understanding their current baseline condition and identifying metrics that can be used to track trends over time. To do this, we had to define what "healthy" is for these species, and for East Bay protected areas more broadly.

There is no single way to define ecological health; it is a term that encompasses a variety of elements and may be used for many different purposes. Ecological health can be hard to pin down, given that constant change can be brought about by factors that are largely beyond our control, such as climate change, wildfire, and disease. Therefore, Network partners determined that a healthy system could best be defined in terms such as resiliency, diversity, and functioning natural processes rather than a specific set of conditions. We also did not want to tie health to a point in the distant past—say, before European contact—because we are not, and will never be, living in those same conditions again. Therefore, we intentionally chose to establish this ecological baseline based on existing conditions inclusive of modern anthropogenic stressors rather than using historical conditions, which can no longer be feasibly achieved.

For the purposes of this project, we define the health for the East Bay as follows:

- Ecosystems are resilient (able to function/recover despite change or shock).
- The full complement of plants, animals, and other life is present and able to find food, shelter, and water, and to reproduce.

- Natural processes occur in a manner and frequency considered “normal” based on best available science.

Process and Methodology

In 2018, staff biologists from the five Network partner agencies began meeting to discuss the possibility of conducting an ecological health assessment. They formed staff-member-led workgroups focused on vegetation (oak woodland and grassland), fishes, amphibians and reptiles, birds, and mammals. These groups considered numerous potential indicator species, including those that are iconic and charismatic, have special conservation status, or reflect the different habitat types or ecosystem processes found across the entire area of focus. (Appendix D provides a table of all health indicators that were considered).

Next, the workgroups began to gather existing data for this initial list. Species that did not have sufficient existing data (e.g., from across the study area, through time, or that could be pooled amongst partners) were removed from consideration unless they were keystone species and/or representative of a key part of the ecology that could not be captured in another way. For example, there are very little data on mammals, but staff felt it was important to include some analysis of them in this report. We conducted additional field work in 2019 to establish sentinel sites for California ground squirrels, start solstice exit surveys for roosting bats, and set up camera stations to support capturing wildlife usage in our land units. These studies provided an early data-collection framework for future analysis.

By 2019, Network partners had settled on indicator species and communities that represented and reflected the health of East Bay ecosystems as we had defined it and for which we had existing information/data. Where we lacked sufficient data or were unable to complete quantitative metrics, we identified “data gaps” for future research or monitoring (see Data Gaps section, following).

Engaging Outside Expertise

With an initial list of ecological health indicators selected, workgroup leads prepared draft worksheets based on available data, reports, and project information (e.g., internal datasets, published papers, and white papers). These worksheets, which were the basis for preliminary drafts of the chapters in this report, included a rationale for choosing the species or community, a description of the resource and its significance, key ecological stressors, presumed current and desired conditions, proposed goals and metrics by which to measure condition and trend, existing information sources (e.g., research data, monitoring, restoration projects, etc.), and known information gaps.

These worksheets were used to acquire additional information and perspectives during the two-day East Bay ecological health assessment expert workshops (January 29–30, 2020), which brought together more than 70 resource managers, academic researchers, and other specialists representing 30 organizations (Appendix E). These experts recommended that some indicators be removed and others added, and provided valuable input, including identifying additional data sources and making suggestions for improved analyses.

Data Management and Analysis

With the revised worksheets in hand, workgroup leads continued to pool and analyze data, revise indicators, and update the assessment. Though each indicator followed the same chapter template (outlined in a following section), individual leads took different approaches to geographic scope, data analysis, and other aspects of their methodology. Rather than summarizing those here, the approach each lead took is described in their respective chapters.

Data Gaps

Almost as important as bringing together what we know to create an ecological health baseline, this process also gave us a clear view of what we do not know. This includes a lack of data for entire communities or taxa that are ideal ecological health indicators as well as understudied aspects of specific species' ecology.

To address the latter, each chapter identifies these data gaps and suggests ways to fill them and to increase our confidence in the data we do have, such as providing greater coverage through more sampling across the area of focus. Some include data gaps important for resource management, such as pond hydroperiod data to help prioritize where restoration efforts should be focused. Identifying these data gaps is an important first step in focusing on how Network partners can continue to gather data to improve our confidence in subsequent analyses and to better detect trends.

In addition to data gaps for specific indicators, entire swaths of ecological health are not discussed in NatureCheck due to a lack of information. One notable example is the lack of a vegetation community analysis and/or comprehensive plant survey. Vegetation communities are the very fabric of the habitat that all animals depend upon, and we must assess vegetation health in order to understand how our natural resources are faring.

For this report, very basic information on vegetation cover (grassland, oak woodland, etc.) was taken from CLN 2.0 data. This comprehensive report provided comparable data for all nine Bay Area counties, but at a very broad scale. Unfortunately, the specific data needed to analyze vegetation indicator metrics—spatial extent, native cover and richness, age structure, recruitment, understory composition, and patch size—have not been collected. However, EBRPD is working to develop a fine-scale vegetation map database for Alameda and Contra Costa Counties, with an anticipated completion date of sometime in 2024. At that time, we plan to revisit the inclusion of vegetation community ecological health indicators for the next NatureCheck update.

The health of our watersheds, streams, riparian areas, ponds, and wetlands is another important component of ecological health not evaluated in this report. California has lost more than 90% of its riparian habitat due to disruption of natural stream flows, urban development, and water diversion (Krueper 1993). However, water is essential to ecosystem health, and wet areas can act as climate change refugia (Morelli et al. 2017). Waterways with shady, cool riparian vegetation are essential for fish and other wildlife, and provide critical movement corridors. Ponds and seasonal wetlands are also home to many of our native amphibians. While we have identified potential aquatic habitat-health data sources, including a benthic macroinvertebrates bioassessment and California Rapid Assessment Method (CRAM) reports, there were an insufficient number of assessments in the area of focus and those we do have were not evenly distributed. As a Network, we can work together to develop a methodology to evaluate these critical habitats in the future.

Finally, another major missing component of ecological health is an assessment of invertebrates, the taxa that constitutes the majority of Earth's biodiversity and provides the pollination necessary to maintain the global food chain. A recent review of scientific papers on the topic of insect population declines (Sanchez-Bayo and Wyckhuys 2019) reported a worldwide decrease of 2.5% per year. We intend to include an assessment of indicator invertebrate species in a future NatureCheck report.

A complete list of indicators considered but not included in is provided in Appendix D.

Report Format and Terminology

This report's chapters are broken out by **indicator** (a resource that reveals something about ecological health) and details the **metrics** used to measure the health of that indicator. Each chapter includes these critical pieces of information as well as the supporting material described in the outline that follows. Although the chapters were written by different individuals, they all used the format and process described here.

EXECUTIVE SUMMARY

An overview of the metrics, findings, and data gaps. This includes a **Metrics Summary at a Glance** that lists each metric used in the chapter, with its condition, trend, and confidence, and a **Condition, Trend, and Confidence Summary** that combines those metrics to give an overall score for the indicator. A graphic (circle and arrow) representation of the overall combined condition, trend, and confidence is included as follows (Figure 1.3).

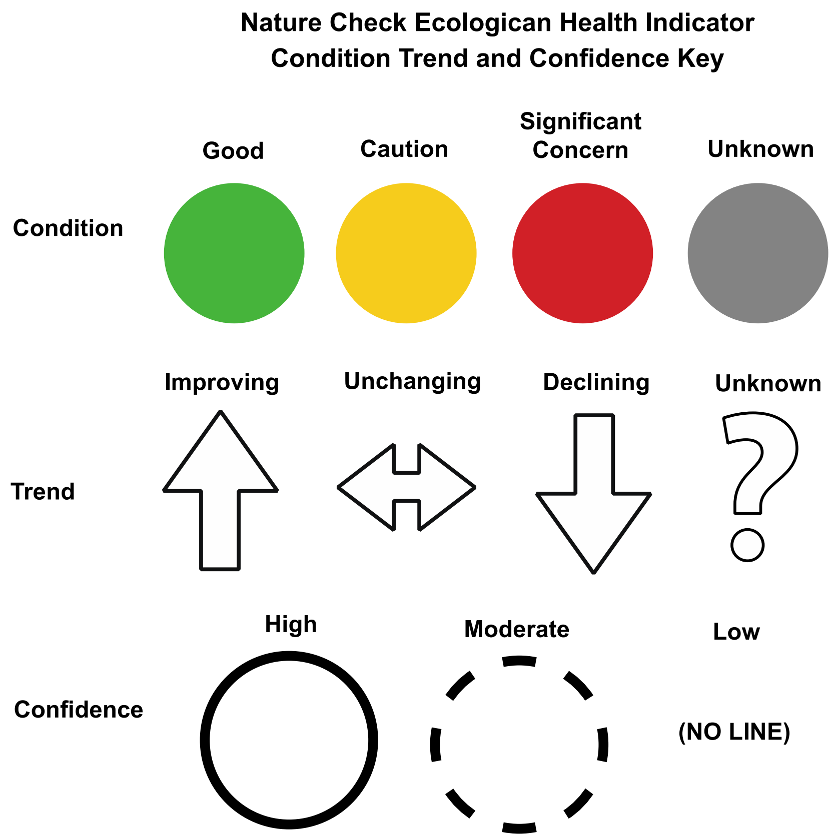

Figure 1.3. NatureCheck condition, trend, and confidence symbology key

This overall score was obtained by averaging the individual scores assigned to each metric's condition, trend, and confidence, as follows. Deviations from this methodology based on best professional judgement are noted in individual chapters where applicable.

Condition

Good = 100

Caution = 50

Significant Concern = 0

Unknown = No score (Not scored or included in these averages to avoid unfairly/inaccurately lowering the overall score)

Trend

Improving = 100

Unchanging = 50

Declining = 0

Unknown = No score

Confidence

High = 100
Moderate = 50
Low = 0

The scores for the condition, trend, and confidence for all of the metrics were added individually, and that number was then divided by the number of metrics used (not including unknowns). The overall average condition/trend/confidence is then:

100–76 = Good/Improving/High
26–75 = Caution/Unchanging/Moderate
0–25 = Significant Concern/Declining/Low

BACKGROUND

Why Is This Resource Included?: Intended to help the reader understand why Network partner agencies care about this particular resource. The discussion includes its protected status, global ranking, agency priority (such as reference documents, policies, or anything else that elevates this resource above others), and iconic standing or functionality in respect to public engagement, community science, and so forth. It also considers how the resource is an indicator of the health of East Bay parks and open spaces and what it tells us about other resources (e.g., water quality, availability of prey species, landscape connectivity, the effects of management actions).

Desired Condition and Trend: Often identified as a recovery target for rare/listed species. This is the goal for the indicator, or the condition and trend at which it would be considered healthy. The desired condition and trend are based on the metrics used in each chapter, which, ideally, measure the difference between this desired state and the current condition and trend, described in the following section.

Current Condition and Trend: This describes the condition and trend (if known) of the indicator at the time of this report. The difference between this and the desired condition and trend is what we hope to help measure with the metrics.

Stressors: Ecological and anthropogenic factors that affect the health of each indicator are summarized in this section. These include, among other things, historical impacts, invasive species, climate change, fire regime change disease, pollution/contaminants, other direct human impacts, habitat disturbance/conversion/loss, predation/competition.

CONDITION AND TRENDS ASSESSMENT

Metrics in Detail: In this section, each metric is individually analyzed, including:

- Rationale: Why this is a useful metric, what it reveals about the difference between desired and current condition, and so forth.
- Condition Goals: A list of what "healthy" looks like for this metric.
- Current Baseline: The current condition, trend, and confidence for this metric (if known), and how we determine that. This may be broken out into different geographic regions, if applicable. Given that this is the first ecological health assessment for this region, the current baseline is often a summary of what is described in detail under the Condition, Trend, and Confidence headers below.

Condition Thresholds: Condition thresholds were established for each indicator based on the metrics and on the author's best professional judgement. While they have not been standardized across the indicators, they are described in each chapter.

- *Good:* The threshold for an assessment of "good" health.
- *Caution:* The threshold for an assessment of "caution."
- *Significant Concern*: The threshold for an assessment of "significant concern."

Condition: The condition for this metric (Good, Caution, Significant Concern, Unknown), which is based on where in the list of condition thresholds above it falls based on existing data and/or expert opinion.

Trend: The trajectory of this metric (Improving, Unchanging, Declining, Unknown) and rationale for that assessment.

Confidence: The level of confidence we feel in this assessment (High, Moderate, Low) based on the following

- *High:* Measurements are based on recent, reliable, and suitably comprehensive monitoring.
- *Moderate:* Monitoring data lacks some aspect of being recent, reliable, or comprehensive; however, measurements are also based on recent expert or scientist observation.
- *Low:* Although monitoring is not sufficiently recent, reliable, or comprehensive, some supporting data exists or measurements can be based on expert or scientific opinion.

Other Metrics Considered but Not Included Here: For some indicators, metrics were suggested but not ultimately included in the final analysis for a variety of reasons, including a lack of data to measure what was being proposed or the belief that the metric was not a good indicator of landscape-scale health.

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

Data Gaps and Data Collection/Management Needs: Identifies information needed to better assess the metrics that we included or to identify other metrics to include in the future.

Past And Current Management: A summary of monitoring, restoration, stewardship, or other activities. This information is intended to help readers understand the ways in which Network partner agencies have been supporting the health of each indicator.

Potential Future Actions: Research, inventory, monitoring, restoration, or management actions that would help move the needle on the condition or trend for this indicator. Rather than a commitment to undertake any particular activity, this list will help us prioritize future work and advocate for support.

Key Literature and Data Sources: Literature, Network partner agency data, and other sources used in this analysis.

Chapter Author(s) and Key Contributors: Names and affiliations of those who wrote the chapter as well as a list of others who participated in the expert workshops, contributed data or other information, helped with analyses, reviewed the chapter, and so forth. It should be noted that this document does not necessarily reflect the opinions or incorporate the suggestions of all participants.

LOOKING AHEAD

Assessing ecological health is an iterative and ongoing process that we intend to revisit on a regular basis (such as every five years) as we acquire more information and undertake resource-based projects, and as our understanding changes and grows over time. However, the process we went through to create this report has already proven highly beneficial.

This first NatureCheck for wildlife health on Network partner lands is a critical first step in setting a baseline against which we can measure change over time. This project has allowed us to leverage multiple datasets to improve our understanding by:

- Pooling amphibian survey data to map metapopulations and subpopulations and to identify the ponds serving as core habitats that can rescue subpopulations from periodic extinction.
- Identifying opportunities for standardizing and sharing data with outside researchers.

- Improving opportunities for community science, including a California ground squirrel mapping project.
- Helping identify standard data to be collected for pond and fish surveys.
- Underscoring the importance of fine-scale vegetation mapping, which served as a springboard for agency cooperation on the mapping effort.
- Initiating a partnership with the California Academy of Sciences to study invertebrates.

We plan to use what we have already learned to direct our land management, restoration, and stewardship efforts to where they are most needed and we can be most effective. Going forward, we expect more of these types of benefits to accrue.

Our intention is to undertake a NatureCheck report for vegetation health, which will be based on a fine-scale map that we expect to have in hand by 2024. Wildlife use of our lands is largely dependent on vegetative cover structure; various species evolved as part of specific plant communities, in some cases, becoming so adapted to certain habitat conditions that they cannot survive without them. A vegetation-community analysis is essential to helping Network partner agencies care for both the region's habitats and wildlife, and to effectively manage both for climate change resiliency.

By the next iteration of this report, we also hope to have filled some of the identified data gaps for existing indicators, as well as perhaps to have developed new indicators that can be added to those used here. In the process, we want to engage the public in data-collection using tools such as eBird and iNaturalist. We also intend to increase our use of camera data to help evaluate the health of our mammal population and incorporate acoustic monitoring to better assess bird and bat abundance and diversity.

Although this initial report is limited to the five Network partner agencies, we anticipate that future iterations will include other East Bay land managers and open-space organizations, which would provide, among other things, additional datasets to improve the robustness of our analyses and also increase opportunities for collaboration and land stewardship.

Finally, we will use this baseline ecological health assessment to help educate the public and increase understanding of these incredible resources. In NatureCheck 2.0, we hope to be able to show how much ecological health has changed and what is most at risk. This information can help garner the support of the public and decision-makers for advancing projects that benefit ecosystem health.

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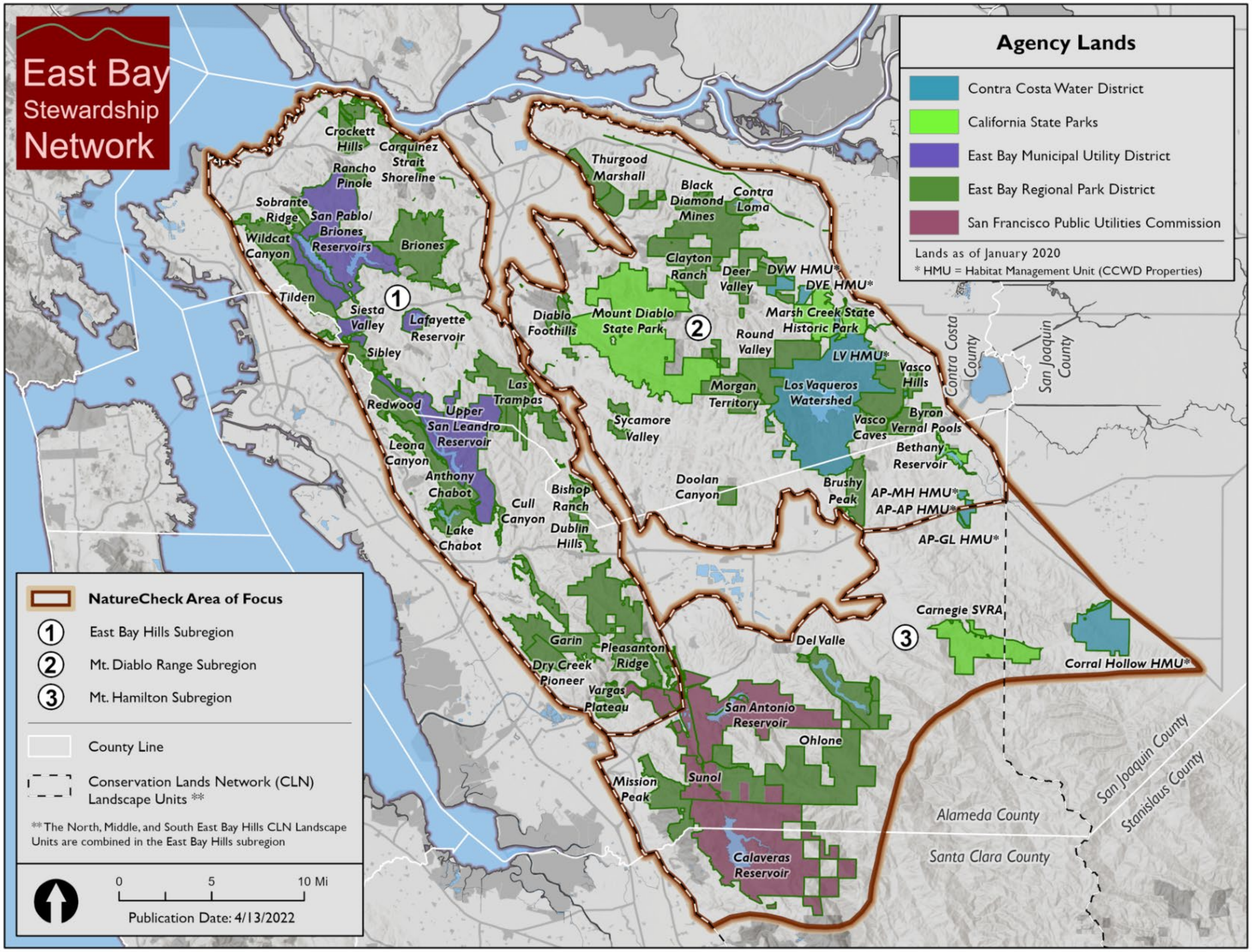


Figure 1.1. The NatureCheck area of focus.

CHAPTER 2. NATIVE FISHES

EXECUTIVE SUMMARY

This chapter presents the results of an evaluation of the current conditions and trends of native fish communities on lands owned and managed by East Bay Stewardship Network (Network) partner agencies within the area of focus for this NatureCheck project. (See map, Chapter 1.) Stream channelization as well as impoundments, diversions, and other in-channel barriers have dramatically altered these watercourses' hydrology and habitats. This chapter evaluates the desired condition of fish populations in the context of these current realities as opposed to using historical conditions as a goal or baseline.

A primary goal of the analyses presented here is to provide a benchmark against which managers can measure future changes and understand the likely trajectories of fishes in watersheds within the area of focus. The baseline data and analyses we developed can also be used to identify restoration projects or management actions that have the potential to achieve multiple benefits.

The evaluation, which only uses available data, also identifies areas where not enough is known to draw meaningful conclusions. Opportunities for future research and collaboration between land managers are also presented.

The following two metrics were used in the evaluation:

- **Metric 1: Native Fish Species Richness.** The presence and persistence of fish species as measured by the percent of species surveyed that were native by year and by watershed. The baseline for this metric was set using data from 2010–2019.

- **Metric 2: Native Fish Abundance.** The percent composition of fish species that were native as measured by year and by watershed. The baseline for this metric was set using data from 2010–2019.

Surveyed streams are grouped by watershed (Pinole Creek, Wildcat Creek, San Leandro Creek, and Alameda Creek), and the condition and trend of associated native fish populations are evaluated at the watershed level (Figure 2.1 at the end of this chapter). The amount of certainty with which the conditions and trends are accurately assessed (i.e., confidence) is also identified**.**

The primary findings of our evaluation include the following:

Pinole Creek watershed: An overall condition of **caution** is assigned to this watershed. Although the Pinole Creek watershed supports several native fish species, the presence of non-native fish in 2017 resulted in the watershed receiving this score. However, non-native fish were only found in one year of the 10-year monitoring period.

Wildcat Creek watershed: An overall condition of **caution** is assigned to this watershed. The vast majority of the individual fish caught here were native. However, because there were often equal numbers of native and non-native species surveyed, and nearly all survey years revealed more than one non-native fish species, the watershed is impaired. The presence of reservoirs in the watershed provide the environment for non-native Centrarchids to thrive as well as the opportunity for them to be swept downstream.

San Leandro Creek watershed: An overall condition of **caution** is assigned to this watershed. Populations of native fishes in San Leandro Creek above Upper San Leandro Reservoir remain largely intact, with headwater streams completely free of non-native fishes. However, non-native fish species are regularly surveyed in lower San Leandro watershed, below Lake Chabot. After the extremely wet year of 2017, several non-native fish species (some not seen in any other year) were collected below Lake Chabot. These likely spilled over from Lake Chabot and did not appear to persist downstream in lower San Leandro Creek in subsequent years.

Alameda Creek watershed: An overall condition of **caution** is assigned to this watershed. Fish populations in the headwaters above Calaveras Reservoir and in Alameda Creek upstream of its confluence with Calaveras Creek remain largely intact, with mostly native fishes. Fish communities in Calaveras Creek and lower Alameda Creek below Calaveras Reservoir, however, often include populations of non-native Centrarchids. The non-native species likely come from reservoir and pond spills during wet years, or upstream migrations from Alameda Creek's confluence with Arroyo de la Laguna (where the California State Water Project flows enter Alameda Creek).

Mt. Diablo Subregion: None of the Network partner agencies conduct fish stream surveys in this subregion.

METRICS SUMMARY AT A GLANCE

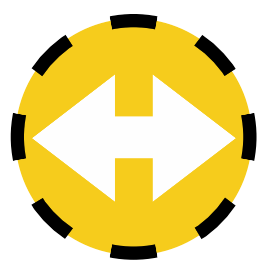
Table 2.1 summarizes the two metrics for native fishes used in this ecological health assessment. Each metric, along with how we arrived at its condition, trend, and confidence, is thoroughly described in the Metrics in Detail section later in this chapter. (See Chapter 1 for definitions and thresholds for condition, trend, and confidence; other terminology used throughout this chapter; how metrics are being used for each indicator; and other project methodology.)

Table 2.1. All native fish metrics, with their respective condition, trend, and confidence. Each metric is described in the Metrics in Detail section later in this chapter.

	Pinole Creek Watershed	Wildcat Creek Watershed	San Leandro Creek Watershed	Alameda Creek Watershed
Metric 1: Native Fish Species Richness–The presence and persistence of fish species as measured by the percent of species surveyed that were native by year and by watershed. The baseline for this metric was set using data from 2010–2019.				
Condition	Caution	Caution	Caution	Caution
Trend	Unchanging	Unchanging	Unchanging	Unchanging
Confidence	Low	Moderate	Moderate	High
Metric 2: Native Fish Species Abundance–The percent composition of fish species that were native as measured by year and by watershed. The baseline for this metric was set using data from 2010–2019.				
Condition	Good	Caution	Caution	Caution
Trend	Unchanging	Unchanging	Unchanging	Unchanging
Confidence	Low	Moderate	Moderate	High

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of native fishes in the area of focus represented by the graphic below is based on the combined values of the individual metrics presented in Table 2.1. Each of these metrics is described in depth in the Metrics in Detail section later in this chapter.



Condition: Caution (color: yellow)

Trend: Unchanging (symbol: horizontal arrow)

Confidence: Moderate (line around circle: dashed)

BACKGROUND

WHY IS THIS RESOURCE INCLUDED?

Streams in the East Bay, including those within the area of focus (see map, Chapter 1) historically provided suitable habitat for a variety of native fish assemblages (Leidy 2007, 2011). The makeup of fish assemblages, however, can be impacted by natural and human-induced environmental changes, including the introduction and establishment of non-native species. Therefore, an examination of stream-fish communities—specifically, their richness and the relative abundances of native and non-native species—can be used as an indicator of stream health. Undisturbed streams and reaches are generally characterized by the complete absence of non-native species, while disturbed streams and reaches generally have an abundance of one or more non-native fish species (Leidy and Fiedler 1985).

DESIRED CONDITION AND TREND

The desired condition is to maintain or increase the native fish species richness and the relative abundance of native fish individuals in streams managed by Network partner agencies, and the desired trend is for native fish populations to be resilient over time (i.e., an unchanging or improving trend would indicate that they are able to persist through and recover after periods of stress, such as drought and climate change). Measuring species richness, or the number of species within an area, can show the presence and persistence of both native and non-native fish species. Species presence counts can indicate intrusion by non-native fishes from reservoirs or the loss of a native fish species from the community. The relative abundances, or the percent composition of a sampled population, can be used to show how dominant native species are in a given watershed. Over time, this trend shows the resiliency of the native fish community to drought and non-native fishes.

CURRENT CONDITION AND TREND

Condition: Caution

Trend: Unchanging

Confidence: Moderate

Streams within the area of focus, which can be ephemeral, seasonal, intermittent, or perennial, typically support multiple native and non-native fish species. The East Bay's native fishes live in numerous habitat types, starting in steep, rocky headwaters, moving through meandering channels with gentle slopes, and into wider, slower-flowing depositional areas before emptying into the greater San Francisco Bay. The aquatic landscape within the area of focus has changed dramatically over time, but despite reservoir and diversion construction, urbanization, and habitat loss, streams managed by Network partner agencies continue to support native fish populations. During the 2014–2016 drought,[1] the number of native fish species held steady, although there were abundance decreases. Community numbers rebounded after above-average rains in 2017.

The most abundant native fishes present in streams within the area of focus include the California roach (*Hesperoleucus symmetricus*), three-spined stickleback (*Gasterosteus aculeatus*), rainbow trout/steelhead (*Oncorhynchus mykiss*), Sacramento sucker (*Catostomus occidentalis*), pricky sculpin (*Cottus asper*), Sacramento pikeminnow (*Ptychocheilus grandis*), *Lampetra* spp., and Pacific lamprey (*Entosphenus tridentatus*). Non-native fish species include the largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), bluegill (*Lepomis macrochirus*), green sunfish (*Lepomis cyanellus*), black crappie (*Pomoxis nigromaculatus*), goldfish (*Carassius auratus*), and common carp (*Cyprinus carpio*).[2] The East Bay Regional Park District (EBRPD), East Bay Municipal Utility District (EBMUD), and San Francisco Public Utilities Commission (SFPUC) conduct annual surveys to document and assess native fish populations and provide data to assist in stream habitat management.

Fishes can move within connected streams and their tributaries and use different habitats for multiple life stages. Consequently, surveyed streams are grouped and evaluated at the watershed level (Table 2.2, Figure 2.1 at the end of this chapter). Pinole Creek, Wildcat Creek, and San Leandro Creek watersheds are located entirely within the East Bay Hills subregion. The majority of the Alameda Creek watershed is located within the Mt. Hamilton subregion, while the portion downstream (west) of Highway 680 (including Stonybrook Creek) is in the East Bay Hills subregion. No streams within the Mt. Diablo Range subregion were included in this analysis because Network partner agencies do not conduct fish surveys in the subregion.

Table 2.2. Surveyed streams within each watershed included in this ecological health assessment.

Watershed Name	Surveyed Streams
Pinole Creek	Pinole Creek
Wildcat Creek	Wildcat Creek
San Leandro Creek	San Leandro Creek Redwood Creek Kaiser Creek Moraga Creek Rimer Creek

[1] The full drought period extended from 2012-2017; 2014-2016 were peak drought years, categorized as exceptional drought (https://www.drought.gov/states/california)

[2] The western mosquitofish (*Gambusia affinis*), a non-native species, is not included in fish numbers because it is intentionally introduced to most freshwater systems for mosquito abatement.

Watershed Name	Surveyed Streams
Alameda Creek	Upper Alameda Creek La Costa Creek Indian Creek Arroyo Hondo Lower Alameda Creek Lower Calaveras Creek Stonybrook Creek

The current condition, trend, and confidence are the average of the condition, trend, and confidence for native fish species in each watershed is shown in Table 2.3. The metrics described in depth in the Metrics in Detail section of this chapter were combined to determine the current condition and trend. These metrics give us a way to measure the difference between what is described in this section (i.e., how things are now) and the desired condition and trend in the preceding section (i.e., what we think "healthy" is for this indicator).

Table 2.3. The overall condition, trend, and confidence for native fish in each watershed in the area of focus. See the Condition, Trend, and Confidence Discussion by Watershed section later in this chapter for details.

	Pinole Creek Watershed	Wildcat Creek Watershed	San Leandro Creek Watershed	Alameda Creek Watershed
Condition	Caution	Caution	Caution	Caution
Trend	Unchanging	Unchanging	Unchanging	Unchanging
Confidence	Low	Moderate	Moderate	High

STRESSORS

Several ecological and anthropogenic factors affect the health of this indicator. These include:

Invasive Species Impacts: Non-native wildlife (i.e., American bullfrogs [*Lithobates catesbeianus*], centrarchids [sunfish and bass species]) can prey upon native fish and can lead to a loss of native fish biodiversity if they outcompete native species (Bunnell and Zampella 2008).

Climate Change: Climate change is altering hydrologic conditions, warming water temperatures, decreasing water quality, lowering dissolved oxygen levels, increasing the frequency of droughts, and causing more dramatic or unseasonable rain events (when they do occur). Periods of drought can also reduce spawning and rearing habitat, lessen habitat connectivity and in-stream mobility, and decrease food resources.

Disease: The native-fish-community surveys conducted in the area of focus are not designed to detect or monitor diseases. However, we know climate change makes fish populations more susceptible to bacterial, viral, and fungal infections (Chiaramonte et al. 2016).

Pollution/Contaminants: Toxic substances from spills or runoff can enter streams and reservoirs directly or through storm drains, resulting in direct harm to aquatic species and their habitat. Mercury from old mines, which continues to seep into water bodies, bioaccumulates up the food chain. Longer-living or predatory fish can contain elevated levels of mercury, which can be harmful to humans or wildlife when consumed in high amounts.

Habitat Disturbance/Conversion/Loss: Although much of the stream habitat in the area of focus is within open space managed and protected by the Network partner agencies, many downstream areas have been heavily modified (e.g., channelized streams, passage barriers), lack riparian vegetation, and are subject to urban runoff.

Direct Human Impacts: People, dogs, or cattle entering a stream can cause the direct loss of spawning habitat, harm fish, and change both stream and adjacent riparian habitat. The loss of native tree canopies can increase water temperature, evaporation rates, and stream turbidity. Although much of the stream habitat in the area of focus is within open space managed and protected by Network partner agencies, upstream private parcels and downstream areas could experience heavy fishing pressure. Illegal poaching can also occur on Network partner agency lands.

Other Stressors:

- **Passage impediments/barriers/reservoirs**. The presence of reservoirs and passage barriers on the landscape can have detrimental effects on native fishes. Populations can become isolated from one another, which could increase the potential risk of small populations dying out during a drought or decrease genetic diversity, making them more vulnerable to diseases. Most reservoirs in the area are also home to reproducing populations of non-native warm-water fishes, which often get pulled in or over dam spillways into streams below.

- **Sedimentation/excess sediment load**. Excessive sedimentation (e.g., as a result of increased intermittent flow from altered weather patterns, increased erosion from recreational trail usage, increased development, lack of riparian vegetation) alters and reduces usable fish habitat by increasing the proportion of fine sediment in riffles and filling pools. Fine sediments also have the potential to affect fish forage by either reducing benthic macroinvertebrate densities or altering community characteristics (Scheurer et al. 2009).

CONDITION AND TRENDS ASSESSMENT

METRICS IN DETAIL

The metrics used in this analysis provide a simple means of assessing native species richness and native species relative abundance. Due to data constraints and variations in data collection methods, the metrics have limited applicability and are intended to show general community trends. Streams were combined by watershed because some are not sampled routinely.

Metric 1: Native Fish Species Richness

Rationale: The presence of native fish populations indicates intact fish communities and associated suitable habitat conditions. Non-native fishes indicate disturbed aquatic ecosystems and altered food webs via competition and predation. This metric captures the species richness of native and non-native fishes by measuring the number of species within an area. With this, we can show the presence and persistence of both native and non-native fish species. This count of species presence can indicate intrusion by non-native fishes from reservoirs or the loss of a native fishes from the community. By considering trends over several years, we can look at the persistence of non-native fish, often swept downstream by rain events from reservoirs. These non-native fishes are often found just downstream of reservoir spillways and are not likely to persist in the stream habitats in the long-term.

Condition Goal: Maintain or increase the native fish species richness within a watershed

Current Baselines: Baseline conditions for each of the four watersheds evaluated follow.

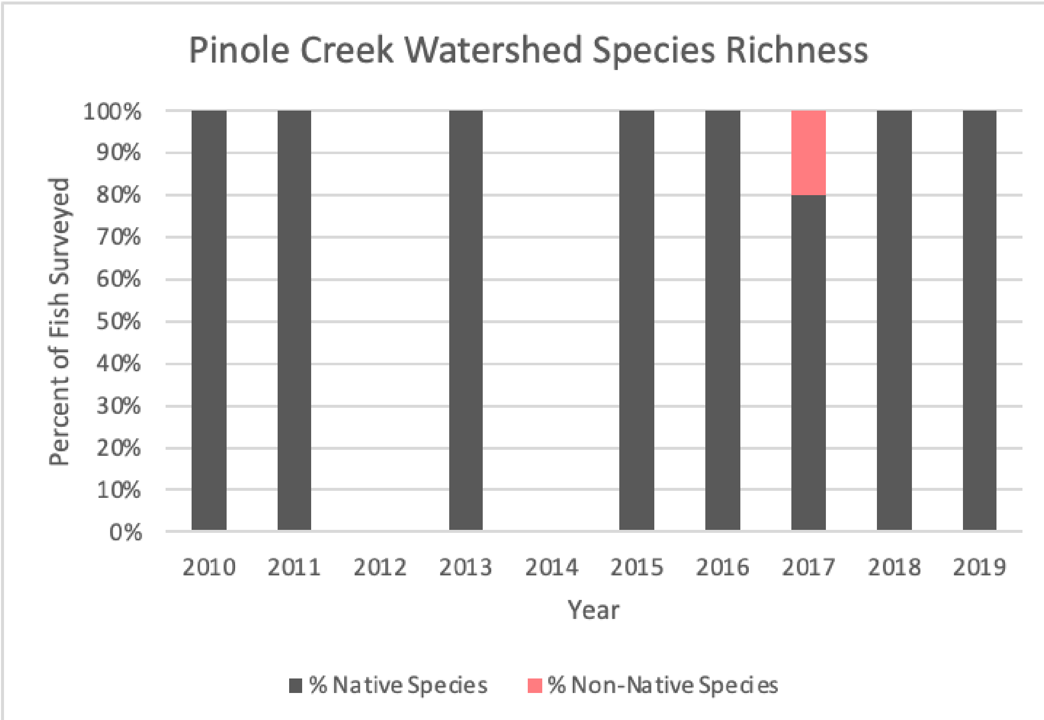


Figure 2.2. Pinole Creek watershed, percent of native and non-native fish species.

Pinole Creek was the only stream surveyed within the Pinole Creek watershed. As shown in Figure 2.2, it was surveyed in eight years of the 10-year period. There were four native fish species and only one non-native fish species, with an individual bluegill collected in 2017. Non-native fish species, which are generally absent from the upper watershed, are mostly found in the lower reaches, particularly downstream of Highway 80. EBMUD fisheries monitoring in Pinole Creek is mainly done in the upper watershed; thus, none of the sites in the lower area were sampled during the study period so we have no way to assess the current state of the lower sections of Pinole Creek.

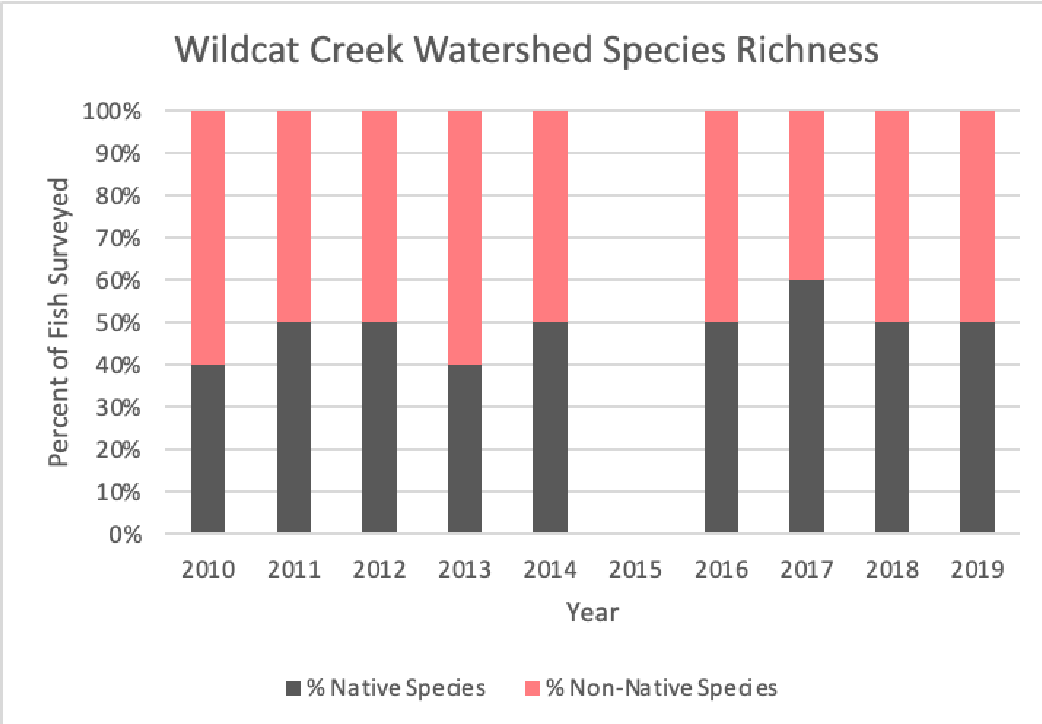


Figure 2.3. Wildcat Creek watershed, percent of native and non-native fish species.

Wildcat Creek was the only stream surveyed within the Wildcat Creek watershed. As shown in Figure 2.3, Wildcat Creek was surveyed nine years during the 10-year period. Three native and three non-native fish species were caught. The three non-native fish species are members of the Centrarchidae family, which had been previously stocked in Jewel Lake and Lake Anza, both man-made reservoirs within the watershed. Jewel Lake dried in 2016 and subsequent years, but populations of sunfish and bass in Lake Anza continue to reproduce, and some of these fish are swept downstream into Wildcat Creek during high-flow events.

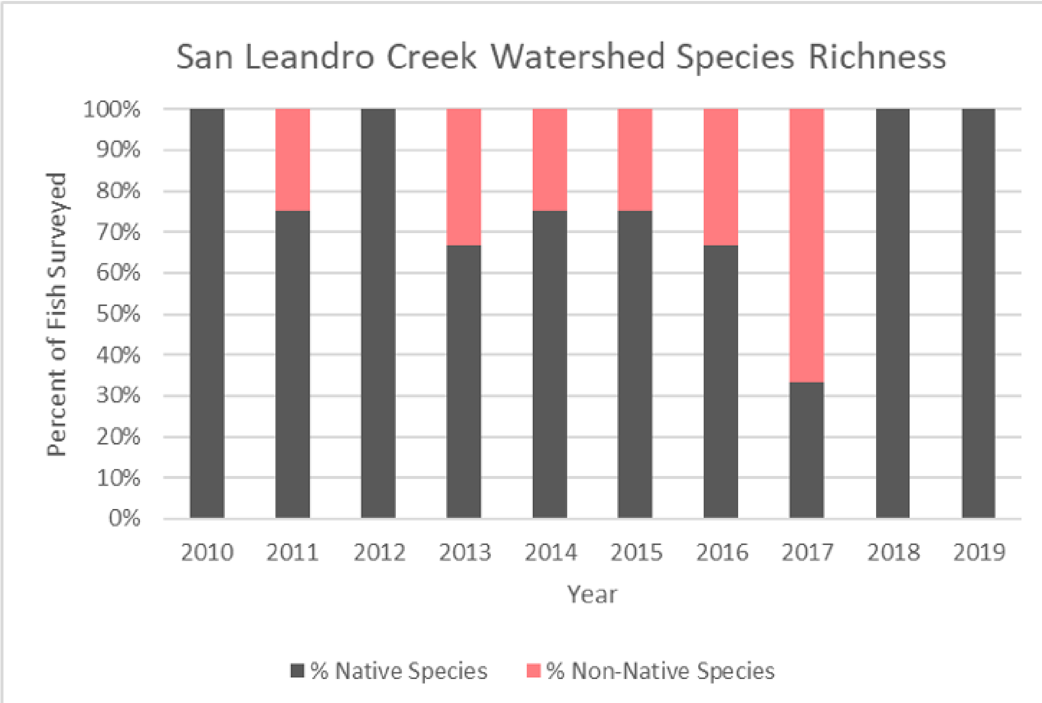


Figure 2.4. San Leandro Creek watershed, percent of native and non-native fish species.

As shown in Figure 2.4, the San Leandro Creek watershed (Kaiser Creek, Moraga Creek, Redwood Creek, Rimer Creek, San Leandro Creek below Lake Chabot, Upper San Leandro Creek) was surveyed every year during the 10-year period. Four native and five non-native fish species were caught in this watershed. All non-native fish species caught in the watershed were collected below Lake Chabot Dam. There are no non-native fishes above Upper San Leandro Reservoir in any of the headwater streams (Kaiser, Moraga, Redwood, Rimer, and Upper San Leandro Creeks).

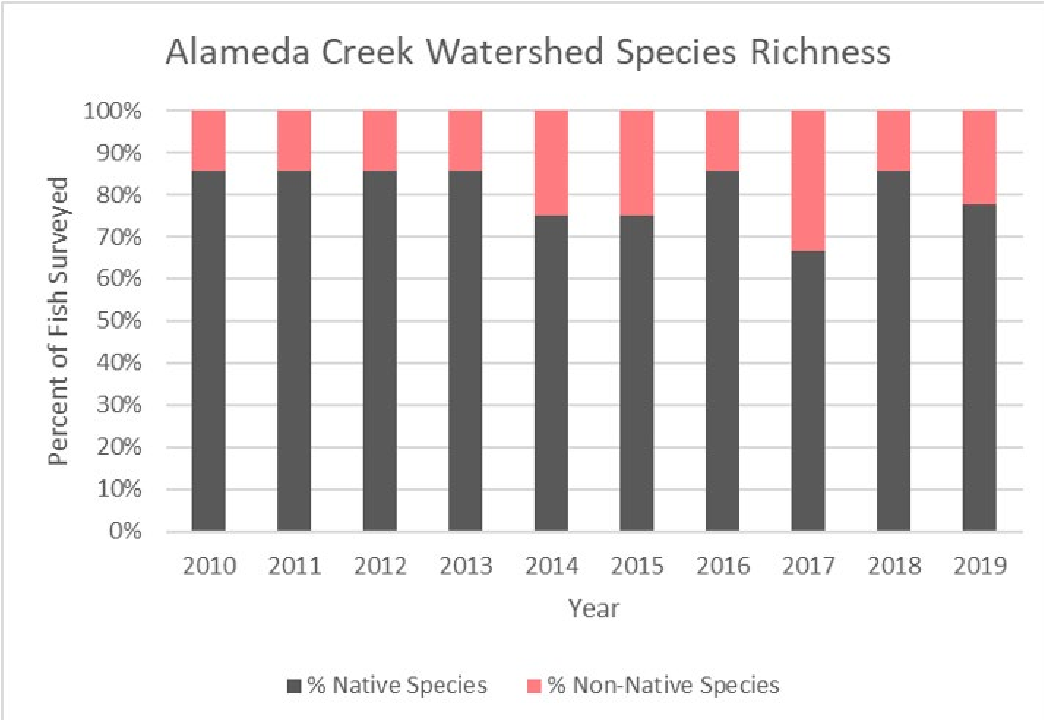


Figure 2.5. Alameda Creek watershed, percent of native and non-native fish species.

The Alameda Creek watershed (Upper Alameda Creek, La Costa Creek, Indian Creek, Arroyo Hondo, Lower Alameda Creek, Lower Calaveras Creek, and Stonybrook Creek) was surveyed during the entire 10-year period. Eight native and four non-native fish species were caught within the watershed (Figure 2.5). Non-native fish species were collected from three of six streams during the 10-year period. All instances of non-native fishes collected in the Alameda Creek watershed over the 10-year period were from Lower Alameda Creek or Calaveras Creek, downstream of Calaveras Reservoir.

Condition Thresholds:

- *Good:* All fish species sampled during stream surveys over a 10-year period are native.
- *Caution:* A combination of native and non-native fish species are sampled over a 10-year period.
- *Significant Concern:* None of the fish species sampled during stream surveys over a 10-year period are native.

Condition:

Caution (Pinole Creek watershed). While generally dominated by natives, a combination of native and non-native fishes was sampled over the 10-year period.

Caution (Wildcat Creek watershed). A combination of native and non-native fishes was sampled over the 10-year period.

Caution (San Leandro Creek watershed). A combination of native and non-native fishes was sampled over the 10-year period in lower San Leandro Creek. Upper watershed creeks are completely dominated by native fish species.

Caution (Alameda Creek watershed). A combination of native and non-native fishes was sampled over the 10-year period.

Trend:

Unchanging (All watersheds). The number of native fish species sampled during stream surveys over the 10-year period did not change.

Confidence:

Low (Pinole Creek watershed). Surveys were not conducted every year of the 10-year period. The maximum number of survey sites (*n*=3) for each year was small compared to other watersheds, and those sites focused on the middle- to upper watershed. Surveys did not capture the status of native or non-native species in the lower watershed.

Moderate (Wildcat Creek watershed). Surveys were conducted nine years of the 10-year period. The maximum number of survey sites (*n*=28) provided additional confidence for this watershed.

Moderate (San Leandro Creek watershed). Surveys were conducted for every year of the 10-year period. Most of the survey sites (*n*=17 of 20) in this watershed are limited to upper watershed streams. Few surveys (*n*=3) are conducted in the lower watershed.

High (Alameda Creek watershed). Surveys were conducted every year of the 10-year period. All surveys (*n*=16) are conducted in upstream areas, with survey sites in headwater streams (La Costa, Indian, and Stonybrook creeks), and in Alameda Creek upstream of its confluence with Calaveras Creek, with largely intact native fish populations.

Metric 2: Native Fish Species Abundance

Rationale: The presence of native fish populations indicates intact fish communities and associated suitable habitat conditions. Non-native fish populations indicate disturbed conditions and disruptions to aquatic ecosystems through competition and predation. This metric captures the relative abundance of native and non-native fishes as measured by the percent composition of a sampled population. We can use relative abundance to show how dominant native species are in a given watershed. Over time, this trend shows the resiliency of the native fish community to drought and non-native fishes.

Condition Goal: Maintain or increase the relative abundance of native fish individuals within a watershed.

Current Baselines: Baseline conditions for each of the four watersheds evaluated follow.

PINOLE CREEK WATERSHED

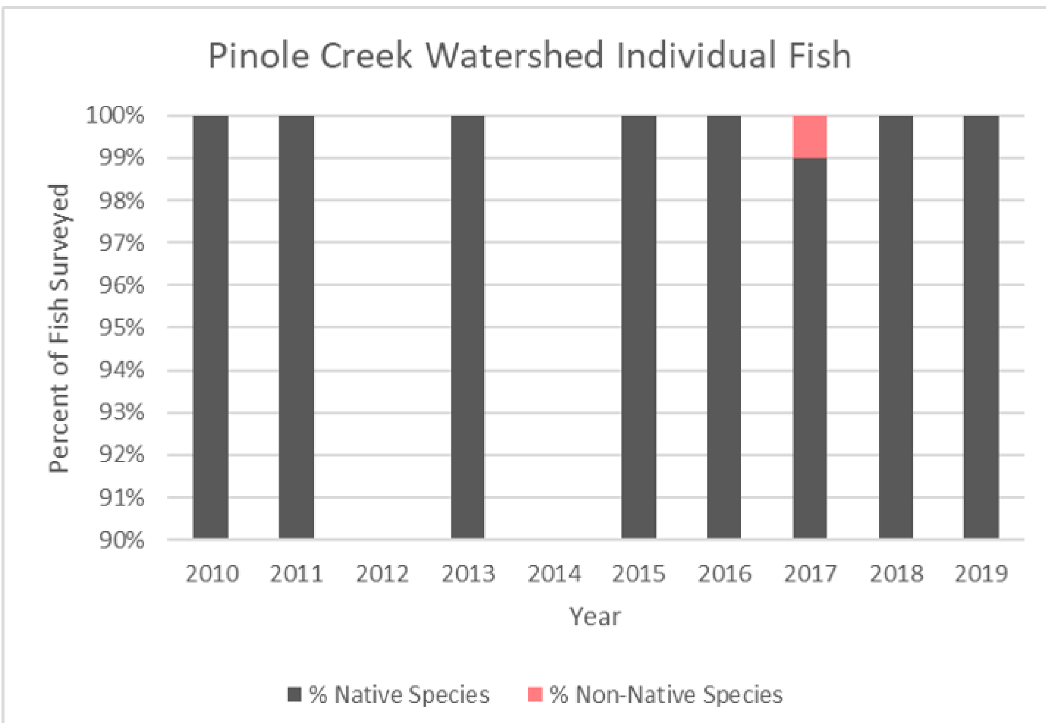


Figure 2.6. Pinole Creek watershed, numbers of individual native and non-native fishes.

As shown in Figure 2.6, individual native and non-native fishes were caught in Pinole Creek. A vast majority of all fishes caught in this watershed are native, with just one non-native bluegill caught in 2017.

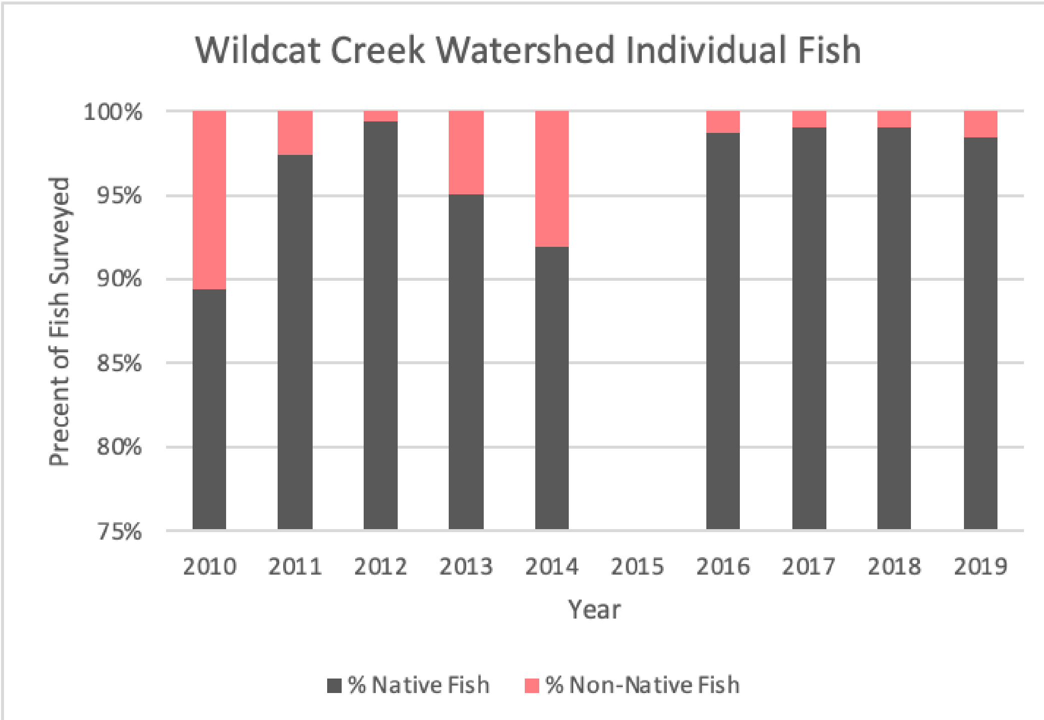


Figure 2.7. Wildcat Creek watershed, numbers of individual native and non-native fishes.

As shown in Figure 2.7, individual native and non-native fishes were caught in Wildcat Creek. The non-native fishes were members of the Centrarchidae family, which had been previously stocked into Jewel Lake and Lake Anza, both man-made reservoirs within the Wildcat Creek watershed. Jewel Lake dried completely in 2016 and has done so in subsequent years as well, but populations of sunfish and bass in Lake Anza continue to reproduce, and some of these fish are swept downstream into Wildcat Creek during high-flow events.

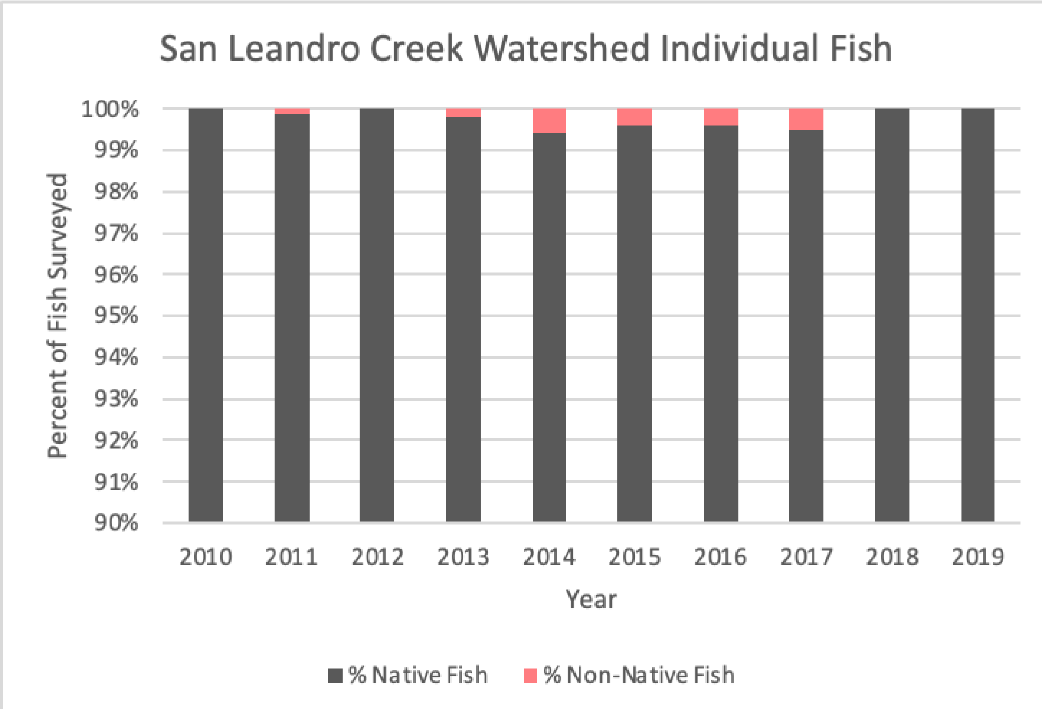


Figure 2.8. San Leandro Creek watershed, numbers of individual native and non-native fishes.

As shown in Figure 2.8, individual native and non-native fishes were caught in the San Leandro Creek watershed. Greater than 99% of all fish collected during the annual surveys were native species. All the non-native fishes caught in the San Leandro Creek watershed were collected below Lake Chabot Dam. There are no non-native fishes above Upper San Leandro Reservoir in any of the headwater streams.

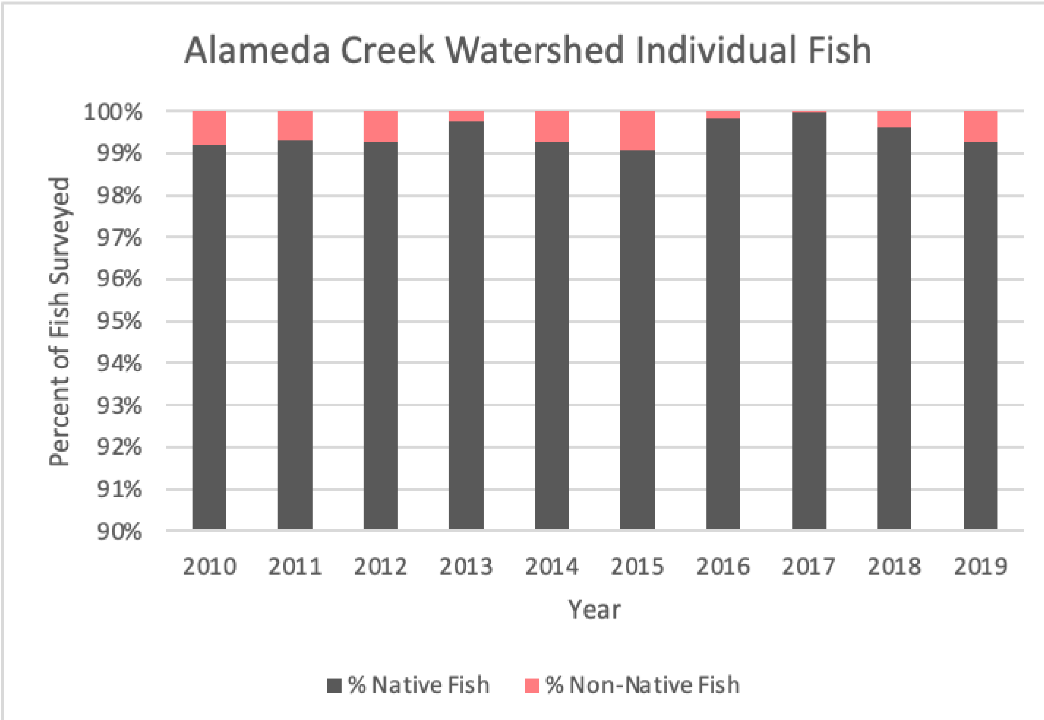


Figure 2.9. Alameda Creek watershed, numbers of individual native and non-native fishes.

The Alameda Creek watershed (Upper Alameda Creek, La Costa Creek, Indian Creek, Arroyo Hondo, Lower Alameda Creek, Lower Calaveras Creek, and Stonybrook Creek) was surveyed during the entire 10-year period. Both native and non-native fishes were caught within the Alameda Creek watershed (Figure 2.9). Greater than 99% of the fishes collected from the Alameda Creek watershed each year were native. Three of six streams surveyed within the watershed had non-native individual fishes during the 10-year period. All instances of non-native fishes collected in the Alameda Creek watershed from 2010 to 2019 were from Lower Alameda Creek or Calaveras Creek, downstream of Calaveras Reservoir.

Condition Thresholds:

- *Good:* The relative abundance of individual non-native fishes has a declining trend and individual non-native fishes are not regularly observed.[3]

[3] For the purposes of this analysis, "not regularly observed" is defined to mean 20% or fewer of the years sampled. This definition was chosen because it addresses transitory conditions, such as when a spill from a reservoir results in observations of non-native fish, but the fish do not persist in the stream.

- *Caution:* The relative abundance of individual non-native fishes does not have an improving or declining trend, with non-native individuals regularly observed.
- *Significant Concern:* The relative abundance of individual non-native fishes has an improving trend, with non-native individuals regularly observed.

Condition:

Good (Pinole Creek watershed). The relative abundance of non-native fish individuals has a declining trend, and non-native fish individuals are not regularly observed. One individual non-native fish was collected in 2017, but subsequent surveys have not detected additional non-native fishes.

Caution (Wildcat Creek watershed). The relative abundance of non-native fish individuals does not have an improving or declining trend.

Caution (San Leandro Creek watershed). The relative abundance of non-native fish individuals does not have an improving or declining trend. Upper watershed creeks are completely dominated by native fish species.

Caution (Alameda Creek watershed). The relative abundance of native fish individuals is high every year, and the ratio of native to non-native fishes does not have an improving or declining trend, but non-native individuals are regularly observed.

Trend:

Unchanging (Pinole Creek, Wildcat Creek, and San Leandro Creek watersheds). The number of native fishes sampled during stream surveys over the 10-year period did not change.

Unchanging (Alameda Creek watershed). The ratio of native to non-native fish individuals sampled during stream surveys over the 10-year period did not change.

Confidence:

Low (Pinole Creek watershed). Surveys were not conducted every year of the 10-year period. The maximum number of survey sites (n=3) for each year was small compared to other watersheds, and those sites focused on the middle to upper watershed. Surveys did not capture the status of native or non-native species in the lower watershed.

Moderate (Wildcat Creek watershed). Surveys were conducted every year of the 10-year period, but the number of sites surveyed fluctuated (Low n=17; High n=28), and the numbers of native fishes decreased during drought years.

Moderate (San Leandro Creek watershed). Surveys were conducted every year of the 10-year period, but the number of sites surveyed fluctuated (Low n=9; High n=20), and the numbers of native fish decreased during drought years.

High (Alameda Creek watershed). Surveys were conducted every year of the 10-year period, but the number of survey sites fluctuated (Low n=6; High n=16), and the number of native fishes decreased during drought years. However, the watershed-wide sampling effort remained robust enough to support an overall high level of confidence.

Condition, Trend, and Confidence Discussion by Watershed

See Table 2.1 for a summary of the condition, trend, and confidence findings for both of the above metrics.

PINOLE CREEK WATERSHED

The Pinole Creek watershed has been assigned an overall condition of **caution**. During surveys over the 10-year period, a combination of native and non-native fish species were collected from Pinole Creek (Metric 1, caution), but non-native fish individuals were not regularly observed (Metric 2, good). Pinole Creek was surveyed eight years during the 2010–2019 period. Of the hundreds of fish sampled in Pinole Creek during those surveys, only one non-native bluegill was collected in 2017. All fish collected during all other surveys were native.

An overall trend of **unchanging** has been assigned to the watershed. From 2010 to 2019, the species of fish surveyed (Metric 1, unchanging), and the numbers of individuals of each species (Metric 2, unchanging) surveyed remained consistent. The sole non-native fish species was collected in 2017. Because non-native fishes were not collected in subsequent years, we are confident that populations of non-native fishes have not established in the middle and upper Pinole Creek watershed.

An overall confidence score of **low** has been assigned to this watershed. It was not surveyed every year of the 2010–2019 period, and only sites in the middle and upper watershed were sampled. Because the Pinole Creek watershed has the fewest survey sites, the survey sites are all located in the middle and upper watershed, and the surveys were not conducted every year, there may be changes in trends in population and species presence that we were unable to detect.

WILDCAT CREEK WATERSHED

The Wildcat Creek watershed has been assigned an overall condition of **caution**. During surveys over the 10-year period, a combination of native and non-native fish species were collected from Wildcat Creek (Metric 1, caution), and a combination of native and non-native fish individuals were collected (Metric 2, caution). Wildcat Creek was surveyed nine years during the 2010–2019 period. Of the thousands of fish sampled, roughly a tenth of the total number were non-native, and a quarter of the total number of fish species collected were non-native.

An overall trend of **unchanging** has been assigned to the watershed. From 2010 to 2019, the species of fish surveyed (Metric 1, unchanging), and the proportion of native and non-native individuals surveyed (Metric 2, unchanging) remained constant. There are two man-made reservoirs within Wildcat Creek watershed, Jewel Lake and Lake Anza. Both reservoirs host reproducing populations of non-native Centrarchidae. These non-native sunfish are often surveyed in sites downstream of spillways associated with each reservoir. We currently do not believe these populations are successfully reproducing within the streams.

An overall confidence score of **moderate** has been assigned to this watershed. The watershed was surveyed each year during the 2010–2019 period. However, during drought conditions, the number of sites surveyed varied, which results in less confidence overall.

SAN LEANDRO CREEK WATERSHED

The San Leandro Creek watershed has been assigned an overall condition of **caution**. A combination of native and non-native fish species were collected over the 10-year survey period (Metric 1, caution), and a combination of native and non-native fish individuals were collected (Metric 2, caution) in the lower watershed. The watershed was surveyed every year during the 2010–2019 period. Of the thousands of fish sampled in the watershed, less than 1% were non-native, and 90% of all species collected were native. The fish populations in the upper watershed's creeks are completely native.

An overall trend of **unchanging** has been assigned to the watershed. From 2010 to 2019, the species of fish surveyed (Metric 1, unchanging), and the numbers of each species surveyed (Metric 2, unchanging) remained constant. Two reservoirs within the San Leandro Creek watershed—Upper San Leandro Reservoir and Lake Chabot—host reproducing populations of non-native Centrarchids and Cyprinids. These non-native fishes are surveyed in sites just downstream from Lake Chabot Dam. We currently do not believe that these populations persist within the stream.

An overall confidence score of **moderate** has been assigned to this watershed. It was surveyed each year of the 2010–2019 period. However, during drought conditions, the number of sites surveyed varied, which results in less confidence overall.

ALAMEDA CREEK WATERSHED

The Alameda Creek watershed is assigned an overall condition of **caution** (Metric 1, caution; Metric 2 caution). Watershed streams were surveyed every year during the 2010–2019 period. Over those 10 years, a combination of native and non-native fishes were collected during each year. Of the thousands of fish sampled over the period, greater than 75% were native species, while non-natives made up less than 1% of the individual fish.

An overall trend of **unchanging** has been assigned to the watershed (Metric 1, unchanging; Metric 2, unchanging). From 2010 to 2019, the ratio of native to non-native fishes, both in terms of the number of species and number of individuals, remained relatively constant. Calaveras and San Antonio Reservoirs support reproducing populations of Centrarchids and other non-native species. Non-native fishes are also found in the vicinity of Alameda Creek's confluence with Arroyo de la Laguna at the downstream end of Upper Alameda Creek. These non-natives, especially bass and sunfishes, are found in portions of the watershed from below the reservoirs down to San Francisco Bay.

An overall confidence score of **high** has been assigned to the Alameda Creek watershed. Streams were surveyed during each year of the 2010–2019 period. During drought years, when upper watershed stream reaches were reduced to relatively small, isolated pools, the total number of sites surveyed decreased. The watershed-wide sampling effort, however, remained robust enough to support an overall high level of confidence.

OTHER METRICS CONSIDERED BUT NOT INCLUDED

- Several metrics, including growth rate and condition-factor calculations, parasite presence/absence, and stream health and condition were considered, but the lack of consistent, complete datasets for native fishes for all watersheds and for all years prevented us from being able to analyze these metrics.
- We also considered separating watersheds by cold- versus warm-water reaches, to show that non-native fishes are typically found in lower, warmer-water parts of the watersheds, but a lack of survey data for these areas prevented this approach.

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

- Fish survey data is not available for all primary and secondary streams within the area of focus.
- Only portions of stream reaches were surveyed, so fish community variability for an overall reach or stream may not be suitably captured.
- Age and growth, weight, and parasite data for native species are only available for steelhead (rainbow) trout (*Oncorhynchus mykiss*).

- Stream habitat quality data of sufficient detail to document stream health and condition are lacking.
- Data for warm- and cold-water reaches or streams are not evaluated independently.

PAST AND CURRENT MANAGEMENT

Some partner agencies conduct annual native fish population monitoring by doing stream electrofishing surveys (EBRPD, EBMUD, SFPUC). EBMUD participated in the Pinole Creek Fish Passage Improvement Project, which included the removal of a migration barrier under Interstate 80, which now allows steelhead access to upstream areas under most flow conditions. This project has also likely increased mobility for other native fish species in the lower watershed. Projects in Alameda Creek watershed are underway (or have been completed) to restore complete volitional anadromy to some of the watershed's upper reaches.

POTENTIAL FUTURE ACTIONS

- Coordinate among Network partner agencies on data collection and use methods.
- Network partner agencies to continue to work together to coordinate and share data.
- Identify opportunities for enhancing fish-bearing stream habitat and the removal of fish barriers.

KEY LITERATURE AND DATA SOURCES

Literature

Bunnell, J. F., and Zampella, R. A. (2008). Native fish and anuran assemblages differ between impoundments with and without non-native Centrarchids and bullfrogs. *Copeia, 2008*(4), 931–939.

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Leidy, R. A., and Fiedler, P. L. (1985). Human disturbance and patterns of fish species diversity in the San Francisco Bay drainage, California. *Biological Conservation*, *33*(3), 247–267.

Scheurer, K., Alewell, C., Bänninger, D., and Burkhardt-Holm, P. (2009). Climate and land-use changes affecting river sediment and brown trout in alpine countries: A review. *Conservation Biology*, *16*, 232–242.

Partner Agency Data Sources

- East Bay Regional Park District (EBPRD): Backpack electrofishing surveys for Wildcat Creek, 2010–2019; Redwood Creek, 2010–2019; Stonybrook Creek, 2017–2019; Upper San Leandro Creek, 2012–2019.
- East Bay Municipal Utility District (EBMUD): Backpack electrofishing surveys for Kaiser Creek, 2013–2019; Moraga Creek, 2016–2018; Pinole Creek, 2010–2019; Redwood Creek, 2016–2018; Rimer Creek, 2018; San Leandro Creek 2010-2019.
- San Francisco Public Utilities Commission (SFPUC): Backpack electrofishing for Alameda Creek, 2010–2019; Arroyo Hondo, 2010–2015; Calaveras Creek, 2011–2019; Indian Creek, 2010–2013; La Costa Creek, 2010–2014.

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The following people attended the East Bay ecological health assessment expert workshops or were otherwise consulted on this project. It should be noted that this document does not necessarily reflect the opinions or incorporate the suggestions of these participants.

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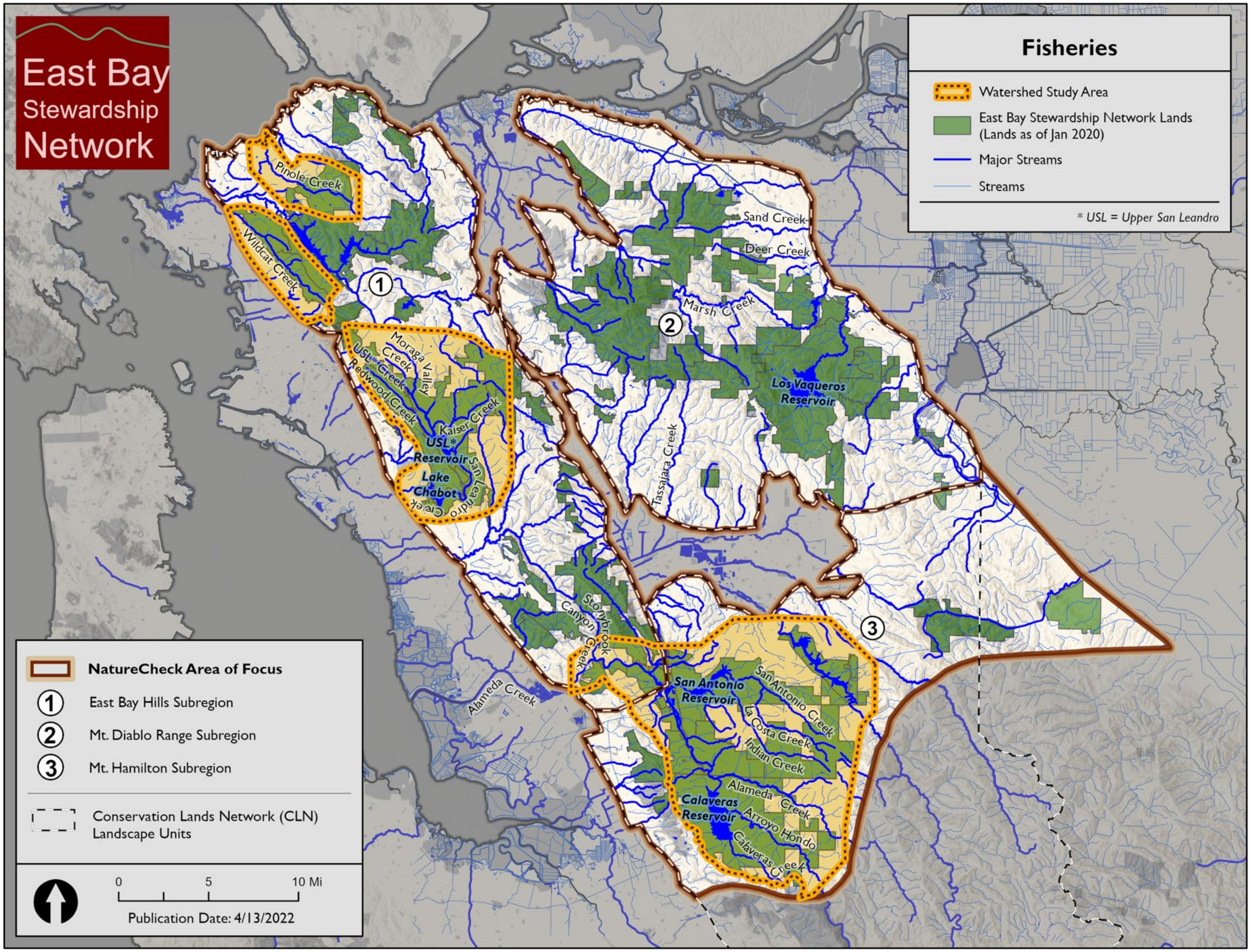

Figure 2.1. Watersheds surveyed by Network partner agencies within the area of focus.

CHAPTER 3. RAINBOW TROUT/STEELHEAD (*ONCORHYNCHUS MYKISS*)

EXECUTIVE SUMMARY

This chapter presents the results of an evaluation of the current condition and trend of steelhead and rainbow trout (*Oncorhynchus mykiss*) on lands owned and managed by East Bay Stewardship Network (Network) partner agencies within the area of focus for this NatureCheck project. (See map, Chapter 1.) The evaluation includes watersheds in the East Bay Hills and Mt. Hamilton subregions. Watersheds in the Mt. Diablo Range subregion are not included because Network partner agencies do not conduct fish surveys there. While steelhead and rainbow trout are the same species, and both spawn in freshwater, the offspring of steelhead migrate to sea to grow, while rainbow trout spend their entire lives in freshwater.[4] It should be noted, however, that steelhead offspring can take on life-history traits of resident rainbow trout, and vice versa.

Stream channelization, impoundments, diversions, and other in-channel barriers have dramatically altered the hydrology and fish habitats of watercourses on Network partner agency lands. This chapter evaluates the desired condition of the *O. mykiss* populations in the context of current realities rather than using historical conditions as a goal or baseline.

A primary goal of the analyses presented in this chapter is to provide a benchmark against which managers can measure future changes and understand the likely *O. mykiss* trajectories within East Bay watersheds in the area of focus. The baseline data and analyses we developed here can also be used to identify restoration projects or management actions that have the potential to achieve multiple benefits.

The evaluation, which only uses available data, also identifies areas where not enough is known to draw meaningful conclusions. Opportunities for future research and collaboration between land managers are also presented.

The following two metrics were used in the evaluation:

1) **Metric 1: Self-Sustaining *O. mykiss* Population**. Percent of years that surveyed streams within each watershed supported at least three *O. mykiss* age classes. The baseline for this metric was set using data from 2010–2019.

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[4] Henceforth, the name "*O. mykiss*" is used unless a distinction between steelhead (i.e., anadromous) or rainbow trout (i.e., freshwater only) is required.

2) **Metric 2: Steelhead Passage and/or Adfluvial *O. mykiss* Population.** Adult steelhead ability to volitionally[5] move upstream from San Francisco Bay to reach suitable spawning and rearing habitat, and/or an adfluvial *O. mykiss* population exists.

Surveyed streams are grouped by watershed (Pinole Creek, Wildcat Creek, San Leandro Creek, and Alameda Creek; Figure 3.1 at the end of this chapter), and the condition and trend of associated *O. mykiss* populations are evaluated at the watershed level. The amount of certainty with which the conditions and trends are accurately assessed is also identified**.**

The primary findings of our evaluation include the following:

Pinole Creek watershed: An overall condition of **caution** is assigned to this watershed. However, confidence in the conclusion is low because, despite the fact that we did not document three age classes during any of the survey years, Pinole Creek supports steelhead anadromy and evidence suggests that it also supports a self-sustaining *O. mykiss* population. Survey constraints or other factors may have contributed to three age classes not being documented despite possibly being present.

Wildcat Creek watershed: An overall condition of **significant concern** is assigned to this watershed. Three age classes were present in all years Wildcat Creek was surveyed. However, given concerns about droughts of increasing frequency and/or severity, that drought extirpated this population in the 1970s, and that it is isolated (i.e., no anadromous or adfluvial fish), there is significant concern about its condition.

San Leandro Creek watershed: An overall condition of **good** is assigned to this watershed. Its *O. mykiss* population includes adfluvial fish in its upper reaches and possible anadromy in the lower. Years in which fewer than three age classes were present corresponded with drought conditions (2014–2015).[6] Following this period, three or more age classes were found to be present again, indicating that the population was resilient enough to remain self-sustaining through a drought of that magnitude.

Alameda Creek watershed: An overall condition of **good** is assigned to this watershed. The *O. mykiss* populations here include resident and adfluvial fish in the upper watershed. Projects have been completed, or are underway, to restore volitional steelhead anadromy to some spawning and rearing

[5] "Volitional" means there are no barriers to movement and anadromous fish can migrate when they are physiologically ready (as opposed to being trapped and hauled around a barrier).

[6] The full drought period extended from 2012-2017; 2014-2016 were peak drought years, categorized as exceptional drought (https://www.drought.gov/states/california).

habitats within upper Alameda Creek and its tributaries. Years in which fewer than three age classes were observed during fall electrofishing surveys corresponded to certain drought years, subsequent post-drought conditions, and related decreased survey efforts (2015–2017). It should also be noted that from 2015 to 2017, three or more age classes were observed during summer snorkel surveys. Following this period, three or more age classes were again found to be present during fall electrofishing surveys, indicating that the populations were resilient enough to remain self-sustaining through the drought.

METRICS SUMMARY AT A GLANCE

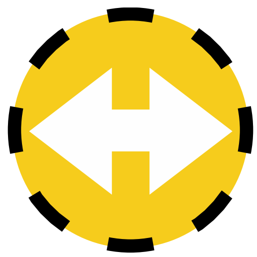
Table 3.1 summarizes the two metrics for *O. mykiss* used in this ecological health assessment. Each metric, along with how we arrived at its condition, trend, and confidence, is thoroughly described in the Metrics in Detail section later in this chapter. (See Chapter 1 for definitions and thresholds for condition, trend, and confidence; other terminology used throughout this chapter; how metrics are being used for each indicator; and other project methodology.)

*Table 3.1. All steelhead and rainbow trout metrics, with their respective condition, trend, and confidence. Each metric is described in the Metrics in Detail section later in this chapter. In addition to the average of the two metrics, overall scores may include decisions based on professional scientific judgment. These are noted with an * in the table below, and our reasoning is explained in the Condition, Trend, and Confidence Discussion by Watershed section later in this document.*

	Pinole Creek Watershed	Wildcat Creek Watershed	San Leandro Creek Watershed	Alameda Creek Watershed
Metric 1: Self-Sustaining Population–Percent of years that surveyed streams within each watershed supported at least three *O. mykiss* age classes. The baseline for this metric was set using data from 2010–2019.				
Condition	Significant Concern	Good	Caution	Good
Trend	Unknown	Unchanging	Unchanging	Unchanging
Confidence	Low	Moderate	Moderate	High
Metric 2: Steelhead and/or Adfluvial *O. mykiss*–Adult steelhead can volitionally move upstream from San Francisco Bay to reach suitable spawning and rearing habitat, and/or an adfluvial *O. mykiss* population exists.				
Condition	Good	Significant Concern	Good	Good
Trend	Unchanging	Unchanging	Unchanging	Improving
Confidence	High	High	High	High
Overall Score (based on combining and averaging Metric 1 and Metric 2, and in some cases, also using professional judgment).				
Overall Condition	Caution	Significant Concern*	Good*	Good
Overall Trend	Unknown*	Unchanging	Unchanging	Improving*
Overall Confidence	Low*	Moderate	Moderate	High

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of *O. mykiss* in the area of focus represented by the graphic below is based on the combined values of the individual metrics presented in Table 3.1. Each of these metrics is described in depth in the Metrics in Detail section later in this chapter.



Condition: Caution (color: yellow)

Trend: Unchanging (symbol: horizontal arrow)

Confidence: Moderate (line around circle: dashed)

BACKGROUND

WHY IS THIS RESOURCE INCLUDED?

The steelhead/rainbow trout is an iconic and charismatic native fish species found in Northern California's coastal areas, making it a compelling tool for public engagement and environmental education. The Central California Coast Steelhead, which is found in the area of focus, is federally listed as threatened. Resident rainbow trout are not state or federally protected, but maintaining and enhancing their populations are natural resource management priorities because of the species' current limited distribution and their important ecological functions. In addition, resident populations are adapted to local conditions and may provide important sources for re-establishing populations in other local streams as they are restored. The East Bay Regional Park District (EBRPD), East Bay Municipal Utility District (EBMUD), and San Francisco Public Utilities Commission (SFPUC) are the only Network partner agencies that have self-sustaining *O. mykiss* populations in their watersheds. These agencies conduct regular fisheries surveys to document and track population trends and to provide data to assist in evaluating the health and management of this and other species.

O. mykiss are ideal stream health indicators because they require a variety of habitat conditions to thrive, including cold waters with adequate dissolved oxygen concentrations, riffles with suitable spawning substrates, rearing habitat (perennial, shaded flatwater), and habitat-enhancing features that provide structure and cover. They also play an important role in the food chain, both as predators for a variety of invertebrates and small fishes and as food sources for numerous mammal and bird species (as well as other fishes). The presence of adult steelhead indicates that streams are free of complete migration barriers, providing opportunities for gene transfer between anadromous and resident populations and for repopulation of the species after local extirpation events. Adfluvial *O. mykiss*—with spawning adults producing juveniles that rear in reservoir tributary streams before returning to these larger bodies of water to feed as subadults and adults—allow the species to retain some steelhead life-history traits in the absence of ocean access.

DESIRED CONDITION AND TREND

The desired condition of this indicator is to maintain or increase the number of streams managed by Network partner agencies that support self-sustaining *O. mykiss* populations, and for these populations to be resilient over time (i.e., an unchanging or improving trend would indicate that they are able to persist through and recover after periods of stress, such as drought and climate change).

CURRENT CONDITION AND TREND

Condition: Caution

Trend: Unchanging

Confidence: Moderate

Oncorhynchus mykiss were historically present in all three area of focus subregions (Figure 3.1 at the end of this chapter).[7] Although the aquatic landscape in the area of focus has changed dramatically, including reservoir and diversion construction, urbanization, and habitat loss, streams here continue to support *O. mykiss* populations. Currently, this species is only present on lands managed by Network partner agencies in the East Bay Hills and Mt. Hamilton subregions. As of 2021, Pinole Creek is the only stream on Network partner agency lands that supports complete volitional steelhead anadromy. However, projects in Alameda Creek (primarily in the Mt. Hamilton subregion) to restore anadromy to some of the watershed's upper reaches are in various stages of completion, and several have been finished. San Leandro Creek may support anadromy in its lowest reach from San Leandro Bay to Lake Chabot Dam. There are no major barriers in the lower reach, but anadromy has not yet been documented. Resident rainbow trout populations occur in multiple streams within the area of

[7] The area of focus includes three subregions: East Bay Hills, Mt. Diablo Range, and Mt. Hamilton.

focus, with some supported by fish exhibiting adfluvial life histories due to dams and their associated reservoirs.

Given that *O. mykiss* have the ability to move between connected streams and their tributaries and use a variety of habitats for different life stages, surveyed streams were grouped and their condition evaluated at the watershed level (Table 3.2, Figure 3.1). Pinole Creek, Wildcat Creek, and San Leandro Creek watersheds are located entirely within the East Bay Hills subregion. The majority of the Alameda Creek watershed is located within the Mt. Hamilton subregion, with the portion downstream (west) of Highway 680 within the East Bay Hills subregion.

Table 3.2. Surveyed streams within each watershed included in this ecological health assessment.

Watershed Name	Surveyed Streams
Pinole Creek	Pinole Creek
Wildcat Creek	Wildcat Creek
San Leandro Creek	San Leandro Creek Redwood Creek Kaiser Creek Moraga Creek Rimer Creek
Alameda Creek	Upper Alameda Creek La Costa Creek Indian Creek Arroyo Hondo Lower Alameda Creek Lower Calaveras Creek Stonybrook Creek

The current condition, trend, and confidence is the average of the condition, trend, and confidence for *O. mykiss* in each watershed as shown in Table 3.3. As appropriate, best professional judgment was also used.[8] The metrics described in depth in the Metrics in Detail section of this chapter were combined to determine this current condition and trend. These metrics give us a way to measure the difference between what is described in this section (i.e., how things are now) and the desired condition and trend in the preceding section (i.e., what we think "healthy" is for this indicator).

[8] For example, based on the condition scores for Metric 1 and Metric 2, San Leandro Creek watershed had an overall condition score that fell between **good** and **caution**. However, for reasons discussed later in this chapter and based on professional judgment, an overall condition score of **good** was given to the watershed.

Table 3.3. Overall condition, trend, and confidence for steelhead and rainbow trout in each watershed in the area of focus. See the Condition, Trend, and Confidence Discussion by Watershed section later in this chapter for details.

	Pinole Creek Watershed	Wildcat Creek Watershed	San Leandro Creek Watershed	Alameda Creek Watershed
Overall Condition	Caution	Significant Concern	Good	Good
Overall Trend	Unknown	Unchanging	Unchanging	Improving
Overall Confidence	Low	Moderate	Moderate	High

STRESSORS

Several ecological and anthropogenic factors affect the health of this indicator. These include:

Invasive Species Impacts: The presence of non-native wildlife (i.e., American bullfrogs [*Lithobates catesbeianus*], Centrarchids [sunfish and bass species]) can prey upon native fish and can lead to a loss of native fish biodiversity if they outcompete native species (Bunnell and Zampella 2008).

Climate Change: Climate change is altering hydrologic conditions, changing water temperatures, decreasing water quality, lowering dissolved oxygen levels, increasing the frequency of droughts, and causing more dramatic or unseasonable rain events (when they do occur). Periods of drought can also reduce spawning and rearing habitat, lessen habitat connectivity and in-stream mobility, and decrease food resources.

Disease: The types of *O. mykiss* surveys conducted in the area of focus are not designed to detect or monitor diseases. However, we know climate change makes fish populations more susceptible to bacterial, viral, and fungal infections (Chiaramonte et al. 2016).

Pollution/Contaminants: Toxic substances from spills or runoff can enter streams and reservoirs directly or through storm drains, resulting in direct harm to aquatic species and their habitat. Mercury from old mines, which continues to seep into water bodies, bioaccumulates up the food chain. Longer-living or predatory fishes can contain elevated levels of mercury, which can be harmful to humans or wildlife when consumed in high amounts.

Direct Human Impacts: People, dogs, or cattle entering a stream can cause the direct loss of spawning habitat and redds (nests), harm fish, and change both stream and adjacent riparian habitat. The loss of riparian cover can increase water temperature, evaporation rates, and stream turbidity. Although much of the stream habitat in the area of focus is within open space managed and protected by Network partner agencies, upstream private parcels and downstream areas could experience heavy fishing pressure. Illegal poaching can also occur on Network partner agency lands.

Habitat Disturbance/Conversion/Loss: Although much of the stream habitat in the area of focus is within open space managed and protected by Network partner agencies, many downstream areas have been heavily modified (e.g., channelized streams, passage barriers), lack riparian vegetation, and are subject to urban runoff.

Other Stressors:

- Passage impediments/barriers. The presence of adult steelhead indicates that streams are free of complete migration barriers and provide some opportunity for gene transfer between anadromous and resident *O. mykiss* populations and potential for repopulation after local extirpation events. The absence of anadromy, or the inability of resident fish to move, makes *O. mykiss* populations more vulnerable to extirpation as populations become isolated and lack a source for repopulation and gene transfer.

- Sedimentation/excess sediment load: Excessive sedimentation (e.g., as a result of increased intermittent flow patterns from altered weather patterns, increased erosion from recreational trail usage, increased development, lack of riparian vegetation) alters and reduces usable fish habitat by increasing the proportion of fine sediment in riffles and filling pools. Fine sediments also have the potential to impact fish forage by either reducing benthic macroinvertebrate densities or altering community characteristics (Scheurer et al. 2009).

CONDITION AND TRENDS ASSESSMENT

METRICS IN DETAIL

The metrics used in this analysis provide a simple means of assessing *O. mykiss* populations and determining whether they are self-sustaining by demonstrating that fish are reproducing and offspring are surviving over multiple years. This analysis also examines the resiliency of *O. mykiss* populations in terms of the benefits provided by anadromous and/or adfluvial fish. Other metrics were considered (see additional details later in this chapter), but were excluded from the analysis due to data constraints.

Metric 1: Self-Sustaining *O. mykiss* Population

Rationale: The presence of three or more *O. mykiss* age classes demonstrates that populations are reproducing and fish are surviving over multiple years, resulting in self-sustaining populations. The metric is evaluated by determining the percent of years during the 10-year period (2010–2019) that surveyed streams in each watershed supported at least three age classes. When survey data were not available for each of the 10 years, the calculation was made using data from the years surveys were conducted.

The self-sustaining *O. mykiss* metric is based on assumptions that were not verified as part of the analysis. The analysis timeframe is assumed to cover multiple *O. mykiss* generations and a variety of water-year types,[9] sampling is assumed to be spatially and temporally adequate to detect all age classes when they are present, and fish age determinations are assumed to be accurate. Where these assumptions may have been violated is discussed in specific watershed sections that follow.

Condition Goal: Maintain or increase the number of streams and watersheds that support self-sustaining *O. mykiss* populations.

Current Baseline: Baseline conditions (i.e., the number of age classes present each survey year) for each of the four watersheds evaluated follow.[10]

[9] A water-year is a period of 12 months for which precipitation totals are measured. Water-year types describe the relative amount of precipitation and generally include very wet, wet, average, dry, and very dry.

[10] Age classes were established based on an analysis of fish scales collected during electrofishing monitoring and trapping, and by using associated data to determine the von Bertalanffy Growth Curve and associated regression equation for each watershed.

PINOLE CREEK WATERSHED

The only stream surveyed within the Pinole Creek watershed is Pinole Creek. As shown in Figure 3.2, Pinole Creek was surveyed in six years of the 10-year monitoring period, and fish two years or older, or more than two age classes, were not detected during any survey year.[11]

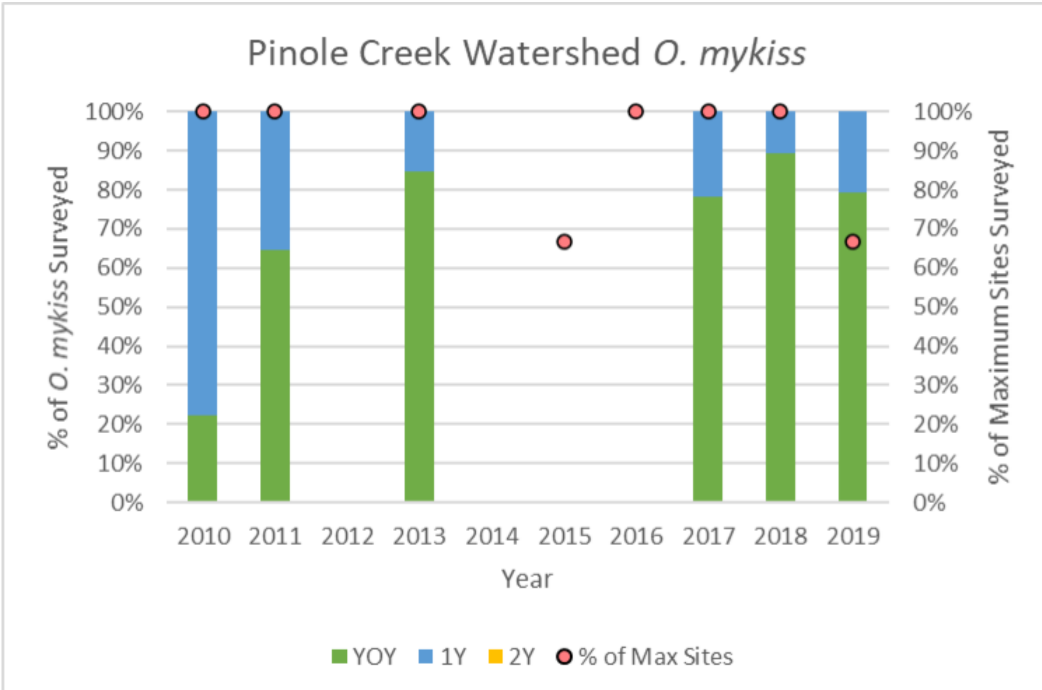


Figure 3.2. Pinole Creek watershed, age classes detected and relative survey effort.

Abbreviations: YoY = young of the year (under one year old), 1Y = one-year-old fish, 2Y = two-year-old fish

[11] As shown in Figure 3.2, surveys were conducted in 2015 and 2016 but no *O. mykiss* were found. Pinole Creek only includes three survey sites; two were surveyed in 2015 and three were surveyed in 2016. This level of effort is not sufficient to determine absence of *O. mykiss* in the stream during those two years. Therefore, it should not be inferred that the species was not present in the stream in 2015 and 2016, but rather, that the species was not found at the sampled sites.

WILDCAT CREEK WATERSHED

The only stream surveyed within the Wildcat Creek watershed is Wildcat Creek. As shown in Figure 3.3, Wildcat Creek was surveyed in nine years of the 10-year monitoring period, and three age classes were present during all survey years.

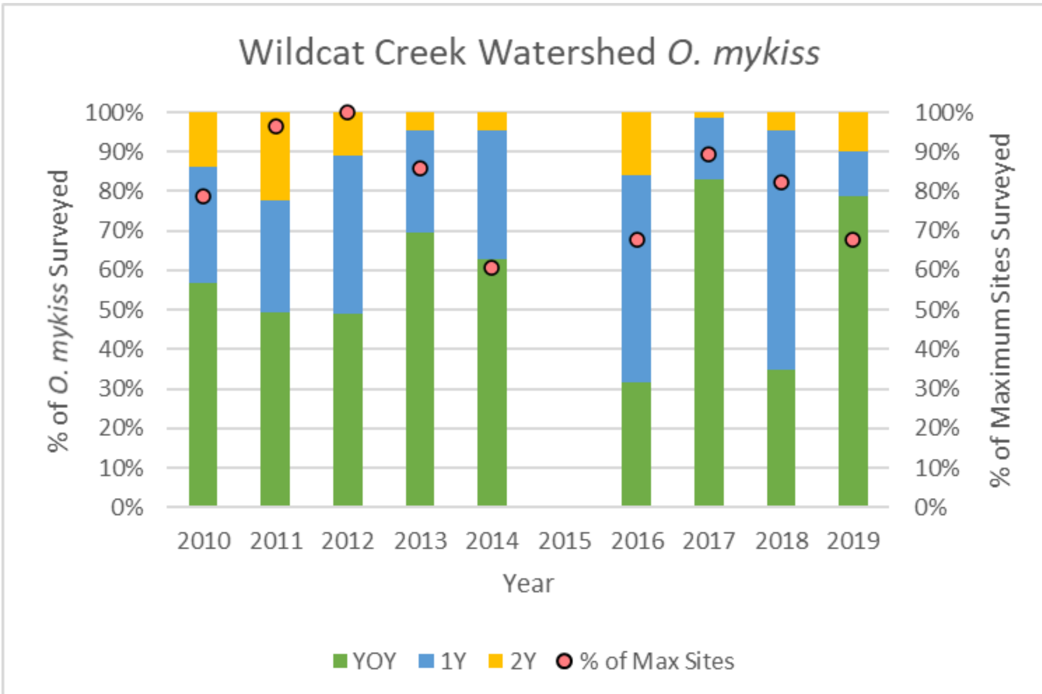


Figure 3.3. Wildcat Creek watershed, age classes detected and relative survey effort.

Abbreviations: YoY = young of the year (under one year old), 1Y = one-year-old fish, 2Y = two-year-old fish

SAN LEANDRO CREEK WATERSHED

The San Leandro Creek watershed (Kaiser Creek, Moraga Creek, Redwood Creek, Rimer Creek, San Leandro Creek below Lake Chabot, Upper San Leandro Creek) was surveyed in all 10 years of the monitoring period, and three age classes were present during eight of those 10 years (Figure 3.4). The years in which fewer than three age classes were present (2014–2015) correspond with drought years and a resulting lower survey effort.

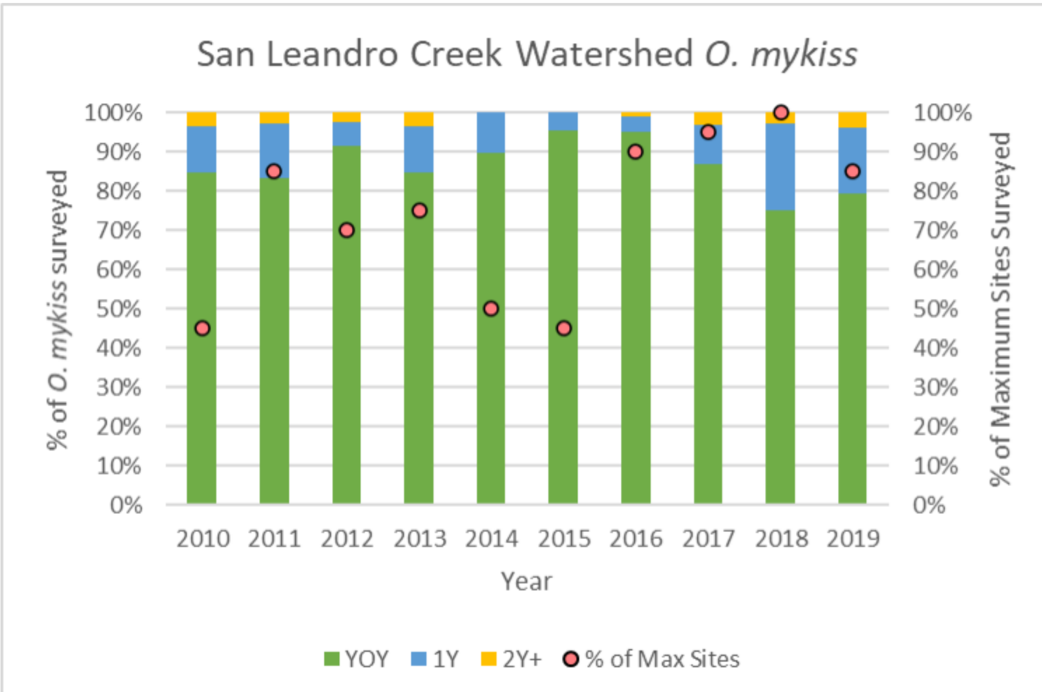


Figure 3.4. San Leandro Creek watershed, age classes detected and relative survey effort.

Abbreviations: YoY = young of the year (under one year old), 1Y = one-year-old fish, 2Y = two-year-old fish

ALAMEDA CREEK WATERSHED

The Alameda Creek watershed (Upper Alameda Creek, La Costa Creek, Indian Creek, Arroyo Hondo, Lower Alameda Creek, Lower Calaveras Creek, and Stonybrook Creek) was surveyed in all 10 years of the monitoring period. At least three age classes were present in seven of the 10 years in which fall electrofishing surveys were conducted (Figure 3.5). The years with fewer than three age classes (2015–2017) correspond to drought and immediately post-drought conditions and reduced survey efforts. Three or more age classes were present in 2015, 2016, and 2017, when summer snorkel survey data were examined and included in the analysis for the Alameda Creek watershed.[12]

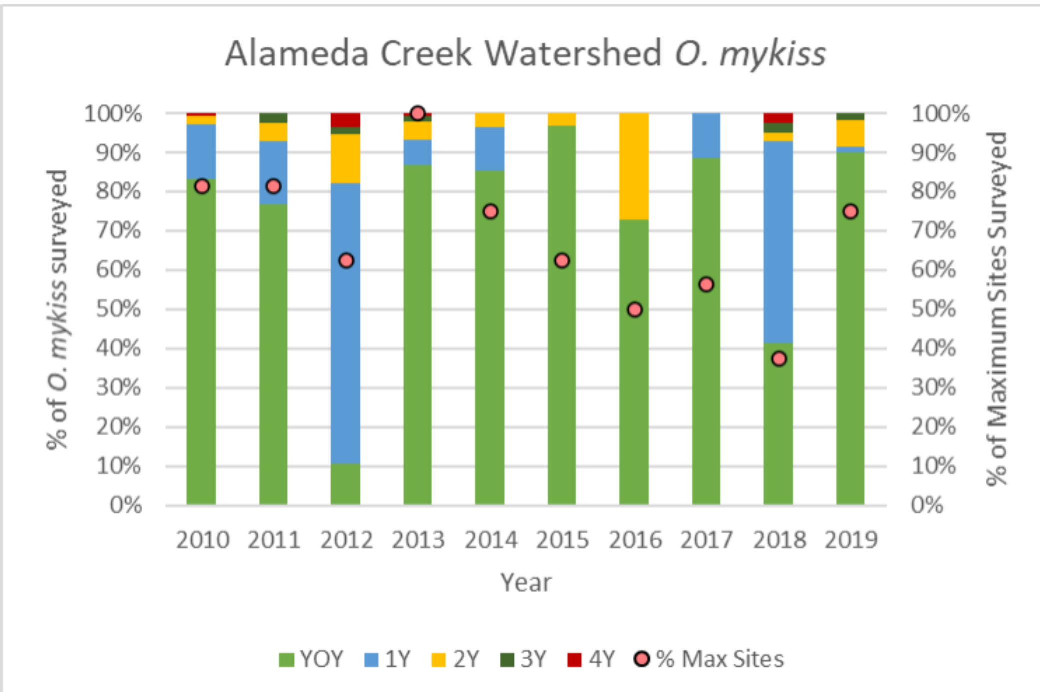


Figure 3.5. Alameda Creek watershed, age classes detected and relative survey effort.

Abbreviations: YoY = young of the year (under one year old), 1Y = one-year-old fish, 2Y = two-year-old fish

Condition Thresholds:

- *Good*: All years a watershed's streams were surveyed over the 10-year period had three or more *O. mykiss* age classes present.

[12] Summer snorkel data were only collected for the Alameda Creek watershed during the survey period evaluated here. While equivalent data were not available for the other watersheds evaluated, a decision was made to include summer snorkel survey data in the Alameda Creek watershed analysis because it was available and provides additional information about the condition of Metric 1.

- *Caution:* Some years a watershed's streams were surveyed over the 10-year period had three or more *O. mykiss* age classes present.
- *Significant Concern*: None of the years a watershed's streams were surveyed over the 10-year period had three or more *O. mykiss* age classes present.

Condition:

Significant Concern (Pinole Creek watershed). Three age classes were not detected during any years of the 10-year survey period.[13]

Good (Wildcat Creek watershed). Three age classes were present during 100% of the 10-year survey period.

Caution (San Leandro Creek watershed). Three age classes were present during 80% of the 10-year survey period.

Good (Alameda Creek watershed). Three age classes were present during 70% of the 10-year survey period; including snorkel surveys in this analysis increased the percentage to 100%.

Trend:

Unknown (Pinole Creek watershed). Several factors may account for the lack of observations of *O. mykiss* two years or older (see the Condition, Trend, and Confidence Discussion by Watershed section). Given that all age classes present were likely not detected, there is inadequate information to describe the trend during the 10-year survey period.

Unchanging (Wildcat Creek watershed). Three age classes were present during each survey year. Therefore, the trend is unchanging during the 10-year survey period.

Unchanging (San Leandro Creek watershed). Three age classes were present during eight years of the 10-year year survey period. The two years that three age classes were not observed corresponded to peak drought years (2014–2015), but three age classes were present in subsequent survey years (2016–2019).

Unchanging (Alameda Creek watershed). When snorkel survey data were included, three age classes were present during each year of the 10-year survey period. Therefore, the trend is unchanging during the survey period.

[13] Several factors may account for the lack of observations of *O. mykiss* two years or older; please see the Condition, Trend, and Confidence Discussion by Watershed section for more information.

Confidence:

Low (Pinole Creek watershed): Several factors may account for the lack of observations of *O. mykiss* two years or older (see the Condition, Trend, and Confidence Discussion by Watershed section).

Moderate (Wildcat Creek watershed): There is robust and consistent data during the survey years, but surveys were conducted in nine years of the 10-year period.

Moderate (San Leandro Creek watershed): There is robust and consistent data during the survey years, but relative survey effort was lower in the two years that only two age classes were observed.

High (Alameda Creek watershed). Surveys were conducted every year of the 10-year period, and sampling was adequate (with the addition of snorkel survey data) to detect all ages present.

Metric 2: Steelhead Passage and/or Adfluvial *O. mykiss* Population

Rationale: This metric measures the ability of adult steelhead to volitionally move upstream from San Francisco Bay to reach suitable spawning and rearing habitat, and/or the existence of an adfluvial *O. mykiss* population. The presence of adult steelhead indicates that streams are free of migration barriers during at least some flow regimes, provides potential for gene transfer between populations, and may allow the species to repopulate after local extirpation events. Similarly, adfluvial populations provide resiliency; *O. mykiss* in reservoirs can potentially repopulate streams after periods of extended drought. Small numbers of steelhead and/or adfluvial adults can also contribute significantly to populations by producing larger numbers of eggs than resident fish.

Condition Goal: Maintain or increase the number and size of anadromous and/or adfluvial *O. mykiss* populations.

Current Baseline:

- **Pinole Creek watershed.** Pinole Creek supports steelhead; it is free of impassible barriers, and adult steelhead spawning is regularly documented. Over the past 20 years, steelhead have sporadically been observed in the creek, and steelhead redds have been observed on the EBMUD watershed in four of the five years since the Pinole Creek Fish Passage Project under Interstate 80 was completed in 2016. During the 10-year period from 2010 to 2019, 14 steelhead redds were documented by EBMUD fisheries biologists, despite limited annual spawning surveys that covered less than one-third of the available spawning habitat.

- **Wildcat Creek watershed.** This watershed does not support anadromous or adfluvial *O. mykiss*. While Lake Anza supports native *O. mykiss*, these fish cannot move freely between the lake and downstream habitat because of the spillway and dam. Additionally, *O. mykiss* can move upstream from the lake only during infrequent high-flow events; during those rare events, fish can access upstream habitat for only a very short distance (to the Botanical Garden). Due to these factors, *O. mykiss* in Wildcat Creek do not function as an adfluvial population.

- **San Leandro Creek watershed**. The creek may support anadromy in its lower reach and supports adfluvial *O. mykiss* above the Upper San Leandro Reservoir. There are no impassible barriers from San Francisco Bay to approximately five miles upstream, at the Lake Chabot Dam; anadromy may occur in the lower reach. Upper San Leandro Reservoir and its associated tributaries support an adfluvial *O. mykiss* population. None of the main tributaries of the Upper San Leandro Reservoir have barriers that would prevent adult *O. mykiss* from reaching suitable spawning habitat.

- **Alameda Creek watershed.** The watershed supports adfluvial *O. mykiss*. The southern portion of the watershed has adfluvial populations that use tributaries to the Calaveras Reservoir (Arroyo Hondo) and the San Antonio Reservoir (San Antonio, La Costa, and Indian Creeks). Projects have been completed, with some still underway, to restore volitional steelhead passage (i.e., anadromy) to some spawning and rearing habitats within upper Alameda Creek and its tributaries.

Condition Thresholds:

- *Good:* Adult steelhead can move upstream from the bay, and/or adfluvial *O. mykiss* can move upstream from reservoirs under some flow regimes to reach suitable spawning and rearing habitat.

- *Caution:* Adult steelhead cannot move upstream from the bay under any flow regime to reach suitable spawning and rearing habitat, and adfluvial *O. mykiss* are not present; suitable stream habitat for resident *O. mykiss* persist annually.

- *Significant Concern:* Adult steelhead cannot move upstream from the bay under any flow regime to reach suitable spawning, and adfluvial *O. mykiss* are not present; suitable stream habitat for resident *O. mykiss* does not always persist annually.

Condition:

Good (Pinole Creek watershed): Pinole Creek supports steelhead that can reach suitable spawning and rearing habitat.

Significant Concern (Wildcat Creek watershed). Wildcat Creek does not support anadromous or adfluvial *O. mykiss.* This is of significant concern because extirpation of *O. mykiss* in this watershed occurred in the 1970s when the stream completely dried; the trout population was subsequently restocked with fish from the San Leandro Creek watershed.

Good (San Leandro Creek watershed): Upper San Leandro Reservoir supports an adfluvial *O. mykiss* population, and anadromy may occur in the lower reach of San Leandro Creek.

Good (Alameda Creek watershed): Calaveras and San Antonio Reservoirs support adfluvial *O. mykiss* populations, and anadromy occurs in the lower reach of Alameda Creek.

Trend:

Unchanging (Pinole Creek, Wildcat Creek, and San Leandro Creek watersheds). The presence/absence of anadromous or adfluvial *O. mykiss* populations in these watersheds is not expected to change in the near future.

Improving (Alameda Creek watershed). Although the presence of adfluvial *O. mykiss* already results in a watershed condition of good, completed and soon-to-be-completed restoration projects will improve conditions by allowing volitional steelhead passage.

Confidence:

High (Pinole Creek watershed): Numerous surveys have documented the presence of steelhead in Pinole Creek.

High (Wildcat Creek watershed): There are known barriers to steelhead movement between the bay and EBRPD lands. *O. mykiss* cannot move freely between the lake and downstream habitat because of the spillway and dam.

High (San Leandro Creek watershed): Numerous surveys conducted within this watershed have documented that the Upper San Leandro Reservoir and its associated tributaries support an adfluvial *O. mykiss* population.

High (Alameda Creek watershed). Numerous surveys conducted within this watershed have documented both steelhead trying to move upstream and adfluvial populations in Calaveras and San Antonio Reservoirs.

Condition, Trend, and Confidence Discussion by Watershed

See Table 3.1 for a summary of the condition, trend, and confidence findings for both of the above metrics.

PINOLE CREEK WATERSHED

The Pinole Creek watershed has been assigned an overall condition of **caution**. Three age classes were not detected during any of the survey years (Metric 1, significant concern), but Pinole Creek supports anadromy, and steelhead are regularly documented in the stream (Metric 2, good). Despite three age classes not being documented during any of the survey years, evidence suggests that Pinole Creek supports a self-sustaining *O. mykiss* population and that survey constraints or other factors may have contributed to three age classes not being documented. For example, annual spawning surveys have documented spawning in nearly all survey years. During the 10-year survey period (2010–2019), 62 *O. mykiss* redds were documented in Pinole Creek, including 14 steelhead redds and 48 resident rainbow trout redds. In addition, EBMUD records indicate that *O. mykiss* have persisted in Pinole Creek for at least 40 years.

It is important to note that Pinole Creek is currently the only stream included in this evaluation that is free of barriers to migration and supports steelhead anadromy. The presence of anadromy offers a potential explanation for the absence of observations of *O. mykiss* two years or older, as fish can migrate out of the stream to the bay. In addition, survey constraints could result in adult fish not being detected. Some pools providing suitable habitat for adult fish were too deep to effectively survey or were difficult to access due to the creek's incised nature. Sampling efficiency in Pinole Creek's deep-water habitats is poor due to high conductivity and limits on electrofishing settings designed to reduce harm to salmonids. Electrofishing is not permitted from November through May, when adult anadromous fish could be present.

An overall trend of **unknown** has been assigned to this watershed. From 2010 to 2019, two *O. mykiss* age classes were detected during each survey year, but it is likely that *O. mykiss* two years and older are present and were not detected (Metric 1, unknown). The presence of anadromy in Pinole Creek is stable (Metric 2, unchanging) and provides opportunity for gene transfer between anadromous and resident *O. mykiss* populations and for repopulation of the species should a local extirpation event occur. While the Pinole Creek *O. mykiss* population is small, the presence of anadromy may contribute to long-term population stability. However, given that all age classes present are likely not being detected, there is inadequate information to describe the trend.

Three age classes were not present during any of the survey years. However, given the persistence of *O. mykiss* for more than 40 years, documented spawning in Pinole Creek, and survey constraints, Metric 1 does not appear to accurately capture the condition of the Pinole Creek *O. mykiss* population. Therefore, while steelhead are known to occur in Pinole Creek and confidence in Metric 2 is high, given the low confidence in the Metric 1 results for this watershed, and the intent of the metric to determine if the population is self-sustaining, an overall confidence of **low** has been assigned to the Pinole Creek watershed.

WILDCAT CREEK WATERSHED

Three age classes were present in all years Wildcat Creek was surveyed (Metric 1, good), but there were no anadromous or adfluvial *O. mykiss* present or expected in the immediate future (Metric 2, significant concern). The isolated nature of this population is of particular concern because *O. mykiss* extirpation in this watershed occurred in the 1970s when the stream completely dried out. The trout population was subsequently restocked with fish from San Leandro Creek watershed. Given concerns about droughts of increasing frequency and/or severity, and that this population was extirpated during a past drought, this watershed has been assigned an overall condition of **significant concern**.

An overall trend of **unchanging** has been assigned to this watershed. Three age classes were detected during each survey year (Metric 1, unchanging), and existing physical constraints (e.g., multiple downstream migration barriers, absence of downstream reservoir), anadromous or adfluvial *O.* mykiss are not expected to occur in the watershed in the foreseeable future (Metric 2, unchanging). Therefore, the trend during the 10-year survey period was unchanging. However, as discussed previously, this population is particularly vulnerable to drought events and there is concern about future trends because the *O. mykiss* population in this watershed was not self-sustaining and resilient during past droughts.

Despite robust and consistent data during the survey years, given the current drought and ongoing climate change, which may result in decline or extirpation of this *O. mykiss* population, an overall confidence of **moderate** has been assigned to the Wildcat Creek watershed.

SAN LEANDRO CREEK WATERSHED

The San Leandro Creek watershed has been assigned an overall condition of **good.** Three *O. mykiss* age classes were present in some (but not all) years that streams were surveyed (Metric 1, caution). Adfluvial *O. mykiss* are present, with possible anadromy in the lower reaches of San Leandro Creek (Metric 2, good). Given that only two metrics were used, the condition average would be caution (see Chapter 1). However, we chose instead to assign an overall condition of good, because the *O. mykiss* population in this watershed is expected to be self-sustaining and resilient for the following reasons:

- Upper San Leandro Reservoir supports adfluvial *O. mykiss*, which can provide population stability during periods of drought when tributaries may provide less suitable habitat or dry out completely.

- San Leandro Creek may support anadromy in its lowest reach from San Leandro Bay to Lake Chabot Dam, which provides opportunities for gene transfer between anadromous and resident populations and for repopulation of the species in that stream reach after local extirpation events.
- Years in which fewer than three age classes were present corresponded with drought conditions (2014–2015). Following this period, three or more age classes were found to be present again, indicating that the population was resilient enough to remain self-sustaining through a drought of that magnitude.

An overall trend of **unchanging** has been assigned to this watershed because the population was resilient enough to remain self-sustaining through a drought of the magnitude that occurred during the survey period. Over the past several decades, this population has demonstrated the ability to quickly occupy and thrive in improved stream habitat conditions in years with average and above average precipitation. A stream restoration project was recently completed at Huckleberry Botanic Regional Preserve, and another is underway at the McCosker property in Sibley Volcanic Regional Preserve, both of which increase habitat for *O. mykiss*.

There is robust and consistent data for the upper watershed, and the presence of adfluvial *O. mykiss* associated with two reservoirs may mitigate the effects of drought. There is less robust data for the lower watershed (below Lake Chabot) and anadromy is assumed based on passage conditions but has not been documented. Therefore, an overall confidence of **moderate** has been assigned to the San Leandro Creek watershed.

ALAMEDA CREEK WATERSHED

The Alameda Creek watershed has been assigned an overall condition of **good**. When snorkel survey data is looked at in addition to electrofishing data, three or more *O. mykiss* age classes were present during each year of the 10-year period (Metric 1, good). Three age classes may not have been observed during the three years of electrofishing due to reduced survey efforts (as a result of low water conditions) and/or a random sampling scheme that may potentially exclude sites with some age classes. Calaveras and San Antonio Reservoirs support healthy adfluvial *O. mykiss* populations that are free to move into upstream tributaries with sufficient flows (Metric 2, good). These fish have also occasionally been observed to be transported downstream when the reservoirs spill during extremely wet years. The *O. mykiss* populations in the Alameda Creek watershed are expected to be self-sustaining and resilient for the following reasons:

- Autumn electrofishing and summer snorkel survey data documents the presence of three or more *O. mykiss* age classes annually, indicating populations resilient enough to remain self-sustaining through (at minimum) a three-year drought.

- Two reservoirs (San Antonio and Calaveras) in the upper portion of the southern watershed support adfluvial *O. mykiss*, providing population stability when streams afford inadequate habitat and/or dry completely during extended droughts.
- Projects have been completed, with some still underway, to restore volitional steelhead passage (i.e., anadromy) to some spawning and rearing habitats within upper Alameda Creek and its tributaries.
- Federal and state permits require minimum cold-water releases from Calaveras Reservoir and reduced diversions from Alameda Creek Diversion Dam, designed to maximize *O. mykiss* spawning and rearing habit downstream through Sunol Valley.
- Resident *O. mykiss* populations in the upper reaches of Alameda Creek are generally healthy despite periods of drought.

An overall trend of **unchanging** was initially assigned, based on the average of the scores for Metrics 1 and 2 and given the resiliency and self-sustainability of the system's *O. mykiss* populations through the 10-year period of the analysis (which included a drought). However, the trend has been upgraded to **improving**, due to completed, underway, and upcoming fish-passage projects designed to restore volitional anadromy to some of the watershed's upper reaches.

There is a robust and consistent dataset for this watershed. Therefore, an overall confidence of **high** has been assigned to the Alameda Creek watershed.

OTHER METRICS CONSIDERED BUT NOT INCLUDED

- Condition factor: Condition factor reflects the physical attributes of individual fish, including the relationship between length and weight, and is typically used to evaluate their health. The metric has the potential to provide valuable insight into the health of discrete *O. mykiss* populations. However, existing datasets lack key and/or consistent information, such as body condition measures and the presence of lesions or parasites. Although some length and weight data are collected, the available information alone was not sufficient to provide a useful condition-factor measure in all of the watersheds being evaluated. Collecting relevant and consistent data to determine condition factor is being explored for future survey efforts and subsequent updates to the ecological health assessment.
- Out migrants and stream flows: The number of out-migrant smolts and the suitability of flows during the out-migration season were considered as metrics. Relevant data, however, is only available for one of the watersheds in the evaluation (Alameda Creek).

- Catch per unit effort: This provides indirect measures of the abundance of individual species. The metric was eliminated from consideration because lower values for *O. mykiss* may be due to streams' carrying capacity, as opposed to less-healthy populations.

- Presence in suitable habitat: A metric examining the number of streams (as a percentage) that have both suitable habitat and *O. mykiss* populations was rejected for the following reasons: (1) the focus of this analysis is on population health, not stream health; (2) data relevant to "suitable habitat" are not available for all streams being evaluated; (3) *O. mykiss* can persist in a variety of habitat conditions; and (4) complications associated with data handling for streams in which only portions provide suitable habitat.

- The National Marine Fisheries Service's Coastal Multispecies Recovery Plan for California Coastal Chinook Salmon, Northern California Steelhead, and Central California Coast Steelhead. Developing a metric based on the goals of the Steelhead Recovery Plan was rejected because it only considers major watersheds, which excludes most streams in the area of focus.

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

- Fish survey data are not available for all primary and secondary streams within the area of focus.

- Habitat quality data are not available for all survey reaches.

- Survey methods and the type of data collected vary among Network partner agencies.

- Not all streams and stream reaches within the area of focus are surveyed.

PAST AND CURRENT MANAGEMENT

Network partner agencies monitor *O. mykiss* populations annually using electrofishing (EBRPD, EBMUD, SFPUC), out-migrant trapping and snorkel surveys (SFPUC), and PIT tag antennae array monitoring (SFPUC). EBMUD participated in the Pinole Creek Fish Passage Improvement Project, which included the removal of a migration barrier under Interstate 80; with its removal, steelhead have access to upstream areas under most flow conditions. Projects in Alameda Creek have been completed, are underway, or are planned to restore volitional anadromy to some of the watershed's upper reaches. In the San Leandro watershed, projects have been completed and are currently underway to improve access to habitat for resident and adfluvial *O. mykiss* populations. Most notable is the daylighting of nearly 3,500 linear feet of Alder Creek, a tributary of Upper San Leandro Creek, which was previously culverted underground. This newly accessible habitat will provide four acres of suitable spawning and rearing habitat for rainbow trout. In addition, EBRPD removed a culvert in Upper San Leandro Creek that was a partial trout barrier, replacing it with an arched culvert. This project makes available nearly one mile of suitable upstream trout habitat. Other notable projects currently in the planning/design phases in Wildcat Creek include removing a migration barrier at Brook Road downstream of Lake Anza, assessing the feasibility of creating a fish passage around Jewel Lake, and improving the function of the fish ladder in Richmond.

POTENTIAL FUTURE ACTIONS

- Coordinate on data collection and use methods with Network partner agencies.
- Continue to work together to coordinate and share data.
- Explore opportunities to better standardize survey protocols and collect data that allow better comparisons between fish populations in Network partner agency watersheds.
- Identify opportunities for enhancing fish-bearing stream habitat and removing potential fish passage barriers.

KEY LITERATURE AND DATA SOURCES

Literature

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Partner Agency Data Sources

- East Bay Regional Park District (EBRPD): Backpack electrofishing surveys for Wildcat Creek, 2010–2019; Redwood Creek, 2010–2019; Stonybrook Creek, 2017–2019; Upper San Leandro Creek, 2012–2019
- East Bay Municipal Utility District (EBMUD): Backpack electrofishing surveys for Kaiser Creek, 2013–2019; Moraga Creek, 2016–2018; Pinole Creek, 2010–2019; Redwood Creek, 2016–2018; Rimer Creek, 2018, San Leandro Creek, 2010–2019
- San Francisco Public Utilities Commission (SFPUC): Backpack electrofishing and snorkel surveys for Alameda Creek, 2010–2019; Arroyo Hondo, 2010–2015; Calaveras Creek, 2011–2019; Indian Creek, 2010–2013; La Costa Creek, 2010–2014

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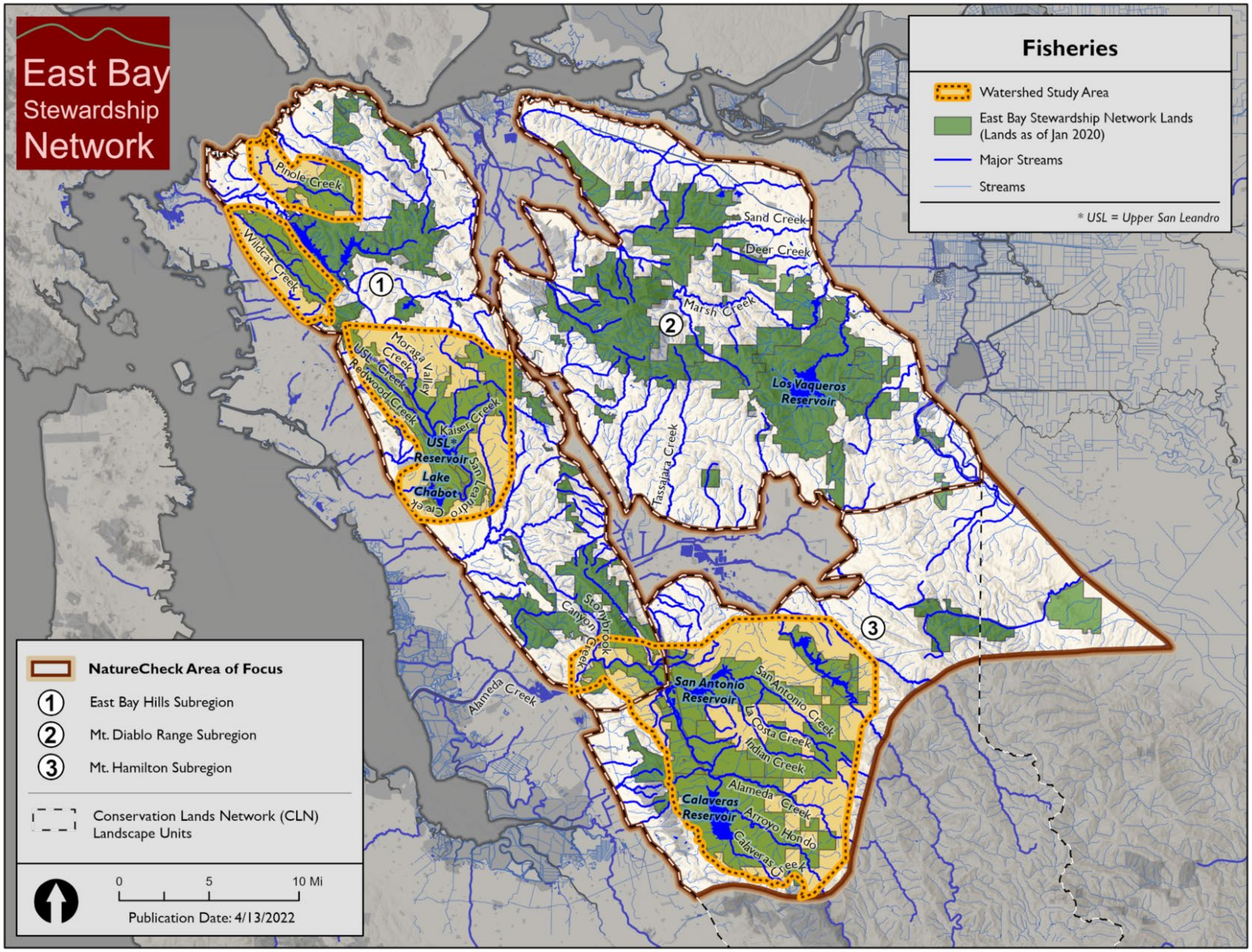

Figure 3.1. Watersheds surveyed by Network partner agencies within the area of focus.

CHAPTER 4. AMPHIBIAN AND REPTILE DIVERSITY

EXECUTIVE SUMMARY

This ecological health indicator includes the distribution of habitat for, and presence of, all six native pond-breeding amphibians and one aquatic reptile species: the California tiger salamander (*Ambystoma californiense*), California newt (*Taricha torosa*), rough-skinned newt (*Taricha granulosa*), western toad (*Anaxyrus boreas*), Sierran tree frog (*Pseudacris sierra*), California red-legged frog (*Rana draytonii*), and western pond turtle (*Actinemys marmorata*). The distribution of one non-native, invasive amphibian, the American bullfrog (*Lithobates catesbeianus*), and several species of non-native, invasive fish have also been included in this indicator.

Our native pond-breeding amphibians and the western pond turtle are good indicators of ecological health on East Bay Stewardship Network (Network) partner lands (see map, Chapter 1) because they depend on a variety of habitats, including ponds and wetlands for breeding and development and uplands for basking, foraging, and dispersal. These lands have been divided into three subregions for the purposes of this analysis. Within these subregions, data came from individual parks, reservoirs, recreation or management areas, and other open spaces that we refer to as "Network partner lands" throughout this chapter.

This chapter presents the results of an evaluation of a suite of three metrics that help reveal the current condition of and trends for these species on Network partner lands. These metrics assess pond quality and hydroperiod, species composition and richness, and the distribution of invasive species (American bullfrogs and fish). In addition to assessing current status, another primary goal of the analysis is to provide a benchmark against which managers can measure future changes.

Using data collected between 2009 and 2019, we found that these indicator species are in "good" condition; however, we were not able to assess trends. A recent paper using much of the same data (Moss et al. 2021) showed that many of our native populations are resilient to drought, with amphibian populations able to recover during normal or above-average precipitation years. However, it should be noted that these analyses did not include the exceptional drought of 2020–2021. Because only available data were used, this chapter also identifies areas where not enough is known to draw meaningful conclusions, as well as opportunities for future research and collaboration between Network partner land managers.

METRICS SUMMARY AT A GLANCE

The table below summarizes the three metrics for amphibian and reptile diversity used in this NatureCheck ecological health assessment. Each metric, along with how we arrived at its condition, trend, and confidence, is thoroughly described in the Metrics in Detail section later in this chapter. (See Chapter 1 for definitions and thresholds for condition, trend, and confidence; other terminology used throughout this chapter; how metrics are being used for each indicator; and other project methodology.) Note that this chapter does not examine condition, trend, and confidence by subregion as many other chapters do because data were limited and confidence was low.

Table 4.1. All amphibian and reptile metrics, with their respective condition, trend, and confidence. Each metric is described in the Metrics in Detail section later in this chapter.

	Area of Focus
Metric 1: Pond Quantity and Pond Hydroperiod–Number of wetlands and ponds in the area of focus that hold water for approximately six months during a normal water year, which represents enough time for most native amphibians to breed successfully.	
Condition	Good
Trend	Unknown
Confidence	Low
Metric 2: Species Composition/Pond Species Richness–Number of different native species (of any life-stage) detected at each surveyed wetland or pond.	
Condition	Good
Trend	Unknown
Confidence	Low
Metric 3: Presence of Non-Native, Invasive Species –Number of wetlands and ponds with American bullfrogs and non-native, invasive fish of any life stage.	
Condition	Caution
Trend	Unknown
Confidence	Moderate

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of six native pond-breeding amphibians and one aquatic reptile species in the area of focus represented by the graphic below is based on the combined values of the individual metrics in Table 4.1. Each of these metrics is described in depth in the Metrics in Detail section later in this chapter.

Condition: Good (color: green)

Trend: Unknown (symbol: question mark)

Confidence: Low (line around circle: none)

BACKGROUND

WHY IS THIS RESOURCE INCLUDED?

This ecological health indicator includes the distribution of habitat for, and presence of, all six native pond-breeding amphibians and one aquatic reptile commonly found within this project's area of focus. (See map, Chapter 1) These include the California tiger salamander (*Ambystoma californiense*), California newt (*Taricha torosa*), rough-skinned newt (*Taricha granulosa*), western toad (*Anaxyrus boreas*), Sierran tree frog (*Pseudacris sierra*), California red-legged frog (*Rana draytonii*), and western pond turtle (*Actinemys marmorata*). Of this group, three species are considered special-status: The California tiger salamander (CTS) is federally and state listed as endangered, the California red-legged frog (CRLF) is federally listed as threatened, and the western pond turtle is a state species of special concern. (Populations of the California newt in southern California are also listed as a state species of special concern, but this designation does not apply to newt populations within the area of focus.) The distribution of one invasive amphibian, the American bullfrog *(Lithobates catesbeianus*), and several species of invasive fish have also been included in this indicator.

Amphibians and aquatic reptiles are particularly vulnerable to ecological change and stressors, and so their assemblages are good indicators of freshwater wetland conditions. Amphibians in particular are uniquely sensitive due to their permeable skin and complex, aquatic larval development. The species included here are relatively long-lived; they depend upon aquatic habitats such as wetlands and ponds for breeding, but spend much of their adult lives on land. Their response to changes in hydrology and precipitation, as well as their susceptibility to pathogens, pollutants, and toxins in a variety of habitat types, make them excellent indicators of ecosystem health.

East Bay Stewardship Network (Network) partner land managers have been working to conserve habitat, construct ponds and wetlands for breeding, remove invasive species, and restore native vegetation to increase amphibian and turtle species' distributions and population sizes. Targeted breeding and non-breeding surveys have been conducted on each of the Network partner agencies' lands (see map, Chapter 1) to document and track amphibian and turtle species' distributions and population sizes across the landscape and to determine where future conservation efforts and habitat enhancement and restoration activities should be targeted.

DESIRED CONDITION AND TREND

Based on available data, amphibian and turtle populations are thought to be stable on protected open spaces within the area of focus. Lacking conclusive data to prove otherwise and considering that the federally listed species are not the rarest, we make the assumption that current condition and trends are equal to desired condition and trends. Maintaining or improving current habitat conditions in the East Bay Hills, Mt. Diablo Range, and Mt. Hamilton subregions will likely lead to sustained native amphibian and turtle populations, absent any unforeseen threats that may arise.

CURRENT CONDITION AND TREND

Condition: Good

Trend: Unknown

Confidence: Low

The suite of metrics described in depth in the Metrics in Detail section of this chapter and summarized in Table 4.1 were combined to obtain this current condition and trend. These metrics provide us with a way to measure the difference between what is described here in the Current Condition and Trend section (i.e., how things are now) and the Desired Condition and Trend section (i.e., what we think healthy is for this indicator).

San Francisco Bay Area (hereafter referred to as "Bay Area") landscapes have changed dramatically over the past 50 years, becoming more urbanized and in the process, losing habitat. Despite this, parks and open spaces within the area of focus have maintained good habitat for many amphibian and reptile species. For example, a CRLF phylogeographic study comparing coastal Bay Area populations to those in other parts of the range found that CRLF populations in the Bay Area are genetically diverse and gene flow is high (Richmond et al. 2014).

Protected wetlands, stock ponds, and other water infrastructure built to support cattle grazing have provided managed habitats for these species to survive. For all species discussed here, population size and species abundance have likely declined regionally, but extant breeding populations of both common as well as threatened and endangered amphibians and reptiles indicate that suitable conditions remain for these species on Network partners' lands.

STRESSORS

Several ecological and anthropogenic factors affect the health of this indicator. These include:

Invasive Species Impacts: Non-native species are known to compete with and prey upon native amphibians. For example, American bullfrogs are often implicated in native amphibian declines (Doubledee et al. 2003, Snow and Witmer 2010, Fisher and Shaffer 1996). Introduced fish and crayfish species are also efficient predators of native amphibians and can effectively preclude them from reproducing (Fisher and Shaffer 1996, Shaffer et al. 1993, USFWS 2017). Invasive fish have been found to have a particularly strong negative effect on amphibian occupancy (Joseph et al. 2016). Abandoned pet red-eared slider turtles (*Trachemys scripta*) are also known to compete with native western pond turtles (Lambert et al. 2019). Finally, terrestrial non-native species such as feral pigs (*Sus scrofa*) and wild turkeys (*Meleagris gallopavo*) may adversely affect amphibian and turtle populations directly through predation (Wilcox and Van Vuren 2009, McRoberts et al. 2014) and indirectly through habitat alteration.

Climate Change: The potential effects of climate change on these species' habitats include shorter hydroperiods, more frequent droughts, more dramatic or unseasonable rain events, and changes in water and air temperatures (Polade et al. 2017, Swain et al. 2018). All of our native species are adapted to seasonal drying, and a few, like the CTS, are further adapted to fairly arid conditions and cyclical drought. However, increases in climatic variability and/or extensive droughts may inhibit successful reproduction or directly cause amphibian and turtle mortality, leading to potential future population declines (USFWS 2017).

Disease: Amphibian diseases have been a focus of conservation efforts in recent decades. In particular, the rapid spread of a fungal pathogen, *Batrachochytrium dendrobatidis* (Bd), and subsequent extirpations and extinctions have been major causes for concern. An emerging disease*, B. salamandrivorans* (Bsal), has also been implicated in salamander population declines in Europe. A third fungal pathogen, *Emydomyces testavorans* (Emte), has recently been observed in western pond turtles in Santa Cruz (Lambert et al. 2021). This fungus causes shell defects and lesions. The health of amphibian populations may also be compromised by ranavirus and parasites such as *Ribeiroia ondatrae*. To date, Bd, ranavirus, *Ribeiroia ondatrae*, and other pathogens and parasites have been documented in the area of focus (Hoverman 2012).

Habitat Disturbance/Conversion/Loss: Lands managed by Network partner agencies in the area of focus are generally protected from habitat loss. However, encroaching urbanization, utility/transportation corridors (e.g., loss of upland habitat, road mortality), and competing interests for renewable-energy development (e.g., solar and wind) may affect amphibian and turtle populations within this project's area of focus (Barry and Shaffer 1994, USFWS 2017).

CONDITION AND TRENDS ASSESSMENT

METRICS IN DETAIL

The three metrics outlined below are a simple but informative way to measure amphibian and reptile diversity across the area of focus. All metrics are based on a period spanning the 10 years between 2009 and 2019. Because this is the first regional data compilation effort and no data for changes in conditions currently exist, our trends are "unknown." Over time, these metrics will be remeasured and compared to the baseline conditions described here to establish trends in pond quantity and pond hydroperiod, native pond species presence/diversity, and invasive species distribution.

Metric 1: Pond Quantity and Pond Hydroperiod

Rationale: This metric was evaluated by determining the total number of ponds within the area of focus and then recording how many of those ponds hold water through spring (June) of a normal water year. In a normal water year (rainfall between October 1st and September 30th), based on native amphibian egg and larvae development times, a pond hydroperiod of six months would allow most native amphibian species to have the opportunity to successfully reproduce (Table 4.2). However, the timing of seasonal rainfall within a water year may also alter a pond's breeding suitability for a given amphibian species.

This metric is important in understanding the health of this indicator. All of the amphibian species considered in this assessment breed within pond habitats even though they vary in their life history traits. For example, some native amphibians (such as the western toad) can develop quickly and thrive in habitats with short hydroperiods (<3 months), while others take advantage of perennial water bodies, which allow for longer larval development times. Stokes et al. (2021) found that preserves in Sonoma County with CTS breeding pools that "held water for at least two months following the breeding season (into late April) even in dry years had substantially lower rates of larval decline." Rough-skinned newt and CRLF larvae have been found to metamorphose in late summer or fall and even overwinter at perennial sites in the East Bay (Moss et al. 2021, USFWS 2017).

Table 4.2. Information on breeding, development, and conservation status compiled from www.amphibiaweb.com, Lannoo (2005), and Thomson et al. (2016) and adapted from Moss et al. (2021).

Survey Species	Common Name	Breeding Season	Development Time (Months)	Conservation Status*
Native Species				
Ambystoma californiense	California tiger salamander	Dec.–Feb.	3–6	Threatened (CA), threatened (federal),**vulnerable (IUCN)
Taricha torosa	California newt	Dec.–May	6–8	Declines observed in southern part of range (outside of the area of focus)
Taricha granulosa	Rough-skinned newt	Mar.–May	4–12+	
Anaxyrus boreas	Western toad	Feb.–April	1–2	
Pseudacris sierra	Sierran tree frog	Nov.–July	2–3	
Rana draytonii	California red-legged frog	Nov.–April	4–7	Special concern (CA), threatened (federal),[ǂ] vulnerable (IUCN)

Survey Species	Common Name	Breeding Season	Development Time (Months)	Conservation Status*
Invasive Species				
Lithobates catesbeianus	American bullfrog	April–July	12+	Invasive

*CA = status under the state of California (Thomson et al. 2016), federal = status under the U.S. Endangered Species Act, IUCN = status under the International Union for Conservation of Nature

**U.S. Fish and Wildlife Service 2017

ǂU.S. Fish and Wildlife Service 2002

Condition Goals:

- Maintain or increase the total number of ponds.
- Maintain or increase the number of ponds that hold standing water long enough for most native amphibian species to successfully breed (i.e., a hydroperiod of approximately six months [January through June] in a normal water year).

Current Baseline: Within the area of focus, the five Network partner agencies manage more than 1,100 ponds that are named or identified in publicly available datasets (SFEI 2017) or in agency-provided GIS data. Slightly more than half of these ponds (*n* = 665) were surveyed in the field between 2009 and 2019. To compensate for a lack of hydroperiod data, pond hydroperiods were visually evaluated using a single aerial photograph taken in June 2018 (National Agriculture Inventory Program [NAIP] 2018).[14]

The type of water year in which the aerial photograph was taken was also considered when selecting the imagery used for this analysis. The amount and timing of precipitation dictates the extent to which ponds are wet or dry at a specific moment in time. The exceptional drought of 2014–2016[15] was followed by a couple of neutral years; precipitation levels in the 2016/2017 water year were considered severely wet and likely bolstered the pond hydroperiod into the next year (Figure 4.1 at the end of this chapter). Based on precipitation data, the 2017/2018 water year was considered neutral in the East Bay Hills and Mt. Diablo Range subregions, while the Mt. Hamilton subregion experienced abnormally dry to moderate drought conditions during this time (Hegewisch et al. 2021).

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[14] NAIP photography was chosen because it is made publicly available at regular three-year intervals, which will facilitate future repeats of this analysis. Additionally, for the entire area of focus, the 2018 photo was the most recent late-spring, fine-scale resolution (60 cm) imagery available.

[15] The full drought period extended from 2012–2017; 2014–2016 were peak drought years, categorized as exceptional drought by the US Drought Monitor (https://www.drought.gov/states/california).

The 2018 NAIP imagery was considered suitable for this analysis for two reasons: (1) It portrays a neutral water year for much of the area of focus, and (2) it was not immediately preceded by a period of prolonged drought (Figure 4.2 at the end of this chapter).

Each pond was viewed at a scale of 1:1,000 and recorded as *wet*, *dry*, or *not visible*. Any depression seen on the aerial imagery, including ephemeral drainages, was evaluated as wet or dry. Of the 989 ponds that were visible in the final dataset, 44% were deemed to be dry and 44% were deemed to be wet. The remaining 12% of ponds were not visible due to canopy cover or ephemerality (Table 4.3). This indicates that almost 500 ponds across the area of focus provided potential breeding habitat for most native amphibians, including those with longer larval development times. Many of the dry ponds and wetlands may also provide breeding habitat for the CTS, western toad, and Sierran treefrog, which can develop in pools or ponds with hydroperiods of just a few months. We recommend that the 12% (137 ponds) not seen on the imagery be visited in the field to determine if they are still viable, and that they be surveyed in the future.

Table 4.3. Metric 1 hydroperiod analysis for the area of focus and subregions.

	Number and Percentage of Ponds in Each Subregion That Fall into Each Hydroperiod Category*							
Hydroperiod	**Entire Area of Focus**		**East Bay Hills**		**Mt. Diablo Range**		**Mt. Hamilton**	
Dry	495	44%	127	33%	213	54%	155	45%
NV**	137	12%	76	20%	34	9%	27	8%
Wet	494	44%	186	48%	146	37%	162	47%
Total	1,126		**389**		**393**		**344**	

*Shaded columns are the total number of ponds in each category
**NV = Not Visible

Condition Thresholds:[16]

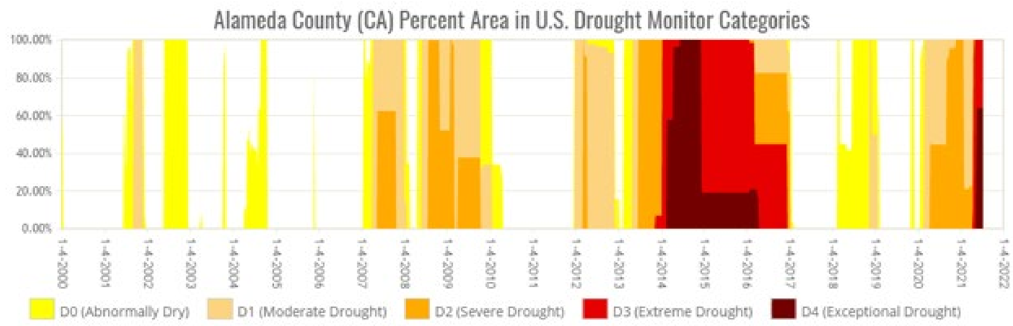
- *Good:* The total number of ponds in the area of focus is maintained, increases, or declines by less than 10% over the next 10 years and the number of ponds with a six-month hydroperiod in an average water year in the area of focus is maintained, increases, or declines by less than 10% over the next 10 years.

[16] The condition threshold percentage values set for each metric in this chapter are based on professional judgment using limited information and were chosen as values that are measurable and likely to have some effect on the indicator species. Where feasible, subsequent analyses will be based on a pond-to-pond comparison, to avoid confounding the effects of increased pond sampling.

- *Caution:* The total number of ponds declines 10%-20% over the next 10 years, or the number of ponds with a six-month hydroperiod in an average water year declines by more than 10% over the next 10 years.

- *Significant Concern:* The total number of ponds declines by more than 20% in the area of focus over the next 10 years, or the number of ponds with a six-month hydroperiod in an average water year declines by more than 20% in the area of focus over the next 10 years.

The U.S. Drought Monitor (USDM) indicates that five of the past 10 years (2009–2019) are considered to have been severe-to-exceptional drought years (Figure 4.3. USDM 2021). If most years within the next 10-year period are drought years, the pond hydroperiod metric and condition-threshold criteria may need to be reevaluated and adapted to changes in climatic norms. Climate change projections for California predict increased volatility in precipitation, from exceptional droughts to flood events (Polade et al. 2017, Swain et al. 2018). For the past 30 years, average precipitation for the three counties within the area of focus has ranged from 20.7 to 22.5 inches. Precipitation trends show a decrease in annual precipitation over the past decade (Hegewisch and Abatzoglou 2021). Though land managers can deepen ponds or create new ponds, these habitats still rely on precipitation and groundwater. Evaluating precipitation patterns and water-year types (i.e., neutral, severe, wet) will allow Network partner land managers to determine if the loss of total ponds (or ponds with a six-month hydroperiod) is due primarily to drought as opposed to land-management activities. A substantial drop in the number of ponds or a reduction in pond hydroperiod due to climate change would be cause for significant concern.



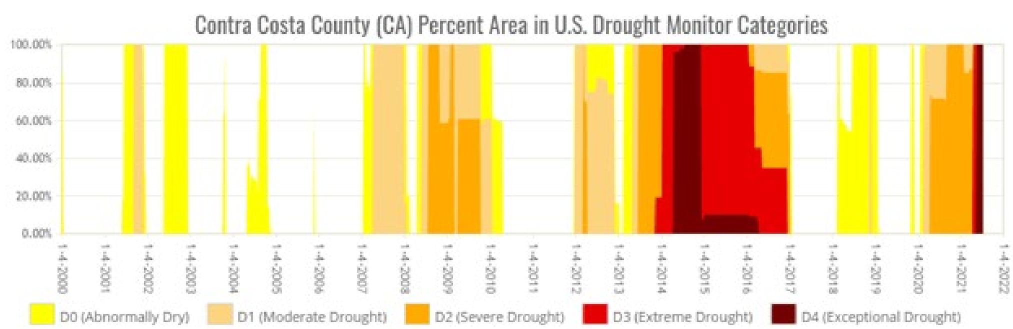


Figure 4.3. Drought recurrence in Alameda and Contra Costa Counties (USDM 2021).

Condition: Good

More than 1,100 ponds are distributed throughout the area of focus (Figure 4.4). Currently, almost 500 of these ponds (or more than 40%) likely provide hydroperiods sufficient to support breeding and development of most native amphibian species (Table 4.3).

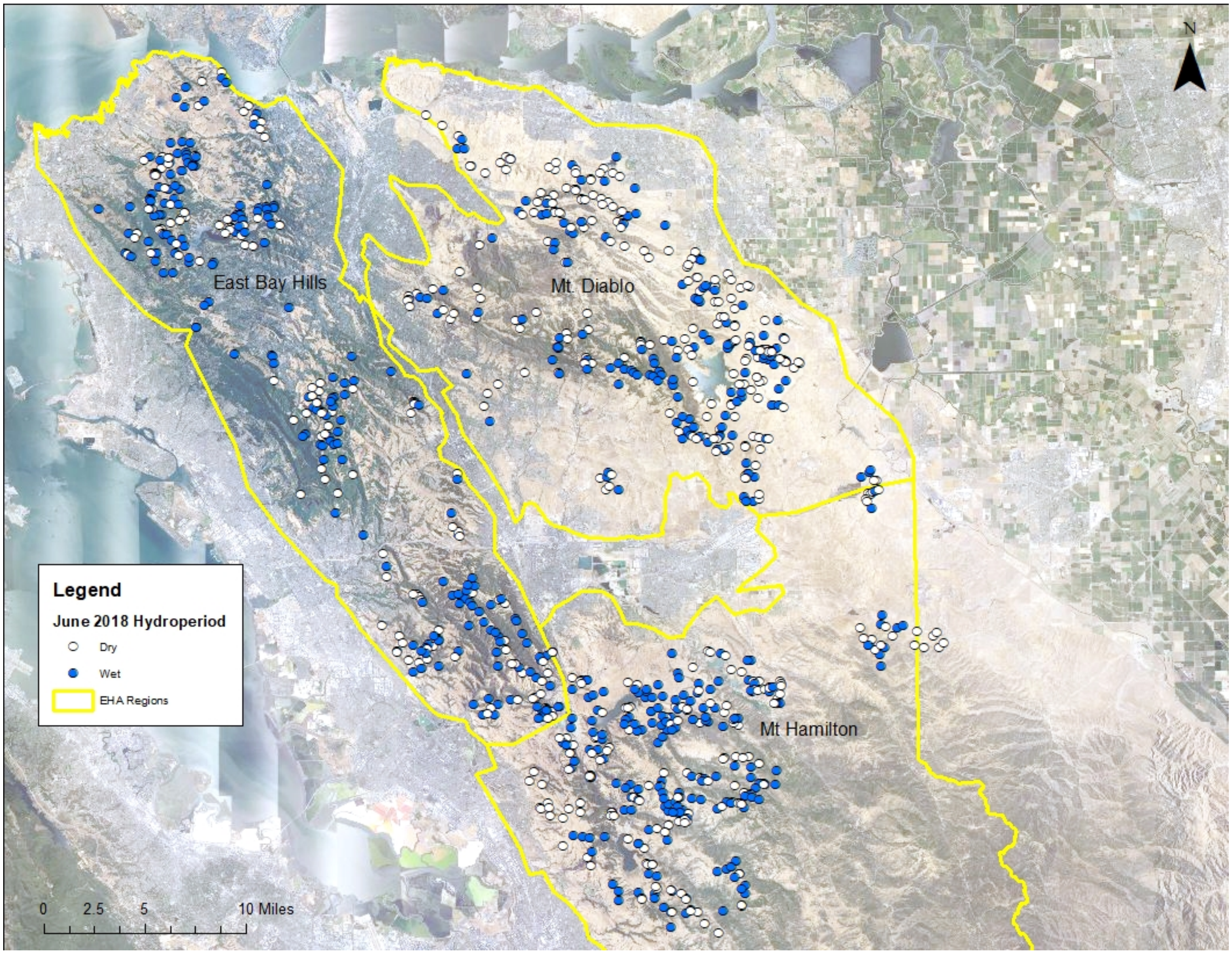


Figure 4.4. Distribution of wet and dry ponds based on the analysis of Metric 1 (ponds classified as "not visible" are not shown on the map).

Trend: Unknown

As this analysis used a single year of aerial imagery, trend data are unavailable for this metric. However, we can estimate some general patterns based on known pond management activities. Most stock ponds require active restoration every couple of decades. Some ponds gradually fill in with sediment and require excavation, and embankments sometimes fail and need repair. Many ponds in the area of focus have been actively restored to provide habitat for the CRLF and/or the CTS as well as to provide water for cattle. Other ponds have been created for wetland and/or listed-species mitigation. Based on these continuing management efforts, it is unlikely that the total number of ponds decreased between 2009 and 2019. Though pond hydroperiods likely decreased during the peak of the drought from 2014 through 2016, the number of ponds that support breeding amphibian populations during normal water years likely did not change significantly between 2009 and 2019.

Confidence: Low

This metric was analyzed by merging pond datasets and reviewing each pond visually. For those that were determined either wet or dry, confidence is high. However, the condition of the 12% of ponds that were "NV" (not visible) is unknown. Also, the analysis only used a single year of normal precipitation over a 10-year period. This is likely a good estimation of pond hydroperiod in an average water year but does not provide a complete picture of pond hydroperiods over a decade. Also, some variation is expected even when comparing normal precipitation years, depending on where and when rainfall is received and on temperature variability between years.

Metric 2: Species Composition/Pond Species Richness

Rationale: Stability in ecological systems is rooted in biological diversity (McCann 2000). The extirpation of amphibians and reptiles across parts of their range can be correlated to the level of urbanization (Davidson et al. 2001 and 2002, Riley et al. 2005) and other stressors. Monitoring species assemblages can identify species that may be more vulnerable to stressors (Fisher and Shaffer 1996, Hamer and McDonnell 2010, Riley et al. 2005) such as climate change (Ochoa-Ochoa 2012). This metric evaluates the distribution of the native amphibians assessed in Metric 1 and adds the western pond turtle (*Actinemys marmorata*). Though pond turtles are reptiles and breed terrestrially, they are included here because they are closely tied to aquatic features for foraging and cover and spend much of their lives in and around ponds. Hatchlings and young turtles feed on larval amphibians or invertebrates and adults subsist on aquatic vegetation. They use basking sites, banks, and open water to thermoregulate, and rely on open water to escape terrestrial predators.

Western pond turtles and pond-breeding amphibians are thought to conform to classic metapopulation dynamics, in which patches of suitable habitat within a matrix are occupied on-and-off over time and dispersal between patches buffers populations from extinction. Using a "pond-as-patch" metapopulation model (Marsh and Trenham 2001), we assume that ponds stand in for discrete patches of habitat within a mostly grassland matrix, and we are basing this species composition metric on pond occupancy. However, Marsh and Trenham (2001) argue that the "pond-as-patch" metapopulation model does not neatly explain real-world amphibian population dynamics. For example, it fails to account for the importance of stream corridors and upland habitats for these species. While recognizing the truth of this statement, an evaluation of amphibian and aquatic reptile pond occupancy was chosen as a proxy for amphibian and aquatic reptile health within the area of focus because nearly all of the data available for this analysis were collected from pond surveys.

Condition Goals:

- Maintain or increase the number of ponds with more than two species.
- Maintain or increase average herpetological species richness.

Current Baseline: Of the 1,100 ponds in the area of focus, 665 have reliable coordinates and were surveyed at least once between 2009 and 2019. The survey methods included daytime and nighttime visual surveys as well as surveys with dipnets and/or seines. We aggregated surveys to obtain the presence/absence of each species at each pond across the past decade, where a species was considered present if any life stage was detected in any year. The California newt and rough-skinned newt were combined in these analyses because, while they are relatively easy to distinguish as larvae, they are more difficult to tell apart as adults and were often recorded as *Taricha* sp. The five other species included in this analysis are native, pond-breeding species and our one aquatic reptile (CTS, western toad, Sierran tree frog, CRLF, and western pond turtle), for a total of six species (for brevity, we will hereafter refer to newts as a single species).

More than 80% of the ponds surveyed (538) had between one and four species (Table 4.5). Only one pond in the Mt. Hamilton subregion had all six species, and only ponds within the Mt. Diablo Range and Mt. Hamilton subregions had five species. This is partially due to a range restriction—only one (adult) California tiger salamander has been recorded in the East Bay Hills subregion, so the maximum potential number of its pond species would be five. Table 4.4 and Figure 4.5 provide a summary showing how common a species was in surveyed ponds. As expected, the Sierran tree frog was the most frequently encountered pond species, followed by the CRLF. The least common species encountered was the western pond turtle (Table 4.5 and Figure 4.5).

Table 4.4. Number of sampled ponds and percentage of sampled ponds with zero to six pond species present, by subregion.

Subregion	Observations Grouped by Number of Species Seen in Ponds in Each Subregion													
	0		**1**		**2**		**3**		**4**		**5**		**6**	
East Bay Hills	30	12%	41	17%	60	24%	82	33%	32	13%	2	1%	0	0.00%
Mt. Diablo Range	43	16%	59	22%	53	20%	43	16%	51	19%	16	6%	0	0.00%
Mt. Hamilton	23	15%	36	24%	23	15%	34	22%	24	16%	12	8%	1	0.65%
Average Percentage	96	14%	136	20%	136	20%	159	24%	107	16%	30	5%	1	0%

Table 4.5. The total count of ponds where a species was observed, by subregion. The last column shows the total percent of ponds where the species has been observed.

Species	Subregions				
	East Bay Hills	Mt. Diablo Range	Mt. Hamilton	Total All Subregions	Percent of Ponds
California tiger salamander	4	128	60	192	29%
Newt (*Taricha* sp.)	173	1	66	240	36%
Western toad	26	125	55	206	31%
Sierran tree frog	205	181	98	484	73%
California red-legged frog	113	120	54	287	43%
Western pond turtle	24	23	13	60	9%
American bullfrog	54	5	28	87	13%
Invasive fish	17	11	15	43	6%

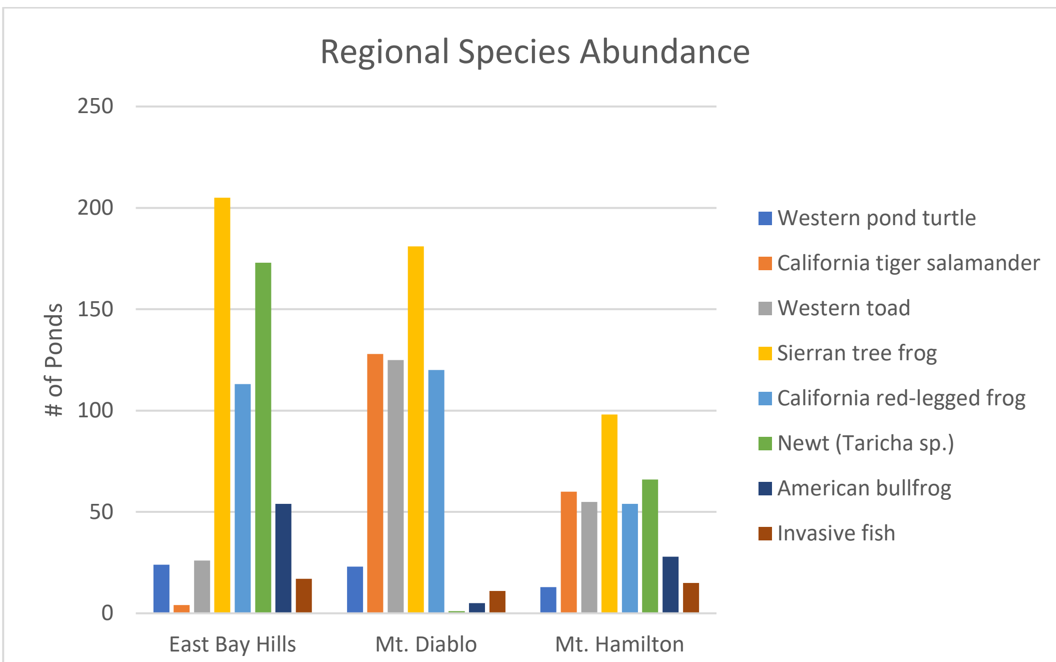


Figure 4.5. Ponds surveyed with species present. The Sierran tree frog (yellow) was consistently the most common species observed between 2009–2019.

Pond-species richness is an average of the count of the number of species observed at each pond. All ponds surveyed at least once from January 1, 2009, through December 31, 2019, were included. Raw pond-survey data collected by each agency within the area of focus was aggregated. If any life stage of a species was observed one or more times at any point from 2009 to 2019, the species was considered present at that pond. Within this time frame, 59% of ponds were surveyed. Of the ponds surveyed, between one and four different species were detected in 80% of them. Despite some variations in the distribution and range of the species analyzed, the results were remarkably similar across subregions: an average of two native species were detected at sampled ponds in each of the subregions. Detailed information on pond-species richness and number of ponds sampled by region is included in Table 4.6.

Table 4.6. Number of ponds sampled and the average number of amphibian or reptile species observed.

Subregion	All Ponds	Number of Sampled Sites 2009–2019	Percent of Sites Sampled	Pond Species Richness
East Bay Hills	389	247	63%	2.20
Mt. Diablo Range	393	265	67%	2.18
Mt. Hamilton	344	153	44%	2.26
Total, All Subregions	1,126	665	59%	2.21

Condition Thresholds:

- *Good:* There is no change or there is an increase in the average pond-species richness at surveyed ponds in any of the subregions in the area of focus.
- *Caution:* There is a more than 0.25-0.5 decrease in average pond-species richness at surveyed ponds in any of the subregions in the area of focus (e.g., East Bay Hills species richness declines from 2.20 to 1.95).
- *Significant Concern:* There is a more than 0.5 decrease in average pond-species richness at surveyed ponds in any of the subregions in the area of focus.

Condition: Good

The Sierran tree frog was present in 73% of ponds surveyed, and average pond-species richness was relatively constant throughout the area of focus (about two species per pond) (Table 4.6). The CRLF, a federally threatened species, was present in more than 40% of ponds and was the second most commonly observed pond species. The Sierran tree frog and CRLF were distributed throughout each region within the area of focus.

The western pond turtle was present at only 9% of ponds, but this was somewhat expected due to its preference for ponds and reservoirs with perennial hydroperiods (see Metric 3). This species may be more common across the area of focus than the analysis of this metric shows, as it heavily utilizes streams and reservoirs, which were not included in this analysis.

The western toad and CTS were not detected in the middle and northern portions of the East Bay Hills subregion, and only one instance of newts was recorded in the Mt. Diablo Range subregion. However, the lack of CTS in this subregion was expected based on past observation levels, which were very low. Despite survey efforts, an adult CTS has only been documented once in the California Natural Diversity Database (CNDDB) within the East Bay Hills at Las Trampas (CDFW 2021). CTS have either never been common in these areas or are largely extirpated from the middle and northern East Bay Hills (north of Hwy 580 and west of Hwy 680).

It is of interest that the western toad was not observed in the middle and northern East Bay Hills, although this may be due to survey timing. There are nine well-documented western toad occurrences in iNaturalist within the one East Bay Municipal Utility District (EBMUD) and East Bay Regional Park District (EBRPD) property in this subregion (iNaturalist 2021). However, adult toads do not spend long periods of time at breeding sites, and most dipnet surveys in these regions were conducted in late spring, when toads may have metamorphosed and left pond sites. Targeted surveys for toads are necessary to determine their presence throughout the East Bay Hills.

The absence of *Taricha* sp*.* observations from the Mt. Diablo Range subregion also merits further review. It is unclear whether newt species were simply not recorded during surveys, or that they were not present (Moss et al. 2021). Only one newt is documented on iNaturalist in the Mt. Diablo Range subregion, though they are well represented in the East Bay Hills and Mt. Hamilton subregions (iNaturalist 2021). Neither species of newts or the western toad is tracked locally in the CNDDB.

Trend: Unknown

This metric combines all data taken during the 2009–2019 period, but because this is the first regional assessment, it is not possible to analyze changes over time.

Confidence: Low

Though the patterns of species observations seem consistent with expected observations, such as the Sierran tree frog being observed in a majority of ponds, most of these pond surveys were conducted for either CTS or CRLF. Ideally, timing and methods used to survey for these two species should largely overlap other species' activity periods; however, the data recorded were focused on the quantity and life stage of CTS and CRLF. Therefore, data for other pond species may not have been consistently recorded even if they were encountered.

Metric 3: Presence of Non-Native, Invasive Species

Rationale: This metric assesses the estimated number of ponds within the area of focus that are occupied by invasive American bullfrogs or predatory fish (e.g., bass [*Micropterus* sp.] or sunfish [*Lepomis* sp.]).

The analysis of pond hydroperiod for Metric 1 was used in the evaluation of this metric because both fish and bullfrogs require permanent water sources. It is important to include this metric because it is well documented that non-native invasive species contribute to the decline of native amphibians as previously described in the Stressors section of this chapter.

Condition Goal: Maintain or decrease the number of ponds in the area of focus that are occupied by invasive species.

Current Baseline: Of 665 ponds surveyed, 87 (13%) had bullfrogs and 43 (6%) had invasive fish. The Mt. Hamilton and East Bay Hills subregions have similar proportions of ponds occupied by these invasive species, while the Mt. Diablo subregion has very few ponds with bullfrogs and fish (Table 4.7). Both of these species require permanent water; bullfrog tadpoles usually need more than a full year to develop, and fish cannot persist without water. As a result, many ponds are seasonal by design to deter colonization by invasive bullfrog or fish. The number of permanent ponds on the landscape is relevant to understanding the potential spread of invasive species. We do not know the total number of permanent ponds in the area of focus because we only assessed inundation in June, nor do we know the total number of ponds containing invasive species, because many ponds were not surveyed. However, it is likely that a subset of the 44% of ponds that held water through June (see Metric 1) continued to hold water throughout the remainder of the water year, and thus could have supported invasive species.

Table 4.7. The total number of surveyed ponds with bullfrogs and fish by subregion, as well as totals for all regions.

Subregion	Total Ponds	Ponds with Bullfrogs		Ponds with Invasive Fish	
East Bay Hills	247	54	22%	17	7%
Mt. Diablo Range	265	5	2%	11	4%
Mt. Hamilton	153	28	18%	15	10%
Total, All Subregions	665	87	13%	43	6%

Condition Thresholds:

- *Good:* The number of ponds in the area of focus occupied by bullfrogs or invasive fish is maintained or decreases.
- *Caution*: The number of ponds in the area of focus occupied by bullfrogs or invasive fish increases by up to 10%.
- *Significant Concern*: The number of ponds in the area of focus occupied by bullfrogs or invasive fish increases more than 10%.

Condition: Caution

Due to the low occurrence of invasive species across the area of focus and the relatively common and widespread abundance of native pond species such as the CRLF (see species richness in Metric 2), we believe that bullfrogs and invasive fish present a real but manageable threat to native amphibians and turtles. The condition of the Mt. Diablo Range subregion is “good,” with less than 2% of ponds occupied by bullfrogs. However, bullfrogs have been detected in more than 15% of ponds in the East Bay Hills and Mt. Hamilton subregions, leading us to an overall condition of “caution.” Bullfrog eradication projects are ongoing in these subregions, which will, it is hoped, reduce their presence and their ability to spread.

Trend: Unknown

This metric combines all data taken during 2009–2019 but does not analyze changes over time. In a future trend analysis, we anticipate that the exceptional drought in 2020–2021 may be found to have disrupted successful breeding for bullfrogs and extirpated fish from ponds that are usually perennial.

Confidence: Moderate

As both bullfrogs and invasive fish are easily detected in surveys, we have moderate confidence in these results. We performed a discrete analysis of the effect that bullfrogs and fish have on the CRLF (see Chapter 5). In that analysis, we found that while the presence of bullfrogs and invasive fish decrease the likelihood of CRLF occurrence, this effect was only observed in a few ponds.

In future surveys, recording the species of fish may help us understand how small-fish species like mosquitofish (*Gambusia affinis*) affect native amphibians and turtles. Differences in fish-species composition are important to track, as larger predatory fish, such as bass, are more likely to have an effect on larval amphibians. We also did not investigate fish and bullfrog occupancy within streams and reservoirs.

OTHER METRICS CONSIDERED BUT NOT INCLUDED

- The presence and distribution of these species in creeks, rivers, seeps, springs, or reservoirs. While these habitats are important for many of the amphibians and the turtle, data for them were sparse and difficult to compare.
- The presence and distribution of parasites and disease, such as Bd, ranavirus, Ribeiroia, and Emte. This information exists but has already been evaluated in a published paper (Hoverman et al. 2012).

- Other aquatic reptiles in the area of focus. Species such as the three garter snake species (*Thamnophis* sp.) for Metric 2 and red-eared sliders for Metric 3 were considered but were not included because data were sparse and not consistently collected.
- For Metric 1, ponds that have a hydroperiod of only three months in an average water year. These ponds could provide habitat for the Sierran tree frog or western toad, but they are unlikely to provide reliable breeding habitat for other amphibian species.
- Short-hydroperiod ponds and pools that may support the western spadefoot toad (*Spea hammondi*). Its range in the area of focus is highly restricted and we had no existing data to analyze.

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

- Our metrics do not account for population estimates. Simple presence and breeding data cannot be easily applied to measures of relative abundance, fecundity, or other measures of population size.
- The survey methodology used by different partner agencies is unlikely to fit into assumptions of statistically robust study designs, and it would be difficult to make assertions about unsampled ponds. Ponds have not been randomly sampled, and uneven sampling decreases statistical power.
- Amphibian diversity can be estimated by presence data, but Network partner agencies have generally conducted targeted-species surveys for the CTS and CRLF. While biologists generally record all amphibians and reptiles found in a pond, the absence of a species in the data is not necessarily indicative of a survey effort with negative findings. To remedy this, a revised data sheet with a checklist for all seven species (separating out the newt species) has been created (an early result of the formation of the Network and these indicator analyses). Network partner agencies will use this revised datasheet to improve data collection in future monitoring efforts. Analyses using data collected from 2021 onward will reflect these data-collection improvements in these amphibian communities. For example, increases in amphibian diversity may be due to improvements in the data collected rather than be true additions to species assemblages.
- Some of these data have been collected during visual nighttime eyeshine surveys, which are very good at detecting ranid frogs (e.g., the CRLF and American bullfrog) but less so for other amphibians and reptiles. Differences in survey time (nighttime vs. daytime dipnet surveys) and

type will influence species captured or identified. Timing of surveys during the year or following major rain events will also affect species observations. Additionally, ponds with repeated surveys are more likely to yield greater species richness, as they can be sampled during multiple species' peak breeding seasons.

- The CRLF and the Sierran tree frog range throughout the area of focus, but there are likely natural range restrictions for some of the other species. For many of the other native pond species, there is no distinct pattern of decline. However, we do not have detection data in parts of their presumed range. Network partner agencies have not detected:
    - the western toad in the north and middle East Bay Hills subregion,
    - the CTS in the north and middle East Bay Hills subregion (except for a lone observation in Las Trampas),
    - the California newt in the Mt. Diablo Range subregion, or
    - the rough-skinned newt in the Mt. Hamilton or Mt. Diablo Range subregions.
- The adverse effects of fish and bullfrogs have been studied, but we have less information on how other non-native species affect amphibians. For example, in a study at Fort Benning, Georgia, feral pigs were documented taking large quantities of reptile and amphibian species (Jolley et al. 2010), but gut content analysis showed that feral pigs in California's oak woodlands consume mostly small mammals (Wilcox and Van Vuren 2009). The wallowing habits of feral pigs may also affect native amphibians by reducing hydroperiods of shallow ponds (Purificato 2018, personal observation). Wild turkeys consume mostly vegetative matter but have been observed eating vertebrates (McRoberts 2014). Crayfish (red swamp crayfish [*Procambarus clarkia*]and signal crayfish [*Pacifastacus leniusculus*]) are also potential CRLF predators (USFWS 2002), as they are known to prey on amphibian eggs and larvae in the lab (Gamradt and Kats 1995).
- Recent droughts may have affected amphibian species in positive or negative ways. The American bullfrog, which requires perennial water to breed successfully, may be extirpated in some areas as usually permanent ponds dry out. However, more frequent, severe, or exceptional droughts such as those experienced in the area of focus in 2014–2016 and 2020–2021 (USDM) are likely to result in poor outcomes for many amphibian and turtle populations. Many of these species are very resilient over a few years of drought (Moss et al. 2021; see also Chapter 5), but in recent years, the increased frequency and severity of drought has been unprecedented. Network partner agencies have documented recent catastrophic losses in newts and pond turtle populations following the exceptional drought of 2020–2021 (unpublished data). In light of potentially extreme precipitation and temperature fluctuations,

future analyses will need to take these singular events into account as they attempt to generate robust trend data.

PAST AND CURRENT MANAGEMENT

Network partner agencies in this area of focus have conducted long-term monitoring coupled with pond maintenance, restoration, enhancement, and creation. These management actions include pond de-sedimentation to lengthen hydroperiods, repairing embankments, removing encroaching emergent vegetation, restoring native vegetation, and removing bullfrogs and fish via periodic draining. Additionally, ponds created on conservation easement lands are monitored post-construction to meet mitigation requirements.

POTENTIAL FUTURE ACTIONS

- Establish more systematic and coordinated data-collection efforts, in which Network partner agencies conduct pond surveys using similar methods and data sheets when possible.
- Continue pond restoration efforts by collaborating on pond restoration priorities, targeting invasive species control where activities benefit multiple Network partner agencies, and improving pond hydroperiods.
- Model a subset of ponds under future climate-change scenarios.
- Consolidate academic disease research across the area of focus.

These actions may increase our confidence in the data used in subsequent analyses; provide greater coverage and more even sampling across the area of focus; help prioritize where pond restoration efforts should be focused; and, in the case of modeling pond hydrology, help partner agencies proactively manage for climate change.

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Partner Agency Data Sources

- East Bay Regional Park District (EBRPD) provided GIS pond shape files and data from 1,209 pond surveys conducted between 1996-2019. Data used in this analysis were collected from 293 of the 441 EBRPD ponds between 2009 - 2019.

- East Bay Municipal Utility District (EBMUD) provided GIS pond shapefiles and data from 2,262 pond surveys conducted between 2007-2020. Data used in this analysis were collected from 148 of the 181 EBMUD ponds between 2009 -2019.
- California State Parks (CSP) provided pond GPS coordinates and data from 233 pond surveys conducted between 2006-2018. Data used in this analysis were collected from 42 of the 104 CSP ponds between 2009 and 2019. :
- San Francisco Public Utilities Commission (SFPUC) provided GIS pond shapefiles and data from 162 pond surveys conducted between 2007-2016. Data used in this analysis were collected from 54 of the 104 SFPUC ponds between 2009 and 2019.
- Contra Costa Water District (CCWD) provided GIS pond shapefiles and data from 3,045 pond surveys conducted between 2005 -2018. Data used in this analysis were collected from 128 of the 157 CCWD ponds between 2009 and 2019.
- The Johnson Lab of the University of Colorado, Boulder provided GIS pond shapefiles (Calpond dataset) and data from 1,446 pond surveys conducted between 2009-2019 on Network partner lands.

Other Data Sources:

- California Department of Fish and Wildlife: California Natural Diversity Database. https://wildlife.ca.gov/Data/CNDDB

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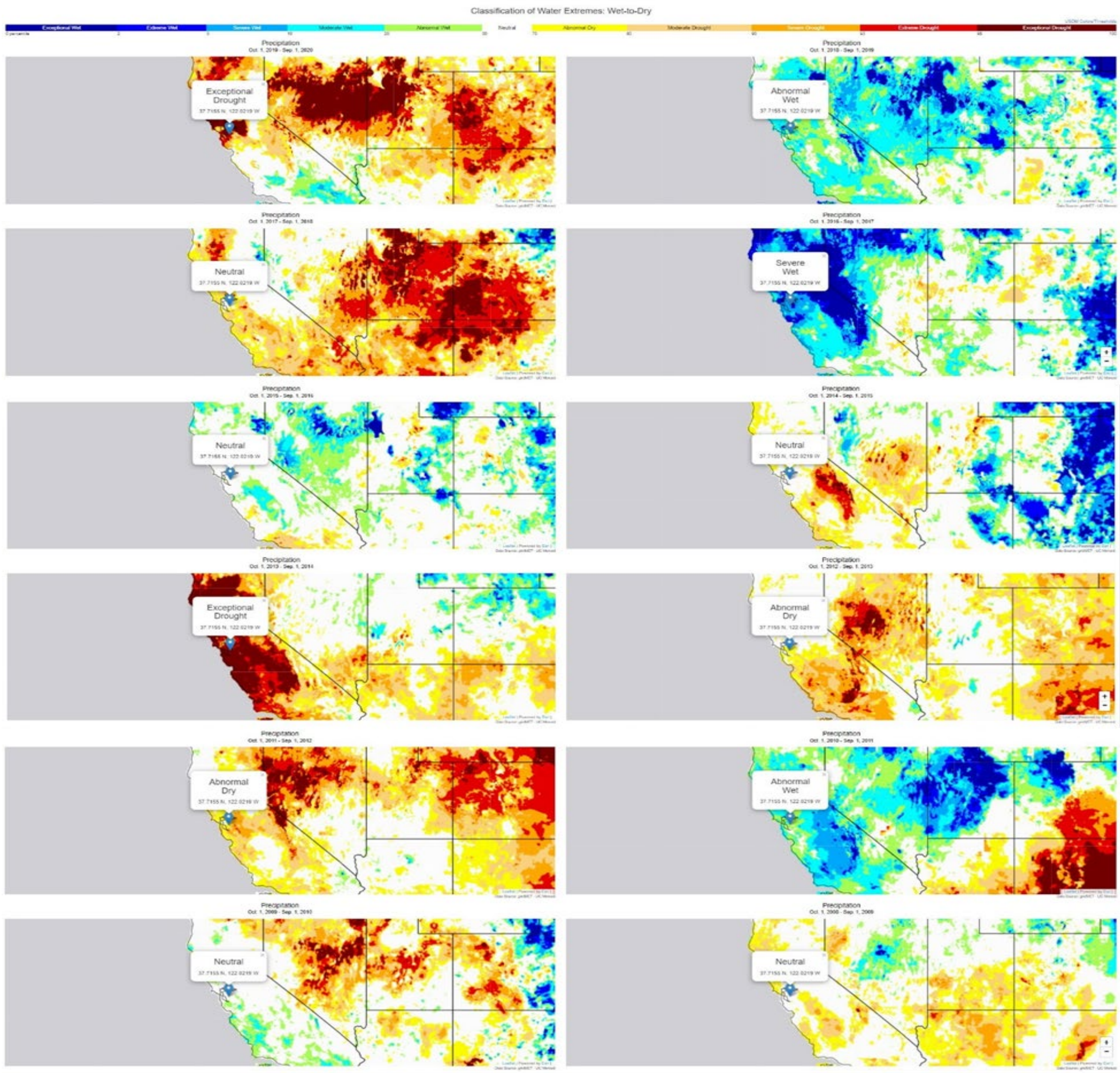

Figure 4.1. Classification of water extremes by water year from October 2008 through September 2020 using a center point in the area of focus. Data were generated using the Climate Toolbox (climatetoolbox.org, Hegewisch et al. 2021). Legend (next page): Percentile values of the drought metrics in the colors and categories used by the U.S. Drought Monitor.

Color		Class	Percentile (Dry to Wet Variable)	Percentile (Wet to Dry Variable)
	D4	Exceptional Drought	0-2	98-100
	D3	Extreme Drought	2-5	95-98
	D2	Severe Drought	5-10	90-95
	D1	Moderate Drought	10-20	80-90
	D0	Abnormal Dry	20-30	70-80
		Neutral	30-70	30-70
	W0	Abnormal Wet	70-80	20-30
	W1	Moderate Wet	80-90	10-20
	W2	Severe Wet	90-95	5-10
	W3	Extreme Wet	95-98	2-5
	W4	Exceptional Wet	98-100	0-2

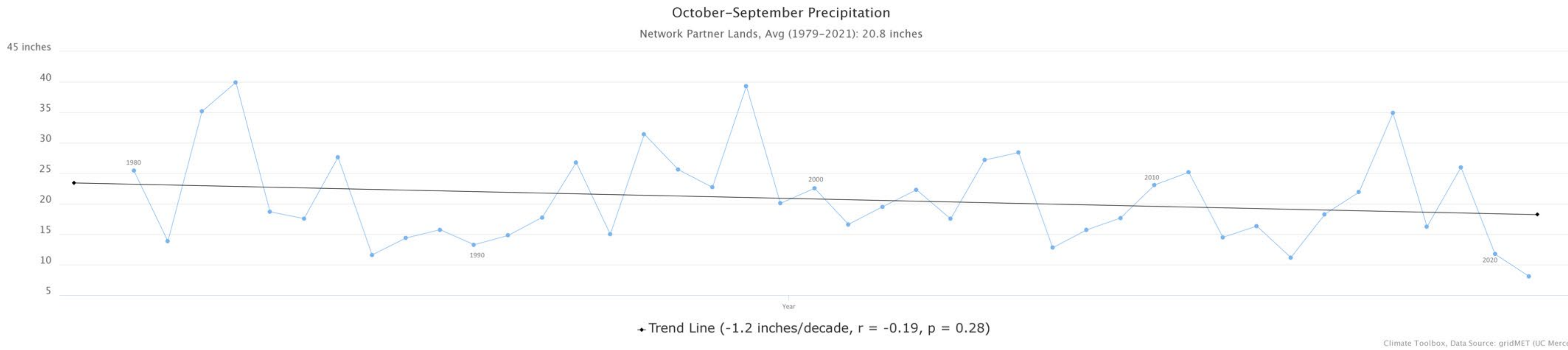

Figure 4.2. Precipitation from 1979 – 2021 for the Network partner lands within the bounding rectangle: 37.4157N to 38.0294N, 122.3318W to 121.6639W. Generated by the Historical Climate Tracker Tool in the Climate Toolbox.

CHAPTER 5. CALIFORNIA RED-LEGGED FROG (*RANA DRAYTONII*)

EXECUTIVE SUMMARY

The California red-legged frog (*Rana draytonii*, CRLF) is found throughout much of the state. However, a decline in both numbers and distribution prompted the species' listing under the federal Endangered Species Act in 1996. This frog is a good indicator of the ecological health of East Bay Stewardship Network (Network) partner lands (see map, Chapter 1) because it can live for up to a decade, allowing us to assess the effects of both natural and anthropogenic changes over time. It also relies upon a variety of habitats, including ponds and wetlands for breeding and development as well as uplands for basking, foraging, and dispersal. These lands have been divided into three subregions for the purposes of this analysis. Within these subregions, data came from individual parks, reservoirs, recreation or management areas, and other open spaces that we refer to as "Network partner lands" throughout this chapter.

This chapter presents the results of an evaluation of a suite of four metrics that help reveal the current condition and trend of this species on Network partner lands. These metrics assess where the CRLF is found in the area of focus, where it breeds, if it is able to disperse, and where it is threatened by invasive species. In addition to assessing current status, a primary goal of this analysis is to provide a baseline against which managers can measure future changes.

Using data collected between 2009 and 2019, we found that the CRLF is in "good" condition, with an "unchanging" trend on Network partner lands for which we have data. A recent paper using much of the same data (Moss et al. 2021) showed that many of our native populations are resilient to drought, with amphibian populations able to recover during normal or above-average precipitation years. However, it should be noted that these analyses do not include the exceptional drought of 2020–2021. Because only available data were used, this chapter also identifies areas where not enough is known to draw meaningful conclusions, as well as opportunities for future research and collaboration between land managers.

METRICS SUMMARY AT A GLANCE

The table below summarizes the four metrics used to evaluate CRLF health in this NatureCheck ecological health assessment. Each metric, along with how we arrived at its condition, trend, and confidence, is thoroughly described in the Metrics in Detail section later in this chapter. (See Chapter 1 for definitions and thresholds for condition, trend, and confidence; other terminology used throughout this chapter; how metrics are being used for each indicator; and other project methodology.)

Table 5.1. All CRLF metrics, with their respective condition, trend, and confidence, by subregion. Each metric is described in the Metrics in Detail section later in this document.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Metric 1: CRLF Presence–Estimated proportion of ponds where any CRLF life stage has been documented to be present in the last 10 years.			
Condition	Good	Good	Good
Trend	Improving	Unchanging	Unchanging
Confidence	High	Moderate	Moderate
Metric 2: CRLF Breeding–Proportion of confirmed CRLF breeding sites within ponds in the last 10 years.			
Condition	Good	Good	Good
Trend	Improving	Unchanging	Unchanging
Confidence	High	Moderate	Low
Metric 3: CRLF Metapopulations–Number and size of CRLF metapopulations that exist across the area of focus, and the expansion or persistence of these metapopulations over the last 10 years.			
Condition	Good	Good	Good
Trend	Unchanging	Unchanging	Unchanging
Confidence	Moderate	Moderate	Moderate
Metric 4: Presence of Non-Native, Invasive Species–Estimated number of ponds occupied by bullfrogs or predatory game fish.			
Condition	Good	Good	Good
Trend	Unchanging	Unchanging	Unchanging
Confidence	High	High	High

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of the CRLF in the area of focus represented by the graphic below is based on the combined values of the individual metrics in Table 5.1. Each of these metrics is described in depth in the Metrics in Detail section later in this chapter.

Condition: Good (color: green)

Trend: Unchanging (symbol: horizontal arrow)

Confidence: Moderate (line around circle: dashed)

BACKGROUND

WHY IS THIS RESOURCE INCLUDED?

The California red-legged frog (*Rana draytonii*, CRLF) was federally listed as a threatened species in 1996 (USFWS 1996). Alameda and Contra Costa County populations have been identified by the U.S. Fish and Wildlife Service (USFWS) as important for the recovery of the species (USFWS 2002).

The CRLF is a good indicator of freshwater wetland condition because it is a relatively long-lived species (lifespan of 8 to 10 years) that breeds in wetlands and other aquatic features. Its sensitivity to changes in hydrology and precipitation, as well as susceptibility to pollutants and toxins, makes the CRLF an excellent indicator of ecosystem health. Amphibians such as the CRLF are uniquely sensitive due to their permeable skin and complex, aquatic larval development. East Bay Stewardship Network (Network) land managers have been working to conserve habitat, construct ponds and wetlands for breeding frogs, remove invasive species, and restore native vegetation. Using various methods over different time periods, Network partner agencies have conducted targeted breeding and non-breeding surveys to document and track CRLF populations across this project's area of focus. (See map, Chapter 1.)

DESIRED CONDITION AND TREND

A CRLF phylogeographic study comparing coastal San Francisco Bay Area populations to those in the northern Sierra Nevada and southern coastal California found that populations in the Bay Area are genetically diverse, with high gene flow (Richmond et al. 2014). CRLF metapopulations are abundant and well-connected in the East Bay (USFWS 2002), and the overall proportion of sites that at least occasionally contain CRLF is quite high (>40%). Within the area of focus, the CRLF appears generally healthy, especially given declines in other parts of the state. Based on the assumption that the CRLF is widely present and well dispersed within the area of focus, the desired condition of the indicator is to maintain or improve current conditions and trends as defined in the metrics used in this ecological health assessment.

CURRENT CONDITION AND TREND

Condition: Good

Trend: Unchanging

Confidence: Moderate

The CRLF has not been recently observed in parts of its historical range within the area of focus, primarily areas west of the East Bay Hills (e.g., Tilden). However, populations along the eastern side of the East Bay Hills ridge managed by the East Bay Municipal Utility District (EBMUD) appear robust and healthy. The CRLF is also found, often in abundance, in the Mt. Diablo Range and Mt. Hamilton subregions. Wetland preservation, pond creation and enhancement, along with the CRLF's ability to colonize and rebound in restored habitats (Riensche et al. 2019) have allowed Network land managers to successfully maintain CRLF populations throughout much of the area of focus.

The sensitivity of CRLF populations to drought (as described in the Stressors section) reinforces that hydroperiod management is an important tool for maintaining stable populations. We note that properties with Habitat Conservation Plans were successful in maintaining and even improving CRLF populations through a combination of invasive-species management and pond restoration; thus, data from these properties may be disproportionately represented in our dataset. In properties where ponds are less actively managed and where data are sparse, it is essential to continue monitoring CRLF populations.

The current condition, trend, and confidence are the average of the condition, trend, and confidence for the CRLF in each subregion as shown in Table 5.2. The metrics described in depth in the Metrics in Detail section of this chapter were combined to determine this current condition and trend. These metrics give us a way to measure the difference between what is described in this section (i.e., how things are now) and the desired condition and trend in the preceding section (i.e., what we think "healthy" is for this indicator).

Table 5.2. The overall CRLF condition, trend, and confidence for each subregion in the area of focus.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Condition	Good	Good	Good
Trend	Improving	Unchanging	Unchanging
Confidence	High	Moderate	Moderate

STRESSORS

Several ecological and anthropogenic factors affect the health of this indicator. These include:

Invasive Species Impacts: Non-native, invasive species are known to compete with and prey upon the CRLF. Introduced fish species are efficient predators of native frogs, can prevent the CRLF from reproducing, and have been found to have a strong negative affect on CRLF occupancy (Joseph et al. 2016). If adult frogs are present, populations can rebound once these invasive fish are removed (Alvarez et al. 2002). In addition, American bullfrogs (*Lithobates catesbeianus*) are often implicated in native amphibian declines (Doubledee et al. 2003, Snow and Witmer 2010). Often, invasive fish and bullfrogs are present in tandem, and ponds with both predatory fish and bullfrogs are particularly associated with a decline in the CRLF and other native amphibians in California ecosystems (Kiesecker and Blaustein 1998, Lawler et al. 1999, Riley et al. 2005). Bullfrogs are often able to re-invade from adjacent ponds and nearby reservoirs even after removal.

Crayfish (red swamp crayfish, *Procambarus clarkii*; signal crayfish, *Pacifastacus leniusculus*) are also potential CRLF predators (USFWS 2002). Crayfish are known to prey on amphibian eggs and larvae in the lab (Gamradt and Kats 1996). Finally, terrestrial non-native species such as feral pigs (*Sus scrofa*) and wild turkeys (*Meleagris gallopavo*) may also adversely affect CRLF populations (Wilcox and Van Vuren 2009, McRoberts et al. 2014).

Climate Change: The potential effects of climate change on this species' habitats include shorter hydroperiods, more frequent droughts, more extreme or unseasonable rain events, and changes in water and air temperatures (Polade et al. 2017, Swain et al. 2018). However, an analysis of their vulnerability to climate change determined that the CRLF is moderately resilient to these anticipated changes (CVLCP 2017).

Disease: Amphibian diseases have been at the forefront of frog conservation efforts in recent decades. The rapid spread of a fungal pathogen, *Batrachochytrium dendrobatidis* (Bd), and subsequent extirpations and extinctions have been major causes for alarm in other amphibian species. In our area of focus, there has been little evidence that CRLF populations are sensitive to Bd. Laboratory (Padgett-Flohr 2008) and field (LaBonte et al. 2014) experiments have found that the CRLF carries the disease but apparently does not succumb to it, though one mortality has recently been documented (Grasso and Kamoroff 2019). Other diseases such as ranavirus (Tornabene et al. 2018) and parasites like *Ribeiroia ondatrae* (Johnson et al. 2013), which causes amphibian deformities, may have impacts on native amphibian populations. Additionally, changes in wetland water temperatures due to climate change may influence amphibian susceptibility to these diseases (Olson et al. 2013, Brand et al. 2016).

Pollution/Contaminants: Davidson et al. (2002) found that the CRLF seems to be affected by pesticide drift. However, this research describes declining populations along the Sierra Nevada foothills directly in the path of prevailing winds from the heavily agricultural Central Valley. The extent to which pesticide drift affects populations in the East Bay is unknown.

Habitat Disturbance/Conversion/Loss: Lands managed by Network partner agencies in the area of focus are generally protected from habitat loss. However, encroaching urbanization, utility/transportation corridors (e.g., loss of upland habitat, road mortality), and competing interests for renewable-energy development (e.g., solar and wind) may affect CRLF populations (USFWS 2002). Across California, the USFWS (2002) estimates that the CRLF has been extirpated from approximately 70% of its historical range.

Other Stressor: Grazing. Cattle grazing has been indicated as a possible stressor to frog populations (USFWS 2002), but more recent evidence indicates that managed grazing is highly compatible with CRLF management (Ford et al. 2013, USFWS 2004). The USFWS acknowledges that routine livestock ranching activities are consistent with CRLF conservation and may provide conservation benefits (USFWS 2010). The agency finalized a special rule under section 4(d) of the Endangered Species Act for the CRLF in 2006 (71 FR 19243, April 13, 2006) that exempts routine ranching operations from take prohibitions. While stock ponds created for cattle can provide excellent breeding habitat for frogs, grazing must be managed to ensure that the ponds provide appropriate hydroperiods for breeding and suitable vegetation for egg-mass attachment. In uplands, managed grazing also keeps down non-native thatch buildup and improves terrestrial migration conditions for many amphibian species.

CONDITION AND TRENDS ASSESSMENT

METRICS IN DETAIL

The four metrics outlined below are a simple but informative way to measure CRLF occupancy across the area of focus. Unless specified otherwise, trends and metrics are based on a 10-year period between 2009 and 2019. For the purposes of estimating trends in CRLF presence, we only considered ponds that had been surveyed more than five times within this 10-year period. In statistical analyses, we also aggregated pond surveys across three-year periods (i.e., a pond was determined to be occupied if the CRLF was observed during any survey of that pond over a three-year interval). This method reduced noise from variable survey efforts, low detection probability, and interannual variation.

Metric 1: CRLF Presence

Rationale: This metric was evaluated by determining the estimated number of ponds where any CRLF life stage had been found in the 10-year interval between 2009 and 2019. CRLF presence is relatively easy to monitor and is the most basic way to confirm habitat for adult or post-metamorphic frogs. We considered presence of the CRLF in ponds or wetlands that met the following criteria: They (1) had been surveyed during the breeding season at least once between 2009 through 2019, (2) did not appear to have too short a hydroperiod,[18] and (3) were located within dispersal distance (3

[18] We have incomplete information on hydroperiod, and only excluded ponds *confirmed* to be too dry for successful breeding in most years. Ponds that were removed due to insufficient hydroperiod were those that were (1) surveyed intensively (in at least three years) and were dry by August in more than half of surveyed years and (2) had no CRLF

kilometers [km]) of a known CRLF population or were observed having CRLF within the past decade. Ponds meeting these criteria were included in this analysis.

Condition Goal: Maintain or increase the number of ponds occupied by the CRLF in the area of focus.

Current Baseline: The Network partner agencies manage a total of more than 1,100 ponds, 665 of which have been surveyed at least once in the past decade. Of these, we excluded 75 sites that were either unoccupied and isolated from other CRLF populations or had insufficient hydroperiods. This left a remaining 582 sites that could be designated as potential CRLF habitat. The CRLF has been documented at 49% (*n* = 285) of these sites within the past decade and is found across the area of focus. The proportion of sites that contain the CRLF varies by subregion, with the East Bay Hills and Mt. Diablo Range subregions having the highest proportion (East Bay Hills: 51%, 111 of 218 sites; Mt. Diablo Range: 50%, 122 of 243 sites). The lowest proportion was observed within the Mt. Hamilton subregion, where 52 of 121 of sites (43%) contained the CRLF (Figure 5.1).

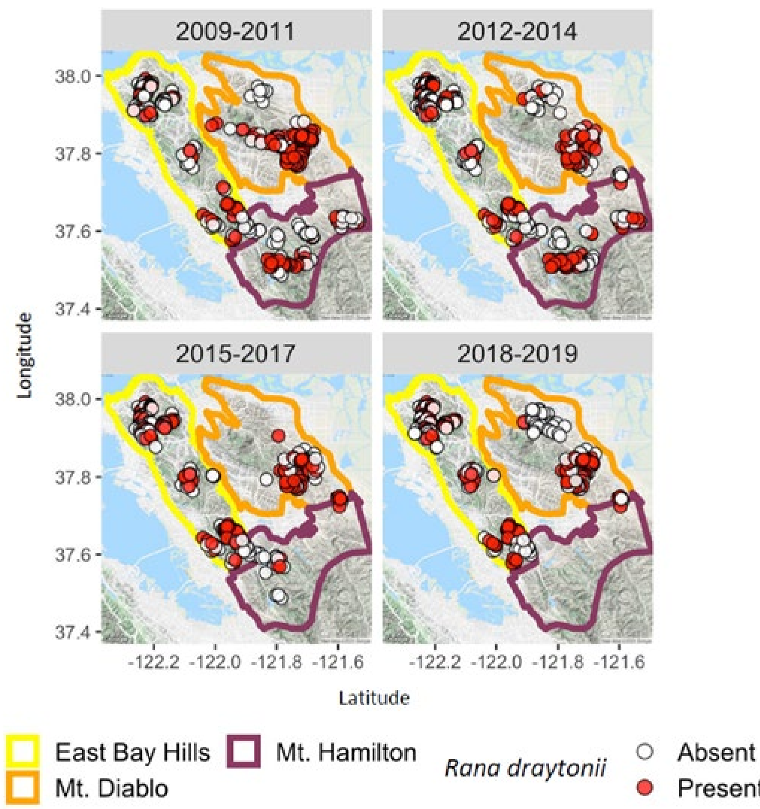

Figure 5.1. CRLF detections at surveyed and potential sites (n = 582) over the past 10 years (2009–2019). Each point represents a pond that was surveyed during the period; the color indicates whether

observations in the past decade. Ponds that were surveyed only once in a season may have been surveyed early in the summer and could potentially have dried by August but were included in the absence of additional data.

any life stage of CRLF was observed at least once during that time period. This species occurs throughout each subregion, although survey efforts have varied across time.

Condition Thresholds: [19]

- *Good:* The number of ponds occupied by the CRLF in the area of focus is maintained, increased, or declines by less than 10% over the next 10 years.
- *Caution:* The number of ponds occupied by the CRLF declines 10%-20% in the area of focus in the next 10 years.
- *Significant Concern:* The number of ponds occupied by the CRLF declines more than 20% in the area of focus over the next 10 years.

Condition: Good (all subregions)

Trend:

Improving (East Bay Hills)

Unchanging (Mt. Hamilton, Mt. Diablo Range)

Overall, when considering the entire area of focus, CRLF presence appeared stable, with improving trends in one of three subregions and no clear trend in two of three subregions (Figure 5.2).

We used several methods to compare CRLF presence across time and to ensure confidence in observed trends. The majority of ponds were not surveyed every year, and many ponds were only surveyed once or twice. These ponds could not be used to reliably analyze trends without introducing potential bias, and were therefore omitted from our analysis. We analyzed a subset of ponds that were surveyed at least five times over the past 10 years (*n* = 229 ponds). Consequently, our results are biased toward properties that contained frequently surveyed sites.

Of the sites we included, we first evaluated the number of sites that appeared to lose or gain the CRLF over the past decade. At the beginning of the decade (2009–2012), 120 ponds contained the CRLF. When these ponds were resurveyed in the latter part of the decade (2015–2019), the majority (*n* =102; 85%) retained the CRLF, with at least one detection after 2015. Eighteen ponds appeared to have lost CRLF within the past decade, the majority of which (*n* = 11) were within the Mt. Diablo

[19] The condition threshold percentage values set for each metric in this chapter are based on professional judgment using limited information and were chosen as values that are measurable and likely to have some effect on the indicator species. Where feasible, subsequent analyses will be based on a pond-to-pond comparison, to avoid confounding the effects of increased pond sampling.

Range subregion. Conversely, of the 77 sites that were surveyed between 2009 and 2012 and did not contain the CRLF, 30 (42%) gained the species in subsequent years. These sites were mostly (*n* = 20) located within EBMUD lands in the East Bay Hills subregion. EBMUD has been actively restoring ponds throughout their watersheds.

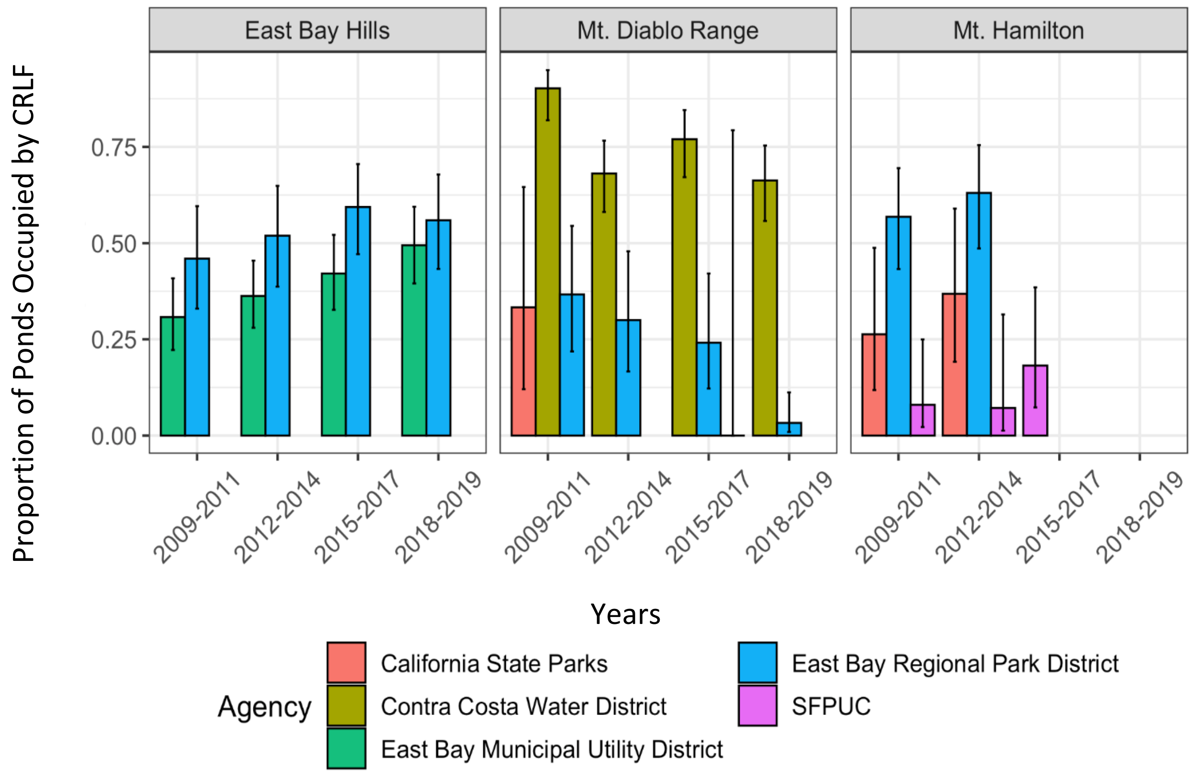

Figure 5.2. Proportion of sites with detections of CRLF across time. Error bars represent a 95% confidence interval. Plotted data include any pond monitored within the past decade. We grouped data such that a pond was considered occupied if CRLF was detected during any survey within a three-year timespan. This enabled us to visualize longer-term trends less likely to be influenced by observer error and variation in monitoring effort.

Next, we used statistical methods (logistic regression) to estimate overall trends in CRLF occurrence. Specifically, we used generalized linear mixed models, which enabled us to test if there were significant differences in the proportion of sites containing the CRLF at the beginning (2009–2011) versus the end (2018–2019) of the decade. In the East Bay Hills subregion, the models estimated a significant gain in predicted CRLF occupancy, from 28% to 58% (P <0.001). In the Mt. Diablo Range subregion, the model estimated a decrease in the CRLF from 87% to 76%, but this was only marginally significant (P = 0.06). We could not statistically evaluate trends in the Mt. Hamilton subregion because very few surveys were conducted in the latter half of the decade (Figure 5.3); however, the first few years of data did not identify strong trends in either direction.

Confidence:

High (East Bay Hills)

Moderate (Mt. Diablo Range and Mt. Hamilton)

Presence data are available for many of the ponds in the area of focus, but survey timing varies. For example, EBMUD consistently conducts presence surveys on a number of ponds each year, but East Bay Regional Park District (EBRPD) has data for all ponds every four years up to 2012. Some partner agencies have only one or two seasons of survey data.

The designation of potential CRLF habitat was contingent on three components. (1) CRLF presence, which we recognize is a circular argument; however, a species' use of a habitat indicates high confidence that the habitat is at least somewhat suitable (for occupancy, if not successful reproduction). If a pond did *not* have CRLF records, we still considered it as potential habitat provided that it had both (2) appropriate hydrology and (3) proximity to other CRLF populations. Our confidence in the hydrology component is moderate; we generally assumed that ponds had a sufficient hydroperiod unless survey data indicated that they consistently dried before September. We did not have hydroperiod data on all of the ponds surveyed, and for the presence analysis, did include ponds that were only surveyed once in a year. Ponds were also considered potential habitat based on sufficient proximity (< 3 km) to other CRLF populations. Our estimate of potential habitat is fairly conservative, as we may have excluded ponds that appeared to be isolated but may have been proximate to ponds that were occupied and not surveyed. Our confidence in this component is also moderate, as most of the seasonal to semi-permanent ponds that were likely CRLF habitat were probably surveyed within the 10-year span. Finally, we note that we only had recent survey data on 665 of the >1,100 ponds managed by Network partner agencies. Ponds without survey data were not considered in our analysis; however, there is a strong possibility that some of these ponds may also contain CRLF.

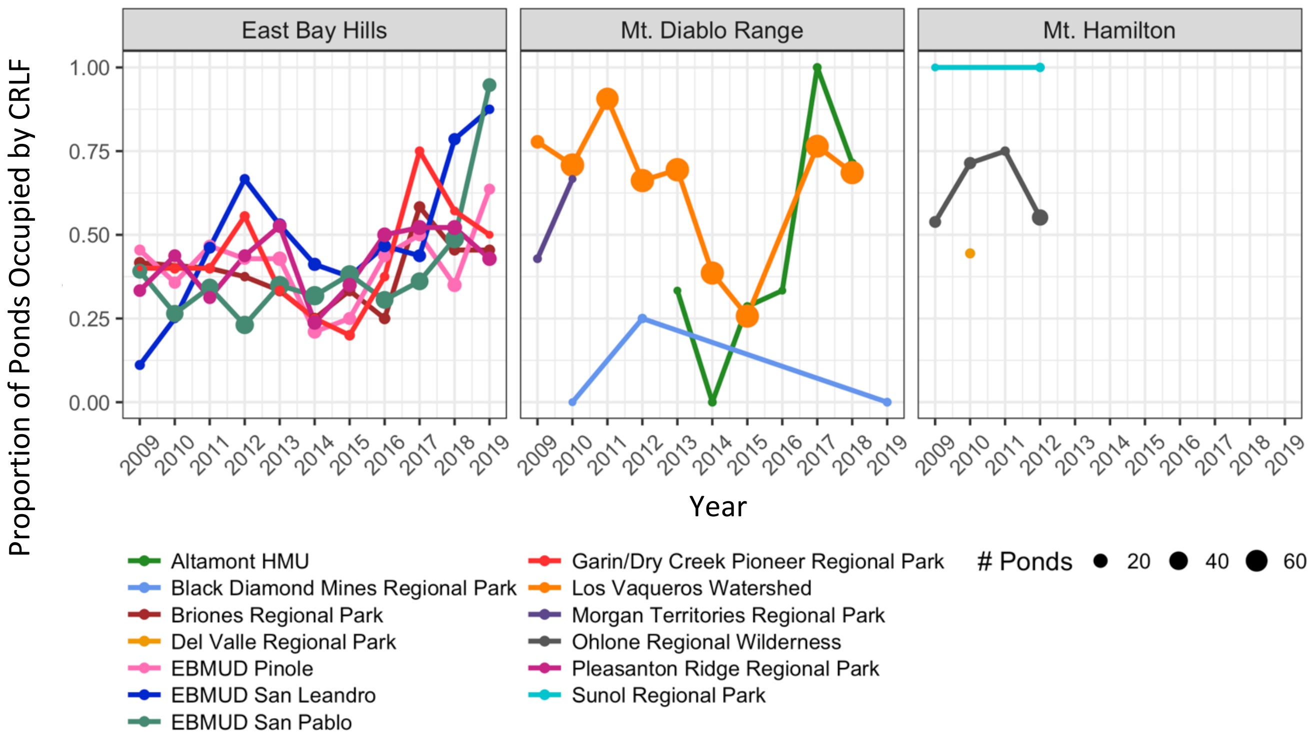

Figure 5.3. The proportion of surveyed ponds containing any life-stage of CRLF in a given year, grouped by property and subregion. Only properties with sufficient data are shown (properties needed to have at least five ponds surveyed at least five times). Point size represents the number of ponds within each property that were surveyed in a given year. Severe drought conditions occurred in 2014 and 2016. 20 While CRLF occurrence generally dropped during these two years, it was followed by recovery on almost every property.

CRLF presence fluctuates according to annual precipitation; therefore, interannual variation in CRLF occurrence must be disentangled from longer-term trends. In years with lower precipitation and shorter hydroperiods, such as 2014 and 2015, CRLF numbers decreased in almost every surveyed property (Figure 5.3). While they appeared to recover in subsequent years, some properties were not surveyed extensively in the years following drought. For example, our dataset did not include any surveys in the Mt. Hamilton subregion after 2016, resulting in uncertainties about whether the CRLF has recovered from drought and the longer-term trend in this region. In the Mt. Diablo Range subregion, numerous properties (Black Diamond Mines, Contra Costa Water District [CCWD] conservation lands, Morgan Territories) were not monitored extensively at both the beginning and

[20] The full drought period extended from 2012–2017; 2014–2016 were peak drought years, categorized as exceptional drought by the US Drought Monitor (https://www.drought.gov/states/california).

the end of the decade. Thus, although there was some evidence of possible declines (Figure 5.2), the resulting trend was not statistically significant (P = 0.06) and we did not have high confidence in this trend. However, in the East Bay Hills subregion, there was both consistent survey effort and robust evidence of stability and/or increasing occurrence. Consequently, we had high confidence in trends in those regions.

An important caveat to our confidence in these analyses is that monitoring efforts may be concentrated on properties where the CRLF is already abundant or where restoration efforts are ongoing. In other words, populations likely to be monitored are also populations likely to increase. This could lead to bias and false confidence. Indeed, both CCWD and EBMUD conducted yearly surveys and both groups concurrently managed ponds extensively for CRLF habitat as part of existing management plans. Our dataset, therefore, may contain a disproportionate number of observations from populations that are already likely to increase due to management plans that target both restoration and monitoring.

Because we observed increases or stability in multiple properties across multiple agencies, we remain confident that robust CRLF populations exist across the landscape. However, we may be missing important declines in areas with less data. For instance, Black Diamond Mines appeared to have CRLF prior to drought (2012) but did not contain the CRLF during recent surveys (Figure 5.3). Most ponds within this property were only surveyed once or twice during the past decade and as a result, the trend is less clear. We caution that more data are needed, especially in properties for which there are lower CRLF densities and less active management of their habitat.

Metric 2: CRLF Breeding

Rationale: This metric assesses the estimated number of ponds that have confirmed CRLF breeding as determined by the presence of egg masses, larvae, or recent metamorphs. The identification of potential breeding habitat for Metric 1 has been used in this metric.

Condition Goal: Maintain or increase the number of ponds occupied by breeding CRLF in the area of focus.

Current Baseline: Of 582 ponds with potential habitat for breeding (see Metric 1), 220 (38%) had evidence of CRLF breeding within the past decade. Many of the sites with no evidence of CRLF breeding (*n* = 362) were simply not surveyed extensively (236 had fewer than three years of summer survey data). Seventy-one sites included in this analysis were surveyed extensively, and yet did not contain breeding CRLF. More than one-third of these (26/71) contained invasive species (fish or bullfrogs), and an additional 48 were observed to be dry at least once during the breeding season. This suggests that poor survey data, invasive species, or insufficient hydroperiod explain why breeding CRLF were not detected at these ponds. We note that CRLF breeding did co-occur with invasive fish and bullfrogs at 11 and 24 ponds, respectively. The distribution of breeding largely mirrored overall occurrence, with the East Bay Hills and Mt. Diablo Range subregions having the highest percentage of sites with breeding observed in the past decade (East Bay Hills: 83/218 sites, 38%; Mt. Diablo Range: 97/239 sites, 41%) and the Mt. Hamilton subregion having the lowest (40/120 sites, 33%).

Condition Thresholds:

- *Good:* The number of ponds occupied by breeding CRLF in the area of focus is maintained or increased, or decreases by less than 10%.
- *Caution:* The number of ponds occupied by breeding CRLF in the area of focus declines by 10%–20% in the next 10 years.
- *Significant Concern:* The number of ponds occupied breeding CRLF in the area of focus declines by more than 20% in the next 10 years.

Condition: Good (all subregions)

Trend:

Improving (East Bay Hills)

Unchanging (Mt. Diablo Range and Mt. Hamilton)

Breeding showed higher interannual variability than overall occupancy. There did not appear to be strong positive or negative trends in the Mt. Diablo Range (Figure 5.4) or Mt. Hamilton (Figure 5.5) subregions, but note that there were limited data for the latter. In the East Bay Hills subregion, we found evidence of a positive trend in CRLF breeding activity using statistical models (described previously). In this subregion, breeding was lowest at the beginning of the decade (2009–2011), with a predicted probability of just 11%, and significantly higher ($P = 0.02$) at the end of the decade (2018–2019), with a predicted probability of 19%.

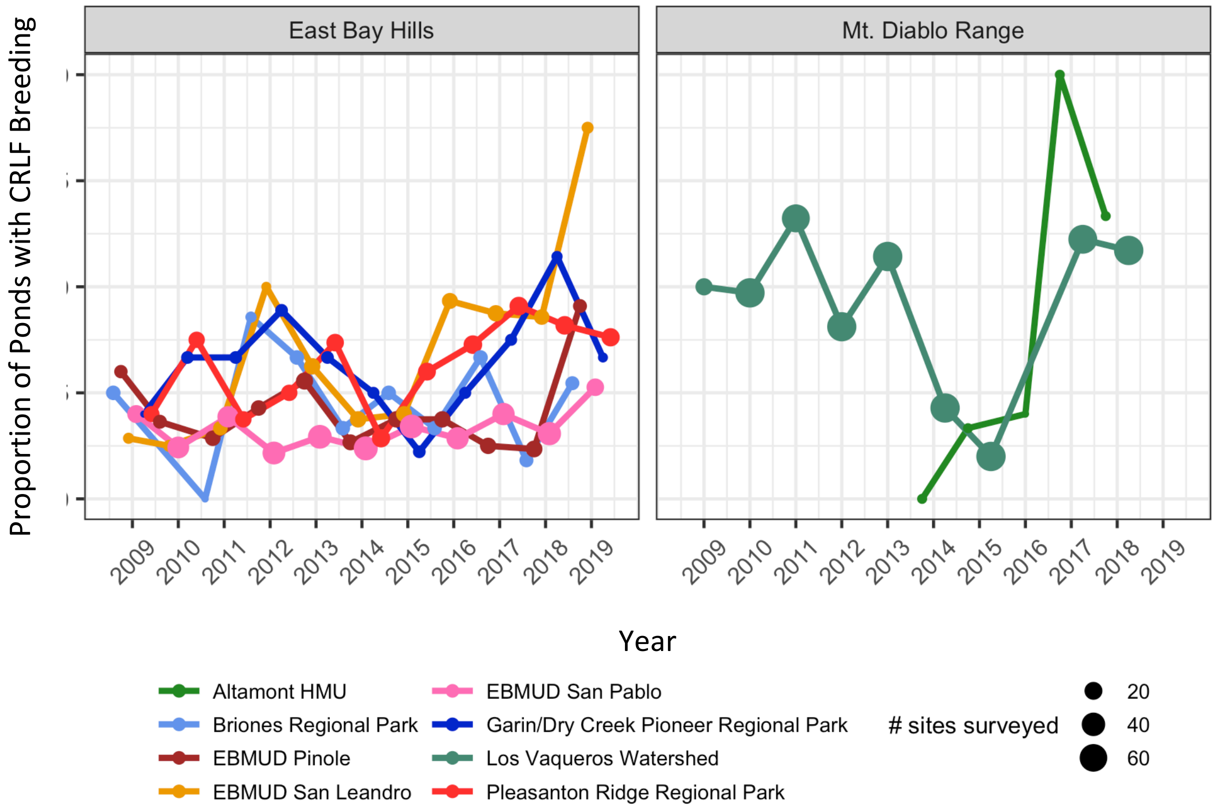

Figure 5.4. The proportion of surveyed ponds containing evidence of CRLF breeding activity in a given year, grouped by property and subregion. Only properties with sufficient data (at least five ponds surveyed at least five times) are shown. Point size represents the number of ponds within each property that were surveyed in a given year. Severe drought conditions occurred in 2014 and 2016.[21]

The Mt. Diablo Range showed the strongest declines of any subregion during the 2012–2017 drought. In 2011, the model-predicted probability of a pond containing breeding activity was 80%, which dropped to just 8% in 2014. However, by 2017, ponds appeared to recover, with the probability of breeding back to 77%. Across the decade, we found no evidence of stable increases or decreases in CRLF breeding in the Mt. Diablo Range subregion.

In the Mt. Hamilton subregion, we could not implement statistical models due to a lack of sufficient data. However, when reviewing the raw data at surveyed sites, we found no evidence of any strong increases or decreases (Figure 5.5).

[21] The full drought period extended from 2012–2017; 2014–2016 were peak drought years, categorized as exceptional drought by the US Drought Monitor (https://www.drought.gov/states/california).

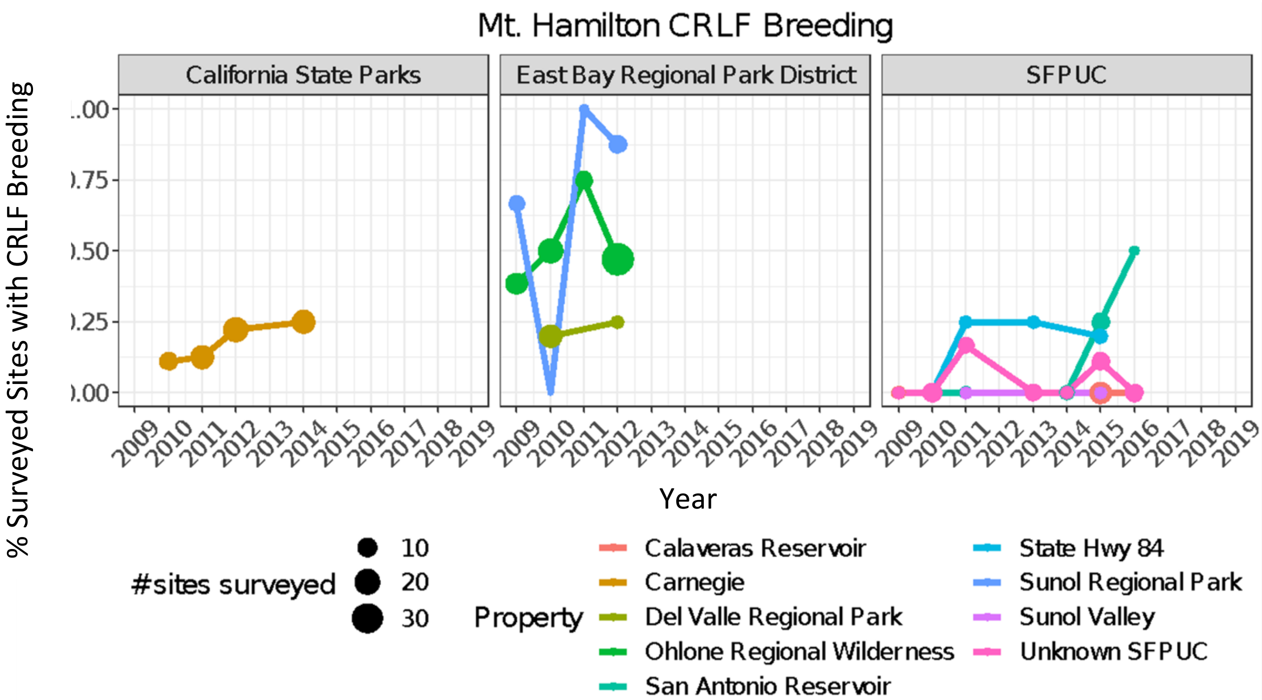

Figure 5.5. The proportion of surveyed ponds containing evidence of CRLF breeding activity in the Mt. Hamilton subregion. All data from Mt. Hamilton are shown. Point size represents the number of ponds within each property that were surveyed in a given year. Severe drought conditions occurred in 2014 and 2016.[22]

In summary, despite the strong impact of drought conditions throughout the area of focus, there appeared to be no permanent reductions in breeding activity as a result of drought, nor long-term trends in two of three subregions. Data suggest that the CRLF is able to recolonize breeding sites fairly quickly following drought, as CRLF breeding returned to pre-drought levels within three years at almost every property. However, the fact that the CRLF shows high sensitivity to drought implies that more frequent and severe droughts may pose a problem, especially if pond hydroperiods are not maintained. Finally, breeding activity generally mirrored overall CRLF presence, indicating that the presence of adults is a good proxy for reproduction.

Confidence:

High (East Bay Hills)

Moderate (Mt. Diablo Range)

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[22] The full drought period extended from 2012–2017; 2014–2016 were peak drought years, categorized as exceptional drought by the US Drought Monitor (https://www.drought.gov/states/california).

Low (Mt. Hamilton)

Breeding data are available for many of the ponds in the area of focus, but there is variation in survey timing. Some partner agencies only have one or two seasons of survey data or do not conduct targeted CRLF surveys, and thus, may miss peak breeding windows. For the reasons delineated previously (top of page 13), we urge caution and continued monitoring, especially in the Mt. Hamilton subregion.

In addition, the presence of eggs and larvae may not represent the most accurate metric for successful breeding (i.e., recruitment). Surveys did not always discriminate between post-metamorphic stages and other juvenile stages, and thus, we grouped them in our analysis. However, metamorphic surveys are important for determining whether ponds support appropriate conditions for larval development. Indeed, several ponds consistently went dry by August but continued to exhibit evidence of CRLF breeding (i.e., eggs or larvae). It is not clear whether these sites produce CRLF that recruit into the population or whether they serve as sinks. Obtaining more complete data on hydroperiod and the presence of metamorphs in late summer will provide evidence as to whether more temporary sites represent quality habitat. Nevertheless, the stability we observed over the past decade suggests that while individual ponds may represent population sinks, sufficient CRLF recruitment is happening on more regional scales.

Metric 3: CRLF Metapopulations

Rationale: CRLF populations are considered metapopulations, or a group of subpopulations that are separated spatially but interact through migration and gene flow (USFWS 2010, Marsh and Trenham 2001). Subpopulations are subject to local extinctions but may be recolonized by adult migrants and dispersing juveniles, which stabilizes the larger metapopulation (Marsh and Trenham 2001). The persistence of the metapopulation is dependent on the dynamics of the subpopulations (USFWS 2010). "Maintaining corridors for dispersal between breeding and non-breeding habitat and between populations is essential in preserving the population structure of the California red-legged frog" (USFWS 2010). The area of focus encompasses disparate land holdings supporting a number of East Bay CRLF metapopulations. The number, size, and connectivity of these metapopulations can be used as metrics for the health of the species. An additional useful metric is the number of potential CRLF sites that are isolated from metapopulations.

We estimated the number of metapopulations by analyzing the spatial proximity of core CRLF sites to one another. We defined "core sites" as ponds that consistently contained the CRLF, as defined by: (1) being consistently surveyed (having more than three years of survey data, including surveys prior to 2009) and having CRLF detections in >50% of the years it was surveyed, or (2) being inconsistently surveyed (three or fewer years) but having CRLF detections in 100% of the years. This allowed us to consider sites that have not been well-sampled but could serve as core sites.

We then defined "metapopulations" as clusters of sites that were within 3 km of each other, containing at least one core site. Because adult CRLF have been observed moving up to 2.8 km per year (Bulger et al. 2003; Fellers and Kleeman 2007), we considered 3 km to be the upper limit of dispersal and a realistic distance to define as a metapopulation. Sites belonging to the same cluster could be expected to exchange individuals and rescue one another from periodic extinction.

For each metapopulation, we calculated the centroid (the geographic center of all core sites within that cluster) and calculated a 3 km buffer from that centroid. This represents the area of metapopulation from which the CRLF could be expected to disperse. Several metapopulations had overlapping buffers, indicating some level of potential connectivity among them. Metapopulations that were within one another's buffer area were defined as a habitat unit (Table 5.3).

Table 5.3. Habitat units, or complexes of metapopulations, clustered spatially. Ponds within the same habitat unit may be expected to show some level of connectivity and gene flow, and larger habitat units should be more robust to periodic extinction events.

Subregion(s)	Habitat Unit Name	Properties Included	Network Agency Land Manager(s)	Number of Total Ponds	Number of Core Sites	Number of Meta-populations
Mt. Hamilton	Mission Peak	Mission Peak Regional Preserve	EBRPD	9	1	1
Mt. Hamilton	Carnegie SVRA	Carnegie State Vehicular Recreation Area	CSP	16	3	1
Mt. Hamilton	Ohlone/Sunol	Ohlone Regional Wilderness, Sunol Regional Park, Calaveras Reservoir	EBRPD, SFPUC	68	30	6
EB Hills	Vargas	Vargas Plateau Regional Park	EBRPD	6	2	1
Mt. Hamilton	Del Valle	Del Valle Regional Park	EBRPD	19	1	1
EB Hills, Mt. Hamilton	Pleasanton/ San Antonio*	St Hwy 84, Pleasanton Ridge Regional Park, San Antonio Reservoir	SFPUC, EBRPD	9	1	1
EB Hills	Pleasanton/ Garin*	Pleasanton Ridge Regional Park, Garin Regional Park, Dublin Hills Regional Park	EBRPD	44	20	5
Mt. Diablo, Mt. Hamilton	Altamont*	Altamont Habitat Management Unit (HMU)	CCWD	13	2	2
Mt. Diablo Range	Diablo Foothills	Diablo Foothills Regional Park, Mount Diablo State Park	EBRPD, CSP	17	5	2

Subregion(s)	Habitat Unit Name	Properties Included	Network Agency Land Manager(s)	Number of Total Ponds	Number of Core Sites	Number of Meta-populations
EB Hills	Briones	Briones Regional Park, EBMUD San Pablo, EBMUD Pinole**, Tilden Regional Park	EBRPD, EBMUD	133	23	7
Mt. Diablo Range	Black Diamond	Black Diamond Mines Regional Park, Clayton Ranch, Contra Loma Regional Park, Deer Valley, Mt. Diablo State Park	EBRPD, CSP	55	4	2
EB Hills	EBMUD South	EBMUD San Leandro	EBMUD	38	8	1
Mt. Diablo Range	Los Vaqueros	Mt. Diablo State Park, Brushy Peak Regional Preserve, Los Vaqueros watershed, Morgan Territories Regional Park, Vasco Caves, Vasco Hills, Cowell Ranch, Morgan Territory HMU, Round Valley Regional Preserve, Byron Vernal Pools	EBRPD, CCWD, CSP	169	86	17
EB Hills	Las Trampas	Las Trampas	EBRPD	5	3	1
	Unassigned			112		
	*A potential barrier (Hwy I-680 or I-580) exists between core sites within this habitat unit.					

Network partner agency abbreviations: CCWD = Contra Costa Water District, CSP = California State Parks, EBMUD = East Bay Municipal Utility District, EBRPD = East Bay Regional Park District, SFPUC = San Francisco Public Utilities Commission.

* * The area referred to as "EBMUD Pinole" refers to the Pinole Valley, which is the northern portion of the San Pablo/Briones Reservoirs land unit.

Condition Goals:

- Maintain or increase the number of metapopulations within the area of focus.
- Maintain or increase habitat connectivity via dispersal corridors and the upland habitat matrix.
- Maintain or increase percentage of ponds within CRLF dispersal distance.

Current Baseline: The Network partner agencies manage a total of 189 ponds that were designated as core CRLF sites (Figure 5.6, points with black outlines). To our knowledge, these ponds contain consistent CRLF populations and could serve as source populations for surrounding ponds. The majority (n = 182; 96%) of core sites were within 3 km of another core site and, on average, core sites were 845 m from the next nearest core site. This close proximity offers a high potential for population connectivity, meaning that metapopulation dynamics (e.g., demographic rescue) could be expected to occur.

We defined 48 metapopulations; 33 of these metapopulations contained three or more core sites, and the largest contained 13 core sites. The largest metapopulation was located on Los Vaqueros watershed (CCWD) and Vasco Hills (EBRPD). There were also larger metapopulations within the San Leandro and San Pablo Reservoirs (EBMUD; eight core sites), Pleasanton Ridge (EBRPD; eight core sites), and the Sunol/Calaveras Reservoir area (EBRPD and SFPUC; eight core sites). The majority of metapopulations contained additional non-core sites.

There were 524 ponds designated as non-core sites, or sites where the CRLF was not reliably detected. On average, these sites were located 1.9 km from the nearest core site. More than 75% (n = 412) were within 3 km of a core site, and therefore fell within a metapopulation boundary, suggesting a high potential for colonization (Figure 5.6, colored points with gray outlines). Although they did not consistently contain CRLF, these sites could potentially contribute to metapopulation dynamics. Indeed, 142 of the sites within dispersal distance of a core site had at least one record of CRLF presence. Importantly, more than half of the non-core sites (n = 276) were surveyed only rarely (i.e., fewer than every four years), and 133 of these sites have not been surveyed since 2010. Therefore, we have poor information on the rates of CRLF occupancy for many non-core sites.

To better understand why some sites were rarely occupied by the CRLF despite being close to a source, we examined only those ponds that were close to core sites, were surveyed intensively (more than five times over the 10-year period), and never contained the CRLF. Of 45 ponds meeting these criteria, more than half (n = 24) contained invaders (invasive fish or bullfrogs) or dried by August. In these ponds, the CRLF appears to be limited by habitat suitability rather than dispersal.

There were 112 non-core sites that were spatially isolated, e.g., located >3 km from a core site (Figure 5.6, black points)**.** Of these, only 11 (10%) contained the CRLF at least once during their monitored history; however, because the likelihood of rescue from nearby populations is low, these sites are at higher risk of local extinction. There were numerous isolated sites at Cowell Ranch (CSP; n = 21), southern Pleasanton Ridge (EBRPD; n = 12), and Calaveras Reservoir (n = 11).

Metapopulations clustered into 14 habitat units that could be expected to share some level of connectivity and be feasibly co-managed (Figure 5.6, colored outlines). Several of these units contain properties managed by multiple Network partner agencies (Table 5.3). The largest complex of CRLF sites was located in and around the Los Vaqueros watershed and included 169 total ponds and 86 core sites. This network of CRLF ponds spans 11 properties and four Network partner agencies. Note that this was also one of the most intensely surveyed regions of the area of focus, which indicates that future surveys in other regions may similarly reveal more extensive CRLF presence and habitat than is currently known.

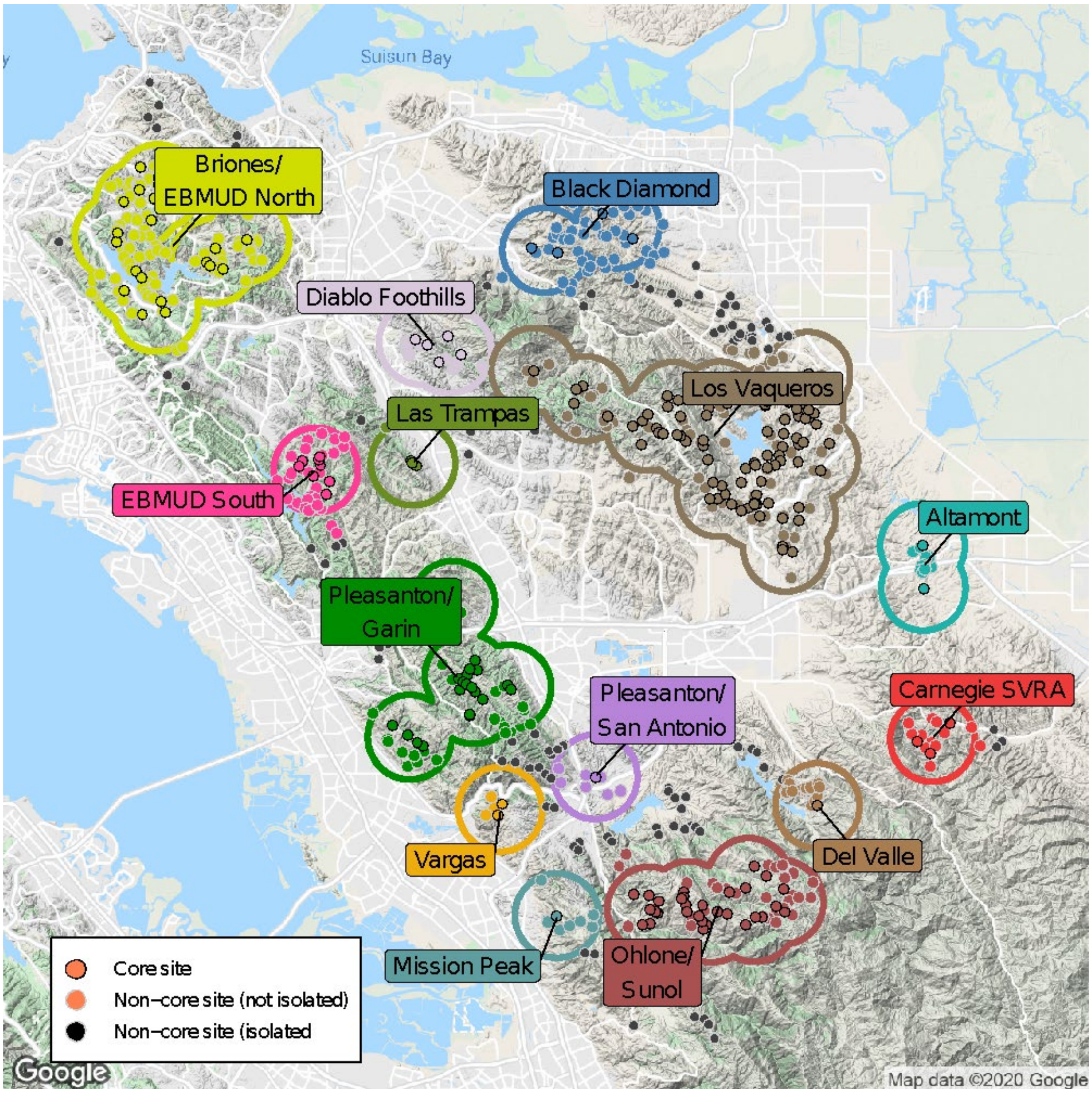

Figure 5.6. Distribution of CRLF core sites. Points with black outlines are core sites with CRLF occurrence, whereas those with gray outlines are non-core sites. Colored outlines show habitat units, or groups of metapopulations with potential gene flow and connectivity. Point colors represent the habitat unit within which they are located. Points in black are non-core sites that fall outside a habitat unit and are located far (>3 km) from a potential source site.

Condition Thresholds:

- *Good:* The number of metapopulations in the area of focus is maintained or increased over the next 10 years or declines by less than 10% over the next 10 years.
- *Caution:* The number of metapopulations within the area of focus declines by 10%–20% in the next 10 years, or there is a loss of connectivity of 10%-20%.
- *Significant Concern:* The number of metapopulations within the area of focus declines by more than 20% in the next 10 years, or there is a loss of connectivity of more than 20%.

Condition: Good (all subregions)

Using a 3 km dispersal distance, we identified several regions that contained more than a dozen occupied ponds that were in close proximity to one another, and the majority of core sites were within dispersal distance of another core site. Although barriers such as interstates separate many of the subregions, there are large and potentially well-connected contiguous CRLF populations within each of the subregions.

Overall, the distribution of CRLF sites suggests that few populations are completely isolated. One exception may be Vargas (EBRPD), which is separated from other metapopulations by two state highways (Figure 5.6). Similarly, the Pleasanton/San Antonio (EBRPD, SFPUC) habitat unit (complexes of metapopulations, clustered spatially) may not represent a connected metapopulation due to the presence of major roadways between ponds. Habitat units that contain only one core site (e.g., Del Valle, Mission Peak), though unusual, are important targets for further monitoring and, potentially, management action. If further surveys confirm no additional core sites within these clusters, maintaining suitable CRLF habitat at existing sites is a high priority, as these are the only potential sources within dispersal distance.

Trend: Unchanging (all subregions)

To estimate trends in metapopulations over time, we repeated the analysis above, this time splitting the data into early (2009–2013) and late (2014–2019) time periods and filtering the data to include only those ponds that were surveyed at least once in both time periods. This dataset included 334 sites. We then defined core sites, metapopulations, and habitat units in early and late time periods, with the only change being that we did not require more than three years of surveys to define core sites.

In the first half of the decade, 112 of the 334 sites were classified as core sites (CRLF present in >50% of years), compared to 113 in the latter half of the decade. Although there was almost no difference in the number of core sites across time, their identities changed. Twenty-nine of the pre-2014 core sites were no longer considered core CRLF sites in the second half of the decade. However, they were replaced by 30 new core sites, many of which were on the same Network partner agency properties. In effect, the distribution of core sites changed very little (Figure 5.7).

The number of isolated non-core sites (>3 km from nearest core sites) was also stable, from 43 sites (19%) in the early years to 46 (21%) in the late years. In the latter half of the decade, a new habitat unit near San Antonio Reservoir emerged, increasing the number of habitat units from 9 to 11 (Figure 5.7). At the same time, a larger habitat unit in the Mt. Diablo Range subregion near Black Diamond Mines and Clayton Ranch appeared to lose core sites and shrank in size.

Despite some shifts in the location of core sites, the trend in population connectivity overall appears to be unchanging. To our knowledge, no new barriers to connectivity appeared within the past 10 years, and the position of core sites was such that the slight shift in the identity of core sites did not affect overall connectivity.

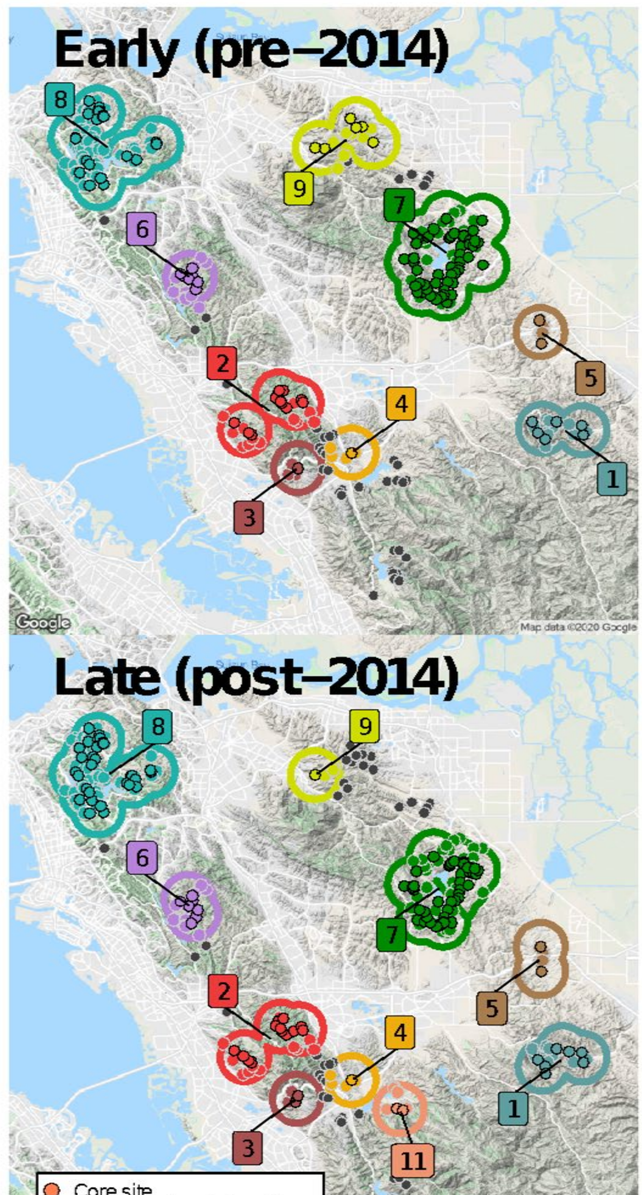

Figure 5.7. Distribution of CRLF core sites and metapopulations across time. There were few changes in the distribution, number, and proximity of CRLF-occupied sites from the early part of the decade (2009–2013) to the late (2014–2019).

Confidence: Moderate (all subregions)

Our analysis did not account for land cover in between core sites, which could affect connectivity estimates. Dispersal probabilities likely depend upon habitat between ponds, with the CRLF often using seeps, springs, and riparian corridors for long-distance movement (Fellers and Kleeman 2007). Similarly, sites within 3 km of each other could be separated by various barriers to dispersal such as roads or impervious land cover. Finally, we did not have population genetic analyses to support our inference that sites that cluster together spatially are functionally connected. Instead, we chose a connectivity metric based on dispersal distances estimated in previously published studies. The analyses herein are sensitive to this choice of dispersal distance.

It is important to note that the dataset we analyzed included only surveyed ponds, and is therefore not an exhaustive list of all ponds on the landscape. Thus, the true number of core sites may be higher because core sites may occur on private lands or in ponds or properties not surveyed extensively. This would lead to higher connectivity among habitat units and metapopulations than described herein. By the same logic, if future updates to this ecological health assessment fill in these gaps with additional surveys, this may falsely appear as an increase in connectivity when it is actually an increase in data. Future analyses with updated datasets should include a direct comparison with the current dataset (i.e., use the same sites).

Metric 4: Presence of Non-Native, Invasive Species

Rationale: This metric assesses the estimated number of ponds occupied by invasive species, defined as the American bullfrog or predatory fish (i.e., bass, mosquito, or sunfish species). The analysis of potential habitat for Metric 1 was used in the evaluation of Metric 4. Invasive species have been well-documented to contribute to population declines in native amphibians. (See details in the Stressors section.)

Condition Goal: Decrease the number of ponds occupied by non-native, invasive species.

Current Baseline: Of 582 sites, 21% contained an invasive species at one point in the past decade. Bullfrogs, which were more widespread than invasive fish, were present at 61 sites alone and at 26 sites in combination with fish. Thirty-eight sites contained invasive fish in the absence of bullfrogs. As expected, the CRLF was less likely to be observed in these sites. Of sites that were occupied by bullfrogs, the CRLF was observed 36% of the time, compared to 45% in sites where there were no bullfrogs. Of sites that contained fish, the CRLF was observed 37% of the time, compared to 51% when fish were absent. Thus, the impact of fish was stronger than that of bullfrogs, which is consistent with previous studies (Joseph et al. 2016, Moss et al. 2021).

Condition Thresholds:

- *Good:* The number of ponds occupied by invasive bullfrogs or fish in the area of focus is maintained or decreases, or increases by less than 10% over the next 10 years
- *Caution:* The number of ponds occupied by invasive bullfrogs or fish in the area of focus increases 10%-20% in the next 10 years.
- *Significant Concern:* The number of ponds occupied by invasive bullfrogs or fish in the area of focus increases by more than 20% in the next 10 years.

Condition: Good (all subregions)

Due to the relatively low occurrence of invasive species across our study area, and the observation of CRLF co-occurring with both fish and bullfrogs, we believe that these invasive species present a slightly smaller threat in the area of focus than they do in other portions of the CRLF's range.

Trend: Unchanging (all subregions)

Despite drought and intensive management, the proportion of sites containing fish and bullfrogs changed very little across time. Of sites that were surveyed both before and after drought, 11% contained invasive fish prior to 2014 compared to 9% afterwards, which translated to a loss of fish at two sites. Bullfrogs were similarly stable but showed higher turnover. Over the course of the decade, they appeared to have lost at 11 sites and gained at eight. Successive droughts may be beneficial, as perennial ponds may go dry only during severe or longer-term droughts, extirpating invasive fish and disrupting bullfrog reproduction. However, drought also adversely affects CRLF reproduction, and vector-control agencies continue to introduce invasive fish to ponds for mosquito control.

Confidence: High (all subregions)

There was no evidence of increases in invasive species on extensively surveyed properties. As both bullfrogs and fish are easily detected in surveys and are a focus of survey efforts, we are confident that survey data reflect real patterns (or lack thereof) in occupancy of these invasive species.

We note several areas where additional data could help quantify the impact of invasive species on CRLF occurrence. First, the type of fish was not always recorded in surveys, thus, we were not able to relate CRLF occupancy to specific fish species. It is possible that co-occurrences of the CRLF and fish, which we did observe, only occurred in sites with smaller species like western mosquitofish (*Gambusia affinis)*. Differences in the species composition of fish are important to track, as larger predatory fish such as bass are more likely to influence CRLF numbers. Moreover, we did not investigate fish and bullfrog occupancy within streams and reservoirs, but these are also habitats where the CRLF might be affected by invasive species. Finally, we analyzed the presence or absence of fish and bullfrogs, whereas more quantitative estimates of abundance (e.g., density or biomass) may be better metrics to assess impacts on native amphibians. While our metric is based on the total number of ponds with invasive fish or bullfrogs, if survey efforts increase and ponds are added, the metric should be adjusted proportionally.

OTHER METRICS CONSIDERED BUT NOT INCLUDED

- Assessment of CRLF presence/populations in streams or reservoirs. Network partner agencies did not have enough data to support this analysis.
- Explicit comparison of CRLF historical and current ranges. Identifying areas of range contractions may show locations that are good candidates for restoration or repatriation.

Range limits, while useful, are a coarser metric and not as high a priority as the four metrics used in this chapter.

- Evaluation of gene flow and genetic diversity. A recent study (Richmond et al. 2014) provides much of this information but the Network partner agencies had no existing data to support this metric. Instead, connectivity was assessed via spatial proximity (Metric 3).

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

- Additional data from the Mt. Hamilton subregion are needed; very few sites were surveyed in the most recent three years.
- Metric 3:
    - More than half of the non-core sites (n = 182) were surveyed only rarely (i.e., in fewer than four years) and 102 of these sites have not been surveyed since 2010. Therefore, there is poor information on the rates of CRLF occupancy in many non-core sites.
    - Our analysis did not account for land cover in between core sites, which could have an impact on estimates of connectivity.
    - We did not have the population genetic analyses to support our inference that sites that cluster together are functionally connected.
- Our metrics do not include population estimates. Simple presence and breeding data cannot be easily applied to measures of relative abundance, fecundity, or other measures of population size.
- The survey methodology used by Network partner agencies likely does not fit into assumptions of statistically robust study designs, and it is difficult to make assertions about unsampled ponds. Ponds likely have not been randomly sampled, and uneven sampling decreases statistical power and can introduce bias.
- Reliable hydroperiod data are limited, particularly when seasonal ponds dried. Most pond surveys are conducted in May or June. Of 582 sites with some hydroperiod data, 131 were never surveyed after the end of June, and 252 of them were never surveyed after the end of July.
- Stressors may affect populations unevenly due to their general location, microhabitat variables, or the synergistic effects of multiple stressors (Davidson et al. 2002, Mihaljevic et al.

2018). Considerations for future monitoring include standardizing survey methods and implementing more consistent monitoring across the area of focus (including poorly surveyed regions).

- An analysis of CRLF presence/absence in stream reaches was not included because consistent sampling within stream habitats across the area of focus has not been conducted, though there are some data from Alameda Creek indicating consistent CRLF breeding. Streams may provide important overwintering habitat, and pools within them may be used for breeding. However, the majority of monitoring programs focus on ponds and reservoirs. As a result, although streams and associated riparian habitat are likely to be important for sustaining CRLF, we lack an understanding of CRLF extent and stability within these habitats. CRLF use of seeps, springs, and upland dispersal habitats is also not monitored. The methods we use to monitor amphibians are biased toward where we are most likely to find the most individuals. Small aquatic resources and overland dispersal routes are rarely surveyed regularly.

- A limited amount of disease data has been collected within the area of focus, in part because protection of CRLF populations limits the collection of specimens. More data, particularly from non-invasive approaches (e.g., skin swabs, fecal analysis) are necessary to evaluate the impacts amphibian diseases have on CRLF populations.

PAST AND CURRENT MANAGEMENT

Network partner agencies in this area have conducted long-term monitoring coupled with regular pond maintenance, restoration, enhancement, and creation. These management actions include pond de-sedimentation to lengthen hydroperiods, repairing embankments, removing encroaching emergent vegetation, restoring native vegetation, and removing bullfrogs and fish via periodic draining. Additionally, ponds created on conservation-easement lands are monitored post-construction to meet mitigation requirements.

POTENTIAL FUTURE ACTIONS

- Establish more systematic and coordinated data-collection efforts, in which partner agencies conduct pond surveys using similar methods and data sheets when possible. Encourage partner agencies to record relevant data on pond conditions and habitat, such as hydroperiod, vegetation, and species-level identification of non-invasive taxa.

- Continue pond-restoration efforts. Collaborate on pond-restoration priorities, target invasive-species control where activities benefit multiple Network partner agencies, and improve pond hydroperiods.

- Colonization of isolated sites could be achieved if nearby sites that support occasional CRLF breeding are converted into source populations, perhaps by habitat improvements. Restoration efforts could be targeted to sites that could serve as "stepping stones" of dispersal from core sites to isolated sites. Finally, assisted colonization and management of seeps, springs, and upland and riparian habitats (i.e., preservation of riparian corridors or creation of new ponds) are important tools for enhancing colonization opportunities to isolated sites.
- Model a subset of ponds under future climate-change scenarios.
- Consolidate academic disease research across the area of focus.

These actions may increase our confidence in the data used in subsequent analyses; provide greater coverage and more even sampling across the area of focus; help prioritize where pond restoration efforts should be focused; and, in the case of modeling pond hydrology, help partner agencies proactively manage for climate change.

KEY LITERATURE AND DATA SOURCES

Literature

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Partner Agency Data Sources

- East Bay Reginal Park District (EBRPD): All ponds were surveyed every four years from 1994 to 2012. Additional data on ponds have been acquired or found since then. This included 1,209 surveys of 399 unique ponds across 28 properties. We did not include surveys of ponds where location data were not available.

- East Bay Municipal Utility District (EBMUD): Annual breeding and adult occupancy surveys are done for 50% to 75% of the ponds annually. The rest are surveyed every two to three years. EBMUD prioritizes surveys in known source-population ponds. If there are confirmed adults, they will do breeding surveys during the same year. Between 2007 and 2019, this included 2,262 surveys of 152 unique ponds.

- California State Parks (CSP): Surveys of 25 ponds in the Carnegie SVRA made during 2011, 2012, and 2014 were included. Approximately 30 ponds and pools in Mount Diablo State Park and Cowell Ranch were surveyed between 2006 and 2016. The dataset had 233 surveys of 76 ponds across three properties.

- San Francisco Public Utilities Commission (SFPUC): Pond surveys and monitoring from 2000 to 2015 were included. A large set of ponds were monitored each year, and additional ponds were monitored as time allowed. Data from SFPUC included 162 surveys of 55 ponds across five properties.

- Contra Costa Water District (CCWD): At the Los Vaqueros watershed, CRLF monitoring has occurred annually since 1999/2000. Reports are available from 2005–2006 and 2010–2018. The intervening years (2007–2009) were not provided. Conservation lands (also known as Habitat Management Units, or HMUs) are spread across Contra Costa, Alameda, and San Joaquin Counties. We obtained surveys in the Altamont, Marsh Creek, and Morgan Territories HMUs from 2013 to present. Data include 2,978 surveys of 110 ponds.

Other Data Source:

The Johnson Lab, University of Colorado, Boulder: Dr. Pieter Johnson and his graduate students have been sampling various ponds on EBMUD, EBRPD, and SFPUC lands for nearly the last decade. Data included 1,446 surveys of 252 ponds across 25 properties.

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CHAPTER 6. CALIFORNIA TIGER SALAMANDER (*AMBYSTOMA CALIFORNIENSE*)

EXECUTIVE SUMMARY

The California tiger salamander (*Ambystoma californiense,* CTS) is found throughout much of the state. However, a decline in both numbers and distribution prompted its listing for this region under the federal Endangered Species Act in 2004. This salamander is a good indicator of ecological health on East Bay Stewardship Network (Network) partner lands (see map, Chapter 1) because it depends on a variety of different habitats, including ponds and wetlands for breeding and development as well as uplands for cover, foraging, and dispersal. These lands have been divided into three subregions for the purposes of this analysis. Within these subregions, data came from individual parks, reservoirs, recreation or management areas, and other open spaces that we refer to as "Network partner lands" throughout this chapter.

This chapter presents the results of an evaluation of a suite of three metrics that helps reveal the current condition and trend of this species on Network partner lands. These metrics assess where the CTS is found in the area of focus, where they co-occur with California ground squirrels (who dig burrows critical to adult CTS survival; see Chapter 12), and if they are able to disperse. In addition to assessing current status, a primary goal of this analysis is to provide a baseline against which managers can measure future changes.

Using data collected between 2009 and 2019, we found that the CTS is "good" with a "declining" trend. A recent paper using much of the same data (Moss et al. 2021) showed that many of our native populations are resilient to drought, with amphibian populations able to recover during normal or above-average precipitation years. However, it should be noted that these analyses did not include the exceptional drought of 2020–2021. Because only available data were used, this chapter also identifies areas where not enough is known to draw meaningful conclusions, as well as opportunities for future research and collaboration between land managers.

METRICS SUMMARY AT A GLANCE

The table below summarizes the three metrics for amphibian and reptile diversity used in this NatureCheck ecological health assessment. Each metric, along with how we arrived at its condition, trend, and confidence, is thoroughly described in the Metrics in Detail section later in this chapter. (See Chapter 1 for definitions and thresholds for condition, trend, and confidence; other terminology used throughout this chapter; how metrics are being used for each indicator; and other project methodology.)

Table 6.1. All CTS metrics with their respective condition, trend, and confidence, by subregion. Each metric is described in the Metrics in Detail section later in this document.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Metric 1: CTS Presence–Proportion of suitable wetlands and ponds where any life stage of CTS has been documented to be present in the last 10 years.			
Condition	Caution	Caution	Caution
Trend	Declining	Declining	Declining
Confidence	Moderate	Moderate	Moderate
Metric 2: California Ground Squirrel Presence–Documented presence of California ground squirrels in parks/units with suitable habitat.			
Condition	Caution	Good	Good
Trend	Unknown	Unknown	Unknown
Confidence	Low	Low	Low
Metric 3: CTS Metapopulations–Number and size of metapopulations that exist across the area of focus, and the expansion or persistence of these metapopulations over the past 10 years.			
Condition	Good	Good	Good
Trend	Unchanging	Unchanging	Unchanging
Confidence	Moderate	Moderate	Moderate

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of the CTS in the area of focus represented by the graphic below is based on the combined values of the individual metrics in Table 6.1. Each of these metrics is described in depth in the Metrics in Detail section later in this chapter.

Condition: Good (color: green)

Trend: Declining (arrow: downward)

Confidence: Moderate (line around circle: dashed)

BACKGROUND

WHY IS THIS RESOURCE INCLUDED?

The large, black-and-yellow-spotted California tiger salamander (*Ambystoma californiense,* CTS) is a charismatic amphibian with wide public appeal. Though rarely seen, its distinct coloring makes adults easily identifiable. Endemic to California, this species has declined throughout its historical range, which is thought to have included much of central California (Bolster 2010). The CTS's Central California Distinct Population Segment (DPS) was federally listed as a threatened species in 2004 (USFWS 2017). This DPS encompasses counties from Tulare and Kern in the south, Sacramento to the north, and Alameda and Contra Costa County populations within the area of focus for this ecological health assessment. (See map, Chapter 1.) East Bay Stewardship Network (Network) land managers have been working to conserve habitat, manage upland habitats, construct ponds and wetlands for breeding salamanders, remove invasive species, and restore native vegetation. Targeted breeding and non-breeding surveys have been conducted on each of the Network partner agencies' lands to track CTS populations across the landscape.

The CTS is a good indicator of freshwater wetland condition because the species is relatively long-lived (up to 10 years) and breeds in wetlands and other aquatic features. It is also very dependent on upland grassland habitats, where adults spend most of their lives in rodent burrows. Its sensitivity to changes in upland refugia, hydrology, and precipitation, as well as susceptibility to pollutants and toxins, makes it an excellent indicator of ecosystem health in grasslands and freshwater wetlands. Amphibians such as the CTS are uniquely sensitive to environmental conditions due to their permeable skin and complex, aquatic larval development.

DESIRED CONDITION AND TREND

As mentioned previously, the historical range of this species is not well defined but is thought to have included much of the central part of the state. On lands managed by Network partner within the area of focus, the CTS is found throughout the Mt. Diablo Range and Mt. Hamilton subregions, occasionally in fairly high numbers. (See Chapter 1 for an explanation of this project's area of focus and subregions.) There have been infrequent sightings from Pleasanton Ridge, and 2021 sightings in Las Trampas (CNDDB 2022), but CTS breeding populations have not been regularly observed in the East Bay Hills subregion in recent decades. Despite regular pond surveys, the East Bay Municipal Utility District (EBMUD) has not encountered CTS on their lands. In fact, the CTS may never have existed in high numbers in the East Bay Hills (Bolster 2010).

Based on the assumption that the CTS's current condition is "caution" in the area of focus, the desired condition of the indicator is to improve current conditions and trends as defined by the metrics used in this ecological health assessment in the Mt. Diablo Range and Mt. Hamilton subregions. Assessment of CTS condition or trend in the East Bay Hills subregion will require continued surveys.

CURRENT CONDITION AND TREND

Condition: Good

Trend: Declining

Confidence: Moderate

In CTS strongholds along the eastern portions of the area of focus, it appears to do well in conjunction with managed grazing and persists even in areas with reservoirs and recreation (e.g., Contra Loma Regional Park). It also responds positively to management efforts such as wetland preservation and pond creation and enhancement.

There is some evidence that CTS populations have declined in several regions of the Bay Area, and in general, there are limited survey data on CTS populations for the past decade. This data gap precludes a rigorous analysis of population trends, with the exception of a few properties that are intensively surveyed. Although CTS populations are widespread and show high potential for connectivity within the Mt. Diablo Range and Mt. Hamilton subregions (see Metric 3), they were also seriously affected by drought (see Metric 1). However, based on the metrics analyzed here, we assign a condition of "good." This condition statement however, is limited to our understanding of CTS populations within the area of focus within the narrow window of a decade. The species has been extirpated from much of its historical range and these metrics do not include the most recent drought of 2021.

The current condition, trend, and confidence are the average of the condition, trend, and confidence for the CTS in each subregion, as shown in the Table 6.2 below. The metrics described in depth in the Metrics in Detail section of this chapter were combined to determine this current condition and trend. These metrics give us a way to measure the difference between what is described in this section (i.e., how things are now) and the desired condition and trend in the preceding section (i.e., what we think "healthy" is for this indicator).

Table 6.2. The overall CTS condition, trend, and confidence for each subregion in the area of focus.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Condition	Good	Good	Good
Trend	Declining	Declining	Declining
Confidence	Moderate	Moderate	Moderate

STRESSORS

Several ecological and anthropogenic factors affect the health of this indicator. These include:

Historical Impacts: CTS adults spend most of the year in mammal burrows. During the summer, burrows provide refuge from hot and dry conditions and are essential to CTS survival (Trenham 2001). The historical (and recent) eradication and poisoning of California ground squirrels (*Otospermophilus beecheyi*) and Botta's pocket gopher (*Thomomys bottae*) in grasslands and along pond berms decreases or even eliminates the suitability of upland habitats for the CTS. Once ground squirrels have been eradicated, they have difficulty re-establishing or repopulating, even after poisoning ends.

Invasive Species Impacts: Non-native, invasive species are known to compete and prey upon the CTS. American bullfrogs (*Lithobates catesbeianus*) are often implicated in native amphibian declines (Doubledee et al. 2003, Snow and Witmer 2010, Fisher and Shaffer 1996). Even after removal efforts, bullfrogs are often able to re-invade from adjacent ponds and nearby reservoirs. Introduced fish and crayfish species (red swamp crayfish, *Procambarus clarkii*; signal crayfish, *Pacifastacus leniusculus*) are efficient predators of native amphibians, and can effectively exclude the CTS from reproducing (Fisher and Shaffer 1996, Shaffer et al. 1993, USFWS 2017). Invasive fish in particular have been found to have a strong negative effect on CTS occupancy (Joseph et al. 2016). Finally, predation by terrestrial non-native species such as feral pigs (*Sus scrofa*) and wild turkeys (*Meleagris gallopavo*) may also adversely affect CTS populations (Wilcox and Van Vuren 2009, McRoberts et al. 2014).

Climate Change: The potential effects of climate change on CTS habitats include shorter hydroperiods, more frequent drought, more extreme or unseasonable rain events, and changes in water and air temperatures (Polade et al. 2017, Swain et al. 2018). The CTS is adapted to fairly arid conditions and cyclic drought, but more climatic variability or extended droughts may hinder successful reproduction (USFWS 2017). Recent research on the CTS in Sonoma County suggests that "active conservation management of preserves, including provision of multiple breeding pools, at least some of which are resilient to variable future precipitation regimes, will be required to effectively conserve CTS" (Stokes et al. 2021).

Disease: Amphibian diseases have been a focus of conservation efforts in recent decades. In particular, the rapid spread of a fungal pathogen, *Batrachochytrium dendrobatidis* (Bd), and subsequent extirpations and extinctions have been a major cause for alarm. Laboratory experiments have found that the CTS can be infected and affected by Bd infection, but no mortalities from the disease have been recorded in CTS (Padgett-Flohr 2008). A related emerging disease*, B. salamandrivorans* (Bsal) has been implicated in salamander population declines in Europe. The pathogen most likely originated in Asia and was spread through the pet trade. More than 200 salamander species have been banned from import into the United States since 2016, and Bsal infections have not yet been detected here. Little is known about the pathogenicity of Bsal on the CTS, but some laboratory studies suggest that *Ambystoma* spp. more generally could be resistant to Bsal (Martel et al. 2013, USFWS 2017). The parasite *Ribeiroia ondatrae*, which causes amphibian deformities, is present throughout the area of focus (Johnson et al. 2013) and has recently been linked to CTS mortality in Santa Cruz county (Keller et al. 2021), although mortality within the area of focus has not been observed.

Pollution/Contaminants: The CTS is susceptible to pesticide drift (Ryan et al. 2012) and may be affected by mosquito abatement chemicals (USFWS 2017).

Habitat Disturbance/Conversion/Loss: Lands managed by Network partner agencies in the area of focus are generally protected from habitat loss. However, encroaching urbanization, the impacts of utility/transportation corridors (e.g., loss of upland habitat, road mortality), and competing interests for renewable-energy development (e.g., solar and wind) may affect CTS populations (Barry and Shaffer 1994, USFWS 2017). Protection of upland habitats surrounding CTS breeding ponds near developed areas may allow populations to persist (Trenham and Cook 2008).

Hybridization: Non-native tiger salamanders (*A. tigrinum*) have been intentionally released by bait dealers and have since hybridized with CTS (USFWS 2017). These hybrid individuals have been observed within our area of focus (USFWS 2017). Hybrid offspring outcompete the CTS, are capable of paedomorphosis (breeding as larvae), and may decrease the survivorship of other native amphibians (Ryan et al. 2009). However, purebred individuals are better adapted than their hybrid or non-native counterparts to shorter hydroperiods and rapidly drying ponds.

CONDITION AND TRENDS ASSESSMENT

METRICS IN DETAIL

The three metrics outlined below are a simple but informative way to measure CTS occupancy across the area of focus. Unless otherwise specified, trends and metrics were based on a 10-year period between 2009 and 2019. For the purposes of assessing trends in CTS presence, we only considered ponds that had been surveyed more than five times within this 10-year period and were within CTS distributional range. For statistical analyses, we also aggregated three-year pond surveys (i.e., a pond was determined to be occupied if any CTS life stage was observed during any survey of that pond over a three-year interval). This method reduced noise from variable survey efforts, low detection probability, and interannual variation.

Metric 1: CTS Presence

Rationale: This metric is defined as the proportion of ponds where any CTS life stage has been documented within the species' current range in the area of focus over the last 10 years. We only considered sites defined as ponds rather than as lakes, streams, or seeps. While we considered all life CTS stages in this metric, larval CTS were the most commonly encountered life stage during summer pond surveys and thus, CTS presence is usually indicative of breeding activity. CTS presence is also relatively easy to monitor during the summer months, when larval individuals are present at high densities.

Condition Goals:

- Maintain or increase the number of ponds that can support CTS breeding within the area of focus.
- Maintain or increase the number of ponds occupied by the CTS in the area of focus.

Current Baseline: Network partner agencies manage more than 1,100 ponds, 508 of which were within the CTS's range (as defined by calculating a polygon around the maximum extent of CTS observations; see Figure 6.1). Of the ponds within the CTS's range, 385 were surveyed within the past decade (2009 – 2019) and did not contain invasive fish. The CTS has been documented at 185 of the 385 ponds (48%) at least once within the past decade; however, presence in a given year fluctuates. The CTS was observed at least once at 61% of sites in the Mt. Diablo Range subregion (124/204) and at 45% of sites in the Mt. Hamilton subregion (58/129). CTS presence was rare within the East Bay Hills subregion, occurring at only three out of 52 (6%) sites and only in the southern portion (Figure 6.1). Rather than a recent trend, the lack of the CTS within the East Bay Hills is consistent with previous studies and maps of CTS distribution.

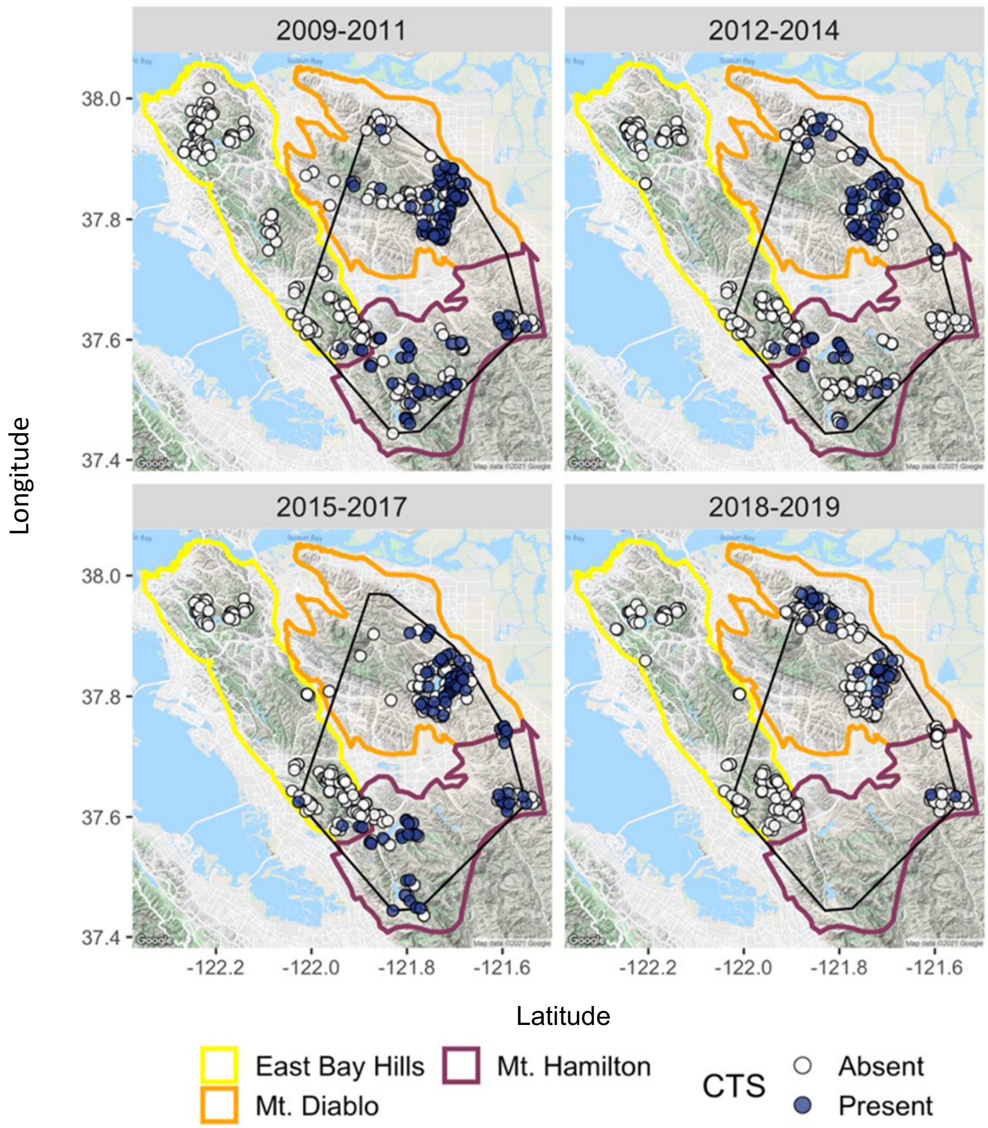

Figure 6.1 CTS detections at surveyed sites over the past 10 years. Each point represents a pond that was surveyed during the period; the color indicates whether the CTS was observed at least once during that time. This species occurs throughout the Mt. Diablo Range and Mt. Hamilton subregions and has been observed occasionally within the East Bay Hills subregion as well (southern area). The black polygon in each of the four images above illustrates the range of known CTS locations within the past decade. The species has not been observed beyond the polygon; thus, points outside the polygon were not used in this analysis.

Condition Thresholds:[24]

- *Good:* The number of CTS-occupied ponds in the area of focus is maintained, increased, or declines by up to 10% in the next 10 years.
- *Caution*: The number of CTS-occupied ponds in the area of focus declines 10%-20% over the next 10 years.
- *Significant Concern:* The number of CTS-occupied ponds in the area of focus declines over 20% over 10 years.

Condition: Caution (all subregions)

Though the CTS is widely distributed across the Mt. Diablo Range and Mt. Hamilton subregions, the evidence of decline shown in the trends assessment is reason for concern.

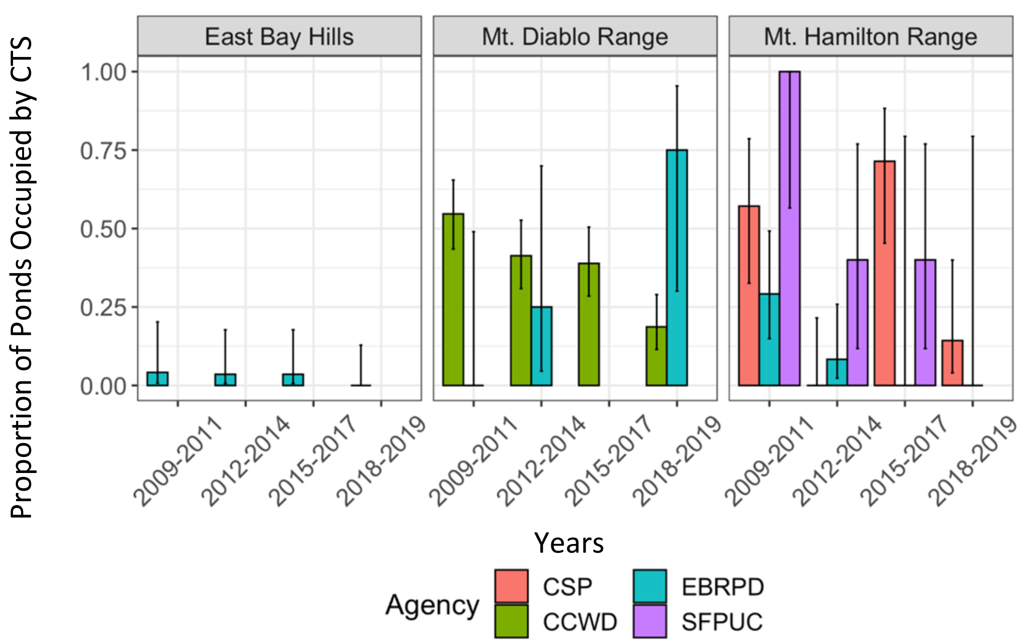

Figure 6.2. Proportion of sites with CTS detections across time. To assess temporal trends, we filtered data to only include sites that were determined to be within the CTS's range, lacked invasive fish, and were surveyed more than five times between 2009 and 2019.

[24] The condition threshold percentage values set for each metric in this chapter are based on professional judgment using limited information and were chosen as values that are measurable and likely to have some effect on the indicator species. Where feasible, subsequent analyses will be based on a pond-to-pond comparison, to avoid confounding the effects of increased pond sampling.

Trend: Declining (all subregions)

In the past 10 years, the number of sites considered as potential habitat increased slightly (from 378 to 385) due to the loss of invasive fish, which declined during the 2012–2017 drought[25]. The number of sites where the CTS was detected varied highly across years (see Figure 6.2), which is not unusual for this species. The lowest annual proportion of sites at which the CTS was observed was in 2014, when they were found at only two of 90 surveyed sites in the Mt. Diablo subregion and one of 37 surveyed sites in the Mt. Hamilton subregion. This corresponded with the most severe year of drought and the loss of many temporary breeding sites.

In the years following drought (2015–2017), the CTS appeared to rebound to pre-drought levels, with 62 of 117 surveyed ponds (53%) in the Mt. Diablo Range subregion and 31 of 57 surveyed ponds (54%) in the Mt. Hamilton subregion. In recent years, and despite a wet 2018–2019 water year, CTS occupancy appeared to decline again in 2017–2019, with the species occurring at 30 of 126 (23%) surveyed ponds in the Mt. Diablo Range subregion and 2 of 28 (7%) in Mt. Hamilton subregion (Figure 6.2). Occupancy in the East Bay Hills subregion remained low throughout the decade, with the CTS observed at only one pond in Vargas Plateau, and a single individual at Las Trampas (an EBRPD property) (Figure 6.2).

We evaluated the statistical significance of trends in CTS occurrence by using generalized linear mixed models on a subset of 150 ponds that had been surveyed at least five times across the decade, were within the species' range, and did not have fish. These models estimated that the proportion of ponds occupied by the CTS in the Mt. Diablo Range subregion had decreased significantly, from an estimated mean of 36% in 2009–2011 to an estimated mean of 18% in 2018–2019 ($P = 0.005$). In the Mt. Hamilton subregion, the estimated proportion of ponds occupied by the CTS declined from 35% in 2009–2011 to 10% in 2018–2019. However, the sample size was small in recent years, and the decline was only marginally significant ($P = 0.06$).

Confidence: Moderate (all subregions)

Presence of pond habitat: Moderate. We defined sites as potential CTS habitat if they did not contain invasive fish and were within the CTS's range as analyzed (maximum extent of known observations). However, it was difficult to ascertain if a site did not contain fish or if fish were simply not recorded. Moreover, we were not able to use other variables known to be important to the CTS (e.g., hydroperiod, water quality, and pond size) to define suitability because these data were not available in sufficient detail throughout the area of focus. Stokes et al. (2021) found that preserves in Sonoma County with CTS breeding pools that "held water for at least two months following the breeding

[25] The full drought period extended from 2012–2017; 2014–2016 were peak drought years, categorized as exceptional drought by the US Drought Monitor (https://www.drought.gov/states/california).

season (into late April) even in dry years had substantially lower rates of larval decline." Ponds that dry during summer often support CTS breeding, although they may not be suitable for breeding in drier years.

Trend in occupied sites: Moderate. Sampling was not consistent across properties, so the sites surveyed in recent years were not the same as those surveyed in earlier years (Figure 6.1). Estimates did not account for variation in survey effort across time, or detection probability, which can be low for this species (Moss et al. 2020, Joseph et al. 2016). Because the CTS shows high interannual variation in breeding activity, more consistent data across time or the use of more sophisticated modeling approaches (e.g., occupancy modeling) will help disentangle variation in sampling effort from trends in CTS occurrence. Additional data from the Mt. Hamilton subregion are needed; very few sites were surveyed in the most recent three years. Despite data gaps, strong evidence of widespread CTS increase or decrease is not apparent; rather, using statistical models, the trend was negative and highly variable.

Metric 2: California Ground Squirrel Presence

Rationale: Adult CTS rely on small-mammal burrows, such as those made by California ground squirrels, in which they spend the majority of the year. (See Chapter 12 for more details about these squirrels and their life history, extent, condition, and trend within the area of focus.)

Condition Goals:

- Maintain a significant percentage (more than 50% of park or land units) of Network agency partner park lands with documented presence of a ground squirrel.
- The spatial extent of occupied habitat (areal extent of active ground squirrel colonies) in grasslands is maintained or increased.

Current Baseline: Current baseline conditions were determined by information from Network partner agencies. We aggregated camera trapping records, data from current surveys, and information from iNaturalist records to determine California ground squirrel presence for each of our land units or parks for each subregion in the area of focus. These findings were compiled into a comprehensive table with locations for each park or land unit. This metric is taken directly from Metric 1 of the California ground squirrel indicator. Details regarding the methodology and results are provided in Chapter 12.

Each subregion is made up of individual parcels of lands referred to as either agency parks or land units ("units"). By adding up the amount of suitable habitat for each unit with a California ground squirrel detection (a "1"), we can show how many square kilometers of lands are represented by the parks with California ground squirrel present. Even though we are using the term "occupied" we are not implying that each land unit with a ground squirrel is entirely occupied with active ground squirrel colonies but that the amount of suitable habitat is potentially available for this species in that park. We took this approach to show how much suitable habitat was being represented by each park; land units varied in size from small to large.

Table 6.3: Number of Agency Park/Lands ("Units") with ground squirrel detections out of the total "units" in each subregion ("No. Units in Subregion) that support grasslands and oak woodland. Area (sq km) of grasslands (Grass) and oak woodland (Oak-Wo) for Agency units and unit areas with one or more ground detections and percentage of available habitat that unit(s) represents ("% Total Available") based on aggregated detections after 2016 [see Figure 6.2]).

Agency/ Subregion	No. Units GrSq Detect	No. Units in Subregion	Units Proportion)	Grass (sq km)	Oak-Wo (sq km)	Total Available (sq km)	Unit Area GrSq (sq km)
EBMUD	1	3	1/3	36	25	61	58[26]
EBRPD	10	35	10/35	73	91	164	124
SFPUC	1	1	1/1	2	2	4	4
East Bay Hills Total	***12***	***39***	***12/39***	***112***	***118***	***229***	***186***
CCWD	2	3	2/3	62	11	73	72
EBRPD	13	21	13/21	100	34	134	129
CSP	2	2	2/2	35	32	67	67
Mt. Diablo Range Total	***18***	***27***	***18/27***	***197***	***77***	***274***	***268***
CCWD	2	2	2/2	17	0	17	17
EBRPD	5	6	5/6	36	24	60	60
SFPUC	6	14	2/2	78	31	110	110
CSP	2	2	2/2	16	9	24	24
Mt. Hamilton Total	***11***	***12***	***11/12***	***147***	***64***	***211***	***211***
Grand Total	***41***	***78***	***41/78***	***455***	***259***	***714***	***665***

Network partner agency abbreviations: CCWD = Contra Costa Water District, CSP = California State Parks, EBMUD = East Bay Municipal Utility District, EBRPD = East Bay Regional Park District, SFPUC = San Francisco Public Utilities Commission.

Condition Thresholds:

- *Good:* Land units and/or parks in Network partner lands with ground squirrel detections maintain their presence within 50% of land units or parks. The number of occupied land unit and/or park (that is, with ground squirrel detected) in Network partner lands is increasing or stable.

[26] The area occupied on EBMUD's property is approximately .0051 km^2 at the Bear Creek Staging Area and .062 km^2 at Rocky Ridge (Total= .0671 km^2; J. Price, EBMUD, personal communication, 2022).

- *Caution:* Ground squirrels detected in fewer than 50%, but more than 20%, of land units or parks in Network partner lands. The number of land units and/or parks with ground squirrel detections decreases by 20% from one year to the next.
- *Significant Concern:* Ground squirrels detected in fewer than 20% of land units and/or parks in the Network partner lands. Also, the currently active ground squirrel units (that is, with a documented ground squirrel presence) decrease by more than 50% from one year to the next.

Condition:

Good (Mt. Diablo Range, Mt. Hamilton). More than 50% of the parks (or land units) have ground squirrel detections.

Caution (East Bay Hills). Of 39 units, 31% have detections.

Trend: Unknown (all subregions)

Three data points are needed to understand change over time. This year is the first, and only, data point we have for this metric.

Confidence: Low (all subregions)

Measurements were based on recent, reliable, and suitably comprehensive monitoring data. We queried each Network partner agency about ground squirrel detections over a period of months and augmented our findings with records from the camera studies, a ground squirrel research project conducted in 2021, and an iNaturalist project that specifically collected reliable ground squirrel records. However, we do not know the abundance or distribution of the ground squirrel population. In addition, this condition assessment relies on trends, and because we lack a time series, the confidence was "low" due to the missing trend data.

Metric 3: CTS Metapopulations

Rationale: CTS populations are considered to be metapopulations, or a group of subpopulations separated spatially but interacting through migration and gene flow (USFWS 2017). Subpopulations are subject to local extinctions but may be recolonized by adult migrants and dispersing individuals (Wang et al. 2009), which stabilizes the larger metapopulation (Marsh and Trenham 2001). Using a "pond-as-patch" metapopulation model (Marsh and Trenham 2001), we assume that ponds stand in for discrete patches of habitat within a mostly grassland matrix, so we based this metric on pond occupancy. However, Marsh and Trenham (2001) argue that the "pond-as-patch" metapopulation model does not neatly explain real-world amphibian population dynamics. For example, it fails to account for the importance of upland habitats to the CTS. The simplicity of the metapopulation model and lack of detailed analysis of upland habitat are therefore important limitations of this analysis.

The area of focus consists of disparate land holdings that support a number of CTS metapopulations within the East Bay. The number, size, and connectivity of these metapopulations can be used as a metric for the health of the species. The number of potential CTS sites that are isolated from metapopulations is an additional useful metric.

We estimated the number of metapopulations by analyzing the spatial proximity of core CTS sites to one another. We defined core sites as ponds that consistently contained CTS, as defined by: (1) being consistently surveyed (having more than three years of survey data, including surveys prior to 2009) and having CTS detections in >30% of the years surveyed, or (2) being inconsistently surveyed (3 or fewer years) but having CTS detections in 100% of the years. This allowed us to consider sites that have not been well-sampled but could serve as core sites.

We then defined metapopulations as clusters of sites that were within 2 kilometers (km) of each other and contained at least one core site. The CTS has among the longest dispersal distance of any salamander—up to 2 km per year (Orloff 2011, Searcy et al. 2013, Trenham et al. 2000). Therefore, we considered this a realistic distance to define as a metapopulation, as sites belonging to the same cluster could be expected to exchange individuals and rescue one another from periodic extinction. Indeed, a population genetic study conducted within our area of focus in the Los Vaqueros watershed found low genetic differentiation (F_{ST} <0.06) among ponds within 2 km, indicative of connectivity (Vincent 2014, Thomas 2017).

For each metapopulation, we calculated the centroid (the geographic center of all core sites within that cluster) and calculated a 2 km buffer from that centroid. This represents the area from each metapopulation from which a CTS could be expected to disperse. Several metapopulations had overlapping buffers, indicating some level of potential connectivity among them. Metapopulations that were within one another's buffer area were defined as a habitat unit.

Condition Goals:

- Maintain or increase connectivity between breeding habitats (i.e., no new barriers to dispersal within or between existing metapopulations).
- Maintain or increase the number of metapopulations.
- Maintain acreage of metapopulations.

Current Baseline: Network partner agencies manage a total of 110 ponds designated as core CTS sites (Figure 6.4, points with black outlines). These sites, to our knowledge, contain reliable CTS populations and could serve as source populations for surrounding ponds. The majority (*n* = 98; 89%)

of core sites were less than 2 km from another core site. On average, core sites were 1.02 km from the nearest other core site, meaning that metapopulation dynamics could be expected to occur.

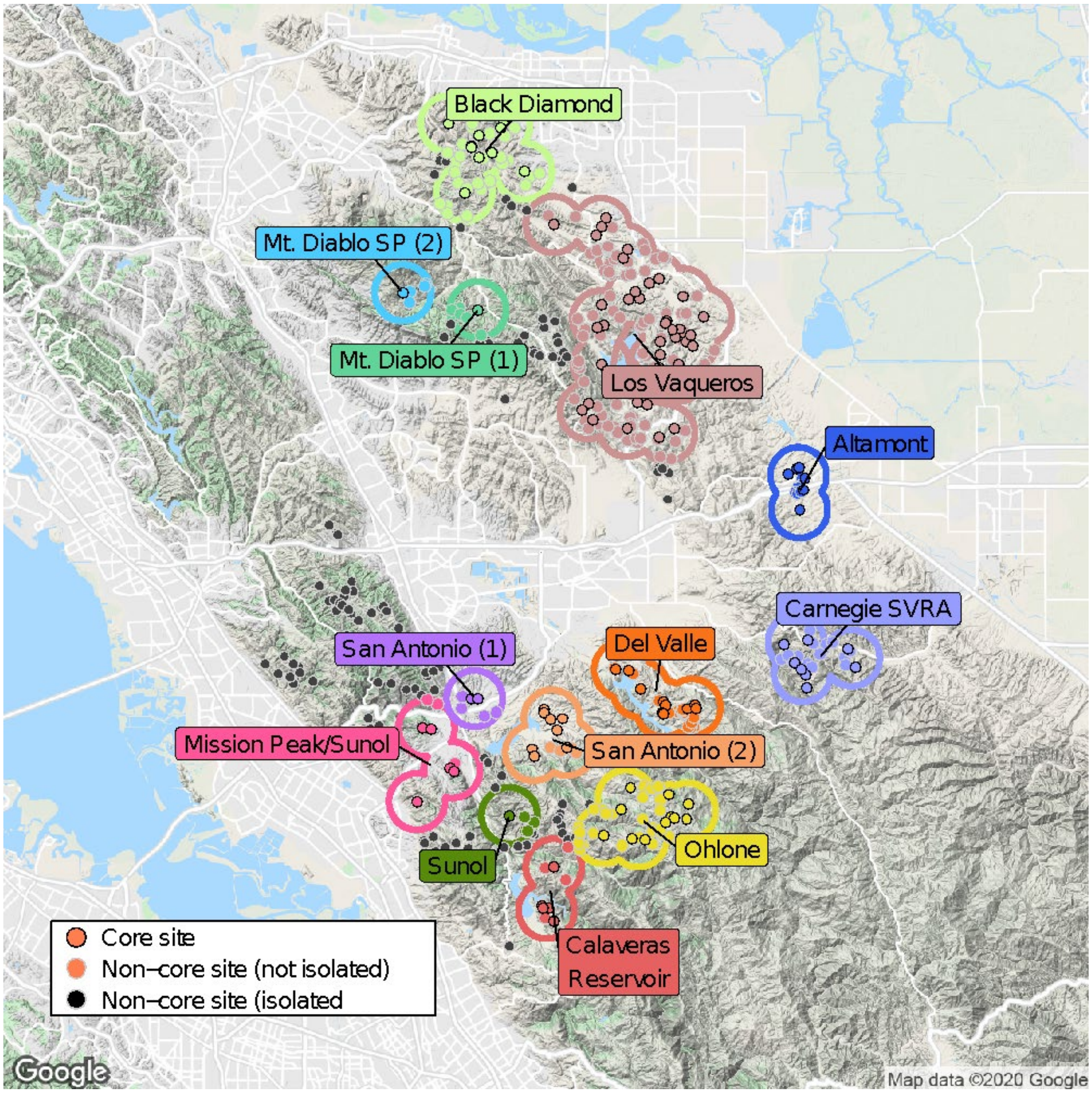

Figure 6.3. Distribution of CTS core sites. Points with black outlines are core sites, with CTS occurrence; those with gray outlines are non-core sites. Colored outlines show habitat units, or groups of metapopulations with potential gene flow and connectivity. Point colors reflect the habitat unit within which they are located. Points in black are non-core sites that fall outside a habitat unit and are located far (>2 km) from potential source sites.

We defined 48 metapopulations (i.e., clusters of ponds within close proximity); 15 of these contained three or more core sites, and the two largest metapopulations contained six core sites each. Both of these were located within Contra Costa Water District (CCWD) lands near Los Vaqueros Reservoir. There were also larger metapopulations within the San Antonio Reservoir property (SFPUC, five core sites), Black Diamond Mines (EBRPD; five core sites), Altamont Habitat Management Unit (HMU) (CCWD; five core sites), and Carnegie State Vehicular Recreational Area (CSP; four core sites). The majority of metapopulations contained additional non-core sites that could also contribute to metapopulation dynamics (Table 6.4).

There were 368 ponds designated as non-core sites, or sites within the CTS's range boundary (as defined under Metric 1 as the maximum extent of known observations) in which they were not detected. More than half (*n* = 230) were within 2 km of a core site, and therefore fell within a metapopulation boundary, suggesting a high potential for colonization (Figure 6.3, colored points with gray outlines). These sites could potentially contribute to metapopulation dynamics, and 101 of the sites within dispersal distance of a core site did have at least one record of CTS presence. Importantly, more than half of the non-core sites (*n* = 182) were rarely surveyed (i.e., in fewer than four years), and 102 of these sites have not been surveyed since 2010. Therefore, we have poor information on the rates of CTS occupancy in many non-core sites.

There were 138 non-core sites that were spatially isolated **(**i.e., located > 2km from a core site) (Figure 6.3, black points)**.** Of these, 22 (16%) contained CTS at least once during their monitored history. These sites are at higher risk of local extinction because the likelihood of rescue (natural recolonization or population rebound) is low. Indeed, several of these contained CTS prior to 2009 but did not during the most recent surveys.

Metapopulations clustered into 13 distinct habitat units, which are expected to have some level of connectivity and could be feasibly co-managed (Figure 6.3, colored outlines). Several of these units contain properties managed by multiple Network partner agencies (Table 6.4). The Los Vaqueros unit, with more than 100 ponds and 36 core sites, had the largest complex of CTS sites. We note that this was also one of the area of focus's most intensely surveyed regions, which suggests that surveys in other regions may similarly reveal more extensive CTS habitat than is currently known.

Table 6.4. Habitat units, or complexes of spatially clustered metapopulations. Ponds within the same habitat unit may be expected to show some level of connectivity and gene flow, and the response of larger habitat units to periodic extinction events should be more robust.

Subregion	Habitat Unit Name	Properties Included	Network Agency Land Manager	Number of Total Ponds	Number of Core CTS Sites	Number of Meta-populations
Mt. Diablo	Los Vaqueros	Brushy Peak Regional Preserve, Cowell Ranch, Deer Valley, Los Vaqueros watershed, Marsh Creek HMU, Round Valley Regional Preserve, Vasco Caves Regional Preserve, Vasco Hills	CCWD, CSP, EBRPD	145	42	17
Mt. Hamilton	Ohlone	Ohlone Regional Wilderness	EBRPD	42	11	5

Subregion	Habitat Unit Name	Properties Included	Network Agency Land Manager	Number of Total Ponds	Number of Core CTS Sites	Number of Meta-populations
Mt. Hamilton	Del Valle	Del Valle Regional Park	EBRPD	25	10	4
Mt. Diablo	Black Diamond	Black Diamond Mines Regional Park, Clayton Ranch, Deer Valley	EBRPD	40	10	5
Mt. Hamilton	San Antonio (2)	San Antonio Reservoir, SFPUC (Unknown property)	SFPUC	12	8	3
Mt. Hamilton	Carnegie SVRA	Carnegie State Vehicular Recreational Area	CSP	22	8	3
Mt. Diablo, Mt. Hamilton	Altamont*	Altamont HMU	CCWD	12	6	2
Mt. Hamilton	Calaveras Reservoir	Calaveras Reservoir, Ohlone Regional Wilderness	EBRPD, SFPUC	10	5	2
Mt. Hamilton	Mission Peak/Sunol*	Mission Peak Regional Preserve, Pleasanton Ridge Regional Park, San Antonio Reservoir, Sunol Valley	EBRPD, SFPUC	8	5	3
Mt. Hamilton	San Antonio (1)	San Antonio Reservoir, PUC (State Hwy 84)	SFPUC	7	2	1
Mt. Diablo	Mt. Diablo SP (2)	Mount Diablo State Park	CSP	5	1	1
Mt. Hamilton	Sunol	Sunol Regional Park	EBRPD	5	1	1
Mt. Diablo	Mt. Diablo SP (1)	Morgan Territories Regional Park, Mount Diablo State Park	EBRPD, CSP	7	1	1
	Unassigned			138		
	*A potential barrier (Hwy I-680 or I-580) exists between core sites within this habitat unit.					

Network partner agency abbreviations: CCWD = Contra Costa Water District, CSP = California State Parks, EBRPD = East Bay Regional Park District, SFPUC = San Francisco Public Utilities Commission

Within the Mt. Hamilton subregion, there were numerous smaller units which, although they were separated by >2 km, did not have other large barriers (e.g., highways or highly developed areas) between them. Alternatively, more intensive surveys at ponds located in between units may reveal additional core sites that connect these units.

Condition Thresholds:

- *Good:* The number or acreage of metapopulations in the next 10 years is maintained, increased, or decreases by less than 10%.
- *Caution:* There is a loss of connectivity of 10%-20%, or loss of acreage of metapopulations of more than 10%.

- *Significant Concern:* There is a loss of connectivity of more than 20%, or loss of acreage of metapopulations of greater than 20%.

Condition: Good (all subregions)

Using our 2 km dispersal distance, we identified several large, contiguous regions where the CTS was detected regularly and core sites were located in close proximity to one another. We observed higher fragmentation in the southern (Mt. Hamilton) subregion, where core sites were separated by >2 km and highways separated habitat units. Smaller metapopulations should be monitored closely over the next decade; periodic extinctions in these smaller metapopulations may be less likely to experience demographic rescue due to fewer nearby source populations.

Trend: Unchanging (all subregions)

To estimate trends in metapopulations over time, we repeated the analysis above, this time splitting the data into early (1996–2012) and late (2013–2019) time periods and filtering it to only those ponds that were surveyed at least once in both time periods. This dataset included 177 sites. We then defined core sites, metapopulations, and habitat units in the early and late time periods.

In the early time period, 70 of the 177 sites were core sites (CTS present in >30% of years), and in the late time period, 56 of the 177 sites were classified as core sites. In other words, at least 14 sites had reliable CTS occurrence prior to 2013 but contained the CTS in fewer than 30% of surveyed years after 2013. Intensive drought, especially from 2014 to 2016, may be responsible for this decline[27].

The decline meant that the number of isolated non-core sites (>2k from nearest core site) also increased slightly, from 34 sites (31%) in the early years to 43 (36%) in the later years. However, the proximity of core sites and metapopulations shifted slightly, such that in later years, metapopulations were closer, resulting in larger and more connected habitat units. In the late period, several smaller metapopulations connected and the number of habitat units decreased from eight to five (Figure 6.4).

[27] The full drought period extended from 2012–2017; 2014–2016 were peak drought years, categorized as exceptional drought by the US Drought Monitor (https://www.drought.gov/states/california).

With this limited dataset, the trend in population connectivity appears to be unchanging. To our knowledge, no new barriers to connectivity have appeared within the past 10 years, and the position of core sites was such that the loss of some of them did not affect overall connectivity.

Confidence: Moderate (all subregions)

Our analysis did not account for land cover in between core sites, which could affect connectivity estimates. Dispersal probabilities likely depend upon habitat between ponds, with some estimates suggesting that the CTS is more likely to disperse through open shrub habitats than oak woodlands (Wang et al. 2009). Similarly, sites within 2 km of each other could be separated by various barriers to dispersal such as roads. Moreover, population genetic analyses could provide us with data to support our inference about the functional connectivity of sites that cluster together spatially. Instead, we chose a metric of connectivity based on dispersal distance in previously published studies. The analyses herein are sensitive to this choice of dispersal distance.

Importantly, the dataset we analyzed included only surveyed ponds, and is therefore not an exhaustive list. The true number of core sites may be higher, and they may also exist on private lands or on unsampled properties, which would lead to higher connectivity among habitat units and metapopulations. By the same logic, if future updates to this ecological health assessment fill in these gaps with additional surveys, this may falsely appear as an increase in connectivity rather than what it actually is: an increase in data. Future analyses with updated datasets should include a direct comparison with the current dataset (i.e., use the same sites).

Despite these caveats, this analysis revealed several clusters of ponds important for the CTS that were close enough to potentially exchange individuals, and that the distribution of

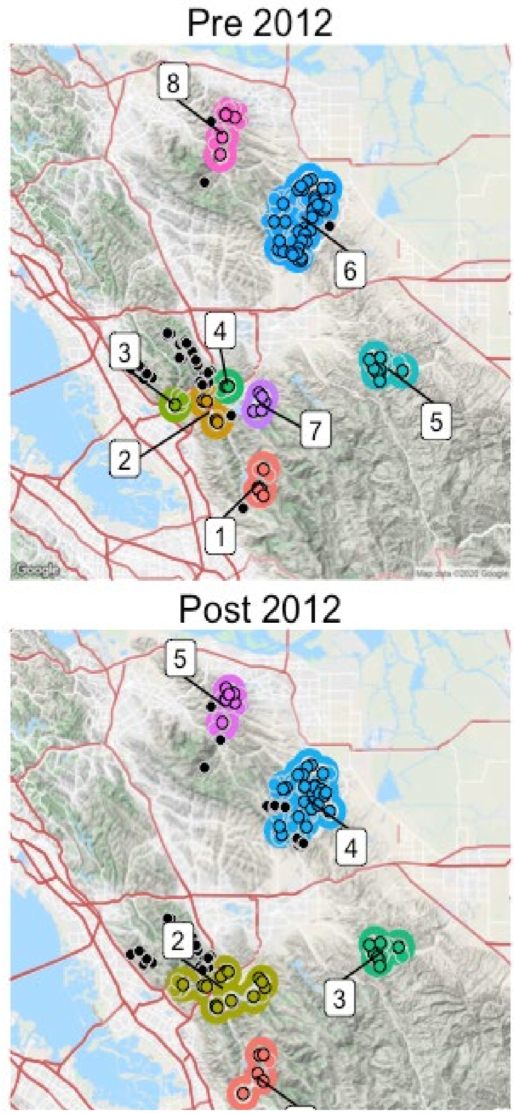

Figure 6.4. Distribution of CTS core sites and metapopulations across time. The earlier time period (1996 to 2012) had fewer isolated sites (in black) than the later time period (2013 – 2019); however, the later time period showed increased connectivity in the Mt. Hamilton subregion.

these clusters did not appear to change significantly over time. Therefore, this metric is useful in defining where high-quality CTS habitat occurs within the area of focus, and where sites may be more (or less) isolated.

OTHER METRICS CONSIDERED BUT NOT INCLUDED

- Explicit comparison of historical and current CTS ranges. Identifying areas of range contractions may show locations that are good candidates for restoration or repatriation. Range limits, while useful, are a coarser metric and not as high a priority as the three metrics used in this chapter.
- Interbreeding with non-native tiger salamanders. This stressor is known to occur within the area of focus, but data are sparse and confirmed reports of hybridization are rare.
- Various diseases that may affect the CTS. We decided against this metric because data are limited and the CTS may be resistant to Bd-caused mortality (Padgett-Flohr 2008), one of the leading causes of global amphibian decline.

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

- Additional data from the Mt. Hamilton subregion are needed; very few sites were surveyed in the most recent three years.
- Metric 3:
    - More than half of the non-core sites (n = 182) were surveyed only rarely (i.e., in fewer than four years) and 102 of these sites have not been surveyed since 2010. Therefore, there is poor information on the rates of CTS occupancy in many non-core sites.
    - Our analysis did not account for land cover between core sites, which could have an impact on estimates of connectivity.
    - We did not have the population genetic analyses to support our inference that sites that cluster together are functionally connected.
- The selected metrics do not account for population estimates. Simple presence and breeding data cannot be easily applied to measures of relative abundance, fecundity, or other measures of population size.

- Survey methodology used by Network partner agencies likely does not fit into assumptions of statistically robust study designs, and it is difficult to make assertions about unsampled ponds. Ponds have not been randomly sampled, and uneven sampling decreases statistical power and can introduce bias.
- Stressors may affect populations unevenly due to their general location, microhabitat variables, or the synergistic effects of multiple stressors (Davidson et al. 2002, Mihaljevic et al. 2018). Considerations for future monitoring include standardizing survey methods and implementing more consistent monitoring across the area of focus (including poorly surveyed regions).
- A limited amount of disease data has been collected within the area of focus, in part because protection of CTS populations limits the collection of specimens. More data, particularly from non-invasive approaches (e.g., skin swabs, fecal analysis) are necessary to evaluate the impacts amphibian diseases have on CTS populations.

PAST AND CURRENT MANAGEMENT

Network land management agencies in this area have conducted long-term monitoring coupled with regular pond maintenance, restoration, enhancement, and creation. These management actions include pond de-sedimentation to lengthen hydroperiods, repairing embankments, removing encroaching emergent vegetation, restoring native vegetation, and removing bullfrogs and fish via periodic draining. Additionally, ponds created on conservation easement lands are monitored post-construction to meet mitigation requirements. Many Network partner agencies also use cattle grazing in uplands to maintain non-native annual grasslands.

POTENTIAL FUTURE ACTIONS

- Establish more systematic and coordinated data collection efforts, in which partner agencies conduct pond surveys using similar methods and data sheets when possible. Data sheets have been revised to include an upland survey for California ground squirrels to close the gap on the ground squirrel distribution map.
- Continue pond restoration efforts. Collaborate on pond-restoration priorities, target invasive-species control where activities benefit multiple Network partner agencies, and improve pond hydroperiods.
- Prioritize restoration efforts to support connectivity between metapopulations. Colonization of isolated sites could be achieved if nearby sites that have occasional CTS breeding are converted into source populations, perhaps by habitat improvements. Restoration efforts

could be targeted to sites that could serve as "stepping stones" of dispersal from core sites to isolated sites. To further enhance colonization opportunities to isolated sites, managers could consider using assisted colonization or management of upland habitats (i.e., preservation of surrounding grassland and shrubland or creation of new ponds). Connectivity among several of the smaller habitat units (e.g., Calaveras Reservoir, Sunol, San Antonio, Ohlone) could also be improved with maintenance of upland habitat.

- Model a subset of ponds under future climate-change scenarios.
- Consolidate academic disease research across the area of focus.

These actions may increase our confidence in the data used in subsequent analyses, provide greater coverage and more even sampling across the area of focus, and help partner agencies proactively manage for climate change.

KEY LITERATURE AND DATA SOURCES

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Partner Agency Data Sources

- East Bay Regional Park District (EBRPD): All ponds were surveyed every four years from 1994 to 2012. Additional data on ponds have been acquired or found since then. This included 1,209 surveys of 399 unique ponds across 28 properties. We did not include surveys conducted in upland habitat (e.g., data from adult trap surveys in Thurgood Marshall Regional Park – Home of the Port Chicago 50). We also did not include surveys of ponds where location data were not available.

- East Bay Municipal Utility District (EBMUD): Annual breeding and adult occupancy surveys are done on 50% to 75% of ponds. The other 35% of ponds are surveyed every two to three years. EBMUD prioritizes surveys in known source-population ponds. If there are confirmed adults, they will do breeding surveys during same year. From 2007 to 2019, this included 2,262 surveys of 152 unique ponds. The major focus of these surveys is the California red-legged frog; the CTS has not been observed on EBMUD properties.

- California State Parks (CSP): Surveys of 25 ponds in the Carnegie State Vehicular Recreational Area from 2011, 2012, and 2014 were included. Approximately 30 ponds and pools in Mount Diablo State Park and Cowell Ranch were surveyed between 2006 and 2016. The dataset included 233 surveys of 76 ponds across three properties.
- San Francisco Public Utilities Commission (SFPUC): CTS surveys and monitoring of ponds from 2000 to 2015 were included. A large set of ponds was monitored each year, and additional ponds were monitored as time allowed. Data from SFPUC included 162 surveys of 55 ponds across five properties.
- Contra Costa Water District (CCWD): This Network partner agency monitors and manages two sets of lands. At the Los Vaqueros watershed, amphibian monitoring has occurred annually since 1999/2000. Reports are available from 2005–2006 and 2010–2018. The intervening years (2007–2009) were not provided. Conservation lands (also known as Habitat Management Units, or HMUs) are spread across Contra Costa, Alameda, and San Joaquin Counties. We obtained surveys in the Altamont, Marsh Creek, and Morgan Territories HMUs from 2013 to present. (We did not include the Los Vaqueros and Corral Hollow HMUs because they had no records of CTS occurrence.) Data include 2,978 surveys of 110 ponds.

Other Data Source:

The Johnson Lab, University of Colorado, Boulder: Dr. Pieter Johnson and his graduate students have been sampling various ponds on EBMUD, EBRPD, and SFPUC lands for nearly the last decade. Data included 1,446 surveys of 252 ponds across 25 properties.

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The following people attended the East Bay ecological health assessment expert workshops or were otherwise consulted on this project. It should be noted that this document does not necessarily reflect the opinions or incorporate the suggestions of these participants.

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CHAPTER 7. BIRDS

EXECUTIVE SUMMARY

This chapter provides the results of this NatureCheck ecological health assessment for birds within the lands owned and managed by the East Bay Stewardship Network (Network) partner agencies. (See map, Chapter 1.). The primary goals of the analysis were to understand the likely trajectory of 28 common species, provide a benchmark against which managers can measure future changes, guide current and future management, and suggest additional research needed to fill data gaps.

The 28 species we analyzed were divided into four groups (with unequal numbers of species in each group) based on the type of vegetation the species are typically found in: riparian, grassland, oak woodland, or shrubland – the latter with an emphasis on birds in chaparral shrublands (see Table 7.3 for the full list). We call these groupings "guilds," and we define them as those species that exploit the same resource—in this case, a vegetation or habitat type.

Using community science eBird data from the 2010–2020 breeding seasons, we evaluated a presence/absence trend (Metric 1) using all available observations, and an abundance trend (Metric 2) using only data from locations where there were repeated annual observations. The two metrics were then combined to provide an overall species condition and trend. From the species metrics, we calculated a guild-level summary evaluation across species (Metric 3). Finally, we describe our confidence in both the metrics and the guild-level summary. The desired condition is, for each species, to have unchanging or improving trends for both metrics, known with high confidence.

Our results suggest that across the 28 individual species, two have a condition of "significant concern," four have a condition of "caution," and 22 have a condition of "good." With 22 species with a "good" condition, it might seem that birds are doing well within the Network agency lands. However, we see that two grassland species have a condition of "significant concern" and two more have a condition of "caution." Thus, we reported our results here at the individual guild level rather than for birds as a whole, as that captures these important differences in ecosystem health at this scale. Looking at guild-level summary evaluations, the riparian, oak woodland, and shrubland guilds have trends that are unchanging. The grassland guild shows a declining trend, which is cause for significant concern.

Beyond reporting guilds separately, this chapter deviates from the health assessment methodology of other chapters in two more ways. First, due to the limited data available for each subregion, this analysis did not evaluate the health of the individual subregions (East Bay Hills, Mt. Diablo Range, and Mt. Hamilton) as did many other chapters in this report. Second, we take a more cautious approach to assigning guild-level condition than the point system introduced in Chapter 1. We do this based on expert opinion comments from attendees of the East Bay ecological health assessment expert workshop (January 2020), and because we focused on *common* birds that we assume will be more resilient to ecosystem change. Any declines in common species might be cause for more concern about ecosystem health than declines in species of conservation interest.

METRICS SUMMARY AT A GLANCE

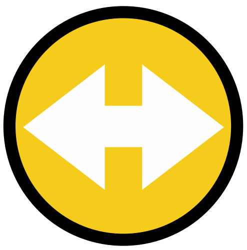
The table below summarizes the three metrics used in this ecological health assessment. Each metric, along with how we arrived at its condition, trend, and confidence, is thoroughly described in the Metrics in Detail section later in this chapter. (See Chapter 1 for definitions of condition, trend, and confidence; terminology relevant to this chapter; how metrics are being used for each indicator; and other project methodology.)

Table 7.1. All birds metrics, with their respective condition, trend, and confidence. Each metric is described in the Metrics in Detail section later in this chapter.

	Summary for the Entire Area of Focus
Metric 1: Single-Species Presence/Absence Analysis–Using all locations where any eBird observer recorded the presence or absence of the focal species, we measured the fraction of occupied sites from 2010 to 2020. Sites were 1- or 4-hectare grid cells (grid-cell size depended on the size of the bird's territory).	
Trend	A trend was measured for Metric 1 (see Table 7.3 and Appendix F, Birds Chapter Supplemental Information, Tables 5–8).
Metric 2: Single-Species Abundance Analysis–Using locations that were repeatedly sampled from 2010 to 2020 (~57 sites were sampled in at least eight out of 11 years), we measured species abundances per grid cell (grid cells were 1 or 4 hectares, depending on the species' territory size).	
Trend	A trend metric was assigned to Metric 2 (see Table 7.3 and Appendix F, Birds Chapter Supplemental Information, Tables 5–8).
Condition and Confidence	Trends for Metrics 1 and 2 were combined to provide each species one species condition and confidence (see Table 7.3 and Appendix F, Birds Chapter Supplemental Information, Tables 5–8).
Metric 3: Summary Evaluation by Avian Guild–We aggregated the single-species trends to a single guild-level summary trend, condition, and confidence.	
Condition, Trend, and Confidence	The single species scores were combined to provide the condition, trend, and confidence of each guild (Table 7.2).

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of each bird guild in the area of focus represented by the graphics below is based on the combined values of the individual metrics presented in Table 7.1. Each of these metrics is described in depth in the Metrics in Detail section later in this chapter.



Riparian Birds

Condition: Caution (color: yellow)

Trend: Unchanging (symbol: horizontal arrow)

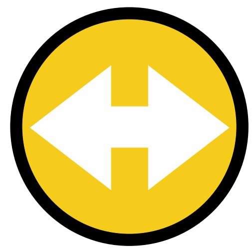
Confidence: High (line around circle: solid)

Grassland Birds

Condition: Significant Concern (color: red)

Trend: Declining (symbol: downward arrow)

Confidence: Low (line around circle: none)

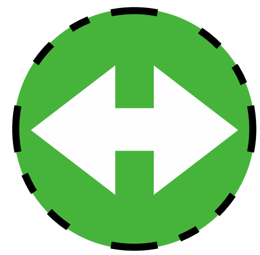


Oak Woodland Birds

Condition: Caution (color: yellow)

Trend: Unchanging (symbol: horizontal arrow)

Confidence: High (line around circle: solid)



Shrubland Birds

Condition: Good (color: green)

Trend: Unchanging (symbol: horizontal arrow)

Confidence: Moderate (line around circle: dashed)

BACKGROUND

WHY IS THIS RESOURCE INCLUDED?

Birds are important to both ecosystems and human health. They provide a wide variety of services, including devouring pests, pollinating flowers, dispersing seeds, scavenging carrion, cycling nutrients, and modifying the environment in ways that benefit other species (Whelan et al. 2015). The San Francisco Bay Area (hereafter referred to as “Bay Area”) is a destination for many bird-watchers—a hobby that can have significant positive impacts on both local and national economies (Carver 2013). Therefore, resource management to promote bird community health is likely to have multiple benefits to non-target species and communities, as well as to promote human well-being.

Birds are highly visible across both urban and natural landscapes, making them a readily observed and frequently monitored natural resource. Considerable public interest in bird watching has also resulted in community science observations through the Cornell Lab of Ornithology's eBird platform, among others (see the Metrics in Detail section for more information on the eBird dataset). The great interest in birds on the part of scientists and community members has led to a detailed understanding of the life histories (e.g., nesting habits, migration, feeding) of many common species.

Because of the relative wealth of data and their widespread distribution across ecosystems, birds are recognized as indicators of ecological change (Carignan and Villard 2002). Indicator species are defined as a species or a "group of species whose population trends, when taken together . . . cast light on trends [within vegetation types] and act as a surrogate for ecosystem health" (Gregory et al. 2005). Considering a group of indicator species, such as a bird guild, allows for multiple observations of health, with specific life-history differences providing clues to ecological conditions that are causing population changes. For example, a recent analysis found that over the last half-century, 57% of North America bird species have declined, with a net loss of 2.9 billion birds (Rosenberg et al. 2019). Because the declines were occurring across so many types of birds, the weight of the evidence pointed to widespread anthropogenic changes causing an alarming gradual decline in many species. Rosenberg et al. (2019) showed that 38 families of birds (e.g., larks, thrushes, wood warblers, finches, blackbirds, American sparrows) have lost more than 50 million individuals each. Even non-native species (e.g., starlings, Old World sparrows), which were assumed to be robust based on their initial population expansions upon introduction into North America in the 1800s, showed similarly drastic declines. Shorebirds and waterbirds have also evidenced serious declines, probably due to the 50% loss of North America's wetlands. The management implications of a decline in non-native birds versus a decline in native birds are quite different, however. Whereas a decline in non-native species might be desirable because it makes resources available for native birds, a decline in native birds suggests an urgent need to identify causal agents and implement conservation efforts. By considering sub-groups (guilds) within the larger category of birds, we can make these more detailed and nuanced management decisions.

DESIRED CONDITION AND TREND

Given the substantial alteration in the natural landscape of Network partner lands (see map, Chapter 1) over the last century, this assessment does not use historical abundance as a realistic surrogate for desired condition. Instead, the desired condition is to have the trend (as measured in 2010–2020) in the presence/absence and abundance of each bird species remain unchanged or to improve (see the Metrics in Detail section for more information). We also calculated a summary evaluation of individual species trajectories for all species within the guilds: riparian, grassland, oak woodland, and shrubland (see Table 7.3 for a full list). The desired condition is that all species within a guild have trends that are unchanged or improving.

CURRENT CONDITION AND TREND

We analyzed trends across 28 species of birds within the Network agency lands' boundaries (Figure 7.1). However, each of the 28 species analyzed has a much broader distribution than the Bay Area. The grassland- and riparian-associated species all have multi-state to hemispheric distributions. Most of the shrubland- and oak woodland–associated birds have somewhat smaller distributions that are generally restricted to California but can extend into Arizona and Mexico (e.g., rufous-crowned sparrow and acorn woodpecker) or, more widely, across North America (e.g., lark sparrow, western bluebird, yellow warbler, ash-throated flycatcher, and blue-gray gnatcatcher).[29]

Globally, all species we analyzed except loggerhead shrike are ranked "least concern" by the International Union for Conservation of Nature (IUCN). Although the loggerhead shrike is ranked as "not threatened" by the IUCN, it has experienced declines across most of its geographic range (Smallwood and Smallwood 2021), and the subspecies that inhabits San Clemente Island, *Lanius ludovicianus mearnsi*, is federally listed as endangered (U.S. Fish and Wildlife Service 2018).

The U.S. Fish and Wildlife Service (USFWS), taking a more cautionary approach, identifies "birds of conservation concern." These are defined as species, subspecies, and populations (hereafter referred to as "taxa") of all migratory nongame birds that, without additional conservation action, are likely to become candidates for listing under the Endangered Species Act. The belted kingfisher, grasshopper sparrow, northern harrier, oak titmouse, Nuttall's woodpecker, wrentit, and California thrasher are all considered birds of conservation concern. Assessments at the state level (Shuford and Gardali 2008) identify the yellow warbler, grasshopper sparrow, northern harrier, and loggerhead shrike as California bird species of special concern.

A number of studies track bird trends across different North American ecosystems. Apparent declines in species that use grassland, shrubland, and agricultural sites are particularly concerning; pesticide exposure and fragmentation have been hypothesized as potential drivers of these decreases (Stanton et al. 2018, Eng et al. 2019). From Mexico to Alberta, grassland habitat conversion has left less than 40% of what was present before European settlement. Even more dramatically, California's native grasslands have also been reduced to less than 1% of what they once were (Wiley et al. 2019), due in part to invasion by non-native annual grasses. However, grassland ecosystems still comprise more than 10% of the state's land area (Corbin et al. 2007). Despite being one of the state's most altered

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[29] For scientific names of species mentioned in this chapter, see Table 7.3.

ecosystems, these grasslands are biodiversity hotspots and provide a wealth of ecosystem services (Eviner 2016). In addition to outright habitat loss, grassland fragmentation can also affect numerous bird species that will not use small patches (Herkert 1994, Vickery et al. 1995). Most recently, Rosenberg et al. (2019) analyzed avian population changes since 1970 across North America and found declines in all of the grassland and shrubland focal species considered here: loggerhead shrike, grasshopper sparrow, horned lark, savannah sparrow, white-tailed kite, western meadowlark, northern harrier, California thrasher, wrentit, and rufous-crowned sparrow, as well as declining populations for the following riparian and oak woodland focal species: Wilson’s warbler, belted kingfisher, tree swallow, song sparrow, yellow warbler, oak titmouse, and lark sparrow.

Lastly, a few studies have analyzed bird trends within the East Bay region. A riparian breeding bird assemblage was monitored from 1994 to 1998 and again from 2004 to 2008 at Coyote Hills Regional Preserve in Fremont, California (Riensche et al. 2010). Although this location is outside of the area of focus for this ecological heath assessment, it is instructive to note that this study detected a significant decline in the common yellowthroat, Wilson’s warbler, and song sparrow, with no apparent change in measured vegetation variables within the study plots.

Across 36 East Bay Regional Park District (EBRPD) rangeland study sites monitored from 2004 to 2011 for three grassland species, Gennet et al. (2017) found overall low but highly variable occupancy between study sites and years. In any given year, western meadowlark occupied from 0% to 90%; horned larks, 10% to 70%; and grasshopper sparrows, 0% to 70% of the study sites. Gennet et al. (2017) also observed no clear occupancy trends for these species over the eight-year study period. Similarly, no trends were reported in riparian birds (including all riparian birds in this report) monitored from 2007 to 2011 along 15 point counts across three stream reaches of the 14-mile stretch of the Alameda Creek watershed (Riensche et al. 2014).

The preceding brief literature summary provides context for trends and conditions measured on lands within Network partner agencies’ boundaries. As far as we know, the analysis presented in this chapter is the first to use eBird data to look at trends within this area across these 28 species. Our results are shown in Table 7.2. The details of this assessment are discussed briefly in Metrics Summary at a Glance, and then extensively in Metrics in Detail, which follows.

*Table 7.2. Summary results of condition, trends, and confidence of bird guilds associated with four vegetation types (habitats). See Appendix F, Birds Chapter Supplemental Information, Table 7.3 and Tables 5–8 for breakdowns of condition, trend, and confidence for each species (by habitat type) used to arrive at these summary findings. Overall scores may include decisions based on professional scientific judgment. These are noted with an * in the table below, and our reasoning is explained in the Metric 3: Summary Evaluation by Avian Guild section. We took a cautious approach to evaluating condition based on input from the East Bay ecological health assessment expert workshop (January 2020), and because we focused on common birds, where we expect common birds to potentially be more resilient to stressors. We were also cautious with respect to confidence (discussed in the Metric 3: Summary Evaluation by Avian Guild section as well).*

	Riparian	Grassland	Oak Woodland	Shrubland
Condition	Caution*	Significant Concern*	Caution*	Good
Trend	Unchanging	Declining	Unchanging	Unchanging
Confidence	High	Low*	High	Moderate*

STRESSORS

Birds in the East Bay could potentially be threatened by climate change, invasive species, disease, altered fire regimes, noise, light and air pollution, human presence, and habitat degradation and fragmentation. A database used for the One Tam ecological health assessment, *Measuring the Health of a Mountain: A Report on Mount Tamalpais' Natural Resources* (Edson et al. 2016), evaluated the impacts of stressors such as these for 24 of our 28 focal bird species.[30] While the One Tam project was focused on Mount Tamalpais in Marin County, many of the analyzed stressors occur at a regional scale. Thus, this database is also relevant to the East Bay. (Unless otherwise stated, the following information on stressors comes from this database.) However, the yellow warbler, spotted towhee, horned lark, and loggerhead shrike were not analyzed in the One Tam report and therefore, we do not have data summarizing vulnerabilities for these species.

Several ecological and anthropogenic factors affect the health of this indicator. These include:

Invasive Species Impacts: The species analyzed in the One Tam report were considered resilient to the impacts of invasive species. However, introduced squirrels and ubiquitous rats can act as

[30] https://docs.google.com/spreadsheets/d/1LzdDeDBdiodyIxThUBKkZEMbuBfJ9FcjZS-dyct7eus/edit#gid=1813066073. This assessment was based on the expertise of local biologists Thomas Gardali (formerly Point Blue Conservation Science, now Audubon Canyon Ranch), Renée Cormier (Point Blue Conservation Science), Allen Fish (Golden Gate Raptor Observatory), and Bill Merkle (National Park Service).

stressors through nest predation and usurpation of nest sites, especially where urban and suburban areas border the area of focus.

Climate Change: For climate change vulnerability, we used Gardali et al. (2012). Species predicted to have a decreasing range or habitat suitability were assumed to be vulnerable to climate change. These include the acorn woodpecker, belted kingfisher, downy woodpecker, grasshopper sparrow, northern harrier, tree swallow, warbling vireo, and Wilson's warbler. Two species—song sparrow and white-tailed kite—were "unknown." The rest were predicted to have unchanging or increasing range or suitability, and so we assumed they are not vulnerable. A 2014 Audubon report, *Survival by Degrees*, (https://nas-national-prod.s3.amazonaws.com/briefs_ca_final.pdf) suggests that the acorn woodpecker, California thrasher, Nuttall's woodpecker, savannah sparrow, and Wilson's warbler are highly vulnerable in the East Bay; the black-headed grosbeak, California scrub-jay, song sparrow, tree swallow, spotted towhee, western bluebird, white-tailed kite, wrentit, and yellow warbler are moderately vulnerable. The rest of the species had low or no predicted vulnerability. Thus, even in the same region, there can be considerable uncertainty about the predicted influences of climate change on birds.

Fire Regime Change: In the One Tam ecological health assessment report (Edson et al. 2016), the downy woodpecker, grasshopper sparrow, lark sparrow, rufous-crowned sparrow, savannah sparrow, western bluebird, white-breasted nuthatch, and wrentit were designated as potentially vulnerable to fire-regime change. Two out of the three species that have an association with shrubland habitat (rufous-crowned sparrow and wrentit) were designated as potentially vulnerable to fire regime change. This is not surprising, given that frequent fire can lead to loss of the chaparral vegetation they depend upon (Syphard et al. 2019). Bird diversity has also been found to decline after prescribed burning and mastication of chaparral to reduce fuel loads (Newman et al. 2018). While bird diversity rebounded in the years following prescribed burning, it never recovered following mastication over the five-year study period (Newman et al. 2018). Models predict greater risk of wildland fire for portions of the greater Bay Area through mid-century (Mann et al. 2018). In 2020, the Santa Clara Unit (SCU) Lightning Complex fire burned more than 396,624 acres of the Northern Diablo Range (https://en.wikipedia.org/wiki/CZU_Lightning_Complex_fires), including 19,372 acres of the subregions where the range overlaps with Network partner lands.

Disease: The California scrub-jay is the only species designated as vulnerable to diseases, specifically conjunctivitis in the nearby Central Valley (Rogers et al. 2019) and West Nile virus (which infects avian hosts). California scrub jay, and possibly acorn woodpecker (although it was not mentioned as disease-vulnerable in the One Tam report), may also be vulnerable to Sudden Oak Death (which affects its oak woodland habitat). Regardless, the etiology of infectious and parasitic avian diseases is an active field of research. Even if a disease does not cause morbidity, it may have wide-ranging effects on individual fitness in terms of immunosuppression and reproduction (Thomas et al. 2008).

The impact of evolving strains of avian diseases such as avian Influenza A—a viral disease present in wild birds that is easily transmitted back and forth to domestic birds and sometime humans—continues to be monitored (https://www.cdc.gov/flu/avianflu/avian-in-birds.htm). Further, climate change, interactions with non-native wildlife, and existing diseases can interact unexpectedly, potentially harming native birds (Tyson-Pello and Olsen 2020). The role of climate change in promoting range expansions of disease vectors that affect birds, as in the case of mosquitos and avian malaria in Hawaii (Liao et al. 2017), should be of increasing concern even at the continental level. For example, a new species of *Plasmodium*, an avian malaria parasite, was recently discovered in California (Walther et al. 2014).

Pollution/Contaminants: The belted kingfisher is assumed to be vulnerable to water pollution due to its piscivorous diet (White and Cristol 2014). Pesticide exposure is also a concern to seed-eating songbirds and species living in agricultural habitats near the area of focus (Eng et al. 2019). In the One Tam report (Edson et al. 2016), the white-tailed kite is the only species designated as vulnerable to pesticides.

Direct Human Impacts: Many human recreational activities—hiking, camping, mountain biking, dog-walking, even bird watching and photography—can negatively impact birds by affecting their physiology, behavior, abundance, and reproductive success (Steven et al. 2011). In the One Tam report, the ash-throated flycatcher, northern harrier, western meadowlark, and white-tailed kite were designated as vulnerable to human presence. The grasshopper sparrow, savannah sparrow, western meadowlark, white-tailed kite, rufous-crowned sparrow, California thrasher, lark sparrow, song sparrow, and Wilson's warbler are designated as vulnerable to compaction or trampling. Four of seven vulnerable grassland species and two of three vulnerable shrubland species may be particularly affected by compaction and trampling. Vegetation management, such as mowing or cutting shrubs and trees, whether for horticultural reasons or to reduce fire fuel loads, can negatively impact birds, especially if conducted during nesting season.

Habitat Disturbance/Conversion/Loss: Although white-tailed kite and belted kingfisher were not identified as vulnerable in the One Tam Report, given the Bay Area's extensive development over the last two centuries, habitat loss and fragmentation continue to be one of the primary stressors to all bird species.

Other Stressors: Within Network partner agency boundaries and surrounding areas, the Altamont Pass Wind Resource Area (APWRA) remains a serious stressor to all flying animals, notably through direct mortality caused by wind turbine strikes (Smallwood and Thelander 2008, Smallwood and Karas 2009, Smallwood and Bell 2020, Smallwood et al. 2009, 2020). In addition, industrial-scale solar farm projects in the area of focus represent serious direct (mortality) and indirect (loss of habitat) stressors to birds (Smallwood in press).

CONDITION AND TRENDS ASSESSMENT

METRICS IN DETAIL

Because there is so much data on North American birds—much of it collected by non-scientists—it is important to describe why we chose to use the data we did and the precautions we took to avoid bias. Here we provide a brief description of species choice, data source, and data filtering. Following these descriptions, we present our methodology for bird ecological health metrics.

Species Choice

Our approach to choosing the bird species to use as indicators in this report followed the philosophy and criteria presented in Chase and Geupel (2005). We included species that represent vegetation-type guilds and that reflect things about habitat characteristics across multiple scales (e.g., microhabitat as well as landscape-scale habitat requirements). For example, within a guild, birds may nest and forage on the ground or in forbs, shrubs, or trees. Looking across a variety of these species' habitat specializations for both residents and migrants within a guild allowed a more complete spatial and temporal assessment of birds in the different vegetation types. Individual species that show trends deviating from the rest of those in their guild may have life history traits that we can use to see how particular stressors are affecting them. We may also be able to see if these effects are occurring within or across species from different guilds.

We primarily chose common bird species. Often common species make the best indicators because there are more opportunities to observe changes in their populations over time. The habitat types chosen to represent each guild— riparian, grassland, oak woodland, and shrubland—are also the most common vegetation communities on Network agency lands. Of these habitats, riparian and grassland are most likely to be degraded or threatened due to anthropogenic influences (Riensche et al. 2010).

The 28 species included in this report were chosen from an initial list of 23 indicator species first proposed at an East Bay ecological health assessment expert workshops held in January 2020. Of these, 20 species were included in this report. The orange-crowned warbler, chestnut-backed chickadee, and Swainson's thrush were not included because they were not as tightly associated with the habitat as other members of their guilds. Emphasizing species that were resident or migrant breeders in the Bay Area, an additional five species were then added: belted kingfisher, loggerhead shrike, white-tailed kite, northern harrier, and ash-throated flycatcher. Three species from an additional guild associated with shrubland landscapes were also added (rufous-crowned sparrow, wrentit, and California thrasher) to arrive at the final list of 28 species.

The following resources were used to generate the indicator species lists by vegetation community (Appendix F, Birds Chapter Supplemental Information, Tables 1–4):

- Discussion at the East Bay ecological health assessment expert workshops (January 2020).
- Central Valley Joint Venture Implementation Plan.
- Point Blue Conservation Science expert opinion in cooperation with Network partner agency representatives.
- Focal species in the California Partners in Flight (PIF) Riparian Bird Conservation Plan that meet one or more of the following criteria: riparian breeder, special-status/of conservation interest, reduction in breeding range, abundant breeder in California, and adequate sample sizes for statistical analysis (RHJV 2004).

For the full species list, see Table 7.3. For a description of species traits, see Appendix F, Birds Chapter Supplemental Information, Tables 1–4.

We also chose species that had the following four properties, where these properties have been previously identified as critical to effective indicator-species choice (Carignan and Villard 2002):

1) Are easy and cost-effective to measure.
2) Provide early warning of responses to environmental impacts.
3) Indicate the cause of change as opposed to the existence of change.
4) Provide continuous assessment over a wide range of stressors.

To address (1), the species chosen here were cost-effective to measure because the data came from free community-science databases (see eBird Data, following). To address (2), trends were analyzed across an 11-year time period (2010–2020) to allow for early warning of recent population changes. To address (3) and (4), we looked at a suite of species for which the relative increase or decrease of specific species could be linked to life-history traits that can reveal things about related stressors.

eBird Data

We used eBird data to analyze trends from 2010–2020 across 28 species associated with four vegetation types: riparian, grassland, oak woodland, and shrubland. These data were collected by community scientists and reviewed by members of the Cornell Lab of Ornithology. (A full description of the eBird dataset, contributors, submission process, and quality control can be found at: ebird.org/about, and additional details about this dataset are provided in Appendix F, Birds Chapter Supplemental Information.)

Briefly, eBird observations, sometimes called “checklists,” can be contributed by anyone with an eBird account. They include:

- Where and when the observation took place (time, date, and duration of the observation).
- The type of observation that occurred (e.g., stationary, traveling, historical).
- A specialized protocol (e.g., the nocturnal flight protocol, or an incidental observation that records only a single species and not all the species at that time and location).
- How far the observers traveled as they observed birds (for traveling counts, which were the majority of observations).
- The number of observers.
- The number of species and individuals observed.

Unusual sightings (e.g., a very uncommon species for a given location or time of year) are double-checked by eBird reviewers to confirm the identification. If a sighting cannot be confirmed, it is filtered out before the eBird data are made publicly accessible.

Data Filtering

The full eBird dataset can be downloaded with an eBird account, but due to its very large size, it requires filtering to be uploaded into the open-source statistical programming software R (www.r-project.org/). We provide statistical code for our analysis at https://github.com/erinconlisk/EBSNEcoHealth.

More details are also included in Appendix F, Birds Chapter Supplemental Information.

We downloaded all eBird observations from 2010–2020 that explicitly recorded each species' presence or absence within Network partner land boundaries (Figure 7.1). We began with 2010 because, starting in that year, there was enough data in any one year to allow for a comparison across years. We chose to include only data from the Network partner land boundaries within the overall area of focus because outside these areas, there were biases towards increased sampling in urban areas and decreased sampling south of Mt. Hamilton. We did not split the trend analysis into subregions (i.e., East Bay Hills, Mt. Diablo Range, Mt. Hamilton) because there were not enough data from the Mt. Hamilton and Mt. Diablo Range subregions, due in part to lack of public access. We also checked for representative sampling across vegetation types and found good general agreement (Figure 7.2) except in grasslands, which were undersampled. Because of this undersampling, we have lower confidence in our assessment of trends for grassland birds than for the other guilds.

We considered only breeding-season data and only species that breed in the East Bay because the number of breeding birds is the most relevant metric of population sustainability. By focusing on this critical season, we also limited variability in the data. For example, the number of individuals for year-round resident species could be biased by an influx of migrants/overwintering birds. Further, during breeding season, individuals are more likely to defend a territory and thus, more likely to be seen or heard and less likely to be moving around the landscape, where they could be double-counted. Nevertheless, we recognize that migratory species that leave the area, such as the yellow warbler, may be subject to stressors on their wintering grounds that affect their breeding numbers.

As was done in Johnston et al. (2021) and Fink et al. (2020), we imposed a grid on the landscape and averaged observations taken on the same day within each grid cell for each of the 66 days in the breeding season. We did this so that observations on a single popular day or in a single popular location would not overwhelm the data from other days and locations. We considered two grid resolutions—100 m (1 hectare [ha]) and 200 m (4 ha)—depending on the species' territory size.

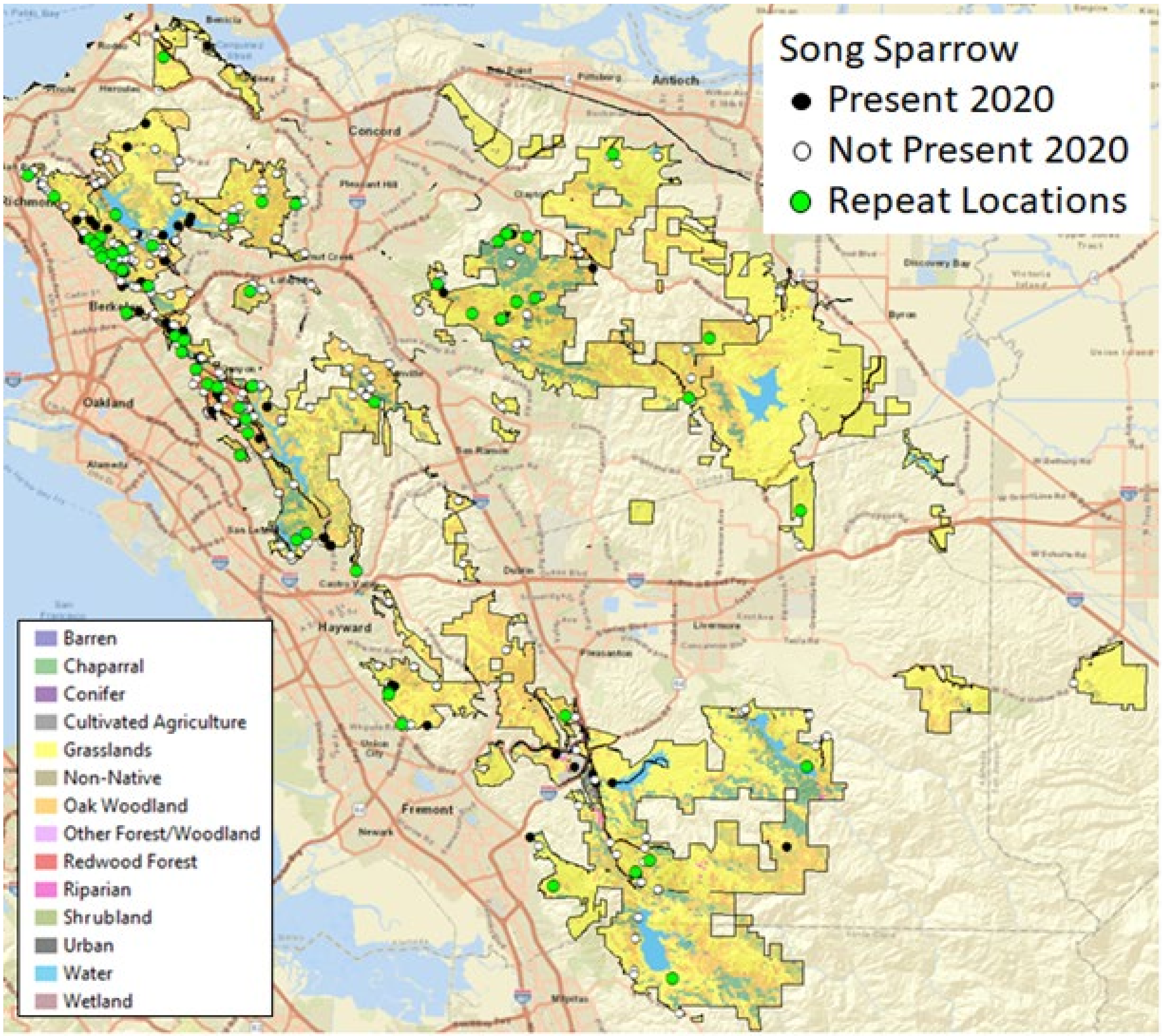

Figure 7.1. Vegetation community types within Network partner agency boundaries (from Conservation Lands Network, CLN, Bay Area Open Space Council 2019). Black points are where song sparrows were present in 2020 and white points are where they were not. Green points represent the 57 locations where there were at least eight bird observations across 11 years (2010–2020, discussed below and in the methodological steps articulated in Appendix F, Birds Chapter Supplemental Information). This song sparrow example illustrates the data's spatial coverage and helps interpret methodological details described elsewhere. Other species would have similar observation locations (although presence observations would be slightly different) because ~95% of the data came from locations where all species were sampled and ~5% of the data are observations of single species.

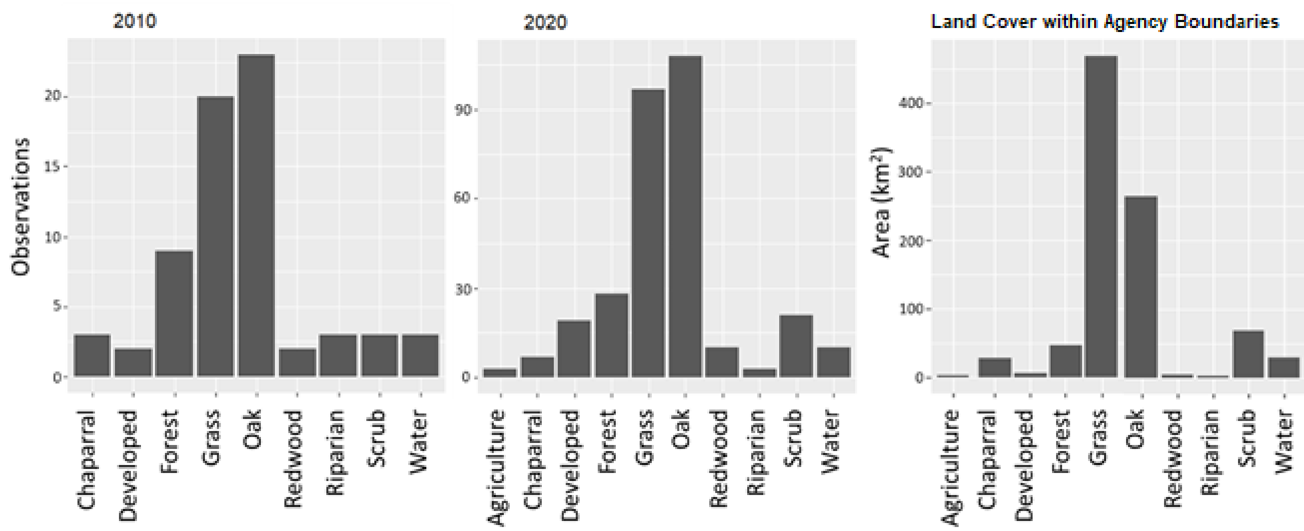

Figure 7.2. Left, comparison of vegetation-cover type underlying eBird observations in 2010; center, eBird observations in 2020; right, land cover across Network partner agency boundaries. eBird observations were largely taken in land-cover types at a rate proportional to the availability of that land-cover type within those boundaries. One notable exception is grassland; it is the most common land-cover type but it was not the most common location for eBird observations in 2010 or 2020.

Metrics Approach and Rationale

With these data-filtering rules in place, we analyzed what we are calling two "single-species trends" for Metrics 1 and 2. These trends were meant to span two possible analytical approaches to monitoring bird health. Namely, measuring the response (dependent) variable (e.g., the variable that is being measured over time that is based upon either presence/absence or observed abundance of the species):

Approach 1: A less precise, but potentially less prone to error, response variable (presence/absence) with a dataset that included all observations from 2010 to 2020. By including all the data, the number of observations grew annually, resulting in a more than three-fold increase from 2010 to 2020. By limiting this analysis to presence/absence data, we removed the possibility that a few high-abundance observations would have a big influence on the results, where we might expect more high-abundance observations with increased sampling.

Approach 2: A more precise response variable (observed abundance or counts) with a conservative dataset (only locations that had repeat observations). "Repeat observations" are any location (grid cell) where an observation was made in at least eight out of 11 years from 2010 to 2020. This gave us ~57 observation locations (where the number of observation locations ranges from 55 to 58 across different species). Some species had more or fewer than 57 observations, the result of different numbers of incidental single-species observations rather than observations of all the species at that time and location. Using locations with observations in eight out of 11 years was a compromise between having most years represented but still having many locations that fit the criteria. Had we increased to nine out of 11 years, many fewer observation locations would have been available. We also excluded observations where data were missing from all years within 2010–2012 because we wanted to have observations that spanned the entire 2010–2020 timeframe.

Trend analyses were combined to create a single-species condition metric. One confidence metric was also assigned to each species. Reduced confidence occurred when a single year exerted a large influence on the dataset or there were too few observations of the focal species (i.e., the species was rare or the observation locations were not in the focal species' preferred habitat). These properties were usually shared across the datasets used in the two trend analyses. Thus, a single confidence metric was assigned to the two trends analyses and the resulting condition metric.

For Metric 3, we combined single-species trends to form a guild condition that summarized the single-species results for each of the four vegetation types: riparian, grassland, oak woodland, and shrubland (Figure 7.3).

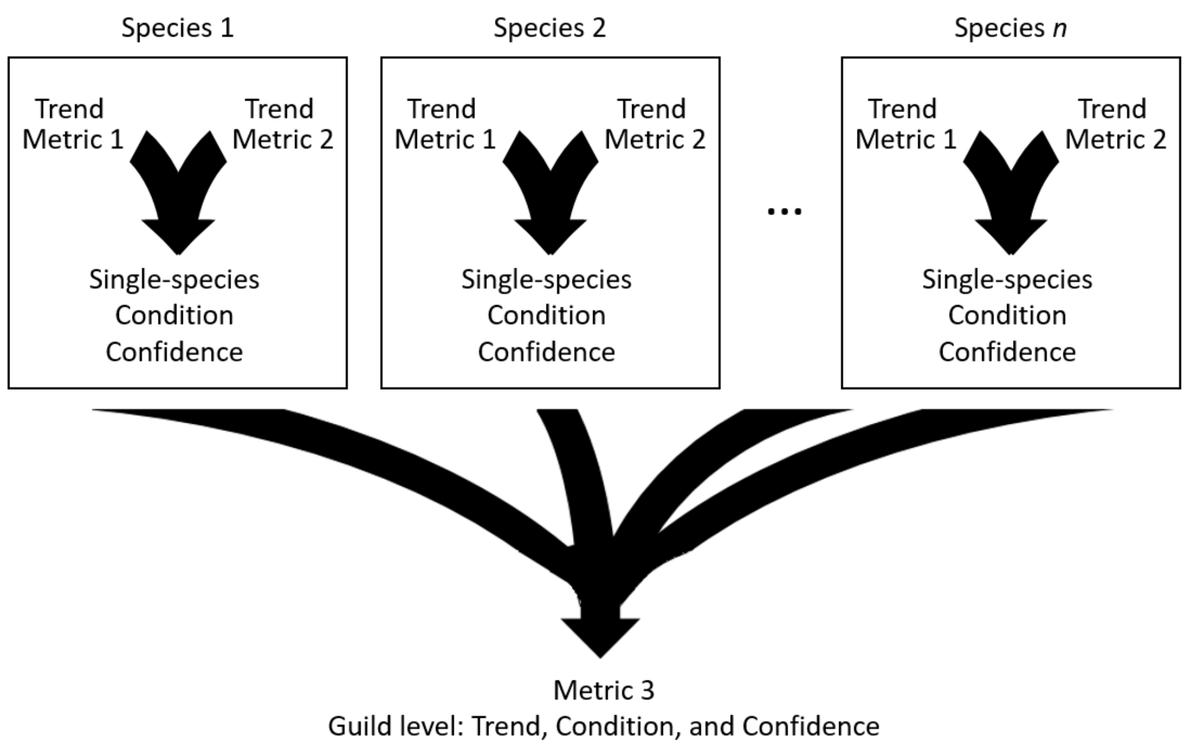

Figure 7.3. Overview schematic of how the individual species trends combine to form single species condition and confidence and the individual species metrics are combined to the guild level. The total number of species in each guild, n, is nine, seven, nine, and three for riparian, grassland, oak woodland, and shrubland birds, respectively.

Metric 1: Single-Species Presence/Absence Analysis

Rationale: Measuring the presence or absence of a species across space and time is a foundational practice of naturalists and ecologists (MacKenzie et al. 2006) and underscores an established relationship between regional occupancy and abundance (Gaston et al. 2002). The fraction of observations of species presence as a function of time is likely to provide useful information on their health and viability trends.

We used presence/absence data that included all breeding-season observations from 2010 to 2020 to look at trends for 28 species. Across years, community scientists reported observations from different locations. This can introduce spatial heterogeneity, which can then lead to highly variable abundance estimates in trend analyses. Hypothetically, an example of important heterogeneity might be that sites sampled in 2012–2015 were mostly low-quality habitat sites, whereas sites sampled in 2016–2020 were mostly high-quality habitat sites. Sampling in high-quality sites may include a few observations with very high abundance, which can skew the overall mean.

Using presence/absence data avoids this problem by virtue of being either 0 (absent) or 1 (present). We therefore converted all abundance estimates to presence/absence by considering a species present if it was recorded in a grid cell in a year at any point during the 66 days of the breeding season. To identify statistically significant trends, we ran a logistic regression to determine whether the probability of observing a species was increasing or decreasing across years. The model also included variables that described how much effort observers dedicated to watching birds (e.g., time observing and distance travelled).

Condition Goals:

Properties suggesting a healthy presence/absence trend include:

- The fraction of sites occupied by a given focal species are not demonstrating a statistically significant decline through time. An increasing fraction of occupied sites could be a sign of ecosystem health.
- The fraction of sites occupied by the focal species are reasonably high (i.e., greater than 10% of observations record the presence of a focal species). This depends somewhat on the fraction of observations that were in a given focal species' preferred habitat. Note that for the song sparrow example in Figure 7.4, that would be riparian areas, which are relatively rare within Network partner agency boundaries.

Current Baseline: The current population baselines for birds on Network partner lands were described in the Current Condition and Trend section. The trend analyses described in this section could also serve as a current baseline for future reports.

Condition: We did not assign a separate condition for each of the two single-species trends (see the Metrics Approach and Rationale sections for a description of these trends). A condition was assigned to each species based on the combined trends of the presence/absence (Metric 1) and abundance (Metric 2) trends (Appendix F, Birds Chapter Supplemental Information, Tables 5–8). Thus, we discuss Condition and Condition Thresholds after introducing Metric 2.

Trend: Figure 7.4 is an example of the song sparrow presence/absence trend from 2010 to 2020. Appendix F, Birds Chapter Supplemental Information, Tables 5–8 show the results for Metric 1 for all 28 species. The y-axis shows the fraction of sites where song sparrows are present, defined as (number of presences)/[(number of absences) + (number of presences)]. On the x-axis are the years. Across years, there are changes in the fraction of occupied sites (the points jump up and down), but there is no clear trend across years. The error bars reflect uncertainty in the annual estimate of the fraction of occupied sites. Thus, points with differing values for the fraction of occupied sites may not be statistically different if their error bars overlap.

The following thresholds were used to define the single-species presence/absence trends.

- *Improving*: A statistically significant increase was observed in the fraction of observations that report a species present.
- *Unchanging*: No significant trend was observed in the fraction of observations that report a species present.
- *Declining*: A statistically significant decrease was observed in the fraction of observations that report a species present.

The single-species results for Metric 1 can be found in Table 7.3, Metric 1: Presence/Absence Trend column.

Confidence: We did not assign a separate confidence for each of the two single-species trends. One confidence assessment was assigned to each species based on the combined confidence of the presence/absence (Metric 1) and abundance (Metric 2) trends. Thus, we discuss Confidence and Confidence Thresholds after introducing Metric 2.

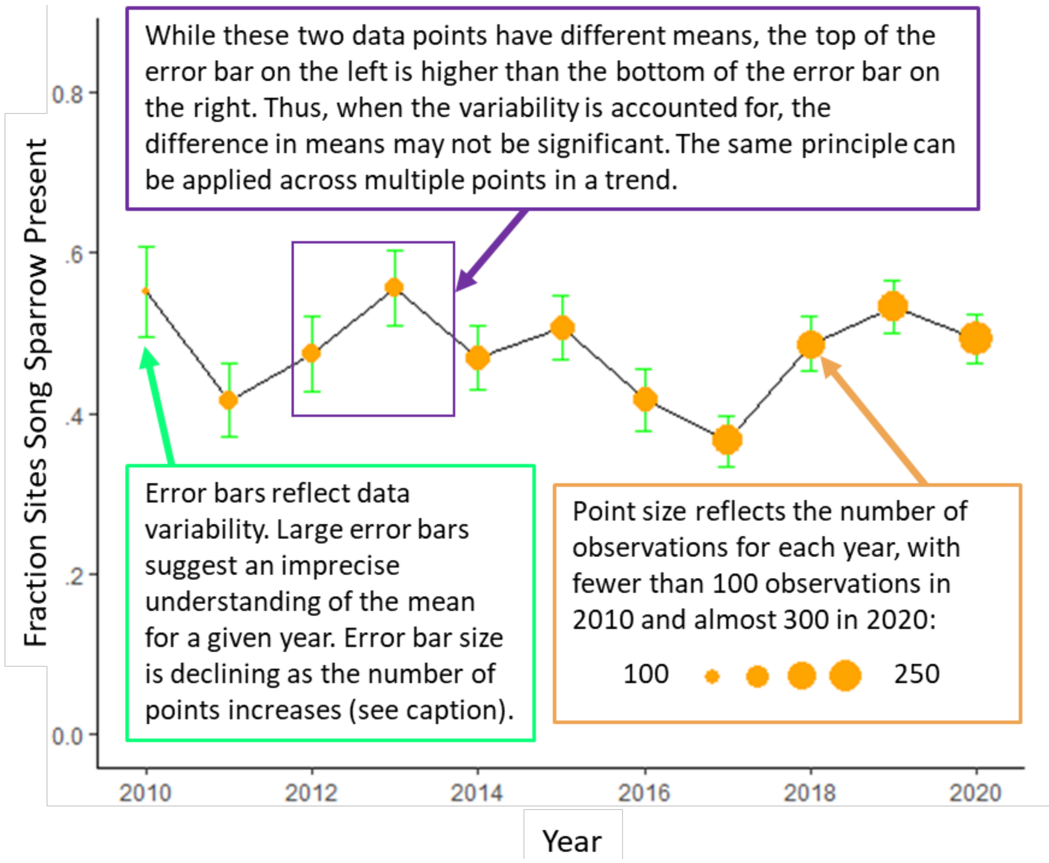

Figure 7.4. An example of song sparrow presence/absence trend from 2010 to 2020, along with a description of how to interpret the points and error bars (all 28 species' trends are shown in Appendix F, Birds Chapter Supplemental Information, Tables 5–8). The error bars on the presence/absence figures are calculated as:

$$\sqrt{\frac{(\text{Probability present, p})(1\text{-p})}{(\text{Number of observations})}}$$

This quantity has a maximum value of 0.05 when 50% of sites are occupied and there are 100 observations. Given a specific value for the fraction of occupied sites, error bars decrease in height as the number of observations (and point sizes) increase.

Metric 2: Single-Species Abundance Analysis

Rationale: The abundance of a species through time, especially during breeding season, is a primary indicator of species health. For example, population decline is one of the four metrics by which the IUCN measures a species' vulnerability to extinction. Because of the widespread use of abundance to measure species' health across systems, we included local abundance of the 28 focal bird species as a measure of their health.

We considered the number of individuals seen across approximately 57 locations where there were observations for a given species in at least eight out of 11 years. In this dataset, we controlled for spatial heterogeneity by sampling in the same locations year after year. Thus, this abundance represents a more refined metric of species health when compared to presence/absence (as in Metric 1). Because we gridded the landscape to avoid multiple observations from the same location on a specific day, the reported abundance is actually a density in individuals/one ha for birds with smaller territories (100 m grid cells), and individuals/four ha for birds with larger territories (200 m grid cells). We had higher confidence in abundance trends when at least 10% of observations recorded the species' presence.

We took the average counts for a grid cell and rounded to integer values for count-based statistical models. Specifically, we analyzed the trend in repeat observations across time using zero-inflated or standard Poisson or negative binomial mixed-effects models (whichever yielded the best fit), controlling for effort variables (number of observers, time spent observing, distance traveled). Using a mixed-effect model allowed us to introduce a random effect for observation location. This random effect accounted for the fact that some of these locations (e.g., birding hotspots) might have higher average counts than other locations.

Condition Goals:

Properties suggesting a healthy abundance trend include:

- The abundance of the focal species is either not changing or is increasing (i.e., statistically significant) through time.
- The abundance does not approach zero in any given year.
- At least 10% of observations record the presence of a given focal species. If fewer than 10% of observations record species presence, then we may have too few observations to accurately estimate abundance.

There is one caveat to the condition goal of increasing focal species abundance. In general, an increasing abundance is preferable to an unchanging abundance, such as may be the case with focal species that endured some sort of decline in the past and are recovering. However, too rapidly increasing populations of a species relative to other members of a guild in the absence of a disturbance could bode badly for the other species. Thus, competitors or other species that share the focal species' vegetation type should be explored as part of a robust health assessment (as was done in this assessment). What defines "too rapidly" is contextual and depends on the responses of other species in the guild.

Current Baseline: The current population baselines for birds on Network partner lands were defined in the Current Condition and Trend section. The trend analyses described in this section could also serve as a current baseline for future reports.

Condition: We did not assign a separate condition for each of the two single-species trends (see the Metrics Approach and Rationale sections for a description of these trends). Instead, we combined Metric 1 and Metric 2 to assess species-specific condition for each of the 28 species, where condition was defined by the combination of the two trend assessments (see Appendix F, Birds Chapter Supplemental Information, Tables 5–8).

In the song sparrow example in Figures 7.4 and 7.5, the song sparrow would be assigned the condition of "caution" because the presence/absence trend is unchanging but the abundance trend is declining.

We defined the condition as the combination of Metrics 1 and 2 because we believed they measured two important characteristics of the population. Taken together, we felt they provided good evidence of a focal species' condition.

Condition Thresholds:

- *Good:* Both single-species trends are improving or unchanging.
- *Caution:* One of the two trends is declining.
- *Significant Concern:* Both trends are declining.

Trend: Figure 7.5 is an example of song sparrow abundance trend from 2010 to 2020. Tables 5–8 in Appendix F, Birds Chapter Supplemental Information show the results for Metric 1 for all 28 species. Across years in Figure 7.5, there are changes in abundance (the points jump up and down), but across eight of the 11 years, abundance decreases such that by 2020, grid-cell abundance is lower for song sparrows than it was in 2010. The error bars, which reflect uncertainty in a given year's abundance estimate, are larger for abundance than for presence/absence data. Despite the overlapping error bars for many of the points, the persistent decline in abundance in Figure 7.5 reveals a significant declining trend.

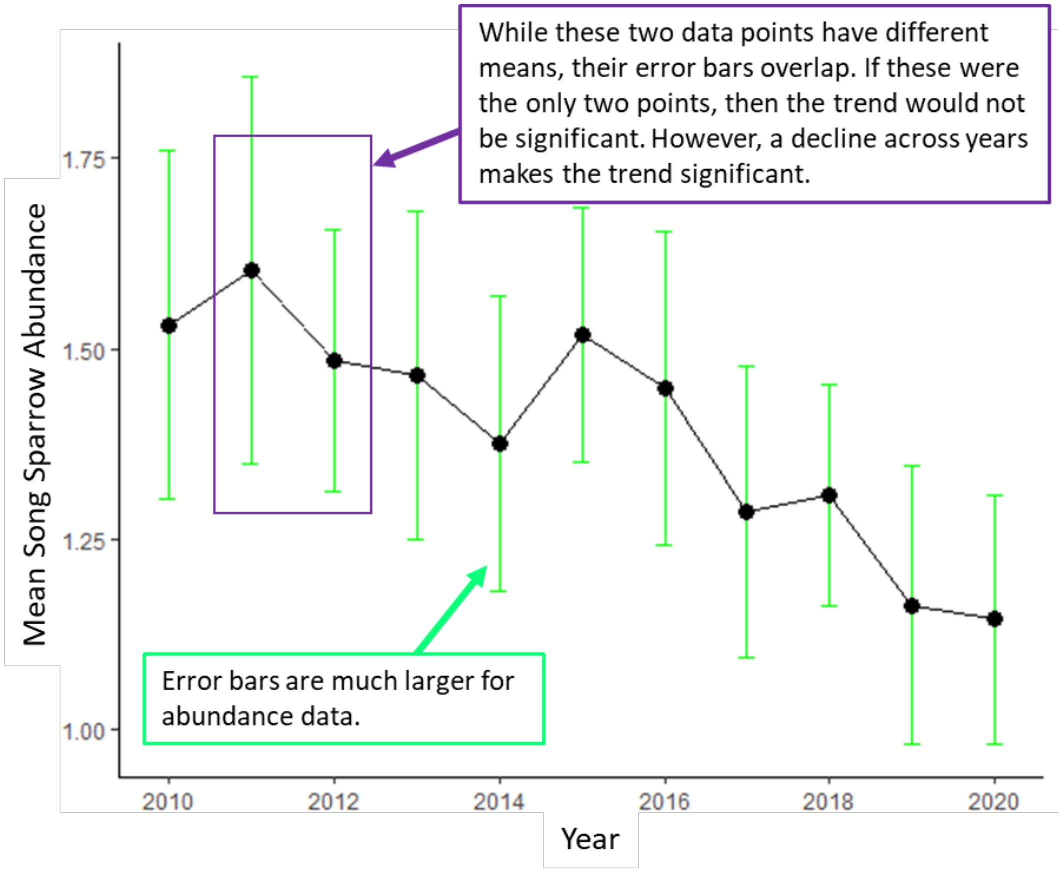

Figure 7.5. An example of an abundance trend for the song sparrow from 2010 to 2020, along with a description of how to interpret the error bars on the presence/absence figures in Appendix F, Birds Chapter Supplemental Information, Tables 5–8. The abundance is actually a density (per one-ha or four-ha grid cell); the song sparrow had one-ha grid cells.

Trend Thresholds:

The following thresholds were used to define the single-species abundance trends.

- *Improving*: There was a statistically significant increase in the average abundance of the species across observation locations.
- *Unchanging*: No significant trend was observed in the average abundance of the species across observation locations.
- *Declining*: There was a statistically significant decrease in the average abundance of the species across observation locations.

As with presence/absence trends, we did not divide the areas within Network partner agency boundaries into subregions because we were concerned that there were not enough data to do so.

For example, for song sparrows, there are 13 repeat bird observations in the Mt. Diablo Range subregion, five in the Mt. Hamilton subregion, and 39 in the East Bay Hills subregion. Recall that we are less confident in our results when there are <10% of observations recording a species present. If we assume that 10% of sites are occupied and we have roughly 50 repeat abundance observations in each year, then our abundance trends are based on five observations of abundance in each year. If we had a longer time series (e.g., 1970 to present), we could work with very few observations in each year. However, with an 11-year time series and considerable potential sources of imprecision and error in eBird data, we believe that observations from at least three locations are needed in each year. Thus, 30 repeat locations are needed for subregional analyses, especially for the less prevalent species. With fewer than 30 repeat observations, a single observation recording high abundance can have a big impact on the results.

Confidence: We did not assign a separate confidence for each of the two single-species trends. Instead, we assessed the combined confidence of Metrics 1 and 2 for each of the 28 species. The criteria for high confidence were: (1) the species was prevalent (meaning there was at least one observation of species presence for Metric 1 and at least 10% of observation locations recorded species presence for Metric 2), (2) no individual observations or years had an overwhelming influence on the measured trends, and (3) the vegetation type was well-represented by the bird observations (i.e., the histograms in Figure 7.2 largely match).

- *High*: Both single-species trends were consistent with all three criteria.
- *Moderate*: One of the three criteria was not met for one of the two single-species trend analyses.
- *Low*: Two or more of the three criteria were not met for at least one of the two single-species trend analyses.

As discussed previously, we assigned one confidence assessment to each species based on the combined confidence of the presence/absence (Metric 1) and abundance (Metric 2) trends. When the focal species was not recorded in many of the locations where observations were made, this decreased our confidence in the trends. Because this property was typically shared across the presence/absence and abundance trend analyses, a single confidence metric was assigned to each species.

Metric 3: Summary Evaluation by Avian Guild

Rationale: Each species has a unique set of life-history traits, including vegetation-type associations. This can provide multiple observations of how a specific vegetation type supports the guild and, in turn, indicate that with healthy habitat, the guild is also healthy. Individual species that deviate from guild-level trends can point to specific life-history traits that may make a species more or less vulnerable.

We chose not to combine the health of the four guilds to get a single overarching bird health because of the differences across the guilds. We did not want to say that all birds were doing well, given that grassland birds are declining, nor did we want to say all birds were doing poorly based on a single guild.

Current Baseline: To our knowledge, this is the first analysis of bird guilds on Network partner lands using eBird data. Thus, this report establishes the current baseline, which we use to describe condition in in Table 7.3.

Condition Goals: Properties suggesting a healthy avian guild include:

- All species within a guild have species with unchanging or improving trends.
- Enough species (greater than five species) richness within a guild to allow inferences to be drawn about its fine-scale habitat preferences (e.g., migratory versus resident riparian birds).

Condition Thresholds:

- *Good*: All species within a guild show unchanging or improving populations.
- *Caution*: One species within a guild (or >10% but <20% of species measured within a guild) shows a declining population.
- *Significant Concern*: More than one species within a guild (>20%) show a declining population.

Condition: We took a cautious approach to guild condition, saying that if more than 10% of species showed any evidence of a declining trend, the condition was designated as “caution,” and greater than 20% was designated as “significant concern.” Note that trend and condition are identical for this first analysis of bird trends using eBird data.

Trend: We based guild trend on the aggregate of the single-species trends. Because this analysis represents the first analysis of trends within Network partner lands, there is no difference between guild trend and condition. However, in future reports, we will be able to see how trends may have changed over time.

- *Improving*: The majority of species show improving or unchanging populations, and none show a decline.

- *Unchanging*: The majority of species show improving or unchanging populations, and between 10% and 20% of species within a guild (one species for all vegetation types except shrubland) show declining populations.
- *Declining*: More than 20% of species (two species for riparian, oak woodland, and grassland and one species for shrubland) show declining populations.

We took a cautious approach to describing guild trends, saying that if more than 20% of species had any sign of a declining trend, then the guild (vegetation type) was declining.

Confidence: We based guild confidence levels on the amount of certainty with which the condition and trend were assessed. The criteria for high confidence were: (1) greater than 50% of individual species analyzed within that vegetation type had high confidence, (2) the analyses across species agreed with one another (i.e., most species had similar trends), and (3) the vegetation type was well-represented by bird observations (i.e., not undersampled, which was only an issue for grassland birds) and more than five species were studied per guild.

- *High*: All of the above criteria were met.
- *Moderate*: Two criteria were met.
- *Low*: One or no criteria were met.

Guild confidence is very similar to the single-species confidence and was meant to address our concerns regarding adequate amounts of data, imprecision of opportunistically collected community science data, and the influence of sampling biases. Further, the vegetation-type analysis also had to incorporate potentially contradictory information from multiple species. Fortunately, most of the analyses here showed similarities within a guild (i.e., there were not multiple species declining while others increased). However, because grasslands were undersampled, the results for this vegetation type were not viewed with high confidence. Similarly, only three shrubland species were explored, so we lowered our confidence in this guild from "high" to "moderate."

Bird-Specific Deviations in Trend and Confidence Assignment: In Table 7.3, we reassign the condition and confidence to some of the Metric 3, guild-level assignments. These reassignments are emphasized with an asterisk (*). We do this based on the following justifications.

The general public's concern for birds was strengthened after media attention given to the high-profile Rosenberg et al. 2019 paper, for which the headline in *Science* read "Three billion North American birds have vanished since 1970" (Pennisi 2019). Potentially spurred by this report, attendees of the East Bay ecological health assessment expert workshop (January 2020) stated that if a single bird species declined, that was cause for a multi-species bird summary condition to be "caution." This is the criterion we applied to the guild-level condition assignment for Metric 3. It deviates substantially from the point system established in Chapter 1. According to the point system, a guild with nine species and only a single species with a condition of caution would have a score of 94, well above the 75-point threshold below which the condition is "caution." Similarly, the grassland guild—where only 3/7 species had condition "good"—had an average score of 57.1, well above the 25-point threshold which would warrant the designation "significant concern." In our expert opinion, if more than half the species have designation of "caution" or "significant concern," then the guild should be given the condition "significant concern."

Further, as we described in the executive summary, we think the extra information provided by the guild level assessments is important and that the relative rankings among the guilds should be preserved. The fact that the grassland guild is doing particularly badly compared to other guilds and that the oak woodland and riparian guilds are doing a little worse than the shrubland birds should be reflected in the final guild-level condition.

Finally, we reassigned two of the final four confidence assignments. We did this based on known biases in the eBird data and a lack of explicit comparisons of scientist-collected versus eBird regional trend analyses. Thus, we wanted to take a conservative approach to assigning confidence. Specifically, with respect to grassland birds, we note that the grassland cover type is the most common on Network partner lands, yet it is not the cover type where most bird observations took place (Figure 7.2). In other words, the grassland cover type is undersampled in eBird data. For the shrubland species, we note that only three species were analyzed and want to specifically account for this small sample size. Thus, despite the point system assigning a score of 43 ("moderate" confidence) to grassland birds and 100 ("high" confidence) to shrubland birds, we believe that the two groups deserve "low" and "moderate," respectively.

Table 7.3. Trend, condition, and confidence results for individual bird species and groups of species, organized by their associated guilds.

Indicator Species	Metric 1 Presence/Absence Trend	Metric 2 Abundance Trend	Condition	Confidence
Riparian Birds (nine species)	***Overall Trend: Unchanging***		***Caution****	***High***
Warbling vireo (*Vireo gilvus*)	Improving	Unchanging	Good	High
Song sparrow (*Melospiza melodia*)	Unchanging	Declining	Caution	High
Black-headed grosbeak (*Pheucticus melanocephalus*)	Improving	Improving	Good	High
Downy woodpecker (*Picoides* or *Dryobates pubescens*)	Unchanging	Unchanging	Good	Moderate
Spotted towhee (*Pipilo maculatus*)	Unchanging	Improving	Good	High

Indicator Species	Metric 1 Presence/Absence Trend	Metric 2 Abundance Trend	Condition	Confidence
Wilson's warbler (*Cardellina pusilla*)	Unchanging	Improving	Good	High
Belted kingfisher (*Megaceryle alcyon*)	Unchanging	Unchanging	Good	Low
Tree swallow (*Tachycineta bicolor*)	Improving	Improving	Good	High
Yellow warbler (*Setophaga petechia*)	Unchanging	Unchanging	Good	Low
Grassland Birds (seven species)	***Overall Trend: Declining***		***Significant Concern****	***Low****
Savannah sparrow (*Passerculus sandwichensis*)	Unchanging	Declining	Caution	Moderate
Grasshopper sparrow (*Ammodramus savannarum*)	Declining	Declining	Significant Concern	Moderate
Western meadowlark (*Sturnella neglecta*)	Declining	Unchanging	Caution	Moderate
Horned lark (*Eremophila alpestris*)	Declining	Declining	Significant Concern	Moderate
Northern harrier (*Circus hudsonius*)	Unchanging	Unchanging	Good	Low
Loggerhead shrike (*Lanius ludovicianus*)	Unchanging	Unchanging	Good	Low
White-tailed kite (*Elanus leucurus*)	Improving	Unchanging	Good	High
Oak Woodland Birds (nine species)	***Overall Trend: Unchanging***		***Caution****	***High***
Oak titmouse (*Baeolophus inornatus*)	Unchanging	Improving	Good	High
Acorn woodpecker (*Melanerpes formicivorus*)	Improving	Improving	Good	High
California scrub-jay (*Aphelocoma californica*)	Declining	Unchanging	Caution	High
Lark sparrow (*Chondestes grammacus*)	Unchanging	Unchanging	Good	High
Western bluebird (*Sialia mexicana*)	Unchanging	Unchanging	Good	High
White-breasted nuthatch (*Sitta carolinensis*)	Unchanging	Improving	Good	High
Ash-throated flycatcher (*Myiarchus cinerascens*)	Improving	Improving	Good	High
Nuttall's woodpecker (*Picoides* or *Dryobates nuttallii*)	Unchanging	Unchanging	Good	High
Blue-gray gnatcatcher (*Polioptila caerulea*)	Improving	Unchanging	Good	High
Shrubland Birds (three species)	***Overall Trend: Unchanging***		***Good***	***Moderate****

Indicator Species	Metric 1 Presence/Absence Trend	Metric 2 Abundance Trend	Condition	Confidence
Wrentit (*Chamaea fasciata*)	Unchanging	Unchanging	Good	High
California thrasher (*Toxostoma redivivum*)	Unchanging	Unchanging	Good	High
Rufous-crowned sparrow (*Aimophila ruficeps*)	Unchanging	Unchanging	Good	High

OTHER METRICS CONSIDERED BUT NOT INCLUDED

We considered a variety of additional metrics that could provide a comprehensive and robust analysis of bird species trends. In the interest of brevity, not all are included here. Instead, we provide a brief description of some of the analyses that were not included in this report:

- We considered one additional species for the shrubland vegetation type (black-chinned sparrow); however, there were not enough observations of this species to accurately measure trends.
- We considered minor modifications to the trend analyses, discussed in Appendix F, Birds Chapter Supplemental Information section "EBird Data and How it Was Used." However, alternative analyses were consistent with results obtained without these changes, so we did not report them.
- We originally considered looking at trends in the larger East Bay region instead of solely within Network partner agency boundaries but found considerably more biases in where observations were made outside those boundaries. While beyond the scope of this analysis, an analysis of trends at different spatial scales would be interesting. Generally, we recommend considering different extents (e.g., local versus regional) and resolutions (e.g., alternative territory sizes to the one- and four-ha grid cells used here). Specifically, we suggest comparing eBird trends within Network partner lands boundaries to regional analyses of the Bay Area and beyond (i.e., California). Of particular interest is how trends within Network partner lands compare to regional species trends.
- We compared the trends from this report to an analysis of all North American birds (Rosenberg et al. 2019). While the relative ranking of our guild-level assessments were consistent with that study, we found that our single-species results suggested more stable populations. (See Appendix F, Birds Chapter Supplemental Information, Interpretation of Results section.)

- We briefly compared our results to those available through the eBird data portal (which does little bias correction). We could not find rigorous documentation of how the eBird portal data summaries were created and thus did not include them here.

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

Before the next assessment, and to the degree possible given resource constraints, we provide the following suggestions for additional information and data collection that would be beneficial to a future assessment:

- There are considerably less eBird data available for the Mt. Diablo Range subregion and very little in the Mt. Hamilton subregion. These areas are also where most of the grassland habitat is, meaning data for that guild are particularly limited. We recommend focusing some Network partner agency resources on sampling in these regions, especially on lands with restricted public access.

- We also recommend that Network partner agencies try to motivate community scientists to visit areas in which they are allowed, and to upload their observations to eBird.

- In future analyses, we might consider other metrics to describe vegetation-type condition (e.g., species richness of eBird observations within Network partner lands through time).

- In addition to comparisons across locations, comparisons across specific species could be interesting. For example, Network partner agencies could identify species of special concern that could be compared to other species with similar vegetation-type preferences. Alternatively, species identified as declining regionally or across California could be compared to trends within Network partner agency boundaries.

- This analysis did not consider specific Network partner lands. Should sufficient eBird data become available across all Network partner lands, it would be advisable to compare trends among them to link trends with management actions or to identify habitat restoration opportunities.

- It would also be interesting to compare eBird observations within Network partner agency boundaries to the urban areas just beyond them. Such a comparison could show if species prefer Network lands to nearby urban areas. For example, Dettling et al. (2021) revealed the value of protected areas for safeguarding riparian avian populations.

- A power analysis could be performed on simulated data. This involves creating a simulated population trend with known change, variability across observations, and error. It could be performed with and without effort variables. Observations from this trend would be selected to recreate observed regional biases (e.g., more observations in East Bay Hills locations). Grid-based averaging would be performed on this simulated dataset. This analysis would look at the ability to detect trends based on bird species prevalence, magnitude of simulated population trend, and number of years of data. While we were unable to run a power analysis for this project, it is worth noting that for the Hawaiian red-tailed tropicbird, Seavy and Reynolds (2007) found a >90% chance of detecting a 50% decline over 10 years using real estimates of total population size. Although their analysis has some differences, it still gives us a degree of confidence that our approach would reveal a very big population change.

- A second power analysis could analyze the influence of increasing data through time. We explored both the influence of increasing numbers of grid cells with eBird observations across the landscape and increasing numbers of observations within each grid cell. We were concerned that with more sampling, there would be more observations of a given species, skewing their prevalence upward through time. We tried to account for this by subsampling the data so that each year contained the same number of observations; however, we found this did not change the results. Another approach would be to include the number of observations within a grid cell as a covariate in the model. We suggest doing this in the future.

- We recommend quantifying population objectives (e.g., ideal abundance levels) for indicator bird species (following Dybala et al. 2017) to complement trend analyses. This would form the basis of a more robust species-level condition assessment that could be incorporated into a vegetation-type condition assessment.

- Constructing a metric looking at species richness (a measure of the number of species present in each location) or species diversity (a metric of both richness and evenness in abundance across species) could be useful. Similar to species trends, considerable care would need to be taken to avoid strong biases in the data.

- Detecting trends across only ten years is difficult, but additional years of data will make this easier. We recommend against starting analyses earlier than 2010; less data are available the further back in time you go. (This could, however, be explored in the previously mentioned power analysis.)

- A peer-reviewed publication on the analytical approach detailed in this report and in Appendix F, Birds Chapter Supplemental Information would further validate and improve this methodology and make it accessible to other networks interested in using eBird data for ecological health assessments.

PAST AND CURRENT MANAGEMENT

As prescribed by regulatory requirements and internal policies, Network partner agencies engage in best management practices and implement avoidance and minimization measures when engaging in landscape and infrastructure maintenance, construction, and development. For example, active vegetation management to reduce fuel loads and wildland fire risk is conducted to the extent practical outside of bird nesting season. If this work is conducted during bird nesting season, biological monitors perform bird-nesting surveys to identify locations of active bird nests. This information is used to establish disturbance-free buffers around the nests as well as timelines for when work can recommence once nesting over. Every effort is made to have biological monitors input all avian observations into eBird.

EBRPD actively engages in habitat restoration that benefits birds both within the area of focus as well as outside its boundaries. This includes volunteer native vegetation planting, habitat clean-up, invasive plant species removal, bird-box installations, and monitoring (Riensche 2008). It also includes grant- or bond-funded major restoration projects, such as the McCosker Sub-Area Creek Restoration and Recreational Improvements Project (https://ceqanet.opr.ca.gov/Project/2017062055), which is restoring more than 1.0 linear mile of highly incised creek bed and riparian habitat in Contra Costa County.

Network partners also have an extensive history of monitoring the focal species analyzed in this report, including area searches from 2000 to 2005 in the East Bay Hills, point counts established at 36 plots in grasslands throughout the area of focus from 2004 to 2011 (Gennet et al. 2017), and long-term riparian bird monitoring both within and outside of the area of focus (Riensche et al. 2010, 2014). Efforts to better understand the impacts of wind energy production on avifauna in the Altamont Pass Wind Resource Area are ongoing (Smallwood et al. 2009, Smallwood and Bell 2020, Smallwood et al. 2020, Smallwood and Smallwood 2021).

POTENTIAL FUTURE ACTIONS

The data gaps described above can be divided into a few specific research, monitoring, management, and restoration suggestions.

- Compare eBird monitoring to focused monitoring using a standard protocol. There is a great need to validate the use of eBird data at the local level and to provide guidance on how to best use eBird data to capture local trends.
- Institute additional bird monitoring in East Bay grasslands and in more remote locations (i.e., not the East Bay Hills). This would augment existing eBird data.

- Repeat the 37 permanent breeding-season grassland point-count surveys on a rotational basis every five to seven years (Bartolome et al. 2013). This would help to more precisely determine the long-term persistence and diversity of grassland birds in relation to grazing management and grassland restoration.
- Create a database locating where management or disturbance has occurred. This could allow eBird data to be divided into treatment groups for analyses.
- Combine additional research and monitoring to make broad management suggestions that might benefit the species studied here.
- Focus future studies and actions on augmenting grassland bird habitat. Consistent with studies outside the Bay Area, we found that grassland birds were not doing as well as riparian, oak, and shrubland birds.

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CHAPTER 8. GOLDEN EAGLE (*AQUILA CHRYSAETOS*)

EXECUTIVE SUMMARY

The golden eagle (*Aquila chrysaetos*) is commonly recognized as an indicator of ecosystem health and was selected as an important indicator species for the ecological health of lands owned and managed by East Bay Stewardship Network (Network) partner agencies within the area of focus for this project (See map, Chapter 1).

Based on national conservation goals and past and current golden eagle research in the area of focus, the desired condition and trend for this indicator species are to: (1) maintain or improve site occupancy by territorial pairs (i.e., the proportion of sites surveyed with at least 1 pair of eagles), (2) maximize reproductive rate (i.e., the proportion of sites surveyed with at least 1 pair of productive eagles), and (3) minimize the occurrence of territorial subadults in the local breeding population. The condition and trend in these three primary metrics were assessed for golden eagles in the area of focus using data from a large-scale demographic study conducted in 2014–2021 by the U.S. Geological Survey (USGS) and others.

Overall, we found a condition of “caution” and an “unchanging” trend for golden eagles in the area of focus. Analyses of site occupancy and reproductive rate indicated that the local breeding population was unchanging (i.e., no evidence of increasing or decreasing time trends in these metrics during 2014–2021). However, a consistently high occurrence of territorial subadults (22%–35%) has been observed at breeding territories near the Altamont Pass Wind Resource Area (APWRA) relative to occupied territories monitored in surrounding regions (~3%). The heightened occurrence of territorial subadults suggested a possible increase in the adult mortality rate of territorial eagles occupying the Mt. Diablo Range and Mt. Hamilton subregions in the area of focus. Thus, although no trends were detected in site occupancy or reproductive rate, caution is warranted given the high observed frequency of territorial subadults, which was predominately associated with pairs monitored near the APWRA.

The USGS golden eagle study was conducted during a period of prolonged and severe drought in the area of focus, which has been shown elsewhere to reduce the reproductive rate of golden eagles. Although we detected no trends in reproductive rate, we identified a condition of “caution” for this metric in the area of focus given that annual estimates were relatively low during the study period, which primarily included years of severe drought conditions in west-central California.

A primary goal of the analysis was to provide a benchmark against which managers can measure future changes and understand the likely trajectory of this species. Baseline data and analyses provided here can be used to identify projects that could help support golden eagle conservation. Given the constraint of using only existing and available data, this evaluation also identified areas where not enough was known to draw meaningful conclusions. Gaps in our understanding include the long-term effects of repeated, extreme climate events (e.g., drought and wildfire) on golden eagle demographics and population sustainability, refined estimates of eagle survivorship and sources of mortality, and whether the APWRA represents a population sink for golden eagles within the northern Diablo Range and surrounding regions. These are described as data gaps at the end of this chapter and may be areas to focus on for future research and collaborations among land managers.

METRICS SUMMARY AT A GLANCE

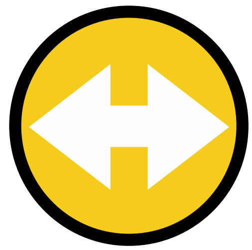
The table below summarizes the three metrics for golden eagles used in this ecological health assessment. Each metric, along with how we arrived at its condition, trend, and confidence, is thoroughly described in the Metrics in Detail section later in this chapter. (See Chapter 1 for definitions and thresholds for condition, trend, and confidence; other terminology used throughout this chapter; how metrics are being used for each indicator; and other project methodology.)

Table 8.1. All golden eagle metrics, with their respective condition, trend, and confidence. Each metric is described in the Metrics in Detail section later in this chapter.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Metric 1: Site Occupancy–The annual probability of a survey site being occupied by at least one territorial pair of golden eagles during the breeding season (December to July). Estimated as the proportion of sample sites surveyed with detections of at least one territorial pair of golden eagles. Estimates are corrected for imperfect detection of eagle pairs during surveys.			
Condition	Good	Good	Good
Trend	Unchanging (None detected)	Unchanging (None Detected)	Unchanging (None Detected)
Confidence	High	High	High
Metric 2: Reproductive Rate–The annual probability of a survey site being occupied by at least one territorial pair of golden eagles with successful reproduction (at least one young fledged). Estimated as the proportion of sample sites surveyed with detections of at least one productive pair of golden eagles. Estimates are corrected for imperfect detection of nests and young during surveys.			
Condition	Caution	Caution	Caution
Trend	Unchanging (but Annually Variable)	Unchanging (but Annually Variable)	Unchanging (but Annually Variable)
Confidence	High	High	High
Metric 3: Occurrence of Territorial Subadults–The annual proportion of territorial pairs monitored with at least one pair member in subadult plumage (typically, birds two to four years old). Estimates include all pairs monitored where the plumage-age class (adult, subadult) of both pair members is established.			
Condition	Good	Caution	Caution
Trend	Unchanging	Unknown (Possibly Improving)	Unknown (Possibly Improving)
Confidence	Moderate	Moderate	Moderate

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of the golden eagle in the area of focus represented by the graphic below is based on the combined values of the individual metrics in Table 8.1. Each of these metrics is described in depth in the Metrics in Detail section later in this chapter.



Condition: Caution (color: yellow)

Trend: Unchanging (symbol: horizontal arrow)

Confidence: High (line around circle: solid)

BACKGROUND

WHY IS THIS RESOURCE INCLUDED?

The golden eagle (*Aquila chrysaetos*), an apex predator with a long lifespan, is widely distributed throughout the Northern Hemisphere. As one of the largest predatory birds in the world, it is an iconic species throughout the Unites States and elsewhere within its Holarctic range. While the global population of golden eagles is considered relatively stable, long-term trends show declines of breeding populations at local and regional scales in some areas of North America (Katzner et al. 2020). The birds are considered a Fully Protected species by the California Department of Fish and Wildlife, and both federal and state regulations (i.e., the Bald and Golden Eagle Protection Act) prohibit “take,” defined as killing, harassing, or disturbing individuals or nests.

The golden eagle is recognized as an indicator of ecosystem health throughout its geographic range (Katzner et al. 2020). Breeding pairs have been found to be especially abundant in the northern Diablo Range of west-central California, where they nest in higher densities relative to other parts of their range in California and North America (Hunt et al. 2017). Historical and current studies of golden eagles in the northern Diablo Range have spatially overlapped with the three subregions of the East Bay Stewardship Network (Network), thereby providing a rich source of information for this species in the area of focus. (See map, Chapter 1.) Thus, the golden eagle was selected as an important indicator species within the area of focus for this NatureCheck ecological health assessment.

Historical records from egg collectors and zoologists active in the late 1800s and early 1900s are housed in several scientific collections (e.g., Museum of Vertebrate Zoology, University of California, Berkeley; California Academy of Sciences, San Francisco; and Western Foundation of Vertebrate Zoology, Camarillo), and various golden eagle studies have been performed in the area of focus since the 1950s (Carnie 1954, DiDonato and Lenihan 1987). Additional studies are continuing throughout much of the northern Diablo Range, including the Altamont Pass Wind Resource Area (APWRA) (Hunt 2002, Hunt and Hunt 2006, Kolar and Wiens 2017, Hunt et al. 2017, Wiens et al. 2015 and 2018, Wiens and Kolar 2021). More recent data on golden eagles were obtained from wind turbine impact studies, radio telemetry, territory occupancy, nest productivity, and some disease/contaminant investigations (Smallwood and Karas 2008, Bell and Wilson 2016, ICF International 2016, Bell 2017a and 2017b, Hunt et al. 2017, Kolar and Wiens 2017). The presence of the APWRA within this project's area of focus and its significant impact on golden eagles due to mortality from wind turbine blade strikes (Smallwood and Karas 2009, Bell and Smallwood 2010, ICF International 2016, Smallwood et al. 2016 and 2017, Hunt et al. 2017, H. T. Harvey and Associates 2021), and the species' susceptibility to changing climatic and wildfire conditions in the region (Wiens and Kolar 2021), further justify including golden eagles as an indicator species for this ecological health assessment.

DESIRED CONDITION AND TREND

Conservation policy for the golden eagle aims to maximize reproductive success and maintain stable to increasing breeding populations (U.S. Fish and Wildlife Service [USFWS] 2013, 2016). Based on these conservation goals, historical studies, and current research on golden eagles (Hunt et al. 2017, Wiens et al. 2018 and 2021), the desired condition and trend for golden eagles in the area of focus are to:

1) Maintain or improve site occupancy (i.e., the probability of a survey site being occupied by at least one territorial pair of golden eagles during the breeding season). Here and below, a 'site' is defined as a 1,385-hectare hexagonal cell within the area of focus (e.g., Figure 8.1). In 2021, site occupancy was estimated to be 0.66 (standard error [SE] = 0.06, 95% confidence interval [CI] = 0.54–0.77) across all subregions.

2) Maximize reproductive rate (i.e., the probability of a survey site being occupied by at least one territorial pair of golden eagles that fledge at least one young during the breeding season). In 2021, the reproductive rate was estimated to be 0.36 (SE = 0.08, 95% CI = 0.23–0.52) across all subregions.

3) Minimize the occurrence of territorial subadults (i.e., territorial pair members observed with subadult plumage, or birds typically aged two to four years old). An increasing occurrence of territorial subadults can indicate that nonterritorial adult birds are unavailable to fill territory vacancies arising from local increases in the mortality rate of territory holders (Hunt et al.

2017, Kolar and Wiens 2017). In 2021, the estimated percentage of pairs monitored with at least one member in subadult plumage ranged from a low of 4% in the East Hills subregion to a high of 12% in the Mt. Diablo subregion.

CURRENT CONDITION AND TREND

Condition: Caution

Trend: Unchanging

Confidence: High

The northern Diablo Range, which includes all three subregions of the area of focus, supports one of the densest known breeding populations of golden eagles in the world (Wiens et al. 2015, Hunt et al. 2017, Katzner et al. 2020). The following analyses of site occupancy and reproductive rate of territorial pairs specific to those parts of the northern Diablo Range that fall within the area of focus indicated that the local breeding population was unchanging (stable) during 2014–2021 (i.e., no evidence of increase or decline in these population metrics). However, a consistently high proportion of territorial subadults has been observed at breeding territories near the APWRA (22%–35%) relative to territories in surrounding regions (~3%; Wiens et al. 2021). The heightened occurrence of territorial subadults suggested an increased mortality rate for territorial eagles occupying the Mt. Diablo Range subregion that overlapped with the APWRA (Figure 8.1). The portion of the Mt. Diablo Range subregion was also where a consistently high fatality rate of golden eagles due to collisions with wind turbines was documented. Thus, while no trends were detected in Metric 1 (site occupancy) or Metric 2 (reproductive rate), caution is warranted based on Metric 3 (occurrence of territorial subadults).

The current condition, trend, and confidence are the average of the condition, trend, and confidence for golden eagles in each subregion as shown in Table 8.2. The metrics described in depth in the Metrics in Detail section of this chapter were combined to determine current condition and trend. These metrics provide a way to measure the difference between observed current conditions and desired conditions considered to be “healthy” is for this indicator.

Table 8.2. Overall golden eagle condition, trend, and confidence for each subregion in the area of focus.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Condition	Good	Caution	Caution
Trend	Unchanging	Unchanging	Unchanging
Confidence	High	High	High

STRESSORS

Several ecological and anthropogenic stressors are known to affect golden eagle populations. These include:

Climate Change: The effects of climate change may adversely affect golden eagle populations through the loss of foraging habitat and nesting substrates, and reduced prey abundance. Large annual fluctuations in temperature and precipitation, such as hot and dry or cold and wet, can decrease annual reproduction of golden eagles if prey populations are negatively affected (Steenhof et al. 1997, Wiens et al. 2018, Smith et al. 2020). More severe weather events, such as strong storms, can cause nesting failures by blowing incubating eagles, eggs, or even nest material from trees (Wiens and Kolar 2021). Large-scale fires, catalyzed by a changing climate, can also lead to loss of foraging habitat and nesting substrates through changes in an area's dominant vegetation (Steenhof et al. 1997, Wiens and Kolar 2021, Heath et al. 2021).

Disease: Several types of ectoparasites and diseases are known to decrease survival of golden eagles and their young (Katzner et al. 2020). In the northern Diablo Range, golden eagles with severe mange have recently been identified. This condition is caused by a novel species of *Micnemidocoptes* mite, which leads to feather loss and, if untreated, death (Mete et al. 2014).

Direct Human Impacts: Golden eagles are susceptible to numerous anthropogenic impacts, including direct and indirect effects of poisoning from secondary exposure to rodenticides (Katzner et al. 2020) and lead (Allison et al. 2017, Kelly et al. 2011), recreation and visitation leading to nest disturbance and abandonment (Spaul and Heath 2016), illegal shooting, and collisions with cars when scavenging roadkill (Lonsdorft et al. 2018).

Habitat Disturbance/Conversion/Loss: Urban development, housing and roads, quarries, developed recreational facilities, and conversion of grassland to agricultural lands (including vineyards) can all lead to a loss of nesting and foraging habitat. Changes in landscape management practices (e.g., elimination of grassland grazing) can also lead to the loss of the golden eagle's prey base.

Other Stressors: Eagle mortality from wind turbine strikes and electrocution by energy infrastructure can lead to population instability and the loss of territorial birds (Hunt et al. 1998 and 2017, Hunt 2002, Hunt and Hunt 2006). The presence of the APWRA within the area of focus represents a significant source of mortality and threat to golden eagles, both locally (Smallwood and Thelander 2008, Smallwood and Karas 2009, Hunt et al. 2017) and globally (Katzner et al. 2017). Energy development can also potentially cause indirect effects from disturbances to used nests and/or loss of foraging habitat (Braham et al. 2015, Watson et al. 2018).

CONDITION AND TRENDS ASSESSMENT

METRICS IN DETAIL

Data Collection: Condition metrics developed for golden eagles were based on a large demographic study conducted by the USGS and others during 2014–2021 (Figure 8.1). This study used a broad-scale sampling design and standardized field protocols to survey and monitor golden eagles throughout much of the northern Diablo Range (Wiens et al. 2015 and 2018, Wiens and Kolar 2021). The area of focus is within the northern segment of the larger USGS study area (Figure 8.1). Areas targeted for golden eagle surveys were randomly selected from a grid of equally sized (1,385 hectare [ha]) hexagonal cells overlaid on the USGS study area (total area = 516,844 ha). The size of each survey hexagon or "site" corresponded to the estimated mean golden eagle territory size. The area of focus included a total of 160 hexagon sample sites, 57 of which had been randomly selected and repeatedly searched for evidence of golden eagle occupancy and reproduction from 2014 to 2021 (no surveys were completed in 2017). An important element of the survey design was that all sample units (hexagons) in the sampling grid were equally available for selection, which permitted statistical inference to the entire sampling grid, including sites not surveyed (Wiens et al. 2015). Pairs of golden eagles were also detected and monitored in sites not included in the focal sample of randomly selected sites (see Data Gaps and Data Collection/Management Needs). These ancillary data were included in Metric 3, but not in Metrics 1 and 2. Note that some survey sites were located on private lands or lands managed or owned by entities other than Network partner agencies.

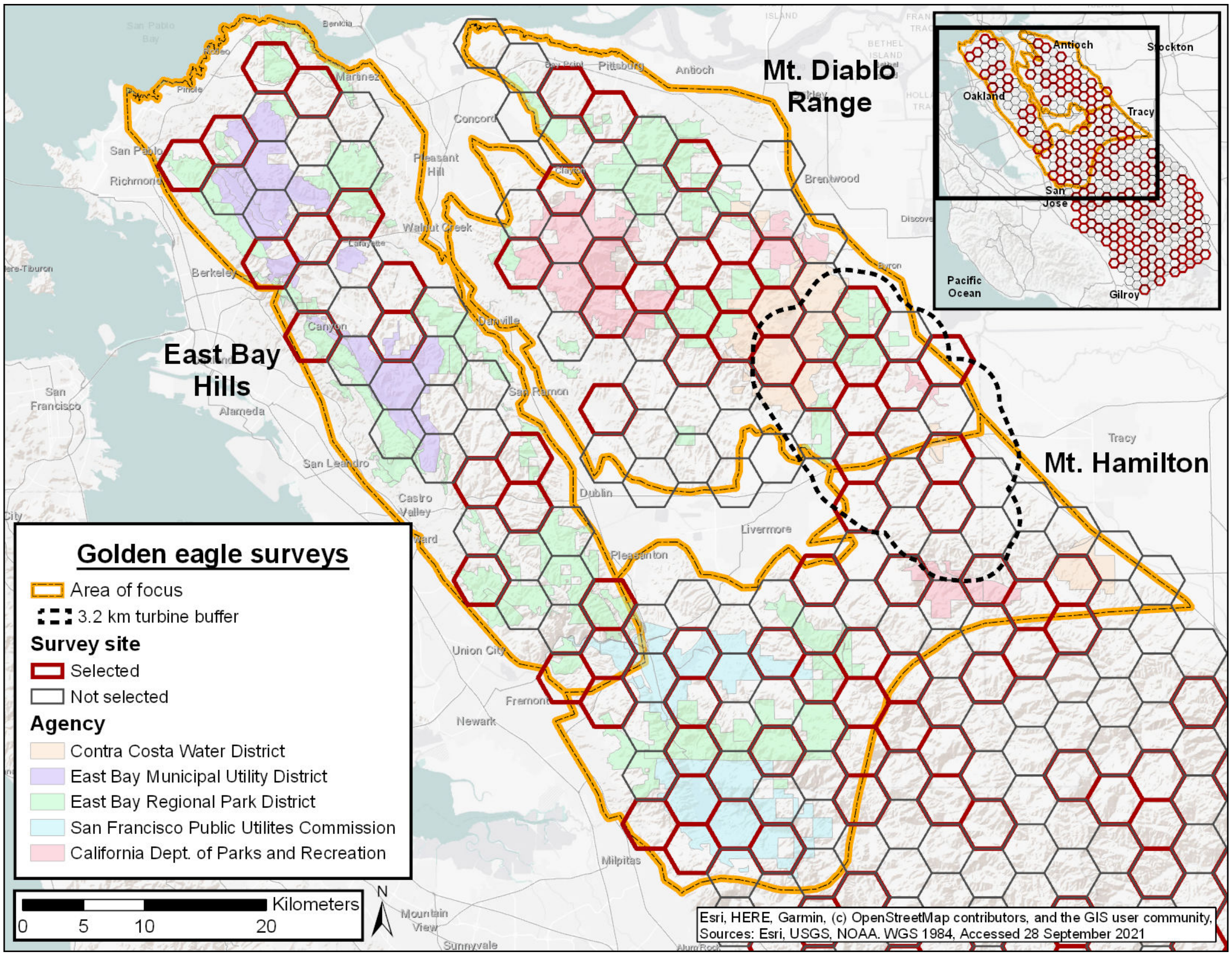


Figure 8.1. The distribution of randomly selected survey sites (13.9 km2 hexagons) that were repeatedly searched to determine site occupancy, reproductive rate, and ages of territorial pairs of golden eagles within the area of focus during 2014–2021 (surveys were not completed in 2017). Also shown is the location of the Altamont Pass Wind Resource Area (polygon with black dashed line), represented as a 3.2 km buffer around wind turbines that were active at some point during the study period. The map inset shows the distribution of sites surveyed across the entire USGS northern Diablo Range study area, which overlapped with this project's three subregions: East Bay Hills, Mt. Diablo Range, and Mt. Hamilton.

Data Analysis: Our analysis of site occupancy (Metric 1) and reproductive rate (Metric 2) was completed using a dynamic multistate occupancy modeling approach (MacKenzie et al. 2009 and 2017). In this approach, each survey visit to a site was classified as being in one of three possible observation states: no territorial pair of eagles detected (state 0), ≥1 territorial pair detected but no evidence of successful nesting (state 1), or ≥1 territorial pair detected with evidence of successful reproduction (i.e., at least 1 young fledged; state 2). This analytical framework allows simultaneous estimation of both site occupancy and reproduction while accounting for imperfect detection of eagle pairs and their young (Wiens et al. 2015, 2018). The analysis also incorporates relationships between site-level habitat conditions, climatic conditions, and site occupancy and reproductive rate of eagles.

Wiens et al. (2018) previously analyzed survey data collected in the USGS golden eagle study area. Their analysis tested a number of hypotheses about relationships between site-level landscape conditions, climate, detection rates, and occupancy and reproductive parameters. The best-supported model they identified contained the following sub-models:

- Detection probability of territorial pairs differed between pairs that nested successfully and those that did not.
- The probability of detecting successful reproduction (i.e., fledged young) was greater at sites where the locations of previously used nests were known.
- Initial occupancy (i.e., the site occupancy rate in the first year of the study) varied between occupancy states.
- Occupancy varied among years, was positively associated with a site's terrain ruggedness and the amount of open grassland vegetation cover, and negatively associated with scrubland/chaparral vegetation.
- Reproductive rate was positively associated with the prior year's nesting status, amount of grassland vegetation in survey sites, and the site-level amount of precipitation during brood-rearing.

Further details on the development and estimation of multistate occupancy models can be found in Wiens et al. (2015, 2018).

We adopted the best-model structure from Wiens et al. (2018) as the baseline model for all analyses presented here, then built onto that structure to: (1) estimate occupancy and reproduction for the area of focus separately from the broader USGS 2014–2021 study area, and (2) test for trends in the parameters over time. For all analyses, we included survey data from the entire USGS study area, then partitioned model estimates among sites within each subregion of the area of focus. First, we tested for annual variation in occupancy and reproductive rate by comparing models with "year" effects to the best model from Wiens et al. (2018), which assumed constancy in these parameters over time. (We fixed transition probabilities in 2017 to zero because surveys were not completed in that year.) Second, we introduced an "area" effect that allowed parameter estimates to vary among subregions (Figure 8.1). This model also permitted grouping different subregion combinations to evaluate evidence for variation in site occupancy or reproduction among subregions (e.g., East Bay Hills versus Mt. Diablo Range and Mt. Hamilton combined). Specifically, we considered the following set of models to test for possible differences in occupancy parameters among subregions:

- Model 1: Site occupancy and reproduction are constant among subregions.
- Model 2: Site occupancy and reproduction vary among subregions.
- Model 3: Site occupancy and reproduction in the Mt. Diablo Range and Mt. Hamilton subregions are different from the East Bay Hills subregion.

Model 3 was included to test whether estimates of site occupancy and reproduction for the East Bay Hills subregion were lower relative to the Mt. Diablo Range and Mt. Hamilton subregions (Table 8.3). Finally, we tested for time trends in occupancy and reproduction parameters by introducing a continuous time covariate to the best supported model of the three alternative models listed above. We compared and ranked all models using information-theoretic methods and Akaike Information Criterion values adjusted for small sample size (AIC_c; Burnham and Anderson 2010). Models within 4 AIC_c units of the top-ranked model are considered to have some support from the data, while those within 2 AIC_c units are considered to have substantial support. We considered regression coefficients (β) with 95% confidence intervals (CI) not including zero to indicate strong evidence for time trend (or area) effects, and coefficients with 95% CIs that overlapped zero by <10% as weaker, but biologically relevant, evidence of an effect (Burnham and Anderson 2010).

We evaluated Metric 3 (occurrence of territorial subadults) using recently published data from the broader USGS study area (Wiens and Kolar 2021). Territorial pair members detected in randomly selected area-of-focus survey sites and non-area-of-focus survey sites were classified as either subadults (birds aged two to four years old) or full adults (birds older than four years) based on visible plumage characteristics during repeated surveys within the breeding season (Bloom and Clark 2001, Kolar and Wiens 2017). Data on the occurrence of territorial subadults were previously summarized for approximately 220 pairs of golden eagles monitored in the USGS study area (Wiens and Kolar 2021). We used these data to approximate the occurrence of territorial subadults within the area of focus and individual subregions.

Metric 1: Site Occupancy

Rationale: Site occupancy estimation and modeling (i.e., the probability that a species is present at a given site; MacKenzie et al. 2017) provide a rigorous and repeatable framework for monitoring the status of wide-ranging species such as golden eagles. The metric can be used to illustrate changes in relationships between the presence of golden eagles and site-specific stressors or climate (e.g., Wiens et al. 2018). Annual estimates of site occupancy also account for imperfect detection of golden eagles during surveys, which, if not accounted for, can lead to inaccurate inferences about population status.

Condition Goal: Maintain an annual site occupancy probability in the area of focus that is within the range of annual estimates reported by Wiens et al. (2018): 0.68 to 0.80.

Estimates reported by Wiens et al. (2018) are comparable to estimates generated from the current analysis to estimate the baseline in the area of focus. These estimates are based on standardized field protocols and have been corrected for imperfect detection rates of territorial pairs of golden eagles and their nests, and thus represent the most reliable information available. Maintaining territory occupancy at or above these levels would indicate little change (or a decrease) in the status of known population stressors.

Current Baseline: On average, at least one territorial pair of golden eagles was detected in 61% of sites surveyed annually within the area of focus during 2014–2021 (Table 8.3). Over a seven-year period, the mean proportion of sites surveyed with detections of eagle pairs was lower in the East Bay Hills subregion (31%) than in the Mt. Diablo Range (76%) and Mt. Hamilton (71%) subregions.

Table 8.3. Survey effort and detections of territorial pairs of golden eagles in the area of focus and subregions, 2014–2021 (surveys were not completed in 2017).

	2014	2015	2016	2018	2019	2020	2021	Study Average
Area of Focus (Subregions Combined)								
Sites surveyed	55	55	55	57	53	53	57	55
Sites with ≥1 pairs	31	36	37	37	31	29	33	33
Proportion of sites with ≥1 pairs*	0.56	0.65	0.67	0.65	0.58	0.55	0.58	0.61
East Bay Hills Subregion								
Sites surveyed	16	16	16	16	16	15	16	16
Sites with ≥1 pairs	5	5	6	5	5	4	5	5
Proportion of sites with ≥1 pairs*	0.31	0.31	0.38	0.31	0.31	0.27	0.31	0.31
Mt. Diablo Range Subregion								
Sites surveyed	23	23	23	25	25	24	25	24
Sites with ≥1 pairs	14	19	19	19	16	15	17	17
Proportion of sites with ≥1 pairs*	0.61	0.83	0.83	0.76	0.64	0.63	0.68	0.71
Mt. Hamilton Subregion								
Sites surveyed	16	16	16	16	12	14	16	15
Sites with ≥1 pairs	12	12	12	13	10	10	11	11
Proportion of sites with ≥1 pairs*	0.75	0.75	0.75	0.81	0.83	0.71	0.69	0.76

* Naïve estimate of site occupancy (does not account for imperfect detection probability of golden eagles)

The best multistate occupancy model (ΔAIC_c = 0.00; Table 8.4) indicated that golden eagle site occupancy varied among years and was similar among the project's subregions (i.e., no evidence of differences in occupancy among subregions). Models that allowed annual estimates of site occupancy to vary among subregions (Models 2 and 3; Table 8.4) received poor support from the data (ΔAIC_c > 4.0). Annual modeled estimates of site occupancy within the area of focus ranged from a low of 0.62 in 2019 to a high of 0.71 in 2016 (Figure 8.2). Site occupancy in the area of focus in 2021 was estimated to be 0.66 (95% CI = 0.54–0.77), which was near the seven-year average (0.67, 95% CI = 0.43–0.92).

Table 8.4. Ranking of dynamic multistate occupancy models used to characterize differences among the East Bay Hills (EBH), Mt. Diablo Range (MDR), and Mt. Hamilton (MH) subregions of the area of focus in site occupancy and reproductive rates of golden eagles, 2014–2021 (surveys were not completed in 2017).

Model Description	*ΔAIC_c	AIC_c weights	Number of Model Parameters	-2log(L)
Model 1 (site occupancy and reproduction are constant among subregions)	0.000	0.750	38	3273.9
Model 1 + annual time trend in reproduction	3.131	0.157	34	3285.7
Model 3 (site occupancy and reproduction in MDR and MH are different from EBH)	4.323	0.086	40	3273.8
Model 2 (site occupancy and reproduction vary among subregions)	9.361	0.007	46	3265.6
Model 1 + annual time trend in site occupancy	79.628	0.000	34	3362.2
Fully Parameterized Model (site occupancy and reproduction vary between years; detection rates vary among years and sampling seasons within years)	269.194	0.000	212	3067.6

*ΔAICc = difference between the AIC_c value of each model and the lowest AIC_c model (= 3353.32)
–2log(L) = –2 log-likelihood. AIC_c value of the overall top model.

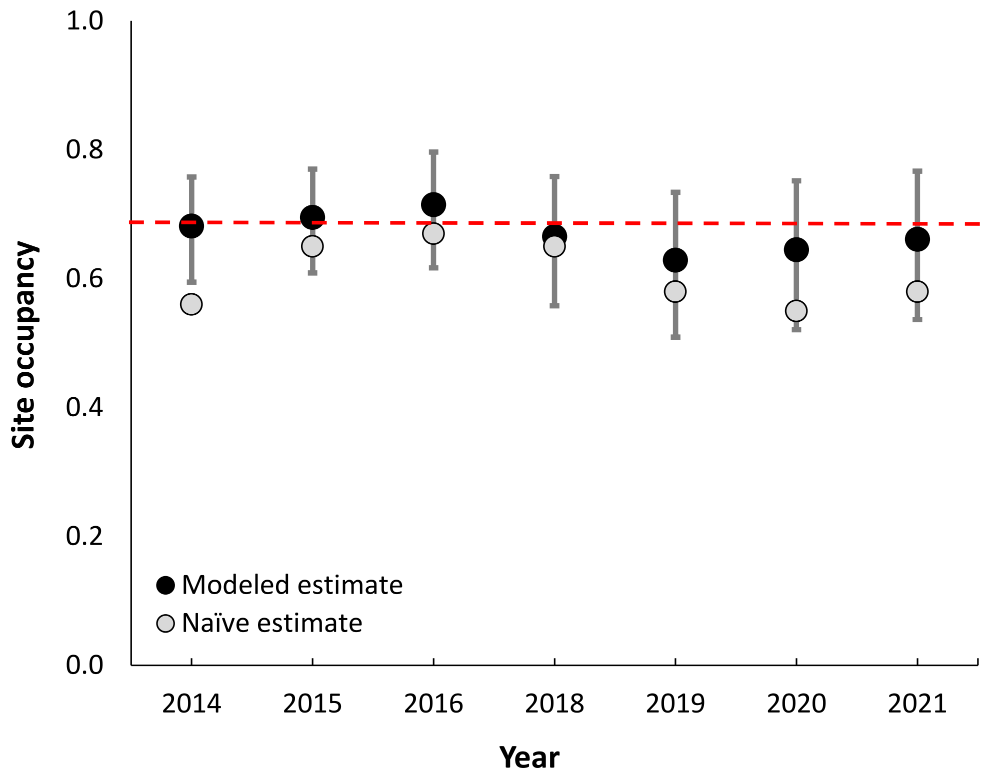


Figure 8.2. Annual estimates of the probability of site occupancy for territorial pairs of golden eagles in the area of focus, 2014–2021 (surveys were not completed in 2017). Modeled estimates are from the best multistate occupancy model with all subregions combined; naïve estimates do not account for imperfect detection of eagle pairs that were present. Error bars represent 95% confidence intervals; the red dashed horizontal line represents the mean of modeled estimates across time (= 0.67, SE = 0.12).

Condition Thresholds:

- *Good:* The probability of site occupancy of golden eagles is maintained.
- *Caution:* Weak evidence of a negative time trend in site occupancy, as shown by a negative time trend estimate with a 95% confidence interval that overlaps zero by <10%.
- *Significant Concern:* Strong evidence of a negative time trend in site occupancy, as shown by a negative time trend estimate with a 95% confidence interval that does not include zero.

Condition: Good (all subregions)

The 2021 baseline estimate of site occupancy by territorial pairs of golden eagles (0.66) was nearly identical to the seven-year average (0.67). The 2021 estimate was <0.01 below the range of estimates previously reported (0.68–0.80; Wiens et al. 2018).

The current analysis showed no evidence of a difference in site occupancy of golden eagles, or an annual trend in this metric, among the three subregions in the area of focus.

Trend: Unchanging (all subregions)

There was no evidence of an annual time trend in expected site occupancy of territorial pairs of golden eagles in the area of focus between 2014 and 2021 (β = –0.046, SE = 0.092, 95% CI = –0.228 to 0.135), as shown by 95% CIs of time-trend coefficients (β) that broadly overlapped zero. Models that incorporated an annual time trend in occupancy received poor support relative to models without a time trend (Table 8.4).

Confidence: High (all subregions)

This metric is based on seven years of survey data on as many as 37 territorial pairs of eagles monitored at 55 sites surveyed in the area of focus, along with a statistically rigorous and well-established sampling design and analytical framework. The estimated precision of annual estimates of site occupancy was high, providing high confidence in the ability to detect annual trends, if present, across the area of focus. The ability to detect time trends by subregion within this area, however, is questionable, given the relatively small number of sites surveyed within each subregion (Table 8.3).

Metric 2: Reproductive Rate

Rationale: A primary motivation for monitoring reproductive rate is the ability to investigate factors affecting site-specific dynamics of successful reproduction over time (MacKenzie et al. 2009, Wiens et al. 2018).

Condition Goal: Maintain a reproductive rate within the area of focus that is either within or above the range of annual estimates reported by Wiens et al. (2018): 0.18 to 0.39.

Estimates reported by Wiens et al. (2018) are comparable to estimates generated from the current analysis to estimate the current baseline in the area of focus. These estimates are based on standardized field protocols and have been corrected for imperfect detection rates of territorial pairs of golden eagles and their nests, and thus represent the most reliable information available.

Current Baseline: On average, at least one territorial pair of golden eagles with a successful nesting attempt (≥1 young fledged) was detected in 15% of sites surveyed annually within the area of focus during 2014–2021 (Table 8.5). Over a seven-year period, the mean proportion of sites surveyed with detections of successfully reproductive eagle pairs was lower in the East Bay Hills subregion (8%) in comparison to the Mt. Diablo Range (19%) and Mt. Hamilton (33%) subregions.

Table 8.5. Detections of nesting golden eagles and successful nests (≥1 young produced) in the area of focus, 2014–2021 (surveys were not completed in 2017).

	2014	2015	2016	2018	2019	2020	2021	Study Average
Area of Focus (Subregions Combined)								
Sites with nesting attempt detected	20	24	27	33	20	29	33	27
Proportion of sites surveyed with nesting	0.15	0.18	0.20	0.24	0.18	0.25	0.25	0.21
Sites with successful nest detected	17	15	20	27	11	20	23	19
Proportion of sites with successful nest*	0.13	0.11	0.15	0.20	0.10	0.17	0.17	0.15
East Bay Hills Subregion								
Sites with nesting attempt detected	1	1	3	1	2	0	2	1
Proportion of sites surveyed with nesting	0.06	0.06	0.19	0.06	0.13	0.00	0.13	0.09
Sites with successful nest detected	1	1	3	1	1	0	2	1
Proportion of sites with successful nest*	0.06	0.06	0.19	0.06	0.06	0.00	0.13	0.08
Mt. Diablo Range Subregion								
Sites with nesting attempt detected	6	9	6	8	5	8	9	7
Proportion of sites surveyed with nesting	0.26	0.39	0.26	0.32	0.20	0.33	0.36	0.30
Sites with successful nest detected	4	5	5	7	2	5	3	4
Proportion of sites with successful nest*	0.17	0.22	0.22	0.28	0.08	0.21	0.12	0.19
Mt. Hamilton Subregion								
Sites with nesting attempt detected	7	6	8	7	5	5	6	6
Proportion of sites surveyed with nesting	0.44	0.38	0.50	0.44	0.42	0.36	0.38	0.41
Sites with successful nest detected	7	4	5	6	4	4	5	5
Proportion of sites with successful nest*	0.44	0.25	0.31	0.38	0.33	0.29	0.31	0.33

* Naïve estimate of reproductive rate (does not account for imperfect detection probability of golden eagle pairs and their nests and young)

The best multistate occupancy model (ΔAIC_c = 0.00; Table 8.3) indicated that the reproductive rate of golden eagles varied among years of the study and was similar among subregions (i.e., no evidence of differences in reproductive rate among subregions). Annual estimates of reproductive rate within the area of focus ranged from a low of 0.22 in 2016 to a high of 0.41 in 2015. (Figure 8.3). The reproductive rate of golden eagles in the area of focus in 2021 was estimated to be 0.36 (95% CI = 0.23–0.52), which was close to the seven-year average (0.31, SE = 0.15).

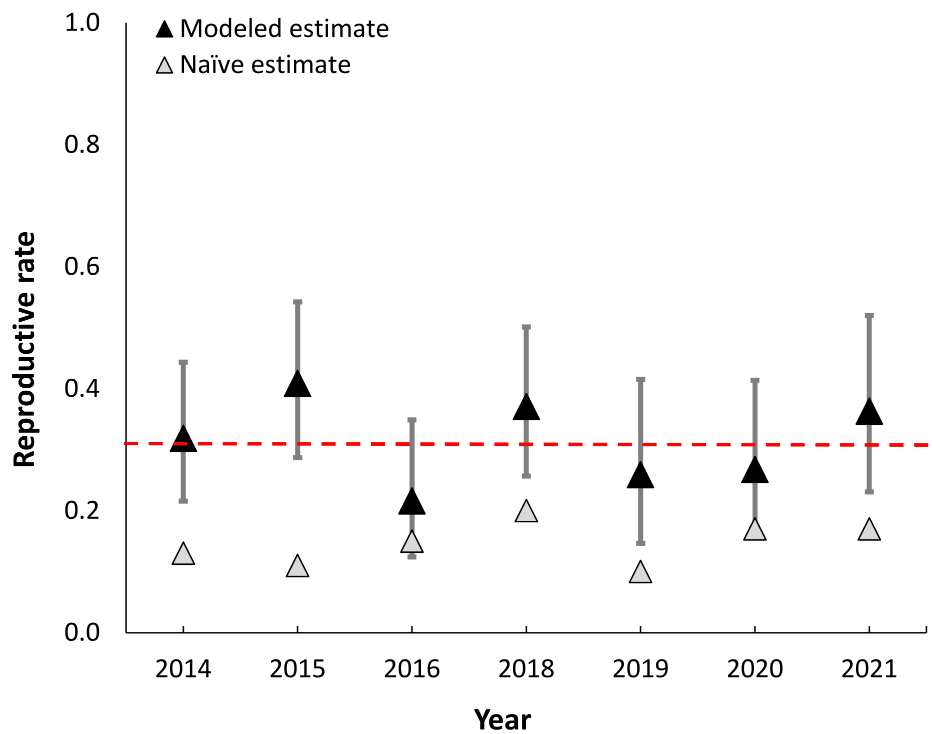


Figure 8.3. Annual estimates of reproductive rate for territorial pairs of golden eagles within the area of focus, 2014–2021 (surveys were not completed in 2017). "Reproductive rate" was defined as the annual probability that a survey site was occupied by at least one territorial pair with successful reproduction (at least one young fledged). Naïve estimates do not account for imperfect detection of pairs and their young during surveys. Error bars represent 95% confidence intervals; the dashed horizontal line represents the mean of modeled estimates across time (= 0.31, SE = 0.15).

Condition Thresholds:

- *Good:* Reproductive rate of golden eagles is maintained or increasing.
- *Caution:* Weak evidence of a negative time trend in reproductive rate, as shown by a negative time trend estimate with a 95% confidence interval that overlaps zero by <10%.
- *Significant Concern:* Strong evidence of a negative time trend in reproductive rate, as shown by a negative time trend estimate with a 95% confidence interval that does not include zero.

Condition: Caution (all subregions)

The 2021 baseline reproductive rate of territorial pairs of golden eagles (0.36) was above the seven-year average (0.31), and near the upper end of the range of estimates previously reported for the study region (0.18–0.39; Wiens et al. 2018). Previous analyses in the study region, however, indicate that golden eagle reproduction is negatively affected by periods of severe and prolonged drought (Wiens et al. 2018, H. T. Harvey and Associates 2020). Given that the current study was conducted during a period of severe drought, observed levels of golden eagle reproduction are likely to be low and insufficient to replace breeder mortalities within the local population. In comparison, Hunt et al. (2017) reported that historical estimates of golden eagle nesting success (i.e., the proportion of pairs monitored with at least one fledgling produced) averaged 0.43 in the study region during 1996–2000.

Trend: Unchanging, Annually Variable (all subregions)

There was no evidence of an annual time trend in the reproductive rate of golden eagles in the area of focus between 2014 and 2021 (β = 0.038, SE = 0.076, 95% CI = –0.111 to 0.188), as shown by 95% CIs of time-trend coefficients (β) that broadly overlapped zero. Models that incorporated an annual time trend in reproduction received poor support relative to models without a time trend (Table 8.4).

Confidence: High (all subregions)

This metric is based on a seven years of survey data that included the entire area of focus, along with a statistically rigorous and well-established analytical framework. The estimated precision of annual reproductive rate was high, providing high confidence in the ability to detect annual trends, if present, across the area of focus. The ability to detect time trends by subregion within the area of focus, however, is unknown and likely weak in the East Bay Hills subregion because of low sample sizes.

Metric 3: Occurrence of Territorial Subadults

Rationale: Hunt et al. (1998, 2002) and others (Balbontín et al. 2003, Ferrer et al. 2003) have suggested that a key sign of population instability in golden eagles would be an increase in the percentage of monitored territorial pairs with one or more subadult members, as this would indicate that insufficient numbers of non-territorial adults were present in the population to fill territory vacancies caused by localized mortality of territory holders. A shift toward younger territorial pair members may indicate declines in numbers of non-breeding adult birds that may not be apparent based on measures specific to the breeding component of the population (Katzenberger et al. 2021), such as site occupancy (Metric 1) and reproductive rate (Metric 2). However, the combination of all three metrics, along with age-specific survival rates from previous and current research in the local area (see Bell and Wilson 2016, Hunt et al. 2017), are reliable indicators of population status (Monzón and Friedenberg 2018).

Condition Goal: Territorial subadult eagles are expected to compose ≤4% of individuals within a focal breeding population under normal conditions (or ≤8% of pairs monitored have at least one subadult member).

Hunt (2002) suggested that if the percentage of individual subadults present as territorial pair members exceeds the approximate annual mortality rate of territorial adults in the population, then the pool of adult floaters is depleted, the overall population is in decline, or both. Thus, given the annual mortality rate of 9.5% (or conversely, the annual survival rate of 90.5%) estimated for territorial adult golden eagles in the Mt. Diablo Range subregion (Hunt et al. 2017), the proportion of territorial subadults should not exceed approximately 9% of all territorial individuals (or 18% of pairs monitored) for the population to be self-sustaining.

Current Baseline: During 2014–2021, Wiens and Kolar (2021) determined the age class (subadult, adult) for as many as 153 territorial golden eagle pairs monitored annually within the broader USGS study area, including as many as 92 pairs of eagles in the area of focus. The sample of individuals aged each year included pairs within the USGS study's focal survey plots in addition to pairs detected and monitored in adjacent, non-focal survey plots. On average, they determined that 8% of the pairs monitored and aged within the area of focus during 2014 – 2021 comprised a mixed-age pair, or two subadult pair members (Table 8.6). During the seven-year study period, the mean proportion of territories occupied by one or more subadult members was considerably lower in the East Bay Hills subregion (4%) and Mt. Hamilton subregion (5%) relative to the Mt. Diablo Range subregion (12%).

Table 8.6. Age-class of territorial pairs of golden eagles in the area of focus and subregions,2014–2021 (surveys were not completed in 2017).

	2014	2015	2016	2018	2019	2020	2021	Study Average
Area of Focus (Subregions Combined)								
Total pairs aged	73	81	82	76	82	86	92	81.71
Adult pairs	68	75	74	70	75	80	85	75.29
Mixed-age pairs	5	6	8	6	7	6	7	6.43
Proportion of mixed-age pairs	0.07	0.07	0.10	0.08	0.09	0.07	0.08	0.08
East Bay Hills Subregion								
Total pairs aged	11	9	11	13	15	11	16	12.29
Adult pairs	11	9	10	13	14	10	15	11.71
Mixed-age pairs	0	0	1	0	1	1	1	0.57
Proportion of mixed-age pairs	0.00	0.00	0.09	0.00	0.07	0.09	0.06	0.04
Mt. Diablo Range Subregion								
Total pairs aged	24	31	32	30	37	36	40	32.86
Adult pairs	20	27	28	26	33	34	34	28.86
Mixed-age pairs	4	4	4	* 4	4	2	6	4.00
Proportion of mixed-age pairs	0.17	0.13	0.13	0.13	0.11	0.06	0.15	0.12

	2014	2015	2016	2018	2019	2020	2021	Study Average
Mt. Hamilton Subregion								
Total pairs aged	38	41	39	33	30	39	36	36.57
Adult pairs	37	39	36	31	28	36	36	34.71
Mixed-age pairs	1	2	3	2	2	3	0	1.86
Proportion of mixed-age pairs	0.03	0.05	0.08	0.06	0.07	0.08	0.00	0.05

* Including one territory occupied by two subadult members

The incidence of subadult pair members was consistently greater for pairs with territories in the Mt. Diablo Range subregion that overlapped with the APWRA. This finding was consistent with previous findings showing that territories overlapping with the APWRA had a consistently greater proportion of pairs with subadult members (mean = 29% across years) relative to pairs monitored outside of the APWRA (mean = 3% across years; Figure 8.4, from Wiens and Kolar 2021:11).

In 2021, the proportion of territorial pair members with subadult plumage near the APWRA exceeded that observed in other studies that tracked the age distribution of territorial pairs of golden eagles (range = 3%–17%; Steenhof et al. 1983, Sánchez-Zapata et al. 2000). A high proportion of territorial subadults associated with APWRA may indicate a high local level of turnover of adult pair members caused by collisions with wind turbines.

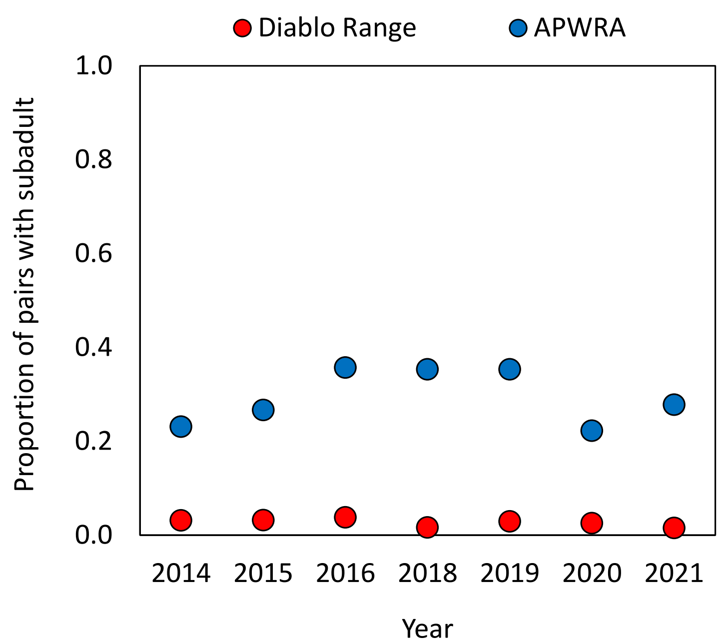


Figure 8.4. Pairs of golden eagles with territories overlapping with the Altamont Pass Wind Resource Area (APWRA) consistently included a higher proportion of subadult pair members in comparison to

those monitored and aged in the broader USGS study region during 2014–2021 (surveys were not completed in 2017). Data and figure from Wiens et al. (2021).

Condition Thresholds:

- *Good:* The proportion of individual territorial subadults in the local breeding population is not increasing and is less than 4% (or, <8% of pairs monitored have at least one subadult).
- *Caution:* The proportion of individual territorial subadults in the local breeding population is ≥4%, but lower than 9% (or, 8% to 18% of pairs monitored have at least one subadult).
- *Significant Concern:* The proportion of individual territorial subadults in the local breeding population is increasing or exceeds 9% (or, >18% of pairs monitored have at least one subadult).

Condition:

Good (East Bay Hills, Mt. Hamilton)

Caution (Mt. Diablo Range)

While the annual mean proportion of territorial pairs with a subadult within individual area-of-focus subregions was below the threshold of 18% for significant concern, it was substantially greater at sites overlapping with the APWRA within the Mt. Diablo Range and Mt. Hamilton subregions (22%–35%) in comparison to areas outside the APWRA, including portions of the area of focus (approximately 3%; Figure 8.4, and Wiens et al. 2021). The levels are greater than what is expected in an unchanging population of breeding and non-breeding golden eagles, where the proportion of individual territorial subadults in the local breeding population is less than 4% or the proportion of pairs with at least one subadult is less than 8% (Hunt et al. 2017). This finding suggests a decline in the nonterritorial adult segment of the local population of golden eagles, especially within the Mt. Diablo Range subregion.

Trend:

Unchanging (East Bay Hills)

Unknown, possibly increasing (Mt. Diablo Range, Mt. Hamilton)

There were no obvious increasing or decreasing trends in the occurrence of territorial subadults within the area of focus. The metric does indicate, however, that pairs of golden eagles with territories overlapping with the APWRA, especially in the Mt. Diablo Range subregions, may be exposed to higher rates of adult mortality relative to pairs occupying territories in surrounding landscape. Given the proximity of golden eagle territories in the Mt. Hamilton region to active turbines in the APWRA, this subregion may need to be considered jointly with the Mt. Diablo Range subregion in future analyses.

Confidence: Moderate (All subregions)

This metric was based on seven years of survey data that included the entire area of focus, but small sample sizes may reduce the overall level of confidence in individual subregions within the area of focus. There was slightly lower confidence in this metric for the East Bay Hills subregion because relatively fewer pairs of golden eagles were aged (9 to 15 pairs, depending on year) relative to the Mt. Diablo Range and Mt. Hamilton subregions.

OTHER METRICS CONSIDERED BUT NOT INCLUDED

We considered analyzing the survey data based on territory locations of golden eagle pairs instead of randomly selected, hexagonal survey plots. This approach was not used, however, because: 1) it would have limited inferences to used territories rather than the entire landscape of interest, 2) the grid-based approach we used to identify focal plots for surveys allowed statistical inferences on site occupancy and reproduction to be extended to sites not surveyed within the defined sampling frame (e.g., the area of focus), and 3) the design we used still provided territory-level information on the distribution and reproductive status of territorial pairs within sample sites (hexagons).

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

- Currently, results from the USGS golden eagle study are limited to years of severe and prolonged drought conditions in west-central California (2014–2021; surveys were not conducted in 2017, which was an exceptionally wet, intervening year). Severe drought in California can negatively affect the reproductive rate of golden eagles, as shown by Wiens et al. (2018), and more recently by Smith et al. (2020). Additional research is needed to capture years with more normal precipitation levels and to quantify how drought conditions impact the local eagle population.

- Several thousand molted golden eagle feathers have been collected from breeding territories and roosting locations in the area of focus over the past seven years. Genetic analyses of molted feathers can be used to estimate site-specific adult survival and turnover rates of breeding territories, in addition to survival and abundance of non-breeding subadult and adult golden eagles. Such information can provide an unprecedented evaluation of the population dynamics of golden eagles in the area of focus, in addition to the anticipated impacts of multiple interacting stressors within this region (including wind-energy production, drought, wildfire, and increasing development/urbanization of the landscapes used by golden eagles).

- We lack information on territory occupancy and productivity of golden eagles in areas immediately adjacent to the northern Diablo Range, such as the southern Diablo Range and the extensive Inner Coast Range across from the Central Valley river systems immediately north. Both regions no doubt harbor golden eagle populations and are well within the dispersal distances of juveniles. Applying Wiens et al. (2015) survey methods and occupancy modelling to these regions would provide a more complete picture of the health of the regional golden eagle population and contribute to a better understanding of the species in California.

- The volunteer Golden Eagle Monitoring Team (GMT, East Bay Regional Park District [EBRPD]) uses the same survey methodology as the Wiens et al. (2015, 2018) studies to augment USGS occupancy modeling in the northern Diablo Range, but also conducts surveys of known territorial pairs for site-specific management purposes. The GMT uses trained volunteers to perform the surveys. Organization, training, and volunteers (who may have a variety of skill levels) require significant supervision and a commitment of time that may limit its application.

- Focused studies of eagle nest sites have been performed by Sunol resident Hans Peeters. Additional studies by Bell (EBRPD) and DiDonato (Wildlife Consulting and Photography, Loleta, California), with assistance from the American Eagle Research Institute (AERIE, Apache Junction, Arizona), have included trapping and banding as well as attaching Global Positioning System/Global System for Mobile Communication (GPS/GSM) satellite transmitters (Cellular Tracking Technologies, https://celltracktech.com) to eagles and monitoring their movements, especially in relation to impacts from wind turbines in the APWRA (see Bell and Wilson 2016, Bell 2017a, 2017b). In addition, satellite telemetry data have been analyzed in conjunction with researchers investigating region-wide movements of eagles and flight behavior in relation to topography (Brown et al. 2017, Duerr et al. 2019, Sur et al. 2020). Further analysis of eagle dispersal, home range, and age-cohort-specific movements in relation to the APWRA and other stressors in the northern Diablo Range could help identify specific areas where eagles of different age classes may be most susceptible to human-caused disturbance or mortality.

- Smallwood et al. (2009, 2016, 2017) have been observing and analyzing inter- and intraspecific eagle behavior and flight patterns in the APWRA for many years. These data, along with satellite telemetry information, have been analyzed in a Digital Elevation Model framework to create eagle-wind turbine collision hazard maps (Risk Maps). The latter are used by some companies to inform wind turbine placement in the APWRA during repowering to potentially lessen impacts to golden eagles. Further analyses are needed to determine if and how eagles react in flight to spinning and stationary wind turbine rotors, the meteorological conditions that may contribute to chances of collisions, and the relative roles of prey hunting/searching behavior versus social interactions in causing eagle-wind turbine collisions.

- Preliminary work on the degree to which local versus non-local golden eagles are killed by APWRA wind projects has been completed (Katzner et al. 2017), but more detailed information on impacts of the APWRA to regional eagle populations is needed. Kolar and Bell have been collecting molted golden eagle feathers from territories and communal roost sites, and Bell has been collecting blood samples from trapped eagles. In addition, feather and blood samples are acquired from wounded golden eagles picked up in the APWRA and taken to local wildlife rehabilitation facilities (e.g., Lindsay Wildlife Hospital), and carcasses of golden eagles killed in the APWRA are sent to the California Department of Fish and Wildlife's Wildlife Investigations Laboratory for necropsy and sampling. These efforts have resulted in the compilation of an extensive set of samples of local and non-local eagles that are available for genetic and isotopic analysis.

- Determining the mortality rate of golden eagles resulting from wind project operations in the APWRA and relating it to the vital rates of golden eagles in the region is key to determining broader impacts of the AWPRA as a potential population sink for golden eagles. Operating since the early 1980s with a rated capacity of 580 megawatts (MW), the APWRA at one time consisted of more than 5,000 old-generation wind turbines that ranged in size from 40 to 400 kilowatts, which collectively represented its "pre-repowered" condition (Smallwood 2008). Because of various settlement agreements (e.g., see Alameda County Community Development Agency 2014), by the mid-2000s project operators in the APWRA began replacing the numerous lower-capacity, old-generation wind turbines with fewer, higher-capacity (> 1MW) wind turbines, an ongoing process known as "repowering." Golden eagle fatality estimates for the pre-repowered APWRA average approximately 55 to 66 eagles per year (Smallwood and Thelander 2008, Smallwood and Karas 2009, ICF International 2016). Hunt et al. (2017) estimated that it would take the reproductive output of 216 to 255 breeding pairs of golden eagles to compensate for this loss and have a self-sustaining population. Wiens et al. (2015) estimated the Diablo Range population of golden eagles at 280 pairs, so possibly large enough to sustain APWRA-related fatalities. However, Wiens et al. (2018) reported exceptionally low productivity of golden eagles during the drought years 2014–2016, which would potentially tip the APWRA into population sink status. More recently, the APWRA has been in the process of repowering (i.e., replacing many smaller, old-generation wind turbines [< 1 MW] with fewer, larger turbines [up to 5MW]. Results from post-monitoring studies of repowered wind farms suggest that cumulative golden eagle fatality rates were not substantially reduced (H. T. Harvey and Associates 2021, 2022a, 2022b). As a consequence, fatality rates of golden eagles at APWRA currently remain a significant management concern.

- Precise estimates of golden eagle fatality rates are key in understanding the possible broader, population-level impacts of the APWRA. However, fatality estimates are prone to many biases (Smallwood 2007). For example, independently derived information on the persistence and scavenging rates of raptors is typically used to correct for these factors in fatality estimates. Information on persistence and scavenging rates for golden eagles is essentially non-existent, however, so the degree to which these factors have affected fatality estimates of golden eagles at APWRA is largely unknown.

- Information on the impacts of human recreation on eagles (e.g., camping, hiking, mountain biking, equestrian activities, and use of off-highway vehicles), and the effectiveness of protective buffers around used eagle nests to alleviate these impacts, would help inform management actions within the area of focus. For example, analyses based upon long-term data on reproductive output of eagle pairs in territories with and without impacts from recreational use could be used to determine impacts, and thus identify the best protective measures near nesting sites during the nesting season.

- Understand nest-site selection by golden eagles in oak/woodland savanna landscapes of the area of focus, and how recent large wildfires have impacted these conditions, would provide information needed to identify and manage specific physiographic conditions that promote golden eagle nesting activities.

- The effects of range management practices on prey species used by golden eagles, particularly those that can either negatively affect or promote ground squirrel populations as a prey source, require further study (e.g., see Smallwood et al. 2008). For example, many private landowners at the APWRA and surrounding landscapes regularly use rodenticides to control ground squirrel populations. Studies of golden eagle demographic performance in areas with and without rodenticide exposure can help determine the ecosystem-level consequences of such actions, leading to more informed land-management decisions.

- The effectiveness of established USFWS mitigation measures for the take of golden eagles at renewable energy facilities (e.g., retrofitting of high-risk power-poles) could be assessed relative to other potential mitigation measures (e.g., maintaining or enhancing prey habitat) to determine the most effective use of limited resources available for these actions.

- Existing historical records, such as golden eagle egg and other specimen collections housed in various scientific institutions (e.g., the Museum of Vertebrate Zoology, University of California, Berkeley), are accessible through web-based Arctos collections (http://arctos.database.museum/home.cfm). This is a rich source of information that could be compiled and analyzed in a GIS framework to better understand the historical distribution of golden eagles in California – an important source of information in determining possible changes in the status and distribution of this species.

- The effect of newly discovered wildlife diseases on golden eagle populations (e.g., mange [Mete et al. 2014]) is largely unknown. Data on emergent disease in golden eagles is needed to better understand how this stressor may impact golden eagles in the area of focus.

- The golden eagle's role in the culture of the region's indigenous peoples is poorly understood by the scientific community. A better understanding of that role would benefit land managers' understanding and protection of culturally significant resources and areas.

PAST AND CURRENT MANAGEMENT

Golden eagles in California and the area of focus are primarily managed under legal protections afforded under state and federal regulations. The USFWS provides a framework for preventing the net loss of golden eagles by incidental take resulting from development activities, such as wind farm projects, using a permit system tied to the Bald and Golden Eagle Protection Act and protocols outlined in the USFWS (2013) Eagle Conservation Plan Guidance. This wholly voluntary permit system provides guidance to, first, avoid and minimize the impact of human activities from individual projects to the maximum degree practical, and second, to offset losses that cannot be avoided by reducing eagle mortality and/or increasing their productivity elsewhere (Allison et al. 2017). Implementation of this voluntary permit system in the APWRA exposes energy companies that do not apply for and receive a take permit to potential enforcement action for take of golden eagles.

For eagles nesting in the APWRA, permitting guidelines have provided recommended distance buffers to avoid incidental take of breeding eagles and prevent disturbance near nests until young have fledged (USFWS 2013). The size of these avoidance buffers varies depending upon intervening topography, or the type and extent of activity, but are recommended to be up to half the mean species-specific inter-nest distance (approximately two miles in the area of focus [Wiens and Kolar, 2021]) from large-scale developments like wind energy facilities (USFWS 2013). One Network partner agency in the area of focus, Contra Costa Water District (CCWD), uses smaller buffers to close recreational trails 0.5 miles of known nesting areas prior to incubation and until either nest failure is confirmed, or 10 days after fledging (H. T. Harvey and Associates, 2020b). Another partner (EBRPD) closes trails on as as-needed basis based on nest monitoring results from its volunteer Golden Eagle Monitoring Team. Such efforts could be expanded to include all Network partner agencies.

Golden eagles are also a species of conservation value in local and regional conservation planning measures, such as in the East Contra Costa County Habitat Conservation Plan/Natural Community Conservation Plan Area (Wiens et al. 2021) and the volunteer East Alameda County Conservation Strategy (http://www.eastalco-conservation.org/). Under USFWS guidance and regional conservation plans, local governments, land agencies, and developers may be required to implement measures to maintain stable golden eagle populations. This process can involve the creation of long-term monitoring plans for local breeding territories, or purchasing lands suitable for breeding and foraging requirements to mitigate development impacts such as those from the construction and operation of wind energy projects, the construction and expansion of reservoirs, and others.

POTENTIAL FUTURE ACTIONS

- Continue monitoring of golden eagles within the area of focus. Continuation of the established golden eagle demographic study in the area of focus would provide the most direct comparisons with established baseline conditions outlined in this assessment. The established framework facilitates future conservation and management options by identify specific areas within the area of focus were conservation actions may be most beneficial to golden eagles.
- Expand and implement volunteer Golden Eagle Management Team efforts among Network partner agencies. These efforts have been effectively used as part of the aforementioned USGS monitoring program for golden eagles and have provided a means to reduce project costs while also promoting educational and outreach opportunities to East Bay communities.
- Genetic and isotopic analysis of extensive eagle feather and blood sample collections from the APWRA and USGS study could be used to better understand key population parameters of interest, such as individual turnover rates at breeding territories exposed to disturbances and annual survival of breeding and non-breeding golden eagles.
- An assessment of the impacts of human disturbance and recreational activities on nesting success of golden eagles could be used to identify and prioritize actions to mitigate those impacts and other stressors.
- More detailed spatial data on land-use within the area of focus could be used to address hypothesized relationships between livestock grazing, range-management practices, status of golden eagle prey populations (e.g., ground squirrels), and dynamics in site occupancy and reproduction of golden eagles.
- The effectiveness of established mitigation measures on reducing or compensating for take of golden eagles at the APWRA (e.g., retrofitting of power poles) could be examined relative to site-specific alternatives (e.g., curtailment of wind-turbines near used nests during the breeding season).
- Broaden regional partnerships with cooperating private landowners to implement all the above actions.

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Partner Agency Data Sources

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CHAPTER 9. MAMMAL METHODS AND DATA ASSEMBLY

INTRODUCTION

This chapter provides background on how the suite of mammal ecological health indicators presented in this report were chosen, how proposed metrics for each indicator were created and shared for expert review, and the methods by which we assembled and analyzed data for these metrics. The tables and figures in this chapter are important references for each of the individual mammal-indicator chapters that follow. See Chapter 1 (section name) for definitions of ecological health, indicators, metrics, conditions, trends, and other terminology used throughout this chapter.

METHODS

MAMMAL INDICATOR SELECTION PROCESS

A list of mammal species that could potentially be used as health-assessment indicators was assembled using a candidate-species mammal list from *Measuring the Health of a Mountain: A Report on Mount Tamalpais' Natural Resources* (Edson et al. 2016) and the mammals section of the Conservation Lands Network 2.0 guide (BAOSC 2019). The list was then refined by evaluating a given species' potential presence within the area of focus (see map, Chapter 1), using the California Department of Fish and Wildlife's (CDFW) California Wildlife Habitat Relationships (CWHR) System (Zeiner et al. 1990) as well as other published geographic range and occurrence data (Grinnell et al. 1937, California Natural Diversity Database [(CNDDB) CDFW], and Arctos [Museum of Vertebrate Zoology (MVZ) Mammal Collection, University of California, Berkeley]).

It is important to note that indicator species were considered even if they were not appropriate for all subregions within the area of focus. For example, some may occur in one or two of the subregions but not all of them (e.g., the San Joaquin kit fox [*Vulpes macrotis mutica*] does not occur in the East Bay Hills subregion), have uncertain status in one or more of the subregions (e.g., the American badger [*Taxidea taxus*] may not be in the East Bay Hills), or may not be representative of mammal species found in one or more subregions (e.g., the dusky-footed woodrat [*Neotoma fuscipes*] in the Mt. Diablo Range and Mt. Hamilton subregions, which are largely grassland and therefore unsuitable for woodrats).

This list of potential mammal indicator species was further refined based on habitat associations and their roles in ecosystem health and function (Tables 9.1 and 9.2) within this project's area of focus.

For example, indicator species show the presence of the habitats upon which they depend (e.g., open grasslands, forests, or a mosaic of habitats) and tell us something about the health of those habitats. Different indicators rely on large, moderate, and small scales of habitat connectivity, depending on their life history needs. A variety of trophic-level indicators tell us about predator-prey relationships, such as mesocarnivores' reliance on smaller prey, which reveals things about the health of small herbivore populations. These small herbivores, in turn, indicate the availability of seed-producing grasses among other types of vegetation. Furthermore, some indicators are considered keystone species for particular ecosystems; that is, they are critically important for the health of upper and lower trophic levels in addition to providing other ecosystem services. Others can act as indirect indicators of unmonitored but critical taxonomic groups or habitat features. An example of this is bats, which rely on insects for food and utilize a diverse range of roosting habitats (e.g., outcrops, caves, tree holes, bark, and mature trees).

Table 9.1: Mammal indicator species considered for inclusion, detection monitoring techniques, and their role in ecosystem health and function.

Indicator Species	Monitoring Techniques	Role in Ecosystem Health
Puma (*Puma concolor*)	Camera traps, telemetry, signs such as scat and kills	Indicator of availability of large prey, habitat connectivity (large scale)
Mesocarnivores	Camera traps, spotlighting, track plates, signs such as scat and tracks	Indicator of variety of prey availability, connectivity (medium scale)
American badger[31] (*Taxidea taxus*)	Camera traps, spotlighting, track plates, signs such as scat and tracks	Indicator of grassland ecosystem health and management, connectivity of open habitats
San Joaquin kit fox[32] (*Vulpes macrotis mutica*)	U.S. Fish and Wildlife Service (USFWS) protocol survey recommendations, which include camera traps, spotlighting, and track plates; surveys for the presence of suitable dens and prey	Conservation focal point as a rare species that may be extirpated from this portion of its range, health of grassland ecosystems
Bats	Mist netting, acoustic monitoring, carcass surveys (at wind power sites), roost exit surveys	Indicator of insect prey availability, suitable roosting habitats, overall ecosystem health
Dusky-footed woodrat (*Neotoma fuscipes*)	Nest surveys, camera traps, small mammal trapping	Indicator of healthy forested ecosystems, important prey for upper trophic levels, ecosystem engineer, keystone species

[31]The badger is considered as a rare species in Chapter 10 (Mesocarnivores).

[32] The San Joaquin kit fox, despite its listing status and substantial survey data, was not chosen as an indicator species based on the recommendation of the majority of consulted experts (including Brian Cypher), as the species has likely been extirpated in this portion of its range.

Indicator Species	Monitoring Techniques	Role in Ecosystem Health
California ground squirrel (*Otospermophilus beecheyi*)	Camera traps, track plates, audio-monitoring; percent present as required for San Joaquin kit fox mitigation	Indicator of healthy grassland ecosystems; keystone species; ecosystem engineer; important for many other listed species, including the burrowing owl (*Athene cunicularia*), California red-legged frog (*Rana draytonii*) (Chapter 5), California tiger salamander (*Ambystoma californiense*) (Chapter 6), San Joaquin kit fox, and American badger

Table 9.2: Habitat and ecosystem associations for each potential mammal indicator species.

Indicator Species	Grassland	Oak Woodland	Forested	Shrub (Chaparral)	Micro-habitats	Insects	Keystone/ Ecosystem Engineer	Habitat Connectivity
Puma							Top Down	
Mesocarnivores								
American badger								
San Joaquin kit fox								
Bats								
Dusky-footed woodrat								
California ground squirrel								

Color definitions: Green = indicator, yellow = moderate association, gray = not associated, no color = neutral

Next, the areal extent (square km [sq km]) of habitat types for each land unit and park was used to assess the proportion of East Bay Stewardship Network (Network) lands within the area of focus that could potentially support the proposed indicator species (see Table 9.3 at the end of this chapter). These habitats fall within many individual parks, reservoirs, recreation or management areas, and other open spaces that we refer to collectively as "Network partner lands" throughout this chapter.

INITIAL DATA GATHERING AND DISCUSSIONS

With a preliminary list of mammal indicators based on the described criteria in hand, in January 2020, we engaged subject-specialist experts from the wider scientific community in a two-day East Bay ecological health assessment workshop. During this workshop, we discussed the proposed indicators' value for assessing overall ecological health, the desired condition for each indicator, which metrics could be used to measure indicator health, and what thresholds might signify changes in the condition or trend of these metrics. The final set of mammal indicators presented in this report, and the metrics and thresholds we used for those indicators, came from those discussions.

Workshop discussions were based on draft worksheets for each indicator, including proposed metrics. These worksheets were prepared by querying publicly accessible databases (GBIF, Arctos, CNDDB among others), which provided basic information on range and occurrences for the proposed indicator mammal species within the area of focus and its subregions. The CNDDB (wildlife.ca.gov/Data/CNDDB) was queried for the candidate listed species, including:

- California species of special concern: badger, San Francisco dusky-footed woodrat (*Neotoma fuscipes annectens*)
- Fully protected: ringtail (*Bassariscus astutus*); special-status bat species (pallid bat [*Antrozous pallidus*], Townsend's big-eared bat [*Corynorhinus townsendii*], red bat [*Lasiurus blossevillii*])
- Federally endangered: San Joaquin kit fox

For portions of the East Bay in the area of focus, the San Joaquin kit fox is the only species that has been surveyed using consistent protocols (based on published USFWS recommendations). While ultimately, the San Joaquin kit fox was not chosen as a NatureCheck ecological health indicator, findings from kit fox survey and monitoring have provided mammal records for species such as mesocarnivores and ground squirrels that were included as part of the following partner data aggregation.

DATA AGGREGATION FROM NETWORK PARTNERS

One outcome of the workshops was that we were able to aggregate Network partner agency data.[33] We identified potential sources of records data, primarily focusing on monitoring with camera traps and acoustic monitors. We identified ongoing and completed camera trapping projects (or studies), which are of particular interest because the images they produce provide date, location, and verifiable records (see Table 9.4 at the end of this chapter, Study, Camera No., and Camera Date Range columns). The status of the images resulting from those efforts fell into three categories: (1) images that were cataloged and available for use (records data or "processed data," i.e., images that have been identified as to species), (2) images that were stored but had not been reviewed and identified (unprocessed data),[34] and (3) cameras that were actively collecting images but from which

[33] See the Study Details section.

[34] Records from studies not available at the time we were aggregating metadata and records for this project but that could potentially be used in the future are summarized in the Data Sources for Future Ecological Health Assessment Updates section later in this chapter.

data had not been recovered (to be collected from the field). Available records aggregation and the accompanying sensor metadata were compiled providing effort and coverage, documenting which Network partner agency lands were being monitored (Figure 9.1). Records and metadata from camera trapping and the East Bay Municipal Utility District (EBMUD) mammal database provided the majority of data for the mammal indicator chapters in this report (Table 9.4, Figure 9.1); however, certain species, such as California ground squirrel and the woodrat, may have been detected by camera monitoring but were not reliably recorded during data processing (not the target species), and acoustic monitors were used to detect bats. Additional databases and research used only for a specific indicator species are described in the relevant chapters.

Available records of indicator species occurrences were aggregated from these camera studies (see Table 9.4, Records Date Range column, and Appendix G, Data Assembly for Mammal Indicators). These data came from:

- East Bay Regional Park District (EBRPD), Carnivore Research Study (Tilden-Sibley Fuels, Eastern Costa Contra County [ECCC], and Sunol-Ohlone)
- Contra Costa Water District (CCWD), Mitigation lands, San Joaquin Kit Fox Monitoring
- California State Parks (CSP), Large Mammal Occupancy Study (Carnegie State Vehicular Recreation Area [Carnegie SVRA]), and Felidae Conservation Fund Study (Mount Diablo State Park)

Metadata were collected for all sensors, which included bat acoustic monitoring studies and AudioMoths (not included in this analysis), audio files of birds and some mammals, including coyotes and California ground squirrels, as well as sound metrics that indicate biodiversity levels (species richness for example). We expect these data to be used in future presence and prevalence assessments.

Data sources were aggregated into two main databases: (1) sensor metadata (location, type, dates active in the field) and (2) records (date, time, location, and species tied to sensors). Other data sources used in this analysis included the mammal database for EBMUD lands in the East Bay Hills subregion, CNDDB for data on the badger, and vetted iNaturalist observations and other sources for California ground squirrels (for details, see Chapters 10, and 12, Mesocarnivores, and California Ground Squirrel, respectively).

As part of this effort, camera data (images) were collected (both processed and unprocessed as available) and the integrity of their metadata was assessed for future inventories. Only processed data were included in this analysis.[35]

DATA COMPILATION RESULTS

STUDY SUMMARY

Ten camera studies conducted on Network partner agency lands were identified as potential sources of information for this report. These included 290 camera locations across the three subregions (71 in the East Bay Hills, 75 in the Mt. Diablo Range, and 144 in Mt. Hamilton [Figure 9.1, Table 9.4 at the end of this chapter]). Metadata were used to plot locations, determine the status of sensors (active and inactive), and see if records were usable for this analysis. Camera studies encompassed one or more parks in one or more subregions. We compiled all the mammal species records we received (Tables 9.5a and 9.5b at the end of this chapter).

Of these (see Table 9.4 for summary efforts), six of the 10 studies (see Records Analysis column in Table 9.4) as well as the EBMUD mammal database (observations from EBMUD staff biologists, Figure 9.1) provided records for this analysis. These studies included 48 cameras in the East Bay Hills subregion (2016–2020), 31 in the Mt. Diablo Range subregion (2017–2020), and 54 in the Mt. Hamilton subregion (2012–2020). However, a lack of critical metadata such as effort (number of operational trap nights) precluded determining detection rates (detections per unit effort). Therefore, we could only report total mammal detections for each park or land unit in each subregion (Tables 9.5a and 9.5b).

For the metrics analysis in the following chapters, we compiled detections and non-detections per park or land unit with sensors or those on EBMUD lands (mammal database; see Table 9.6 at the end of this chapter for a summary) and used that information to total annual detections (Tables 9.5a and 9.5b).

Bat detections were recorded in the EBMUD mammal database, but bats were not reported (and are rarely recorded) from camera studies records. Network partner agency bat records were compiled from ad hoc bat surveys, and additional efforts, such as roost exit data, were also compiled and included in Chapter 14 (Bats). Some of the acoustic bat monitors are shown on the sensor figure (Figure 9.1).

[35] See the Data Sources for Future Ecological Health Assessment Updates section for more information on how unprocessed data will be used in later updates to this report.

STUDY DETAILS

The six camera studies and one additional database that provided data used for the mammal chapters in this report include:

1. The EBRPD Tilden-Sibley Fuel Carnivore Research Study, conducted from 2016 to 2020 in the East Bay Hills subregion, included 48 unique camera locations that provided 26,902 records, a subset of which included indicator species. This study focused on deer and mesocarnivores; species such as the woodrat and ground squirrel were not recorded. Deployment dates (start date and end date for each camera) were not available, so effort was not assessed. Additionally, the number and location of cameras that were up and functioning in any given year were not available.

2. The EBRPD ECCC Carnivore Research Study spanned 2019 to 2020 in the Mt. Diablo Range subregion, with 5,283 records from 10 camera locations. Trap nights (effort) were available from Clayton Ranch (2,121 records from 1,036 trap nights), Morgan Territory (2,825 records from 2,276 trap nights), and Round Valley (336 records from 285 trap nights) (Table 9.4). This study focused on carnivores, so woodrats and ground squirrels were not reported (Bobzien and Douglas 2020).

3. The EBRPD Sunol-Ohlone Carnivore Research Study conducted from 2012 to 2020 in the Mt. Hamilton subregion yielded records from nine unique camera locations. Records from 2012 to 2018 were available for this analysis (see Table 9.5a and 9.5b), but because deployment dates were not available, effort was not assessed. Target species included carnivores and small mammals such as the woodrat. The number and location of cameras operational in any given year were not available.

4. The CSP Large Mammal Occupancy Study at the Carnegie SVRA in the Mt. Hamilton subregion provided records from 2017 to 2020 from 27 camera locations. Records included carnivores and ground squirrels. Effort or trap night information was not available for each camera.

5. Seven Habitat Management Units (HMUs) were monitored as part of mitigation for the San Joaquin kit fox for CCWD's Los Vaqueros Reservoir Expansion Project. Five HMUs with a total of 15 cameras were located in the Mt. Diablo Range subregion and two HMUs with a total of 18 cameras were in the Mt. Hamilton subregion. This study went from 2014 to 2020, and records from 2017 to 2020 were available for this analysis (Figure 9.1). The HMUs varied in size from 80 acres (Los Vaqueros HMU) to 3,021 acres (Corral Hollow HMU). Target species included carnivores, although other species were also recorded. For data processing, only one record of a target species was reported for each month of operation and available to use in this analysis.

6. Ten cameras were deployed by Felidae (www.felidaefund.org) in Mount Diablo State Park in 2020, and records from six of these cameras were available and used in this analysis. Effort was reported and the cameras are still deployed. While carnivores were the target species, other species were also recorded.

7. EBMUD provided a records database of notable mammal sightings (records with date, time, and location) beginning in 1869 (one record) to 2020 with 845 records in total. We included this study because the indicator species location and date were available (e.g., a ringtail record and the puma records; see Tables 9.5a and 9.5b) for a large portion of the lands in the East Bay Hills subregion. Additionally, EBMUD had unprocessed image data from six cameras (EBMUD ad hoc). Records were not available for inclusion in this data aggregation; however, sensors were documented (Figure 9.1) and image data were obtained to be processed in the future.

Annual detections for each subregion were tallied for puma, California ground squirrel, dusky-footed woodrat, and mesocarnivores (badger, bobcat, coyote, and gray fox) (Tables 9.5a and 9.5b; also see Appendix G, Data Assembly for Mammal Indicators). The number of cameras (Table 9.4) varied per site per year, trap nights were not consistently available, and image data were processed differently. Therefore, tallies reflect reported total detections (Tables 9.5a and 9.5b).

To see which Network partner lands had detections or not, totals were converted into "detected" (1) and "not detected" (0) status for each area for which we had active sensor data. These data were used in the analysis presented in the individual mammal indicator chapters of this report. Additionally, knowing the sensor locations provided insight into which portions of Network partner agency lands have been, or are currently being, monitored for mammals.

DATA SOURCES FOR FUTURE ECOLOGICAL HEALTH ASSESSMENT UPDATES

Current camera trapping studies, as well as unprocessed data from earlier studies, will provide additional records data covering lands and longer time series (see Figure 9.1 for active cameras). Active studies include on-going camera studies at Carnegie SVRA, San Joaquin kit fox mitigation HMUs, and Felidae cameras at Mount Diablo State Park (see Table 9.4, Study column). Other active cameras are part of new studies, including the Post-Fire Monitoring Study (40 cameras set up in November 2020 in burned and unburned parks, including Round Valley and Morgan Territory [EBRPD] and Los Vaqueros Watershed [CCWD]) and an EBRPD Panthera study, with 18 cameras in the East Bay Hills and 91 cameras in the Mt. Hamilton subregion set up in 2020 and early 2021. Unprocessed images from earlier studies, including EBMUD ad hoc cameras (six; see Figure 9.1, inactive sensors), EBRPD Carnivore Research Studies (Sunol-Ohlone; 2018–2020; see Figure 9.1, inactive sensors), CCWD's San Joaquin kit fox monitoring (2014 to 2017, unprocessed images), and CSP's Carnegie SVRA camera records (2014–2016) could provide additional information (Table 9.4).

Only records from processed image data were included in this analysis. For unprocessed data (images to be reviewed and identified), we are starting the planning process for uploading images into a comprehensive online camera trap species database called Wildlife Insights. This global network of camera trapping data can be used by organizations to identify, store, organize, and analyze images. In the future, these data will be used to augment the analyses in this report. Data from AudioMoths will be also be used to augment findings.

The current condition assessments for each indicator chapter were limited to Network partner lands with camera sensors and available data records. Data gaps remain for those areas with no sensors and no data (see Figure 9.1., gray areas). As part of our planning for future landscape-level camera trapping and acoustic monitoring activities, it is important that we identify these areas so we can fill in these gaps.

KEY LITERATURE AND DATA SOURCES

Literature

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Edson, E., Farrell, S., Fish, A., Gardali, T., Klein, J., Kuhn, W., Merkle, W., O'Herron, M., and Williams, A. (Eds.). (2016). *Measuring the health of a mountain: A report on Mount Tamalpais' natural resources*.

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Zeiner, D. C., Laudenslayer, W. F., Mayer, K. E., and White, M. (Eds.). (1990). *California's wildlife* (Vol. III: *Mammals*). California Statewide Wildlife Relationships System. California Department of Fish and Game.

Partner Agency Data Sources

- East Bay Municipal Utility District (EBMUD), Mammal Database
- East Bay Regional Park District (EBRPD), Carnivore Research Studies (Tilden-Sibley, Eastern Contra Costa County [ECCC], Sunol-Ohlone)
- Contra Costa Water District (CCWD), San Joaquin Kit Fox Monitoring (Habitat Management Units)

- California State Parks (CSP), Large Mammal Occupancy Study (Carnegie State Vehicular Recreation Area) and Felidae Conservation Fund Study (Mount Diablo State Park)

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Agency codes (alphabetical by acronym; applies to Tables 9.3, 9.4, 9.5a, 9.5b, 9.6): CCWD = Contra Costa Water District, CSP = California State Parks, EBMUD = East Bay Municipal Utility District, EBRPD = East Bay Regional Park District, SFPUC = San Francisco Public Utilities Commission

Table 9.3: Habitat (sq km) for each agency in each subregion (number of parks or units in Parks/Units column) and total acreage and percent of each habitat type available for each subregion and area of focus.

Subregion	Parks/Units	Agency	grass	oak_wo	forest	scr_chap	water	rip	Tot_km	grass	oak_wo	forest	scr_chap	water	rip
East Bay Hills totals	3	EBMUD	36.3	24.9	7.4	27.6	9.1	0.4	107.2	34%	23%	7%	26%	9%	0%
East Bay Hills totals	37	EBRPD	73.0	90.7	12.2	16.3	1.3	0.2	196.8	37%	46%	6%	8%	1%	0%
East Bay Hills totals	1	SFPUC	2.2	2.0	0.3	0.5	0.0	0.7	8.0	27%	25%	3%	6%	0%	8%
Subregion Totals (sq km)			*111.5*	*117.6*	*19.9*	*44.4*	*10.5*	*1.3*	*312.1*	*36%*	*38%*	*6%*	*14%*	*3%*	*0%*
Mt. Diablo Range totals	3	CCWD	62.0	11.3	0.0	2.8	6.0	0.1	83.2	75%	14%	0%	3%	7%	0%
Mt. Diablo Range totals	22	EBRPD	99.6	34.2	0.2	2.8	0.4	0.1	138.8	72%	25%	0%	2%	0%	0%
Mt. Diablo Range totals	2	CSP	35.3	31.7	0.7	21.7	0.0	0.3	91.1	39%	35%	1%	24%	0%	0%
Subregion Totals (sq km)			*196.9*	*77.3*	*1.0*	*27.3*	*6.4*	*0.5*	*313.1*	*63%*	*25%*	*0%*	*9%*	*2%*	*0%*
Mt. Hamilton totals	2	CCWD	16.7	0.0	0.0	0.8	0.0	0.0	17.6	93%	0%	0%	4%	0%	0%
Mt. Hamilton totals	6	EBRPD	36.2	24.2	7.8	12.8	0.0	0.7	81.8	44%	29%	10%	16%	0%	1%
Mt. Hamilton totals	2	SFPUC	78.4	31.2	19.1	10.6	9.3	1.3	149.9	52%	21%	13%	7%	6%	1%
Mt. Hamilton totals	2	CSP	15.5	8.6	3.0	0.6	2.8	0.3	30.9	50%	28%	10%	2%	9%	1%
Subregion Totals (sq km)			*146.8*	*64.0*	*29.9*	*24.9*	*12.1*	*2.4*	*280.1*	*52%*	*23%*	*11%*	*9%*	*4%*	*1%*
		Total	*455.2*	*258.9*	*50.8*	*96.5*	*29.1*	*4.2*	*905.2*	*50%*	*29%*	*6%*	*11%*	*3%*	*0%*

Habitat type abbreviations: grass = grassland, oak_wo = oak woodland, scr_chap = scrub chaparral, rip = riparian.

Table 9.4: Camera trapping study, camera number (camera number with records), camera date range, and date range for camera with records used in analysis for each subregion in the area of focus

Area of Focus	Agency	Study	Camera No.	Camera Date Range	Records Date Range	Indicator
East Bay Hills	EBRPD	Carnivore research (Tilden-Sibley)	(48)	2016–2020	2016–2020	Mesocarnivores
East Bay Hills	EBMUD	Ad hoc	5	2010–2020	Not included	Mammals
East Bay Hills	EBRPD	Panthera	18	2021–2021	Not included	Mammals
		Total, East Bay Hills (no. analysis)	***71 (48)***			
Mt. Diablo Range	EBRPD	Carnivore research (ECCC*)	(10)	2019–2020	2019–2020	Mesocarnivores
Mt. Diablo Range	CSP	Felidae (Mount Diablo State Park)	10 (6)	2019–2021	2020–2020	Mammals
Mt. Diablo Range	EBRPD	Post-Fire Monitoring	40	2020–2021	Not included	Mammals
Mt. Diablo Range	CCWD	Mitigation lands, San Joaquin kit fox monitoring	(15)	2014–2020	2017–2020	Mesocarnivores
		Total, Mt. Diablo Range (no. analysis)	***75 (31)***			
Mt. Hamilton	CSP	Large Mammal Occupancy Study	(27)	2017–2021	2017–2021	Mammals
Mt. Hamilton	CSP	Large Mammal Occupancy Study	Unknown	2014–2016	Not included	Mammals
Mt. Hamilton	EBRPD	Carnivore research (Sunol-Ohlone)	(9)	2012–2018	2012–2018	Mesocarnivores
Mt. Hamilton	EBRPD	Carnivore research (Sunol-Ohlone)	9	2018–2020	Not included	Mesocarnivores
Mt. Hamilton	EBRPD	Panthera	81	2020–2021	Not included	Mammals
Mt. Hamilton	CCWD	Mitigation lands, San Joaquin kit fox monitoring	(18)	2014–2020	2017–2020	Mesocarnivores
		Total, Mt. Hamilton (no. analysis)	***144 (54)***			
All Areas		***Total cameras (no. analysis)***	***290 (133)***			

*Eastern Contra Costa County

Table 9.5a: Detections (tallied totals of records) of indicator species, number of cameras (No. cams), date range (Range), and number of years (No. years).

Agency	*Subregion/ Park*	Study	Indicator Species						Cameras		
			Bobcat	**Coyote**	**Gray fox**	**Puma**	**GRSQ***	**TOTAL**	**No. cams**	**Range**	**No. years**
EBRPD	Sibley	*CR (T-S)*	620	2,203	997	56	nr	3,876	16	2016–2020	5
EBRPD	Tilden	*CR (T-S)*	661	7,689	1,255	12	nr	9,617	32	2016–2020	5
EBMUD	EBProp[36]	OBS**	32	49	7	23	4	111	Obs.	All years	n/a
EBMUD	LAFRES	OBS**	2	1	0	7	0	10	Obs.	All years	n/a
EBMUD	SPRES	OBS**	3	0	1	3	0	7	Obs.	All years	n/a
	East Bay Hills	***Total***	***1,318***	***9,942***	***2,260***	***101***	***4***	***13,713***	***48***		
EBRPD	CLRA	*CR (ECCC)*	379	1,057	6	0	0	1,442	2	2019–2020	2
EBRPD	MOTE	*CR (ECCC)*	213	824	53	0	0	1,090	6	2019–2020	2
EBRPD	ROVA	*CR (ECCC)*	17	125	0	0	0	142	2	2019	1
CSP	Mount Diablo	*FEL*	264	903	42	0	0	1,209	6	2020	1
CCWD	AP-AP HMU	*KFM*	1	71	0	0	37	72	4	2017–2020	4
CCWD	DVE HMU	*KFM*	1	32	0	0	34	33	2	2017–2020	4
CCWD	DVW HMU	*KFM*	1	28	0	0	3	29	4	2017–2020	4
CCWD	LV HMU	*KFM*	7	32	0	0	0	39	2	2017–2020	4
CCWD	AP-MH HMU	*KFM*	18	39	0	0	28	57	3	2017–2020	4
	Mt. Diablo Range	***Total***	***901***	***3,111***	***101***	***0***	***102***	***4,113***	***31***		
CCWD	CH HMU	*KFM*	2	90	0	0	6	92	14	2017–2020	4
CCWD	AP-GL HMU	*KFM*	3	72	0	0	47	75	4	2017–2020	4
CSP	CSVRA	*LMS*	345	517	242	116	81	978	27	2017–2021	4

[36] EBProp = EBMUD property that includes San Pablo/Briones Reservoir, Siesta Valley Recreation Area and Upper San Leandro Reservoir.

Agency	*Subregion/ Park*	Study	Indicator Species						Cameras		
EBRPD	Ohlone	*OHWICO*	430	40	1269	409	0	879	5	2012–2018	7
EBRPD	Ohlone	*OHWlow*	757	1,290	421	125	0	2,172	4	2012–2018	7
	Mt. Hamilton	***Total***	***1,537***	***2,009***	***1,932***	***650***	***134***	**6,128**	***54***		
	Grand Total		***3,756***	***15,062***	***4,293***	***751***	***240***	**23,862**	***112***		

Park codes: EBProp = EBMUD Property, LAFRES = Lafayette Reservoir, SPRES = San Pablo Reservoir, CLRA = EBRPD Clayton Ranch, MOTE = EBRPD Morgan Territory, ROVA = EBRPD Round Valley, Mt. Diablo = Mount Diablo State Park, AP-AP HMU = Altamont HMU, DVE HMU= Deer Valley East, DVW HMU = Deer Valley West, LV HMU = Los Vaqueros HMU, AP-MH HMU = Mountain House HMU, CH HMU = Corral Hollow HMU, AP-GL HMU = Grant Line HMU, CSVRA = Carnegie State Vehicular Recreation Area, Ohlone = EBRPD Ohlone Wilderness

Study type abbreviations: CR (T-S) = carnivore research (Tilden-Sibley), CR (ECCC) = carnivore research (Eastern Contra Costa County), FEL = Felidae, KFM = kit fox monitoring, LMS = Large Mammal Study, OHWICO = carnivore research (Sunol-Ohlone), OHWlow = carnivore research (Sunol-Ohlone).

*California ground squirrel

**Obs. = Observation, staff observation, not from a camera

Table 9.5b: Detections of indicator species (tallied totals) and number of cameras, camera date range, and number of years of camera data used for this analysis.

Agency	***Subregion*/Park**	Study	Indicator Species				Cameras		
			American badger	Ringtail	Woodrat	Total	No. of Cameras	Camera Date Range	No. of Years Camera Data
	East Bay Hills								
EBRPD	Sibley	*CR (T-S)*	0	0	0	0	16	2016–2020	5
EBRPD	Tilden	*CR (T-S)*	0	0	0	0	32	2016–2020	5
EBMUD	EBProp	OBS*	4	1	59	64	Obs.	All years	
EBMUD	LAFRES	OBS*	0	0	23	23	Obs.	All years	
EBMUD	SPRES	OBS*	0	0	1	1	Obs.	All years	
		Total	***4***	***1***	***83***	88	***48***		
	Mt. Diablo Range					0			
EBRPD	CLRA	*CR (ECCC)*	0	0	0	0	2	2019–2020	2
EBRPD	MOTE	*CR (ECCC)*	0	0	0	0	6	2019–2020	2
EBRPD	ROVA	*CR (ECCC)*	0	0	0	0	2	2019	1

Agency	*Subregion*/Park	Study	Indicator Species				Cameras		
CSP	Mount Diablo	*FEL*	0	0	0	0	6	2020	1
CCWD	AP-AP HMU	*KFM*	1	0	0	1	4	2017–020	4
CCWD	DVE HMU	*KFM*	7	0	0	7	2	2017–2020	4
CCWD	DVW HMU	*KFM*	2	0	0	2	4	2017–2020	4
CCWD	LV HMU	*KFM*	0	0	0	0	2	2017–2020	4
CCWD	AP-MH HMU	*KFM*	10	0	0	10	3	2017–2020	4
		Total	***20***	0	0	20	***31***		
	Mt. Hamilton					0			
CCWD	CH HMU	*KFM*	2	0	0	2	4	2017–2020	4
CCWD	AP-GL HMU	*KFM*	1	0	0	1	4	2017–2020	4
CSP	CSVRA	*LMS*	0	0	0	0	27	2017–2021	4
EBRPD	Ohlone	*OHWICO*	0	0	61	61	5	2012–2018	7
EBRPD	Ohlone	*OHWIow*	0	0	0	0	4	2012–2018	7
		Total	***3***	***0***	***61***	64	***54***		
	Grand Total		***27***	***1***	***144***	172	***133***		

Park codes: EBProp = EBMUD Property, LAFRES = Lafayette Reservoir, SPRES = San Pablo Reservoir, CLRA = EBRPD Clayton Ranch, MOTE = EBRPD Morgan Territory, ROVA = EBRPD Round Valley, Mt. Diablo = Mount Diablo State Park, AP-AP HMU = Altamont HMU, DVE HMU= Deer Valley East, DVW HMU = Deer Valley West, LV HMU = Los Vaqueros HMU, AP-MH HMU = Mountain House HMU, CH HMU = Corral Hollow HMU, AP-GL HMU = Grant Line HMU, CSVRA = Carnegie State Vehicular Recreation Area, Ohlone = EBRPD Ohlone Wilderness

Study type abbreviations: CR (T-S) = carnivore research (Tilden-Sibley), CR (ECCC) = carnivore research (Eastern Contra Costa County), FEL = Felidae, KFM = kit fox monitoring, LMS = Large Mammal Study, OHWICO = carnivore research (Sunol-Ohlone), OHWIow = carnivore research (Sunol-Ohlone)

* Obs. = Observation, staff observation, not from a camera

Table 9.6: Detection (1; detected in park) and non-detection (0; not detected/no record from tallied records) for indicator species in 18 monitored parks or land units.

Subregion	Agency	Park	Park Code	American badger	Bobcat	Coyote	Gray fox	GRSQ*	Puma	Ringtail	Woodrat
East Bay Hills	EBMUD	EBMUD Property	EBProp	1	1	1	1	1	1	1	1
East Bay Hills	EBMUD	Lafayette Reservoir	LAFRES	0	1	1	0	0	1	0	1
East Bay Hills	EBRPD	Sibley Volcanic	Sibley	0	1	1	1	0	1	0	0
East Bay Hills	EBMUD	San Pablo Reservoir	SPRES	0	1	0	1	0	1	0	1
East Bay Hills	EBRPD	Tilden (Nature Area)	Tilden	0	1	1	1	0	1	0	0
Mt. Diablo Range	CCWD	Altamont Subunit	AP-AP HMU	1	1	1	0	1	0	0	0
Mt. Diablo Range	EBRPD	Clayton Ranch	CLRA	1	1	1	1	0	0	0	0
Mt. Diablo Range	CCWD	Deer Valley East	DVE HMU	1	1	1	0	1	0	0	0
Mt. Diablo Range	CCWD	Deer Valley West	DVW HMU	1	1	1	0	1	0	0	0
Mt. Diablo Range	CCWD	Los Vaqueros	LV HMU	0	1	1	0	0	0	0	0
Mt. Diablo Range	CCWD	Mountain House Subunit	AP-MH HMU	1	1	1	0	1	0	0	0
Mt. Diablo Range	EBRPD	Morgan Territory	MOTE	0	1	1	1	0	0	0	0
Mt. Diablo Range	CSP	Mount Diablo State Park	Mt. Diablo	0	1	1	1	0	0	0	0
Mt. Diablo Range	EBRPD	Round Valley	ROVA	0	1	1	0	0	0	0	0
Mt. Hamilton	CCWD	Corral Hollow HMU	CH HMU	1	1	1	0	1	0	0	0

Subregion	Agency	Park	Park Code	American badger	Bobcat	Coyote	Gray fox	GRSQ*	Puma	Ringtail	Woodrat
Mt. Hamilton	CSP	Carnegie State Vehicular Recreation Area	CSVRA	0	1	1	1	0	1	0	0
Mt. Hamilton	CCWD	Grant Line Subunit	AP-GL HMU	1	1	1	0	1	0	0	0
Mt. Hamilton	EBRPD	Ohlone Wilderness	Ohlone	0	1	1	1	0	1	0	1
		Total detections		***8***	***18***	***17***	***9***	***7***	***7***	***1***	***4***
		Proportion occupied		**0.44**	**1.00**	**0.94**	**0.50**	**0.39**	**0.39**	**0.06**	**0.22**

*GRSQ = California ground squirrel

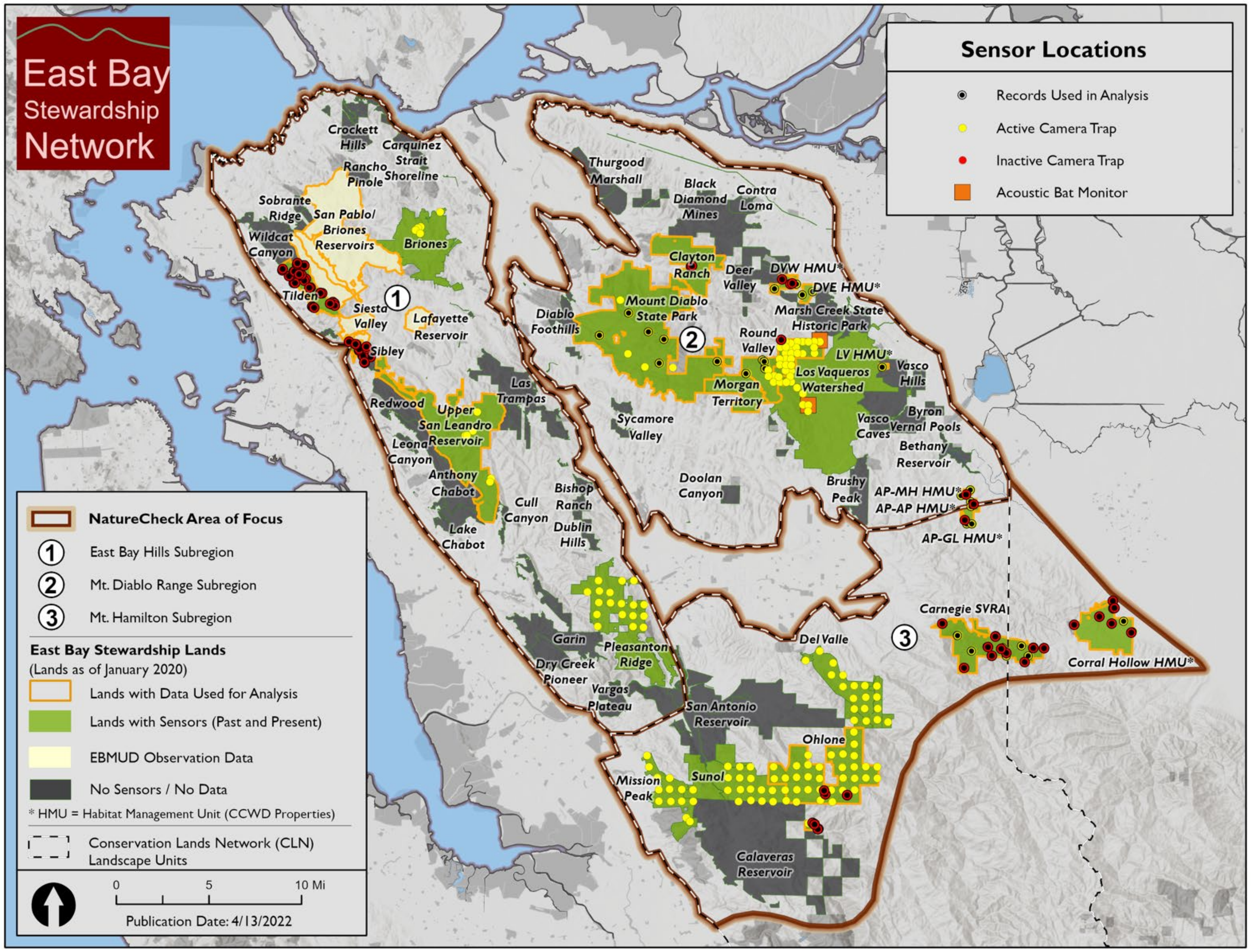


Figure 9.1. Location of active and inactive camera traps (see "Records Used In this Analysis" – black dot) on Network lands. Those lands with data used in this analysis shown with orange boarder ("Lands with Data Used for Analysis"); these lands consisted in "Lands with Sensors – Past and Present"- green shading and "EBMUD Observation Data" – light yellow shading. Network partner lands that did not have records for this analysis ("No Sensors/No Data") shown in dark gray shading.

CHAPTER 10. MESOCARNIVORES: BOBCAT, COYOTE, GRAY FOX (COMMON); BADGER, RINGTAIL, LONG-TAILED WEASEL, SPOTTED SKUNK (RARE)

EXECUTIVE SUMMARY

This ecological health indicator includes a suite of medium-sized, carnivorous mammal species (mesocarnivores) that are bellwethers of ecosystem health. Mesocarnivores in general are indicators of ecosystem productivity and can be used as proxies for overall ecosystem stability and integrity. The species selected for this indicator include common species [bobcat (*Lynx rufus*), coyote (*Canis latrans*) and gray fox (*Urocyon cinereoargenteus*)] and rare species [(ringtail (*Bassariscus astutus*), spotted skunk (*Spilogale gracilis*), long-tailed weasel (*Mustela frenata*) and American badger (*Taxidea taxus*)]. Together, this suite of species rely on a variety of habitats including grasslands, brush, and forests. Badgers, in particular, are a strong indicator of grassland health and habitat connectivity because they require large, connected patches of healthy grasslands and xeric landscapes with sufficient prey. The presence of both common and rare species also indicates an intact community (that is, one that has its constituent members).

We used three metrics to evaluate mesocarnivore condition and trends: The presence of common species (Metric 1), breeding for these common species (Metric 2), and the presence of rare species (Metric 3). We assessed these metrics using records from Network partner agency monitoring efforts and the East Bay Municipal Utility District (EBMUD) mammal database from 2012 until 2020 covering different subregions of East Bay Stewardship Network (Network) lands within the area of focus. (See map, Chapter 1.) Data came from individual parks, reservoirs, recreation or management areas, and other open spaces (land units and parks) that we also refer to as “Network partner lands” throughout this chapter. A description of data sources and methodology can be found in Chapter 9.

What we learned reveals that the overall condition is “caution”, and the trend is “unchanging.” Metric 1 indicated that the condition of all common species was “good”, and the trend was “unchanging. Because Metric 2 was data deficient, we could not determine a condition or trend at this time. Finally, Metric 3 for rare species showed mixed results. For example, the ringtail’s condition was “significant concern” for all subregions. However, the badger was in good condition with an unchanging trend in all subregions. Long-tailed weasels were in good condition in the East Bay Hills and Mt. Diablo Range subregions but of significant concern in the Mt. Hamilton subregion. The western spotted skunk was in good condition for the Mt. Diablo Range subregion but of significant concern for the East Bay Hills and Mt. Hamilton subregions. It is important to note that these individual species’ conditions and trends were averaged to arrive at the overall score for each subregion presented in Table 10.2. We recognize that this methodology obscures some of these nuances among the species in each subregion.

Given the constraint of using only existing data, the evaluation also identified areas where not enough is known to draw meaningful conclusions and opportunities for future research and collaboration among land managers. There are past camera data that have not yet been analyzed and may provide evidence of breeding (images of young). Moving forward, the review and processing of ongoing camera data will provide needed additional records. These records will create a time series over a larger proportion of the area of focus, so our findings can be sufficiently comprehensive. Common mesocarnivore abundance metrics (assessed through occupancy and detection rates) and rare mesocarnivore distribution records over a longer time frame will help us assess current conditions. Trend assessments will then allow us to understand if local mesocarnivore populations are stable or declining. A primary goal of the analysis was to provide a benchmark against which managers can measure future changes and understand the likely trajectory of these species. Data gaps are described at the end of this chapter and identify where we can focus future work to best manage ecosystem health.

METRICS SUMMARY AT A GLANCE

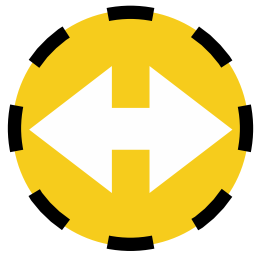
The table below summarizes the three metrics for mesocarnivores used in this NatureCheck ecological health assessment. Each metric, along with how we arrived at its condition, trend, and confidence, is thoroughly described in the Metrics in Detail section later in this chapter. (See Chapter 1 for definitions and thresholds for condition, trend, and confidence; other terminology used throughout this chapter; how metrics are being used for each indicator; and other project methodology.)

Table 10.1. All mesocarnivore metrics, with their respective condition, trend, and confidence for each subregion. Each metric is described in the Metrics in Detail section later in this document.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Metric 1: Presence of Common Mesocarnivores–Bobcat, coyote, and gray fox are documented in monitored Network partner lands for each subregion annually.			
Condition	Good (All)	Good (Bobcat, Coyote, Caution (Gray Fox)	Good (All)
Trend	Unchanging	Unchanging	Unchanging
Confidence	Moderate	Moderate	Moderate
Metric 2: Breeding– Breeding for three common mesocarnivores (bobcat, coyote, gray fox) occurs in the majority of Network partner lands in each subregion within the area of focus, as measured in five-year intervals.			
Condition	Unknown	Unknown	Unknown
Trend	Unknown	Unknown	Unknown
Confidence	Low	Low	Low
Metric 3: Rare Species–Rare mesocarnivores (badger, long-tailed weasel, spotted skunk, ringtail) are detected in each subregion in five-year intervals.			
Condition	Good (Badger, Long-tailed Weasel) Significant concern (Spotted Skunk, Ringtail)	Good (Badger, Long-tailed Weasel, Spotted Skunk) Significant concern (Ringtail)	Good (Badger) Significant concern (Ringtail, Spotted Skunk, Long-tailed Weasel)
Trend	Unchanging (Badger) Unknown (Other rare species)	Unchanging (Badger) Unknown (Other rare species)	Unchanging (Badger) Unknown (Other rare species)
Confidence	Moderate (Badger) Low (Other rare species)	Moderate (Badger) Low (Other rare species)	Moderate (Badger) Low (Other rare species)

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of the suite of mesocarnivores in the area of focus represented by the graphic below is based on the combined values of the individual metrics in Table 10.1. Each of these metrics is described in depth in the Metrics in Detail section of this chapter.



Condition: Caution (color: yellow)

Trend: Unchanging (symbol: horizontal arrow)

Confidence: Moderate (line around circle: dashed)

BACKGROUND

WHY IS THIS RESOURCE INCLUDED?

The presence, abundance, and population stability of mesocarnivores,[37] both common and rare, are indicators of a healthy ecosystem and can be used as proxies for overall ecosystem stability and integrity. Mesocarnivores are indicators of functional connectivity for medium-sized terrestrial species. Common mesocarnivores indicate the overall productivity of an ecosystem, and rare ones can indicate the presence of the unique niches associated with maintaining their presence. Determining the status of the rarest and least-known of our carnivore species that may be on the brink of, or already have become, extirpated is also key in assessing the health of East Bay ecosystems. Of the rare mesocarnivores, the American badger (*Taxidea taxus*) is a California species of special concern, and the ringtail (*Bassariscus astutus*) is a California fully protected species. The spotted skunk (*Spilogale gracilis*), ringtail and long-tailed weasel (*Mustela frenata*) remain data deficient and their current status, distribution, and population trends are unknown; however, they are members of this community and thereby represent “intactness.” We hope to have a better understanding of their current status by including them here.

[37] Small to mid-sized species in the Order Carnivora (Roemer et al. 2009).

It is also important to include a suite of mesocarnivores because no single dominant species can indicate a stable community structure. This is evidenced by mesocarnivore release (when one species becomes abundant relative to the others), which can occur in the absence of top trophic-level carnivores. Including a suite of mesocarnivores also represents a variety of habitats. The bobcat (*Lynx rufus*) prefers open areas, brush, and moderate canopy forests. The gray fox (*Urocyon cinereoargenteus*) is considered arboreal but also uses a variety of other habitats. The coyote (*Canis latrans*), badger, and long-tailed weasel require grasslands and prefer open habitats. These common mesocarnivore species (bobcat, coyote, gray fox) indicate overall ecosystem productivity, while the rare species (badger, ringtail, long-tailed weasel, spotted skunk) can indicate the presence of the unique ecological niches necessary to maintain their populations.

DESIRED CONDITION AND TREND

Common species (bobcat, coyote, gray fox): Common species are present in the habitats where they are expected to occur, and their abundance is stable or increasing within monitored Network partner lands in each subregion.[38]

Rare species (badger, ringtail, long-tailed weasel, spotted skunk): The presence of each rare species within each subregion is documented every five years.

CURRENT CONDITION AND TREND

Condition: Caution

Trend: Unchanging

Confidence: Moderate

Common species: Bobcat, coyote, and gray fox were detected in each subregion of monitored Network partner lands in the area of focus between 2012 and 2020 (records from camera studies and mammal database; see Appendix G, Data Assembly for Mammal Indicators, for more details on the studies and findings). These species are considered present in many of the parks and lands throughout the area of focus (see map, Chapter 1.); however, we do not know if their populations are stable, declining, or increasing.

Rare species:

- The **badger** was detected in 2020 on monitored Network partner lands in each subregion where it had been previously detected. This shows that at least in these lands, the badger is

[38] A systematic approach to camera trapping and data management is needed to determine trends.

present (good condition). How widespread the badger currently is in the area of focus and the stability of its populations are not known.

- The **ringtail** was detected more than five years ago (1997) in the East Bay Hills subregion.
- The **long-tailed weasel** was detected within the past five years (2018) in the East Bay Hills subregion (East Bay Municipal Utility District [EBMUD] mammal database) and in the Mt. Diablo Range[39].
- The **spotted skunk** was detected in the Mt. Diablo subregion[40] .

This overall condition, trend, and confidence is the average of the condition, trend, and confidence for common mesocarnivore species in each subregion as shown in Table 10.2. The metrics described in the Metrics in Detail section of this chapter were combined to obtain this current condition, trend, and confidence. They give us a way to measure the difference between what is described in this section (i.e., how things are now) and the desired condition and trend described in the preceding section (i.e., what we think "healthy" is for this indicator).

Table 10.2. Overall mesocarnivore condition, trend, and confidence for each subregion in the area of focus. The scores for each species included in a given metric were averaged for each subregion.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Condition	Caution	Good	Caution
Trend	Unchanging	Unchanging	Unchanging
Confidence	Moderate	Moderate	Moderate

STRESSORS

Several ecological and anthropogenic factors affect the health of these indicators. These include:

Historical Impacts: Fur trapping, hunting and predator control programs affected all mesocarnivores, most notably the coyote but also, the bobcat and gray fox.

Climate Change: Loss of habitat due to wildfire and habitat degradation due to drought conditions are likely to be both directly and indirectly affecting mesocarnivore populations on Network partner lands and nearby areas.

Pollution/Contaminants: Exposure to rodenticides is considered to have deleterious effects on mesocarnivores both by direct mortality (e.g., from ingestion of poisoned prey) and indirect mortality

[39] This detection was from the Vasco Road Amphibian Undercrossing Pilot Study (2019)

[40] This detection was from the Vasco Road Amphibian Undercrossing Pilot Study (2019)

(e.g., from long-term exposure to poisoned prey, leading to ill health, liver damage, and decreased immune function).

Direct Human Impacts: While hunting is prohibited on all Network partner lands, fur trapping on adjacent lands continues to threaten these mesocarnivores. All species, except the ringtail, have bag limits during certain times of the year. Coyotes can be legally shot or poisoned at will, and depredation permits are issued for gray fox and bobcat for taking livestock including chickens. Badgers can also be taken under the California Fish and Game Code. Exposure to human activity can affect foraging, breeding, and raising young for these shy carnivores. Mesocarnivores, particularly the badger, are subject to road mortality.

Habitat Disturbance/Conversion/Loss: Loss of habitat and connectivity through land-use change (including roads and highways) has affected mesocarnivore species by decreasing the ability of these species to disperse and breed.

CONDITION AND TRENDS ASSESSMENT

METRICS IN DETAIL

This analysis relied upon camera trap records from six different studies as well as records from the East Bay Municipal Utility District (EBMUD) mammal database (staff observations with locations and dates). The six studies included 48 camera locations in the East Bay Hills subregion (2016–2020), 31 in the Mt. Diablo Range subregion (2017–2020), and 54 in the Mt. Hamilton subregion (2012–2020) (see Chapter 9, Figure 9.1). Available data records were aggregated, but it is important to note that these studies were not standardized in terms of how image records were recorded or managed. Additionally, the number of trap nights were not reliably determined for all studies, so detection rates could not be calculated and compared across studies.

Total annual detections (records) for common (bobcat, coyote, and gray fox) and rare (badger) mesocarnivores were converted to 1s (detected) or 0s (not detected) in the monitored parks or land units shown in Figure 10.1 – 10.4. In the case of EBMUD land units in the East Bay Hills, records from the mammal database were used (see Table 11.3). Unmonitored Network partner lands (no camera trap effort with results) were shown as No Data. Each subregion is considered separately to determine condition, trend and confidence, and then these findings are combined for the entire area of focus.

Badgers are considered rare because they occur at very low densities relative to other mesocarnivores and they are extant (present) in the area of focus. Long-tailed weasel and the spotted skunk were detected on Network partner lands from outside studies and were not detected as part of this effort. One record of the ringtail was obtained from the EBMUD database.

Metric 1: Presence of Common Mesocarnivores (Bobcat, Coyote, Gray Fox)

Rationale: The presence of this suite of common mesocarnivore species (bobcat, coyote, and gray fox) is a sign of overall ecosystem productivity. Therefore, a way to measure ecological health is to see if Network partner lands are supporting these species and if they are detected annually.

Condition Goals: Bobcat, coyote,[41] and gray fox are documented within monitored Network partner lands for each subregion annually.

Current Baseline: Bobcat, coyote, and gray fox were detected in each subregion but not in all Network partner lands and not in all years (total detections for the area of focus included 3,756 bobcat records, 15,061 coyote records, and 2,260 gray fox records; see Table 9.5a in Mammal Introduction and Figures 10.1, 10.2, and 10.3; see Appendix G, Data Assembly for Mammal Indicators, Tables 4a, 4b, and 4c for annual tallies of each of these species). We did not use tallied totals to determine abundance or trend because we could not standardize the findings by unit effort (number of detections per unit effort [trap nights]); instead, we converted these "total detections" to a 1 (detection) for the unit or park in which it was recorded (Table 10.3; Figures 10.1, 10.2, and 10.3).

Based on findings from the Network partner agency data for the monitored lands (Chapter 9, Figure 9.1) and the EBMUD mammal database, bobcats were detected in all 18 monitored Network partner lands (100%) (Figure 10.1 and Table 10.3). Coyotes were detected in 17 of the 18 monitored lands (94%): four of five units in the East Bay Hills (80%) (Figure 10.2 and Table 10.3), nine units (100%) in the Mt. Diablo Range, and four units (100%) in Mt. Hamilton. Gray foxes were detected in nine of 18 monitored lands (50%): four of five in the East Bay Hills (80%), three of nine in the Mt. Diablo Range (33%), and two of four in Mt. Hamilton (50%) (Figure 10.3 and Table 10.3).

Table 10.3. Detections (1s) and non-detections (0s) in monitored areas on Network partner lands for subregions within the area of focus. (Data are from 2012–2020; Figures 10.1–10.4.)*

Agency	Monitored Network Partner Lands	Park Code/ Land Unit	Bobcat	Coyote	Gray Fox
EBMUD	EBMUD Property	EB Property	1	1	1
EBMUD	Lafayette Reservoir	LAFRES	1	1	0
EBRPD	Sibley Volcanic	Sibley	1	1	1
EBMUD	San Pablo Reservoir	SPRES	1	0	1
EBRPD	Tilden (Nature Area)	Tilden	1	1	1
	East Bay Hills Total		***5/5***	***4/5***	***4/5***
CCWD	Altamont Subunit Altamont	AP-AP HMU	1	1	0
EBRPD	Clayton Ranch	CLRA	1	1	1
CCWD	Deer Valley East Subunit Deer Valley	DVE HMU	1	1	0
CCWD	Deer Valley West Subunit Deer Valley	DVW HMU	1	1	0

[41] Any interpretation of fluctuations in coyote occurrence should note that their numbers can be influenced both positively and negatively by humans; therefore, changes are not necessarily the result of ecosystem conditions.

Agency	Monitored Network Partner Lands	Park Code/ Land Unit	Bobcat	Coyote	Gray Fox
CCWD	Los Vaqueros	LV HMU	1	1	0
CCWD	Mountain House Subunit Altamont	AP-MH HMU	1	1	0
EBRPD	Morgan Territory	MOTE	1	1	1
CSP	Mount Diablo State Park	Mt. Diablo	1	1	1
EBRPD	Round Valley	ROVA	1	1	0
	Mt. Diablo Range Total		***9/9***	***9/9***	***3/9***
CCWD	Corral Hollow HMU	CH HMU	1	1	0
CSP	Carnegie State Vehicular Recreation Area	CSVRA	1	1	1
CCWD	Grant Line Subunit Altamont	AP-GL HMU	1	1	0
EBRPD	Ohlone Wilderness	Ohlone	1	1	1
	Mt. Hamilton Total		***4/4***	***4/4***	***2/4***
	Total Sites with Detections		***18***	***17***	***9***
	Proportion of the Total Area of Focus		***1.00***	***0.94***	***0.50***

Network partner agency abbreviations: CCWD = Contra Costa Water District, CSP = California State Parks, EBMUD = East Bay Municipal Utility District, EBRPD = East Bay Regional Park District

*Note: Data for this table are from specified Network monitoring efforts only. We relied on these data so that we could establish an official baseline for measuring change. In particular, documentation of these mammals in community science data bases (such as iNaturalist) was not used because we don't want to encourage approaching these species for photographs. Also, some Network partner lands are not publicly accessible which could skew results. Lastly, lack of detection of mammals using that method is not a good indicator of absence due to the fact that they are rarely observed.

Condition Thresholds:

- *Good:* Mesocarnivores (bobcat, coyote, gray fox) are present in 50% or more of monitored parks and/or land units in each subregion in Network partner lands. These species show stable or increasing presence in monitored parks and land units in each subregion of Network partner lands. (An increase or decrease in coyote presence [percentage of parks with detections] should be assessed relative to the other mesocarnivores.)
- *Caution:* Common mesocarnivores are present in less than 50% of monitored parks or land units in each subregion of Network partner lands. The proportion of monitored areas on Network partner lands where common mesocarnivores were previously present decreases more than 30% in any subregion within a three-year period for one or more of the three common species. For example, if 50% of monitored parks in any one subregion recorded gray fox and bobcat present, but then the proportion of occupied parks decreased to 10% for gray fox and 20% for bobcat in a subsequent year, the condition threshold would be caution.
- *Significant Concern:* Common mesocarnivores are present in less than 20% of monitored Network partner lands in each subregion. The proportion of monitored areas on Network partner lands where common mesocarnivores were previously present declines more than

60% within any one subregion in a three-year period for one or more of the three common species.

Condition: Good (average of all conditions below)

Bobcat: Good (All subregions)

Coyote: Good (All subregions)

Gray fox: Good (East Bay Hills, Mt. Hamilton), **Caution** (Mt. Diablo Range). The gray fox was detected in three of nine monitored parks in the Mt. Diablo subregion (Table 10.4).

Table 10.4. Summary of common mesocarnivore condition, based on percent detected in monitored Network partner lands in each subregion. (Data are from 2012–2020; also see Figures 10.1–10.4 for detection maps.)

Common Mesocarnivore Species	East Bay Hills	Mt. Diablo Range	Mt. Hamilton	Condition
Bobcat	Detected (100%)	Detected (100%)	Detected (100%)	Good
Coyote	Detected (80%)	Detected (100%)	Detected (100%)	Good
Gray fox	Detected (80%)	Detected (33%)	Detected (50%)	Good

Trend: Unchanging (all subregions)

Detection history (see Table 5d in Appendix G, Data Assembly for Mammal Indicators) shows consistent detections from monitored parks with multiple years (time series); in this case, we have data to support our finding of an unchanging trend for this metric.

Confidence: Moderate (all subregions)

Monitoring data were recent and reliable but not comprehensive in their coverage of the Network partner lands in each subregion. Network partners provided records from camera traps studies and from the EBMUD mammal database, which were aggregated and used as the basis for this metric (Chapter 9, Tables 9.5a and 9.5b and Appendix G, Data Assembly for Mammal Indicators). These verifiable records cover 18 Network partner lands from 2012 to 2020 and represent high-quality reliable data, but we lacked this type of data from other parks and land units. The parks and land units for which we had these data represent only a portion of each subregion. If we had additional monitoring data from other parts of each subregion and better metadata and consistency between monitoring protocols, our confidence would have been "high."

Metric 2: Breeding

Rationale: Breeding (i.e., the presence of young) indicates that the habitat can support potential source populations of common mesocarnivores on Network partner lands and the surrounding landscape in the areas of focus. It also indicates that these Network partner lands are likely not functioning as population sinks. For the ecosystem to remain healthy and resilient, successful breeding ensures presence over time, whether individuals can immigrate from other areas.

Condition Goals: Breeding in the three common mesocarnivores occurs in the majority of Network partner lands in each subregion within the area of focus, as measured in five-year [42] intervals.

Current Baseline: The current condition is unknown because the aggregated camera data and EBMUD mammal database yielded no records of young (documentation) to indicate that breeding is occurring. However, because young animals were likely not identified as such (e.g., as young or juveniles) when images were categorized (processed), this lack of records is presumed to be an artifact of the way the data were processed, not necessarily an indication that no young were present. Camera trapping is a suitable method of capturing mesocarnivore breeding events. Records from recently implemented camera trapping studies as well as unprocessed images from past camera efforts should provide baseline data for this metric in the future, as instances of young will be noted and recorded during image processing.

Condition Thresholds:

- *Good:* Young of the three common mesocarnivores are documented in more than 50% of monitored Network partner lands in the area of focus within a five-year period.
- *Caution:* Young of the three common mesocarnivores are documented in 50% or fewer of monitored Network partner lands in the area of focus within a five-year period.
- *Significant Concern:* Young of only one or two of the three common mesocarnivores are documented in any one subregion of the area of focus within a five-year period.

The documentation of young in more than 50% of monitored Network partner lands indicates not just that adults are resident but also, that breeding is occurring.

Condition: Unknown (Bobcat, coyote, gray fox, all subregions).

The condition is unknown at this time due to lack of photo evidence of young common mesocarnivores described in the Current Baseline above. Camera trapping is a suitable method of documenting mesocarnivore breeding, but previous studies did not record age class.

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[42] Note that East Bay ecological health assessment expert workshop participants recommended a three-year time frame for detecting breeding. However, Network partners are anticipating revisiting the metrics every five years, so the timeframe for the metric was changed to reflect the evaluation frequency.

Trend: Unknown (Bobcat, coyote, gray fox, all subregions).

The trend is unknown at this time due to lack of photo evidence of young common mesocarnivores described in the Current Baseline above.

Confidence: Low (Bobcat, coyote, gray fox, all subregions).

Monitoring data did not include photographs or other evidence of young; however, this absence of detections is because young were not recorded, or if they were, we did not have access to that information.

Metric 3: Rare Species

Rationale: Healthy ecosystems support the entire suite of expected mesocarnivores, including rare species. Therefore, documenting rare species in each subregion within a five-year period (the past five years and within each five-year period moving forward) would reveal something about how intact these ecosystems are and might indicate the presence of the unique ecological niches necessary to maintain populations of relatively rare mesocarnivores.

Condition Goal: Rare mesocarnivores are detected in each subregion within five years.

Current Baseline: The badger was detected in each subregion and eight of 18 Network partner lands (44%), based on camera monitoring data and EBMUD records. This includes one of five Network partner lands in the East Bay Hills (20%), five of nine (56%) in the Mt. Diablo Range, and two of four (50%) in Mt. Hamilton (Table 10.3, Figure 10.4).

Although the badger is present in each subregion, it does not appear to be widespread in any, and is absent from some of the monitored Network partner land units where it would be expected to occur. For example, grasslands constitute a large proportion of the Mt. Diablo Range and Mt. Hamilton subregions which is typically suitable badger habitat. Therefore, the fact that badgers were not detected in Ohlone Wilderness and Carnegie State Vehicular Recreation Area (CSVRA) in the Mt. Hamilton subregion is unexpected.

According to the California Natural Diversity Database (CNDDB), the badger was detected in all subregions prior to 2016, but only in Mt. Hamilton after 2016 (albeit not on Network partner lands). However, our data indicate that the badger was detected in four of five Contra Costa Water District (CCWD) HMUs (2017–2020) in the Mt. Diablo Range subregion and both CCWD HMUs in the Mt. Hamilton subregion (2017–2020). Note that grasslands extent, connectivity, and prey availability were not assessed. Presumably, based on badger records and distribution, some connectivity likely remains between these subregions, although this inference is made with low confidence.

Network partner agency data records included a ringtail from 1997 (N37.929797, -122.236644; northeast of San Pablo Reservoir [EBMUD]) and a long-tailed weasel from 2018 (N37.7530, -122.070568; southeast of San Leandro Reservoir [EBMUD]) from the East Bay Hills subregion. No ringtails or long-tailed weasels were recorded from Network partner agency studies in the Mt. Diablo Range and Mt. Hamilton subregions. Spotted skunks were not documented in the Network's aggregated records from the area of focus.

Other non-Network partner agency records from the Vasco Road Amphibian Undercrossing Pilot Study (2019) included long-tailed weasel and spotted skunk detections in the Mt. Diablo Range subregion (January 2017–May 2018), with 10 instances of spotted skunks and two instances of long-tailed weasels recorded in culverts under Vasco Road. These culverts are located between Vasco Caves and Byron Vernal Pools, both part of the East Bay Regional Park District (EBRPD) system.

Condition Thresholds:

- *Good:* Each rare species is documented within each subregion at least once in each five-year period.
- *Caution:* Each rare species is documented within the area of focus but not in each subregion in a five-year period.
- *Significant Concern:* None of the rare species is documented within the area of focus in a five-year period.

It is worth noting that rare species are not as commonly detected using camera monitoring and that targeted surveys (such as spotlighting) may be needed to detect these rare species. However, given longer monitoring timeframes, they may be documented. Moving forward, we will be evaluating detections for longer monitoring periods, allowing us to collect more information on the suite of mesocarnivores (including rare ones) present in the area of focus.

Table 10.5. Summary of rare mesocarnivore detection, in monitored Network partner lands in each subregion. (Data are from 2012–2020; also see Figures 10.1–10.4 for detection maps.)

Rare Mesocarnivore Species	East Bay Hills	Mt. Diablo Range	Mt. Hamilton	Condition
Badger	Detected	Detected	Detected	Good
Ringtail	Detected (1997)	Not Detected	Not Detected	Significant Concern
Long-tailed weasel*	Detected (2018)	Detected (2018)	Not Detected	Caution
Spotted skunk*	Not Detected	Detected (2018)	Not Detected	Caution

*These species were detected in Mt. Diablo Range in 2018, however, they were not detected as part of the Network partners' monitoring effort. These rare species are more difficult to detect with cameras and therefore this external data has included in the overall evaluation.

Condition: Caution (average of all conditions below)

Badger: Good (all subregions)

The badger was detected in all subregions, so it met the threshold for "good."

Long-tailed weasel: Good (East Bay Hills, Mt. Diablo Range), **Significant Concern** (Mt. Hamilton).

The long-tailed weasel was detected in the East Bay Hills in 2018 (within five years of this analysis) and from a record in the Mt. Diablo Range subregion (2018), which meets the "good" threshold. The long-tailed weasel was not detected in the Mt. Hamilton region making it "significant concern" for this subregion.

Western spotted skunk: Good (Mt. Diablo Range), **Significant Concern** (East Bay Hills, Mt. Hamilton).

The western spotted skunk was detected in the Mt. Diablo Range subregion (2018), meeting the "good" threshold.

Ringtail: Significant Concern (all subregions)

The ringtail record from the East Bay Hills subregion is more than five years old (from 1997), and this puts it in the "significant concern "condition.

Trend: Unchanging (average of all trends below)

Badger: Unchanging (all subregions)

The badger was detected in 2020 in monitored parks where they had been detected previously; in no case was a badger not detected in a monitored park within Network partner lands where it had been detected previously (Table 10.5).

Long-tailed weasel, western spotted skunk, ringtail: Unknown (all subregions)

Observations for these species were not associated with a time series of other detections, so we were not able to determine a trend, such as consistent presence in five-year increments.

Confidence: Low (average of all confidence levels below)

Badger: Moderate (all subregions)

Monitoring data were recent and reliable but not did not comprehensively cover Network partner lands in each subregion.

Long-tailed weasel, western spotted skunk, ringtail: Low (all subregions)

Monitoring was insufficient in terms of its comprehensiveness, both in time and space.

OTHER METRICS CONSIDERED BUT NOT INCLUDED

Additional metrics were considered for evaluating the American badger including breeding and habitat suitability and connectivity. However, these metrics are data deficient and we lacked the information necessary to evaluate them. More information on grassland suitability will be evaluated as part of the California ground squirrel indicator and in the overall vegetation health of the area of focus.

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

- Some Network partner lands were not monitored, so no Network partner agency data were available to evaluate species presence/absence in those areas (see Figures 10.1–10.4, gray areas).
- Common species were not recorded in a systematic manner, making it impossible to get an accurate assessment of abundance for areas monitored using camera traps.
- The lack of a central database precluded timely data analysis, as data acquisition required a high level of effort (e.g., information recorded in reports required pulling data from Microsoft Word tables).
- The lack of useful metadata (e.g., data record location, date, time, and level of survey effort) precluded useful analyses in some instances.
- Unprocessed data (uncatalogued images and siloed raw data) were not available for this assessment.
- The lack of systematic surveys across each subregion means we do not have useful real-time baselines upon which to measure change.

PAST AND CURRENT MANAGEMENT

Monitoring for species such as the San Joaquin kit fox and puma have incidentally recorded other carnivores as well as other studies explicitly included carnivores as the target species, which provided the records used for this analysis. From these and other efforts, ten camera studies conducted by Network partners were identified as potentially able to provide information for this ecological health assessment; these efforts included 299 camera locations in the area of focus (71 in the East Bay Hills subregion, 75 in the Mt. Diablo subregion, and 144 in the Mt. Hamilton subregion (Chapter 9, Figure 9.1). Of these, six, plus the EBMUD mammal database, provided records used for this data assembly effort (Chapter 9, Table 9.4). These six studies included 48 cameras in the East Bay Hills subregion (2016–2020), 31 in the Mt. Diablo Range subregion (2017–2020), and 54 in the Mt. Hamilton subregion (2012–2020).

Current studies that were identified but did not contribute records to the analysis for this chapter include post-fire monitoring (Mt. Diablo Range subregion) and a puma study (East Bay Hills and Mt. Hamilton subregions). Data from these projects will help illuminate future species-specific occupancy for target mesocarnivores and document breeding, as well as provide evidence of the four rare mesocarnivores, should they be detected (Chapter 9, Figure 9.1). This will give us more information and allow us to set baselines and current conditions as well as to assess trends over time. Current and ongoing camera trapping projects (e.g., CCWD's kit fox monitoring and the California State Parks (CSP) Large Mammal Occupancy Study at CSVRA) will also continue to provide data that may inform trends, reveal presence/absence, and document young for future updates to this chapter.

Also, additional unprocessed images from camera studies included here could be used in future updates. These include EBMUD ad hoc cameras (six), EBRPD carnivore research (Sunol-Ohlone, 2018–2020), CCWD San Joaquin kit fox monitoring (prior to and after 2017), and CSP CSVRA camera records (2014–2016) to update the baseline condition assessments and provide findings to assess trends (are conditions improving or declining, for example).

Sensor coverage for the Post-Fire Monitoring Study including audio recorders (AudioMoths, results not included in this analysis) will yield audio files for coyotes, which could serve as an additional source of data to assess coyote presence and activity.

POTENTIAL FUTURE ACTIONS

- Implement metadata standards and survey protocols to improve data quality and its usefulness in the evaluation of current conditions.
- Pursue adequate survey coverage to fill data gaps in survey efforts for each subregion and to improve confidence in establishing baseline conditions.
- Process unprocessed data and centralize data access to leverage efforts toward establishing current conditions with high confidence.

- Aggregate and then incorporate additional Network partner resources for some species in future assessments (e.g., the long-tailed weasel, which could be available in the Alameda whipsnake survey reports [T. Lim, personal communication, 2019]).

- Locate additional sources for mesocarnivore data records (e.g., the Eastern Contra Costa County Habitat Conservation Plan).

KEY LITERATURE AND DATA SOURCES

Literature

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Partner Agency Data Sources

- East Bay Municipal Utility District (EBMUD), Mammal Database

- East Bay Regional Park District (EBRPD), Carnivore Research (Tilden-Sibley, Eastern Contra Costa County [ECCC], Sunol-Ohlone)

- Contra Costa Water District (CCWD), San Joaquin Kit Fox Monitoring (Habitat Management Units)

- California State Parks (CSP), Large Mammal Occupancy Study (Carnegie State Vehicular Recreation Area), and Felidae Conservation Fund Study (Mount Diablo State Park)

Additional details about all of these data sources are provided in Appendix G, Data Assembly for Mammal Indicators.

CHAPTER AUTHORS AND KEY CONTRIBUTORS

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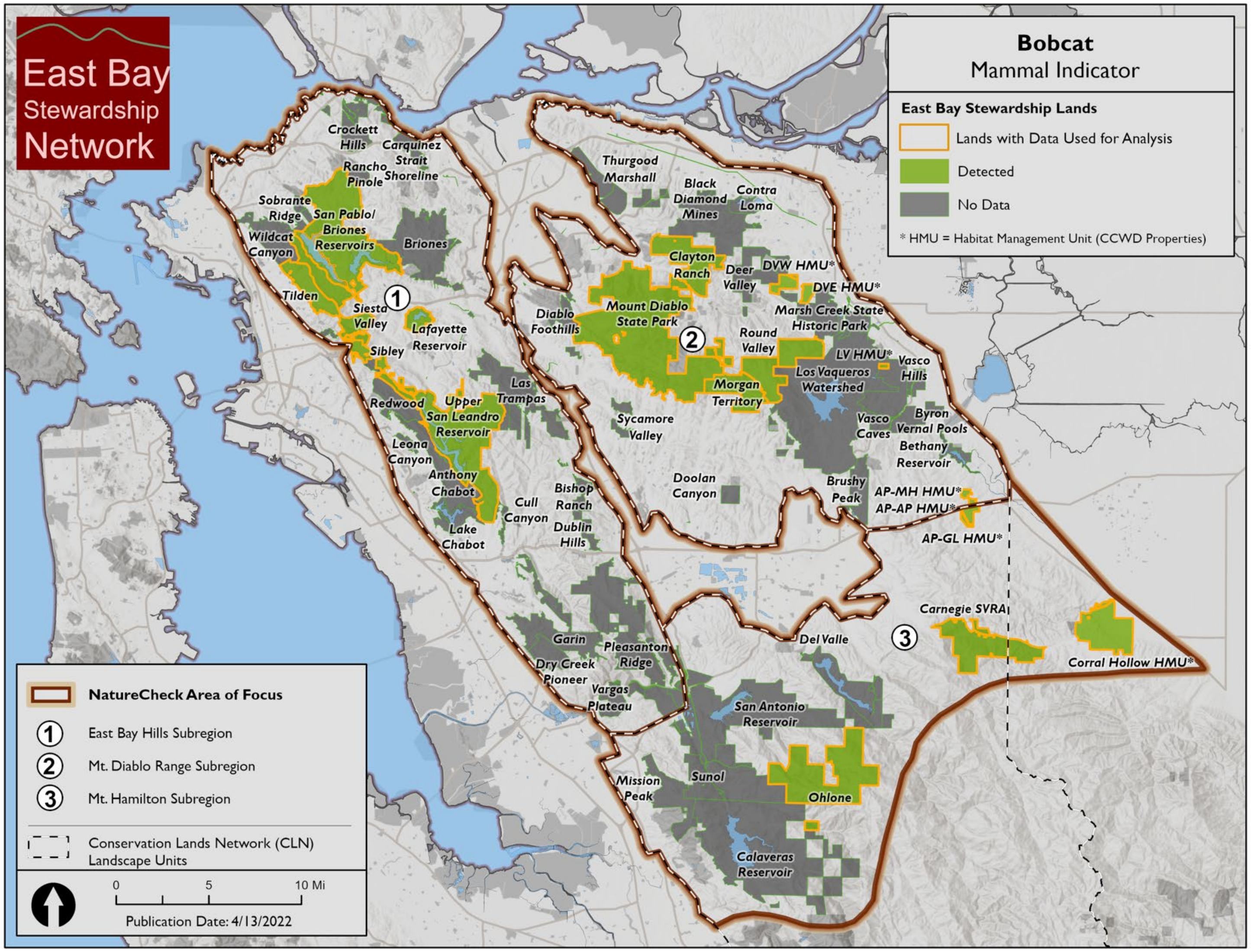


Figure 10.1. Bobcat detected (green) in monitored Network partner lands (orange border) for subregions within the area of focus (2012–2020; see Table 9.4.). Unmonitored Network partner lands ("No Data") shown in dark gray.

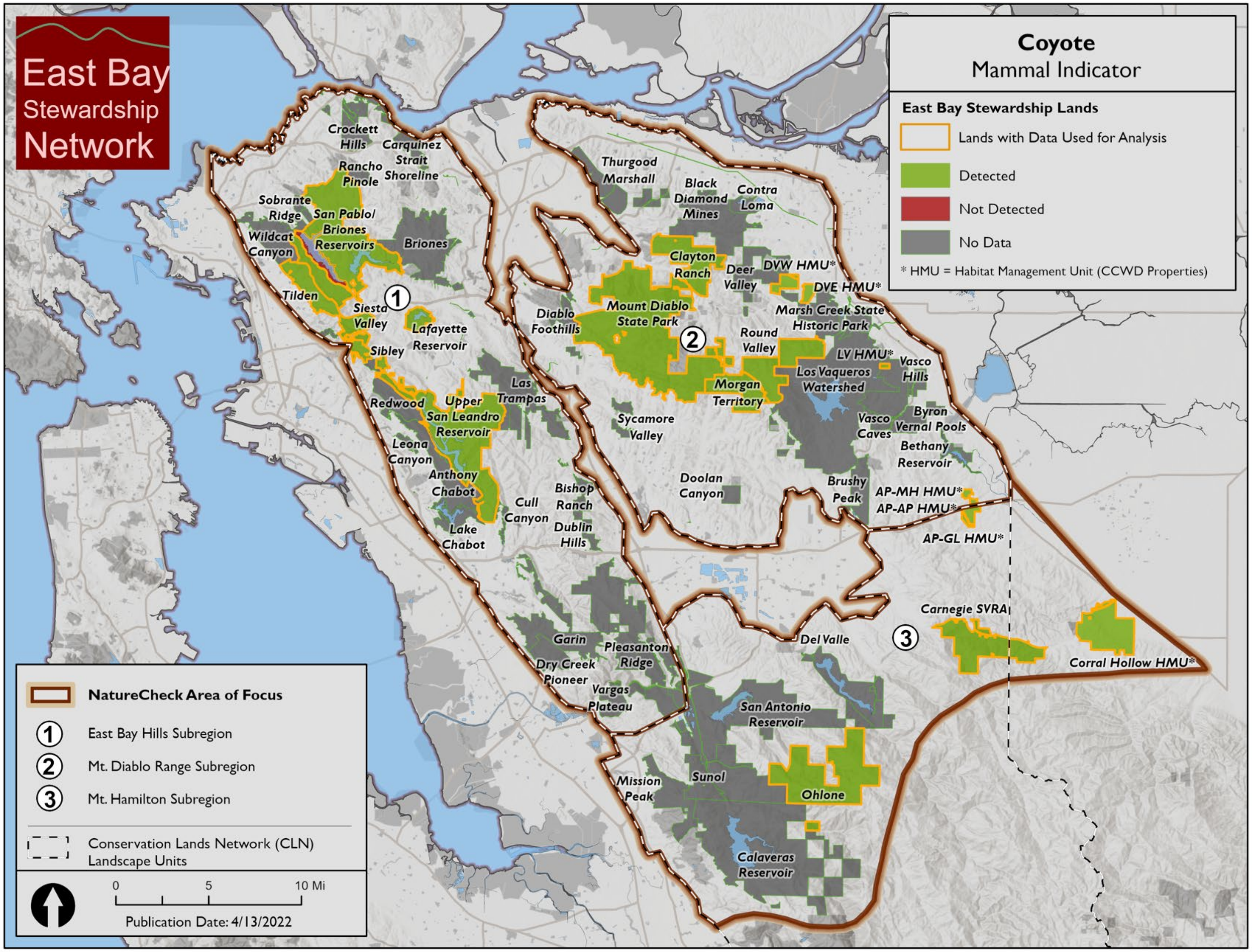


Figure 10.2. Coyote detected (green) or not detected (red) in monitored Network partner lands (orange border) for subregions within the area of focus (2012–2020; see Table 9.4). Unmonitored Network partner lands ("No Data") shown in dark gray.

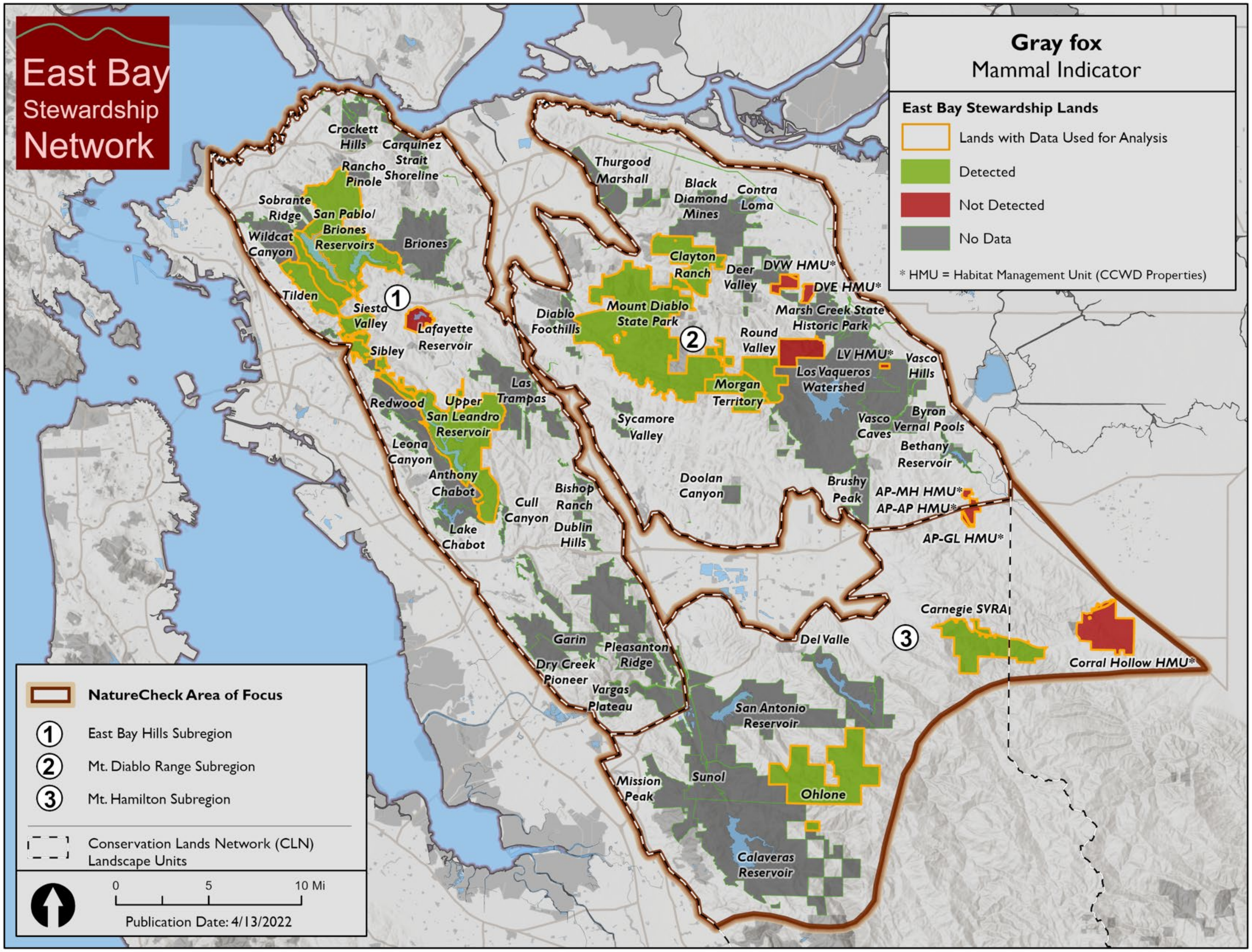


Figure 10.3. Gray fox detected/not detected in monitored Network partner lands (orange border) for subregions within the area of focus (Data are from 2012–2020; see Table 9.4Unmonitored Network partner lands ("No Data") shown in dark gray.

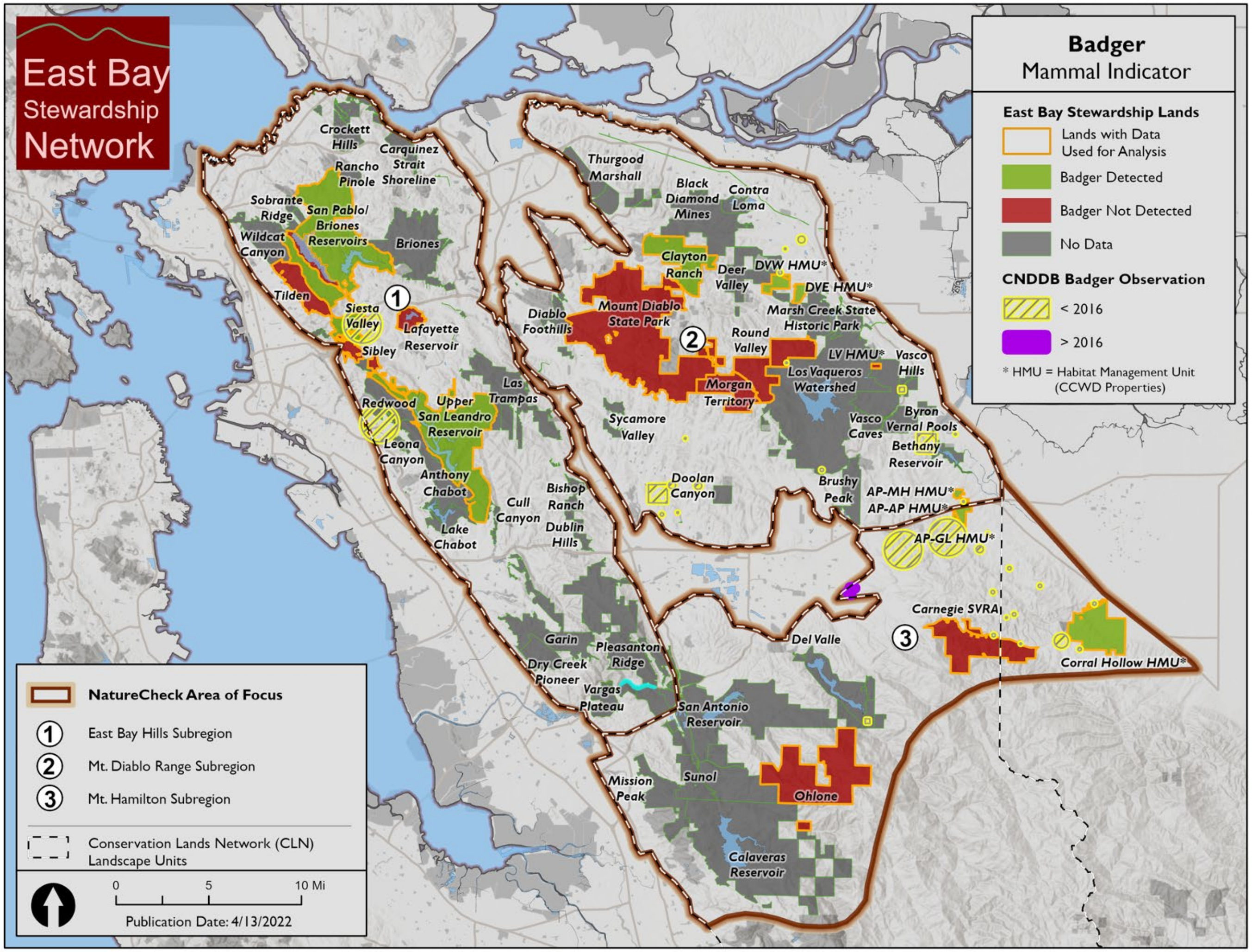


Figure 10.4. Badger detected(green) or not detected (red) in monitored Network partner lands (orange border) for subregions within the area of focus (Data are from 2012–2020; see Table 9.4.). Unmonitored Network partner lands ("No Data") shown in dark gray. Other data sources include CNDDB Badger Observations (shown before 2016 and 2016 and later).

CHAPTER 11. PUMA (*PUMA CONCOLOR*)

EXECUTIVE SUMMARY

This ecological health indicator focuses on the puma (*Puma concolor*), a large, charismatic species that can reveal a variety of information about habitat quality and connectivity as well as the species it preys upon within the three subregions of East Bay Stewardship Network (Network) lands. (See map, Chapter 1.) Within these subregions, data came from individual parks, reservoirs, recreation or management areas, and other open spaces that we refer to as "Network partner lands" throughout this chapter. A description of data sources and methodology can be found in Chapter 9.

We used two metrics to evaluate the puma's condition and trend within the three subregions: detecting its presence (Metric 1) and documenting breeding through records of young (Metric 2). We analyzed these metrics using Network partner agency monitoring studies data and an East Bay Municipal Utility District (EBMUD) mammal database (see Chapter 9).

What we learned reveals that the overall condition is "caution" and the trend is "unchanging." The data we used have consistently recorded puma presence in the East Bay Hills and Mt. Hamilton subregions; however, the puma remains undetected in the Mt. Diablo Range subregion despite similar monitoring efforts, which strongly suggests that it may be absent there.

A primary goal of the analysis was to provide a benchmark against which managers can measure future changes and understand the likely trajectory of this species. Baseline data and analyses can be also used to identify projects that achieve multiple benefits for this species.

Given the constraint of using only existing data, the evaluation identified portions of Network lands that lack monitoring records but that would provide a more comprehensive picture of the status of the puma on those lands. In the future, it will be important that these data are provided from monitoring efforts and are not just "presence" only. Monitoring data provides the ability to set a baseline upon which to measure change because it includes the level effort. A case in point is the lack of puma detections in the Mt. Diablo Range subregion despite monitoring efforts to do so. Opportunities for future research and monitoring could provide more information for a greater proportion of the study area and facilitate collaboration between land managers. These data gaps are identified at the end of this chapter and may be areas on which attention should be focused in the future.

METRICS SUMMARY AT A GLANCE

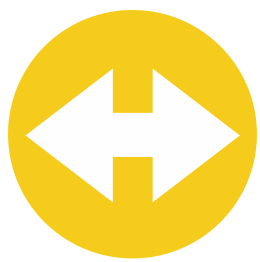
The table below summarizes the two puma metrics used in this NatureCheck ecological health assessment. Each metric, along with how we arrived at its condition, trend, and confidence, is thoroughly described in the Metrics in Detail section later in this chapter. (See Chapter 1 for definitions and thresholds for condition, trend, and confidence; other terminology used throughout this chapter; how metrics are being used for each indicator; and other project methodology.)

Table 11.1. All puma metrics, with their respective condition, trend, and confidence for each subregion. Each metric is described in the Metrics in Detail section later in this document.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Metric 1: Presence–Puma documented annually in each subregion.			
Condition	Good	Significant Concern	Good
Trend	Unchanging	Unknown	Unchanging
Confidence	Moderate	Moderate	Moderate
Metric 2: Breeding–Young puma documented within a three-year period in each subregion.			
Condition	Unknown	Unknown	Unknown
Trend	Unknown	Unknown	Unknown
Confidence	Low	Low	Low

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of the puma in the area of focus represented by the graphic below is based on the combined values of the individual metrics presented in Table 11.1. Each of these metrics is described in depth in the Metrics in Detail section later in this chapter.



Condition: Caution (color: yellow)

Trend: Unchanging (symbol: horizontal arrow)

Confidence: Low (line around circle: none)

BACKGROUND

WHY IS THIS RESOURCE INCLUDED?

At the time of publication of this report, the California Department of Fish and Wildlife (CDFW) had the following status for puma:

> In July 2019, the Center for Biological Diversity and the Mountain Lion Foundation petitioned the Fish and Game Commission to list mountain lions as a candidate species under the California Endangered Species Act (CESA) within a proposed evolutionarily significant unit (ESU) located in Southern California and the central coast of California. In April 2020, the Commission found that listing of this ESU may be warranted and designated mountain lion

within the ESU as a candidate species. As a result, CDFW is now completing a 12-month status review of mountain lions within the proposed ESU. At the end of the review, CDFW will make its recommendation on listing to the Commission. Under CESA, species classified as a candidate species are afforded the same protection as listed species. As a result, mountain lions in this proposed ESU are CESA-protected during the review period. (source: https://wildlife.ca.gov/Conservation/Mammals/Mountain-Lion).

The central coastal ESU includes Network partner lands in the area of focus (see map, Chapter 1), making the puma here a state-protected species at the time of this assessment.

Despite their listed status in certain parts of the state, pumas are found in virtually all habitats in California that have a sufficient prey base. One of the primary reasons we included this species is because, as a top carnivore, the puma is thought to play an important role in structuring the ecosystems where it occurs by influencing the abundance, distribution, and behavior of prey, other carnivores, and scavenger species (Ripple and Beschta 2006, Allen et al. 2014, Yovovich et al. 2021). The puma is also used as a proxy for connectivity for terrestrial vertebrates at both local and regional scales, in part because it has a large home range (80 to 250 sq km) and requires a sufficiently large ungulate prey base, which in turn indicates adequate forage, connectivity, and breeding habitat for large-bodied herbivores.

DESIRED CONDITION AND TREND

The desired condition for this species is that it is present and breeding within each subregion at least once every three years (Metrics 1 and 2), and that this condition is stable. Another desirable condition, one not measurable with currently available data, is that pumas are able to move between subregions and immigrate into the area of focus from neighboring populations to the south and west; these include the Santa Cruz population. Combined, these three measures of health would indicate that the area of focus supports a puma population.

CURRENT CONDITION AND TREND

Condition: Caution

Trend: Unchanging

Confidence: Low

Published accounts of the puma's geographic range within the area of focus included only the Mt. Hamilton subregion and did not include the East Bay Hills and Mt. Diablo Range subregions (Zeiner et al. 1990). However, some historical records suggest that the puma did, at one time, occupy the entirety of the area of focus (CDFW 2019, Dellinger and Torres 2020). For example, bounty records suggest that the puma was nearly extirpated from parts of the greater Bay Area, such as the Santa

Cruz Mountains and East Bay Hills, by the 1930s (Division of Fish and Game of California 1932). The estimated carrying capacity based on the size (area) of potentially suitable habitat for the three subregions indicates that at least a few individuals could be supported (Table 11.2). Pumas in the area of focus could also provide a link between neighboring populations.

There is some supporting evidence that pumas have been resident in the Mt. Hamilton subregion in the recent past. For example, collared pumas were studied on Mount Hamilton in the Mt. Hamilton Range (Hopkins 1989). The Bay Area Puma Project and the Felidae Conservation Fund have documented pumas in all three subregions in the last 10 years, and a few roadkill have been recorded in each subregion. Depredation permits and take records also document some take from within the area of focus (CDFW 2019). Pumas have been documented crossing Highway 24 above the Caldecott Tunnel, and individuals have been documented moving between two East Bay Regional Park District (EBRPD) parks—Sibley Volcanic and Tilden—in the East Bay Hills subregion (S. Bobzien, personal communication, 2020). Pumas have also been documented crossing under Highway 680 near the Calaveras Reservoir (S. Bobzien, personal communication; documented by F. Schilling, UCD) and a mountain lion got hit and killed on Calaveras Road about 3-4 years ago near the SFPUC Sunol Valley Water Treatment Plant. (Mia Ingolia, SFPUC, pers. comm., 2022).

Table 11.2. Estimated puma carrying capacity for adults only (male and/or female) and adults (male and female) with one offspring for each subregion, based on area (km2).

Subregion	Area (km^2)	Estimated Carrying Capacity (1.2 per 100 km^2) Number of adults	Estimated Carrying Capacity (2.2 per 100 km^2) Number of adults with one young
East Bay Hills	313	3.8	6.9
Mt. Diablo Range	312	3.7	6.9
Mt. Hamilton	280	3.4	6.2
Total	***905***	***10.9***	***19.9***

In general, puma-movement data are lacking for the area of focus. However, the scant genetic data that have been collected from this population indicates that pumas living here are most closely related to those living in the Santa Cruz Mountains, an area where the species is threatened by low genetic diversity (Gustafson et al. 2018).

The current condition, trend, and confidence are the average of the condition, trend, and confidence for the puma in each subregion as shown in Table 11.3. The suite of metrics described in depth in the Metrics in Detail section of this chapter was combined to obtain this current condition and trend. These metrics are how we are measuring the difference between what is described in this section (i.e., how things are now) and the desired condition and trend in the preceding section (i.e., what we think "healthy" is for this indicator).

Table 11.3. Overall puma condition, trend, and confidence for each subregion in the area of focus.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Condition	Good	Significant Concern	Good
Trend	Unchanging	Unknown	Unchanging
Confidence	Low	Low	Low

STRESSORS

Several ecological and anthropogenic factors affect the health of this indicator. These include:

Historical Impacts: California's puma numbers were severely reduced during the years when the species was listed as a bountied predator, as well as afterward, when take was unregulated. Though it is now protected statewide, it continues to be lawfully killed when conflicts with humans arise such as livestock predation. Increasing residential and business development and the concomitant road and highway density have also resulted in habitat loss and decreased connectivity. Human intolerance has resulted in the puma being extirpated from many areas.

Climate Change/Fire Regime Change: Drought and wildfire exacerbate pressure from other stressors by reducing habitat suitability and permeability, as well as by reducing prey density (Jennings et al. 2016). These dynamics may lower carrying capacity. Research is currently being conducted to investigate the degree of impact to wildfire on wildlife.

Pollution/Contaminants: Primary and secondary poisoning from toxicants (e.g., rodenticides, pesticides, poison baits associated with marijuana production) can reduce puma numbers. Anticoagulant toxicity may kill pumas directly, and elevated levels of rodenticide exposure may increase puma mortality from advanced mange disease (Riley et al. 2014).

Direct Human Impacts: In addition to the impacts described above, road mortality and poaching both result in puma deaths.

METRICS IN DETAIL

Puma detections on monitored Network partner lands (those with processed data from camera trapping studies) and also EBMUD lands with mammal database (staff observation) records from each subregion of the area of focus were tallied (see Chapter 9, Table 9.5a) and converted to a binary measure of "Detected" and "Not Detected" (see Figure 11.1, at the end of this chapter) or "yes" and "no" (Table 11.4). Areas with "No Data" were those lands that lacked camera effort (with processed camera records; see Figure 11.1, gray areas). The EBMUD mammal database also provided records for their land units in the East Bay Hills (staff observations considered reliable, not from camera efforts; Figure 11.1). Please note that elements of the monitoring effort (i.e., number of days cameras were deployed) were not available for several of the camera studies (see Chapter 9, Table 9.4, and Appendix G, Data Assembly for Mammal Indicators, for more details). In addition, camera numbers varied per site per year, and image data were processed differently for each study. The resulting total counts were not used in the analysis for these metrics because we could not standardize the number of images per unit effort.

Metric 1: Presence

Rationale: Documentation of puma presence in each subregion would establish that the species is extant here. Occurrence may also be useful, as it suggests some level of connectivity, dispersal, and reproduction.[43]

Condition Goal: Verified documentation of puma presence each year in each of the three subregions.

Current Condition: Pumas were detected in the East Bay Hills and Mt. Hamilton subregions in records obtained from studies conducted by the Network partner agencies (see Chapter 9, Table 9.5a and Appendix G, Data Assembly for Mammal Indicators, Table 4e, for time series on puma detections). The lack of records from the monitored parks in the Mt. Diablo Range subregion could be due to insufficient monitoring efforts and/or because there are few or no pumas present there; the species' current status is unknown in this subregion.

Network partner lands and cameras with puma detections were plotted (Figure 11.1) and tallied (see Chapter 9, Table 5a; see also Appendix G, Data Assembly for Mammal Indicators). Pumas were detected in seven of the 18 (39%) monitored land units or parks (Table 11.4). They were detected in the five land units or parks for which we have records in the East Bay Hills subregion (101 records; incidental puma observations from EBMUD properties [1992—2018]; Table 11.4; Figure 11.1). Two of four monitored parks (CSVRA [2017–2020] and Ohlone Wilderness [2012–2018]) produced 650 records from the Mt. Hamilton Range subregion. Despite camera trapping efforts in the Mt. Diablo Range subregion, there were no puma detections (31 cameras in nine areas [2017–2020]; see Chapter 9, Table 9.4 and Figure 9.1). Camera trapping effort, both by year and by number of cameras, was greater in both the East Bay Hills and Mt. Hamilton subregions relative to the Mt. Diablo Range subregion (54, 48, and 31 cameras, respectively; see Chapter 9, Table 9.4). However, other unverified observations (Figure 11.1) suggest possible puma presence within the Mt. Diablo Range subregion.

[43] R. Hopkins and Y. Wang, personal communication, 2020).

Table 11.4: Puma detection (yes = 1 or more records) on monitored Network partner lands in each subregion, including EBMUD records from their land units in the East Bay Hills subregion (2012–2020). Proportion (percentage) of total units with a "yes" for each subregion and for the area of focus.

Agency	Monitored Network Partner Land	Park Code	Puma Detected
EBMUD	EBMUD Property	EBProp	Yes
EBMUD	Lafayette Reservoir	LAFRES	Yes
EBRPD	Sibley Volcanic	Sibley	Yes
EBMUD	San Pablo Reservoir	SPRES	Yes
EBRPD	Tilden (Nature Area)	Tilden	Yes
	East Bay Hills Subregion		***5/5 (100%)***
CCWD	Altamont Subunit Altamont	AP-AP HMU	No
EBRPD	Clayton Ranch	CLRA	No
CCWD	Deer Valley East Subunit Deer Valley	DVE HMU	No
CCWD	Deer Valley West Subunit Deer Valley	DVW HMU	No
CCWD	Los Vaqueros	LV HMU	No
CCWD	Mountain House Subunit Altamont	AP-MH HMU	No
EBRPD	Morgan Territory	MOTE	No
CSP	Mount Diablo State Park	Mt Diablo	No
EBRPD	Round Valley	ROVA	No
	Mt. Diablo Range Subregion		***0/9 (0%)***
CCWD	Corral Hollow HMU	CH HMU	No
CSP	Carnegie State Vehicular Recreation Area	CSVRA	Yes
CCWD	Grant Line Subunit Altamont	AP-GL HMU	No
EBRPD	Ohlone Wilderness	Ohlone	Yes
	Mt. Hamilton Subregion		***2/4 (50%)***
	Total Sites with Detections		***7***
	Proportion of the Total Study Area		***0.39***

Network partner agency abbreviations: CCWD = Contra Costa Water District, CSP = California State Parks, EBMUD = East Bay Municipal Utility District, EBRPD = East Bay Regional Park District

Condition Thresholds:

- *Good:* Pumas are detected annually in each subregion.
- *Caution:* Pumas are not detected in one or more of the subregions in any given year.
- *Significant Concern:* Pumas are not detected in any of the subregions over a two-year period.

These thresholds are predicated on the idea that documenting puma presence in each subregion indicates that the species is extant in that subregion. This conclusion will be bolstered by Metric 2.

Condition: Caution (average of all conditions below)

Good (East Bay Hills, Mt. Hamilton)

Pumas were documented in both the East Bay Hills and Mt. Hamilton subregions as recently as 2020 (Figure 11.1), which meets the threshold for a condition of “good.”

Significant Concern (Mt. Diablo Range)

Pumas were not detected in the Mt. Diablo Range subregion in monitored Network partner lands.

Trend: Unchanging (average of all trends below)

Unchanging (East Bay Hills, Mt. Hamilton)

Pumas were detected in monitored parks in the East Bay Hills and Mt. Hamilton subregions from 2012 to 2020 (Figure 11.1), with some detections each year.

Unknown (Mt. Diablo Range)

Without detections for the Mt. Diablo Range subregion in the monitored parks, it is not clear if the monitoring was insufficient to detect any pumas that may be there, or that pumas are not there; there were no time series to support a trend.

Confidence: Moderate (all subregions)

Monitoring data (camera trap studies) and records from EBMUD lands were recent and reliable for a subset of Network partner agencies, which provides a benchmark against which to determine condition. These data contained detections from the Mt. Hamilton subregion (2012–2020) and from the East Bay Hills subregion (2016–2020) that provided a trend (showing an “unchanging” trend, with pumas detected annually). Despite recent camera trapping monitoring efforts in the Mt. Diablo Range subregion, which detected other carnivore species, no pumas were detected during those efforts. Recent and reliable monitoring data (i.e., from lands with presence/absence data due to some level of monitoring effort) were not available from more Network partner lands, so confidence is “moderate” due to the lack of comprehensive monitoring.

Metric 2: Breeding

Rationale: Successful breeding indicates that resident individuals and breeding females are likely in the area. This is particularly important because puma population stability is driven by the number of females (V. Yavovich, personal communication, 2021). Detecting adults without young may indicate that the subregion is only able to support transient or non-breeding adults, and bolsters assertions that the Mt. Diablo and potentially East Bay Hills subregions may be functioning as a sink (an opinion expressed by puma experts R. Hopkins, Y. Wang, and M. Elbroch, as well as others, during the workshop). Such an area, where local mortality is greater than the reproduction rate or where reproduction is not occurring, may be subject to population decline if pumas from other areas do not migrate there.

Condition Goal: Breeding is detected in each subregion at least once every three years, as documented by a mother with young, or just young.

Current Baseline: The current baseline is unknown because data (image records) of young pumas from camera studies were not documented.

Condition Thresholds:

- *Good:* Breeding is detected (likely via photos of a mother with young, or just young) in each subregion within three years.
- *Caution:* Breeding is not detected within one or more subregions within three years.
- *Significant Concern:* Breeding is not detected in two or more subregions within three years.

These thresholds relate to the idea that breeding indicates that pumas may be resident and able to reproduce, which is essential for a sustainable population.

Condition: Unknown (all subregions)

No current data were available to assess condition.

Trend: Unknown (all subregions)

No breeding-related time series documentation was available.

Confidence: Low (all subregions)

Monitoring data did not record young pumas as part of data processing.

OTHER METRICS CONSIDERED BUT NOT INCLUDED

We recognize that a regional connectivity analysis would be critical for understanding the health of puma populations in and around the area of focus and how the area of focus may act as a source or a sink for other areas; however, we have no data to inform this analysis at this time.

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

- Connectivity Study - We lack a study to establish if there is large-scale functional connectivity on the landscape for puma that includes documenting successful dispersal. M. Elbroch (January 2020) suggested that genetic metrics (scat or hair snares) can help with understanding connectivity and diversity, and others (V. Yovovich, S. Bobzien, and J. Brashares, January 2020) suggested including CDFW records for data sources.

- Modeling and Genetic Studies - There are sophisticated methods and modeling available to evaluate habitat connectivity, and genetic tools that can estimate dispersal or gene flow. These data can be difficult to collect without collaring and tracking individuals or building a large, multiyear genetic database. Scat-sniffing dogs can greatly enhance these efforts and this approach also requires a high level of effort.

- Population Study - At present, there are only a handful of genetic samples from the area of focus (Gustafson et al. 2019). Genetic samples and/or movement data provide information needed to understand functional habitat connectivity more broadly. Scat collection, hair snares, and tissue sampling would all be means of building a genetic dataset for the area. CDFW is also conducting research that will help build a statewide genetic dataset for pumas. Supporting this type of study could help shed light on the genetic structure of local populations (i.e., in the area of focus) as well. Finally, genetic mark-recapture studies would be an alternative method for estimating local population size, and long-term monitoring could provide data on population changes over time.

- Camera Data Processing - Some records from past and present camera studies were not available at the time data were assembled for this project; there is a lag time between collecting camera data and images and reviewing those photographs for use for an analysis.

- Best Management Practices for Camera Data - Metadata and best management practices in camera trapping greatly enhance our ability to monitor change over time. Well-designed studies with sufficient effort can provide abundance metrics to measure change over time. Because pumas occur at very low densities, camera traps need to cover sufficiently large areas in sufficient numbers to get meaningful confidence intervals.

PAST AND CURRENT MANAGEMENT, MONITORING, AND RESEARCH EFFORTS

Recently initiated landscape-level camera trap studies, which include the EBRPD Post-Fire Monitoring Study (40 cameras set up in November 2020 in burned and unburned areas in Round Valley, Morgan Territory, and Los Vaqueros Watershed [Contra Costa Water District (CCWD)] will provide a potential source of puma records, in addition to measuring differences in mammal communities between burned and unburned lands.

In 2020, Panthera and EBRPD initiated a study in the East Bay Hills and Mt. Hamilton subregions using camera traps to estimate wildlife abundance. This study established a 100-camera monitoring grid that will operate seasonally to provide data on several indicator species, including the puma. The photo data generated will be analyzed using a Space-to-Event and/or Time-to-Event modeling framework to estimate species abundance. The first year of data will provide a current population estimate for the puma, and continued monitoring could provide time-series data that are useful for determining local puma trends. Longitudinal data could allow land managers to assess whether local activities are influencing that trend. These data will also provide a way to document puma breeding in the East Bay Hills and Mt. Hamilton subregions. In addition to pumas, the cameras are set to reliably detect other species, and similar analyses could be performed for those species as well.

POTENTIAL FUTURE ACTIONS

- Participate in the previously described statewide efforts to collect genetic information on puma populations and the relatedness of pumas on Network partner lands and in neighboring populations.
- Support the identification and creation of wildlife corridors and highway crossings for wildlife. Related to this, assemble designated corridors for large mammals for this region and overlay them onto existing camera trap studies, which could verify both the puma's presence and use of corridors.
- Conduct other studies to infer population stability from age structure, possibly from camera data (J. Brashares, January 2020), and use roadkill and depredation as data sources to make inferences about demographics (Y. Wang, January 2020).[44]

KEY LITERATURE AND DATA SOURCES

Literature

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Partner Agency Data Sources

- East Bay Municipal Utility District (EBMUD), Mammal Database
- East Bay Regional Park District (EBRPD), Carnivore Research Studies (Tilden-Sibley, Eastern Contra Costa County [ECCC], Sunol-Ohlone)
- Contra Costa Water District (CCWD), San Joaquin Kit Fox Monitoring (Habitat Management Units)
- California State Parks (CSP), Large Mammal Occupancy Study (Carnegie State Vehicular Recreation Area), and Felidae Conservation Fund Study (Mount Diablo State Park)

Additional details about all of these data sources are provided in Appendix G, Data Assembly for Mammal Indicators.

Other Data Sources:

- Bay Area Puma Project (bapp.org/puma-sighting-map)
- Conservation Lands Network 2.0
- California Roadkill Observation System (https://www.wildlifecrossing.net/california/map)

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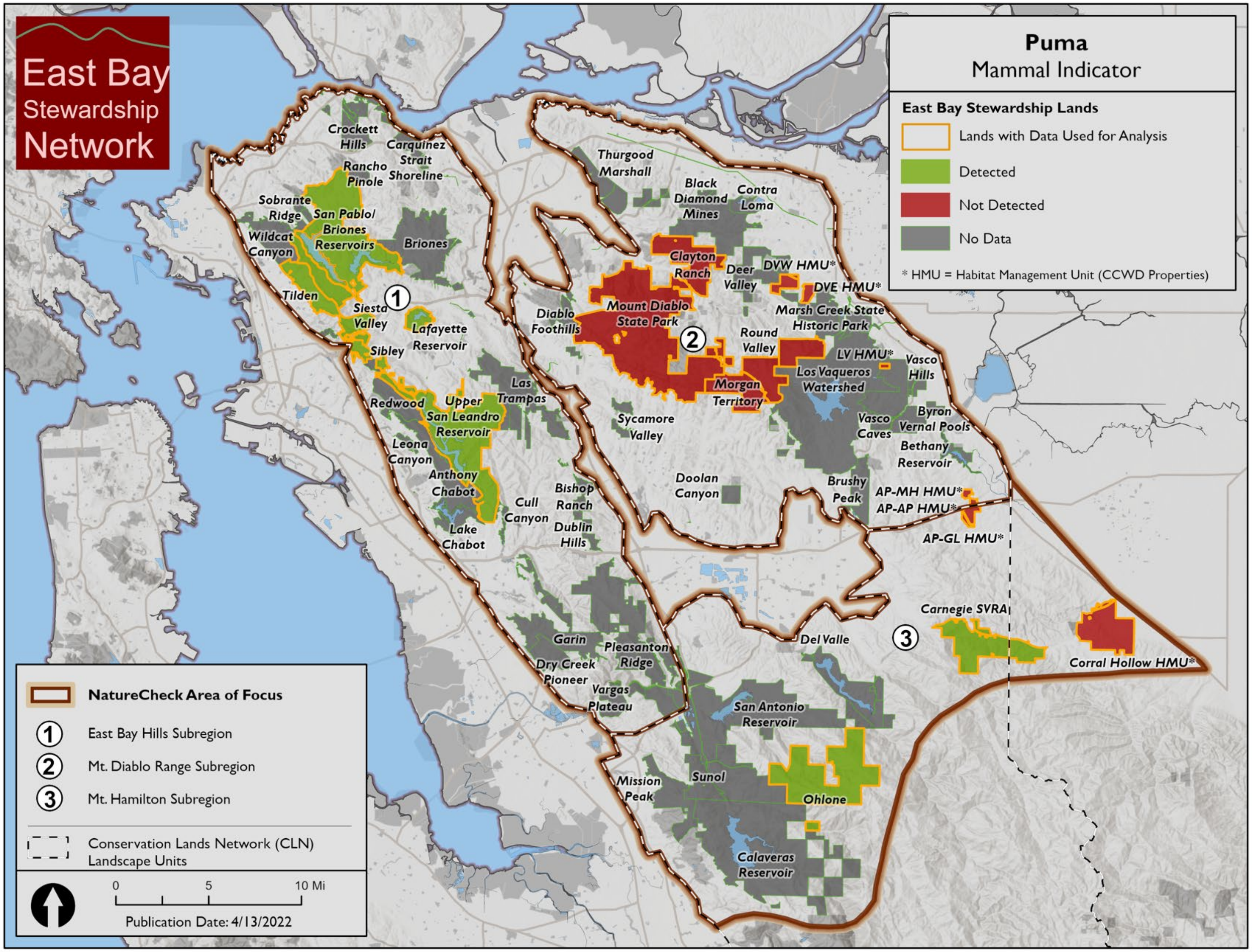

Figure 11.1. Puma detected or not detected in monitored Network partner lands (orange border) for subregions within the area of focus (data are from 2012–2020; see Table 11.4). "No Data" indicates unmonitored Network partner lands.

CHAPTER 12. CALIFORNIA GROUND SQUIRREL (*OTOSPERMOPHILUS BEECHEYI*)

EXECUTIVE SUMMARY

The California ground squirrel (*Otospermophilus beecheyi*) is an indicator of ecosystem health because it is a grassland keystone species and ecosystem engineer that plays a critical role in ensuring that grassland fauna and flora thrive in the East Bay region (Davidson et al. 2012, Lenihan 2007, Swaisgood et al. 2019). In addition, ground squirrels serve as an important food resource and various taxa rely on their burrows for shelter. Ground squirrel population health serves as an indicator for the health of the soils, plant communities, and the suite of species that benefits from its presence. Since many taxa are dependent on and benefit from ground squirrels, understanding their population health and monitoring them over time could help provide an early warning system regarding the effects of climate change on local populations.

We used three metrics to evaluate California ground squirrel condition and trend in the three subregions of the area of focus. (See map, Chapter 1.) These include species presence in specific parks and lands units (Metric 1), trends in abundance at sentinel sites (Metric 2) and Residual Dry Matter (RDM) as a measure of grassland suitability (Metric 3). We analyzed these metrics using a variety of available data sources (Chapter 9). These data came from interviewing partners about ground squirrel presence, iNaturalist records, a recent ground squirrel study (Appendix H: Ground Squirrel Research Report), and monitoring records in individual parks, reservoirs, recreation or management areas, and other open spaces, which we refer to as "Network partner lands" throughout this chapter.

While we have evidence of ground squirrel occupancy at the majority of our land units (Metric 1), we do not know their distribution or abundance. We hope to improve our data for this keystone species and gain clearer understanding of its presence, distribution and abundance on our lands. For Metric 2, the selection of sentinel sites and abundance findings from them has a set a benchmark upon which to measure trends in subsequent years. Metric 3 was data deficient; however, with some effort by Network partners, these data may be available to make this assessment. Based on these data, we found that the overall condition is "good" and trend for the California ground squirrel is "unknown."

A primary goal of the analysis was to provide a benchmark against which managers can measure future changes and understand the likely trajectory of this species. Baseline data and analyses can also be used to identify projects that achieve multiple benefits. Continued data collection in subsequent years will provide the time series to determine metric trends and condition of this important member of the grassland community.

METRICS SUMMARY AT A GLANCE

The table below summarizes the three metrics used in this NatureCheck ecological health assessment of the California ground squirrel. Each metric, along with how we arrived at its condition, trend, and confidence, is thoroughly described in the Metrics in Detail section later in this chapter. (See Chapter

1 for definitions and thresholds for condition, trend, and confidence; other terminology used throughout this chapter; how metrics are being used for each indicator; and other project methodology.)

Table 12.1. All California ground squirrel metrics, with their respective condition, trend, and confidence for each subregion. Each metric is described in the Metrics in Detail section later in this chapter.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Metric 1: Presence in Park or Land Unit with Grassland and Oak Woodland Habitat–Maintain a significant percentage (more than 50% of park or land units) of Network partner lands with active ground colonies and the spatial extent of occupied habitat (areal extent of active ground squirrel colonies) in grasslands is maintained or increased.			
Condition	Caution *	Good*	Good*
Trend	Unknown	Unknown	Unknown
Confidence	Low	Low	Low
Metric 2: Abundance at Sentinel Sites–Stable or increasing max counts and burrow density estimates in all sentinel sites in each subregion over three-year intervals.			
Condition	Unknown	Unknown	Unknown
Trend	Unknown	Unknown	Unknown
Confidence	Moderate	Moderate	Moderate
Metric 3: Residual Dry Matter (RDM)–A portion of managed grazed grasslands have prescribed RDMs that meet targets within an acceptable range for ground squirrels (generally less than 800 1bs/acre).			
Condition	Unknown	Unknown	Unknown
Trend	Unknown	Unknown	Unknown
Confidence	Low	Low	Low

* The condition for Metric 1 noted presence of ground squirrels in identified land units; meaning documented presence of a single ground squirrel in a land unit was considered “good.” However, the percent of those land units with active colonies and spatial extent of occupied habitat is unknown. There was not a survey to confirm “absence” of ground squirrels.

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of the California ground squirrel in the area of focus represented by the graphic below is based on the combined values of the individual metrics in Table 12.1. Each of these metrics is described in depth in the Metrics in Detail section of this chapter.

Condition: Good (color: green)

Trend: Unknown (symbol: question mark)

Confidence: Low (line around circle: none)

BACKGROUND

WHY IS THIS RESOURCE INCLUDED?

The California ground squirrel (*Otospermophilus beecheyi*) is a keystone species and ecosystem engineer that plays a critical role in ensuring that grassland fauna and flora thrive in the East Bay region (Davidson et al. 2012, Lenihan 2007, Swaisgood et al. 2019). Keystone species exert a disproportionate role on community structure relative to other species. Ecosystem engineers are those species that alter the environment in a way that increases habitat value for other species. In addition, ground squirrels serve as an important food resource, and various taxa such as invertebrates, amphibians, reptiles, and small mammals rely on their burrows for shelter. As ecosystem engineers, ground squirrels aerate the soil as they dig. In fact, in grassland ecosystems where similar species were observed to dig, increased local plant biodiversity and pollinator diversity and numbers have been documented (prairie dogs: Davidson et al. 2012; Siberian marmot: Yoshihara et al. 2010a, Yoshihara et al. 2010b) and increased soil moisture (gophers: Smallwood and Geng 1997).

By maintaining healthy, widespread populations of ground squirrels, grassland-dependent, federal- and state-listed species such as the San Joaquin kit fox (*Vulpes macrotis*), American badger (*Taxidea taxus*), California red-legged frog (*Rana draytonii*) (Chapter 5), California tiger salamander (*Ambystoma californiense*) (Chapter 6), Alameda whipsnake (*Masticophis lateralis euryxanthus*), and burrowing owl (*Athene cunicularia*) will continue to have suitable habitat in this portion of their range. Other listed species such as the golden eagle (*Aquila chrysaetos*) (Chapter 8), bald eagle (*Haliaeetus leucocephalus*), Swainson's hawk (*Buteo swainsoni*), ferruginous hawk (*Buteo regalis*), white-tailed kite (*Elanus leucurus*), northern harrier (*Circus hudsonius*), prairie falcon (*Falco mexicanus*), long-eared owl (*Asio otus*), and short-eared owl (*Asio flammeus*) that include the California ground squirrel in their diet will also benefit. In particular, California ground squirrels are the primary prey species for golden eagles in regions of the northern Diablo Range and form the largest component of mammalian prey for prairie falcons (D. Bell, unpublished data).

Documenting the presence of the ground squirrel and its burrows establishes an informed baseline from which to then assess how widespread and persistent these populations are. Since many taxa are dependent on and benefit from ground squirrels, understanding their population health and monitoring them over time could help provide an early warning system regarding the effects of climate change on local populations.

It is important to note that the ground squirrel is considered a pest; the species actively persecuted and receives no formal protection. Indeed, both governmental and university agricultural extensions provide information on how to poison and otherwise eradicate this species. The California Fish and Game Code classifies ground squirrels as nongame mammals. Landowners or tenants may control ("take"), in any legal manner, any nongame mammals that are damaging growing crops or other property. Despite this lack of protected status, there has been growing concern over the potential decline of this species based on recent anecdotal observations by researchers in the East Bay region and studies that have been conducted in the area of focus. (See map, Chapter 1.) While Network partners do not practice eradication of ground squirrels on their wildlands[45], the history of persecution and ongoing, unregulated ground squirrel control on private lands has a demonstrated effect on the overall population.

DESIRED CONDITION AND TREND

The desired condition and trend are that ground squirrels are present in at least 50% of Network partner lands (land units or parks) with grasslands in each subregion in the area of focus (Metric 1). Also, that ground squirrel abundance is stable or increasing in a majority of the sentinel sites (that is, established areas that are monitored on a regular basis) in each subregion (Metric 2) (Appendix H, Ground Squirrel Research Report, Townsend and Lenihan 2021). Finally, that grasslands suitable for the ground squirrel are maintained in the majority of Network partner lands (Metric 3).

CURRENT CONDITION AND TREND

Condition: Good

Trend: Unknown

Confidence: Low

[45] In this context, wildlands are undeveloped areas that do not have infrastructure such as levees, dams, and buildings.

Network partner lands consist largely of grasslands and other open habitat (e.g., oak woodland) suitable for ground squirrels. The area of focus includes 456 sq km of grasslands: East Bay Hills subregion, 112 sq km (36%); Mt. Diablo Range subregion, 197 sq km (52%); and Mt. Hamilton subregion, 147 sq km (63%) (see Chapter 9, Table 9.3; habitat layers for area calculations were taken from CLN 2.0). Ground squirrels are considered widespread and patchy in their distribution in areas where they occur.

Ground squirrel studies have been conducted over the years in parts of the area of focus, but no recent comprehensive assessment of their status over a large geographic area exists (although, see Townsend and Lenihan 2021, Appendix H, Ground Squirrel Research Report). However, recent severe drought conditions and wildfires are likely affecting the numbers and areal extent of their presence. Some evidence suggests that this species is on the decline (see studies cited in later in this chapter as well as anecdotal observations by researchers); however, to date, we do not clearly understand whether this species' population is increasing, decreasing, or stable or if its range is shrinking or expanding. Furthermore, due to the differences between the subregions (such as ruggedness, mosaic of habitats, aspect, soils, level of development, land use, and even local climatological differences), ground squirrels' condition and trends may vary between them.

Lenihan (2002–2004) documented several stable ground squirrel populations in five study sites in the Mt. Diablo Range and Mt. Hamilton subregions. Of these, four included Network partner lands in San Antonio Reservoir (two sites), Brushy Peak, and Vasco Caves (Lenihan 2007). Ground squirrel densities were estimated at 23 to 29 individuals per hectare (ha). Historical density estimates were reported at 50 to 190 individuals/ha, with more recent estimates at 11 to 39 individuals/ha (see Lenihan 2007 for discussion and citations). These estimates indicate that the ground squirrel's current presence and density are well below historical numbers. Monitoring results from Contra Costa Water District's (CCWD) Habitat Management Units (HMUs) in the Mt. Diablo Range and Mt. Hamilton subregions showed stable trends from 1998 to 2006. However, Smallwood (2014) observed declines in the density of ground squirrel burrow complexes at Vasco Caves (Mt. Diablo Range subregion) from 2006 to 2014, noting declines in both grazed and ungrazed areas.

In the spring and early summer of 2021, a study—"California Ground Squirrel Presence, Areal Extent (Active), and Abundance Within the East Bay Regional Park District Lands in the Area of Focus for the Ecological Health Assessment for the East Bay Stewardship Network" (Appendix H, Ground Squirrel Research Report)—was conducted to augment our existing understanding of ground squirrel presence for some of the Network partner lands; work included visiting parks to note presence (Metric 1) and to establish baselines for selected sentinel sites to be surveyed annually (Metric 2).

The current condition, trend, and confidence are the average of the condition, trend, and confidence for the ground squirrel in each subregion as shown in Table 12.2. The suite of metrics described in depth in the Metrics in Detail section of this chapter was combined to obtain this current condition and trend. These metrics are how we are measuring the difference between what is described in this section (i.e., how things are now) and the desired condition and trend in the preceding section (i.e., what we think "healthy" is for this indicator).

Table 12.2. Overall California ground squirrel condition, trend, and confidence for each subregion in the area of focus.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Condition	Caution	Good	Good
Trend	Unknown	Unknown	Unknown
Confidence	Low	Low	Low

STRESSORS

Several ecological and anthropogenic factors affect the health of this indicator. These include:

Historical Impacts: Because poisoning and other eradication efforts have been underway for decades, this species has likely been extirpated from much of its former range. In particular, widespread eradication programs undertaken in Contra Costa and Alameda Counties have affected this species within the area of focus. Control programs reduced most populations to below carrying capacity (Marsh 1987), with some local populations reduced by 90% to 95% (Hunt et al. 1995). Alteration and loss of grassland habitat as a result of the introduction of non-native grasses, as well as infrastructure and development in the region over time, have likely also had a long-term degrading effect on ground squirrel distribution and populations. It is important to note that this species remains the target of unregulated eradication efforts to protect infrastructure, crops, and landscaped areas (see Direct Human Impacts).

Climate Change: Increased drying and drought conditions may affect the carrying capacity of grassland ecosystems. Small, isolated ground squirrel populations would be more vulnerable to extirpation under these conditions.

Fire Regime Change: Temporary disruption to life history may result from fire (lack of forage, for example); however, wildfires likely enhance grassland habitat for ground squirrels. Fire can be used to enhance grasslands for a number of reasons, such as reducing woody forbs, dried vegetation, or tall thatch, as well as increasing forage-nutrient availability. All these could also be considered enhancements for the California ground squirrel.

Disease: Ground squirrels are susceptible to outbreaks of bubonic plague, which is 100% lethal for them and causes periodic die-offs.

Direct Human Impacts: Poisoning ground squirrels is common and largely unregulated. Ground squirrel eradication efforts continue, particularly to protect infrastructure such as levees and crops. Other reasons for poisoning include maintaining lawns and other landscaped areas. Because they have no formal protection, no effort is made to avoid ground squirrel burrows during activities that cause ground disturbance unless listed species that use their burrows may be present. This species can be hunted without any regulation, and they are often controlled that way on cattle ranches and farms. While some of these activities do not occur on Network partners lands, the impacts from surrounding lands can affect presence and abundance in Network partner lands. Network partners may restrict or prohibit the use of rodenticides in portions of their wildlands and may restrict certain types of animal control. EBRPD and SFPUC prohibit the use of rodenticides on their grazed open space and/or wildland locations. EBMUD prohibits the use of rodenticides on their East Bay watershed lands. No ground squirrel control efforts of any kind occur in the Diablo Range District of California State Parks.

Habitat Disturbance/Conversion/Loss: Insufficient grazing, mowing, or burning results in non-native grasslands that are unsuitable for ground squirrels. The reason for this is that non-native grasses evolved in ecosystems with grazers, and therefore, in the absence of grazing, burning, or mowing, the grasses can grow too high, become thatchy and thick, and lose nutritional value. Grassland loss and fragmentation results from roads, infrastructure development, or conversion to vineyards or dryland farming. These grasslands may be less accessible to ground squirrels, and their presence may degrade the overall quality of adjacent grasslands. They may also make it difficult for ground squirrels to safely move between suitable patches of grassland habitat.

CONDITION AND TRENDS ASSESSMENT

METRICS IN DETAIL

Metrics were developed to measure trends in ground squirrel presence in each subregion with relatively low level of effort (presence or presumed absence by park or land unit recorded by each Network partner agency on an annual basis). In this approach, the presence of a single ground squirrel means that the entire land unit was identified as “occupied”, regardless of the size of the land unit. Note that except for rare instances (e.g., sentinel surveys), we have no data on ground squirrel distribution and abundance, which are significant data gaps. Documenting ground squirrel presence in the land units is an essential first step. We hope to have more information on distribution and abundance in future analyses which will likely result in drastically different results than just documenting presence/absence of an entire land unit.

Rolling these detections up into a percentage of parks (or land units) with one or more ground squirrel recorded is the first step in monitoring if ground squirrels are starting to disappear from the landscape over time. Moving forward, these annual detections will also be supported by other monitoring efforts and studies (e.g., camera trapping). We also used iNaturalist records, which were bolstered by an iNaturalist ground squirrel project (www.inaturalist.org/projects/california-ground-squirrel-census) initiated in late October 2020. Ground squirrels, unlike other mammals, are good candidates for using community science (such as iNaturalist) to collect data because they are diurnal and are tolerant of humans.

Sentinel sites were established in each subregion to measure trends in ground squirrel numbers and burrow densities annually. We used max counts to estimate numbers and densities of ground squirrels and distance sampling to estimate burrow density and level of activity; these efforts represent a high level of survey effort that generates reliable results that determine trends over time and may serve as an early warning system in case there are marked declines at these sites.

Metric 1: Presence in Park or Land Unit with Grassland and Oak Woodland Habitat

Rationale:

California ground squirrels provide ecosystem services to many taxa in the area of focus. Documenting their presence in each subregion ensures that this keystone species (important to ecosystem functioning) is able to continue to play that role.

Condition Goals:

- Maintain a significant percentage (more than 50% of park or land units) of Network partner lands with documented presence of a ground squirrel.
- The spatial extent of occupied habitat (areal extent of active ground squirrel colonies) in grasslands is maintained or increased.

Current Baseline: Current baseline conditions were determined based on information from Network partner agencies who were queried about ground squirrel presence records or observations within the past year for each of their land units or parks for each subregion in the area of focus. These findings were compiled into a table with ground squirrel locations for each park or land unit. To supplement this information, we included these sources:

- Aggregated ground squirrel camera trapping records from Network partner lands (land unit or park) and by subregion (Chapter 9, Table 9.4).
- A ground squirrel research study conducted in the spring of 2021 (Townsend and Lenihan 2021; Appendix H, Ground Squirrel Research Report), for which East Bay Regional Park District (EBRPD) parks were visited to document whether or not ground squirrels were present.
- An iNaturalist California ground squirrel project initiated in October 2020, which provided research-grade observations that we collated and cross-referenced to determine locations within parks and land units in Network partner lands in each subregion (iNaturalist, queried August 4, 2021).

These efforts (Table 9.5a) resulted in a detection (1) and/or a non-detection (0) for each park or land unit that makes up the Network partner lands (Table 12.3, Figure 12.2). These detections were added together to determine the percentage of agency parks or land units ("units") in each subregion that had one or more detections (Table 13.3, Figure 12.4). Each subregion is made up of individual parcels of lands referred to as either "land unit" or "park." For example, of 39 units (includes parks and land units) with suitable habitat (grassland or oak woodland) in the East Bay Hills, 12 had detections. By adding up the amount of suitable habitat for each unit with a ground squirrel detection (expressed by the number 1), we can show how many square kilometers (sq km) of lands are represented by those with ground squirrels present. Even though we are using the term "occupied," we are not implying that each land unit with a ground squirrel is entirely occupied by active ground squirrel colonies. In addition, we added information on the amount of suitable habitat that is potentially available for this species in each land unit. We took this approach to show how much suitable habitat was being represented by each park although land units varied in size from small to large.

In the case of EBMUD lands in the East Bay Hills subregion, ground squirrel detections are relatively recent with some supporting evidence that they had been absent (Jones and Stokes 1995, and Stebbins 1996). According to Jonathan Price (EBMUD, pers. comm., 2022), ground squirrels are absent from nearly all of EBMUD's East Bay watershed lands. While they do not conduct California ground squirrel monitoring, evidence suggests that ground squirrel were absent and it was not until 2008 (Rocky Ridge) and 2016 (Bear Creek Staging) that ground squirrels were observed in the EBMUD watershed for the first time in several decades. EBMUD's two 'populations' are along the edge of the property boundary, adjacent to obvious source populations on EBRPD's land. It seems likely that California ground squirrel on EBMUD property came from the neighboring source populations. There is no evidence to suggest that California ground squirrel have been observed elsewhere on the watershed since the 1970s. EBMUD rangers, biologists and ranchers are aware that California ground squirrel haven't been observed on the watershed for a long time and new sightings would likely get attention and be documented quickly, as they had in 2008 and 2016. Ground squirrels were detected in 41 of 78 park or land units in Network partner lands (Tables 12.3, and Figure 12.2) based on data from all the sources described above. From the aggregated camera data alone, seven of the 18 monitored parks recorded ground squirrels. However, it is important to note that ground squirrel images may not have been catalogued if they were not a target species of a given camera study. From the iNaturalist ground squirrel query, research-grade and select user observations resulted in 1,430 observations for the area of focus (iNaturalist, August 4, 2021). Of these, 203 observations were from 2004–2016 and 1,227 observations were from 2017–2021 (Chapter 9, Table 9.5a).

The results indicate that in the East Bay Hills subregion, 12/39 of the park or land units in Network partner lands, had at least one documented ground squirrel detection. In the Mt. Diablo Range subregion, 18/27 of the park or land units had at least one documented ground squirrel detection. In the Mt. Hamilton subregion, 11/12 of the park or land units had at least one documented ground squirrel detection.

Table 12.3: Number of Agency Park/Lands ("Units") with ground squirrel detections out of the total "units" in each subregion ("No. Units in Subregion) that support grasslands and oak woodland. Area (sq km) of grasslands (Grass) and oak woodland (Oak-Wo) for Agency units and unit areas with one or more ground detections and percentage of available habitat that unit(s) represents ("% Total Available") based on aggregated detections after 2016 (see Figure 12.2).

Agency/ Subregion	No. Units GrSq Detect	No. Units in Subregion	Units Proportion)	Grass (sq km)	Oak-Wo (sq km)	Total Available (sq km)	Unit Area GrSq (sq km)
EBMUD	1	3	1/3	36	25	61	58[46]
EBRPD	10	35	10/35	73	91	164	124
SFPUC	1	1	1/1	2	2	4	4
East Bay Hills Total	***12***	***39***	***12/39***	***112***	***118***	***229***	***186***
CCWD	2	3	2/3	62	11	73	72
EBRPD	13	21	13/21	100	34	134	129
CSP	2	2	2/2	35	32	67	67
Mt. Diablo Range Total	***18***	***27***	***18/27***	***197***	***77***	***274***	***268***
CCWD	2	2	2/2	17	0	17	17
EBRPD	5	6	5/6	36	24	60	60
SFPUC	6	14	2/2	78	31	110	110
CSP	2	2	2/2	16	9	24	24
Mt. Hamilton Total	***11***	***12***	***11/12***	***147***	***64***	***211***	***211***
Grand Total	***41***	***78***	***41/78***	***455***	***259***	***714***	***665***

Network partner agency abbreviations: CCWD = Contra Costa Water District, CSP = California State Parks, EBMUD = East Bay Municipal Utility District, EBRPD = East Bay Regional Park District, SFPUC = San Francisco Public Utilities Commission.

Condition Thresholds:

- *Good:* Land units and/or parks in Network partner lands with ground squirrel detections maintain their presence within 50% of land units or parks. The number of occupied land units and/or parks (that is, with ground squirrels detected) in Network partner lands is increasing or stable.
- *Caution:* Ground squirrels detected in fewer than 50%, but more than 20%, of land units or parks in Network partner lands. The number of land units and/or parks with ground squirrel detections decreases by 20% from one year to the next.
- *Significant Concern:* Ground squirrels detected in fewer than 20% of land units and/or parks in Network partner lands. Also, currently active ground squirrel units (that is, with a documented ground squirrel presence) decrease by more than 50% from one year to the next.

[46] The area occupied on EBMUD's property is approximately .0051 km² at the Bear Creek Staging Area and .062 km² at Rocky Ridge (Total= .0671 km²; J. Price, EBMUD, personal communication, 2022).

Because the ground squirrel has no special status and is fairly common, its presence or absence is usually not systematically recorded. By recording a simple "yes, present/detected" or "no, not observed" for each park or land unit and then converting those results to numerals (1, present; 0, not present), it is possible to calculate a number of "occupied" parks out of the total units within each subregion.

This simple metric was crafted because of the low effort it requires of each agency to report if they have observed ground squirrels (yes or no) in a park or land unit; no special survey effort or estimation of abundance is required. These percentages can be used to show trends of increasing, decreasing, or stable ground squirrel presence for each subregion.

Condition: Good (average of all conditions below)

Good (Mt. Diablo Range, Mt. Hamilton)

More than 50% of the parks (or land units) have ground squirrel detections.

Caution (East Bay Hills)

Of 39 units, 31% have detections.

Trend: Unknown (all subregions)

Three data points are needed to understand change over time. This year is the first, and only, data point we have for this metric.

Confidence: Low (all subregions)

Measurements were based on recent, reliable, and suitably comprehensive monitoring data. We queried each Network partner agency about ground squirrel detections over a period of months and augmented our findings with records from the camera studies, a ground squirrel research project conducted in 2021, and an iNaturalist project that specifically collected reliable ground squirrel records. However, we do not know the abundance or distribution of the ground squirrel population. In addition, this condition assessment relies on trends, and because we lack a time series, the confidence was "low" due to the missing trend data[47].

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[47] For these reasons, EBRPD staff chose to deviate from the primary author's findings of a "moderate" confidence for this metric. A confidence of "low" here also means that there is a confidence of "low" for the indicator overall, which they felt more accurately reflected the current state of knowledge given that the other two metrics do not have a condition or trend at this time. Future updates to this assessment will draw on ongoing studies and should therefore have sufficient data to update all three metrics to provide more refined results.

Metric 2: Abundance in Sentinel Sites

Rationale: To understand how ground squirrel populations are faring, particularly as climate change effects such as severe drought and wildfire are prevalent in the area of the focus, trends in ground squirrel abundance should be monitored using reliable, repeatable methods. For ground squirrels to persist on the landscape, healthy source populations need to be maintained. To ensure healthy source populations are present, some effort is needed to identify these populations and monitor them both to ensure they remain present on the landscape but also to indicate what may also be occurring in other nearby populations.

Current Baseline: To set a baseline upon which to measure abundance trends, two study areas ("sentinel sites") within each subregion were established: Briones and Garin (East Bay Hills), Brushy Peak and Morgan Territory (Mt. Diablo Range), and Del Valle and Sunol (Mt. Hamilton); all are managed by EBRPD. These sites were chosen as well established ground squirrel colonies that may be less subject to disappearing from year to year. These six study areas are sentinel sites because they can act as proxies for how other local ground squirrel populations may be doing and also as an early warning system. These sentinel sites will be revisited for annual monitoring and abundance-trend assessment (May 2021; see Appendix H: Ground Squirrel Research Report*).* Estimates of individuals (adults and young) and burrow density that were obtained in early summer 2021 using max counts and distance sampling (Appendix H: Ground Squirrel Research Report) will serve as a benchmark for this metric. By using the same methods in the same locations in subsequent years, we can determine if these sentinel sites have stable, increasing, or decreasing populations via several reliable measures.

To estimate the density of California ground squirrels, we conducted complete visual counts on each designated four-hectare plot (sentinel sites, Figures 12.4 and 12.5). Visual counts conducted over at least three days produce the best correspondence to mark-recapture population estimates (Fagerstone 1984; Severson and Plumb 1998). Count numbers varied somewhat by sentinel site location (range = 88–210; Figure 12.1). Overall species density ranged from 22/ha at Brushy Peak to a high of 52/ha at Sunol (22/0.01 sq km and 52/0.01 sq km, respectively), with a mean estimated density of 29/ha (29/0.01 sq km). Litter counts, although not the focus, correlated with site abundance ranking. Young of the year constituted the most numerous age group for this count and represented the majority of the count total.

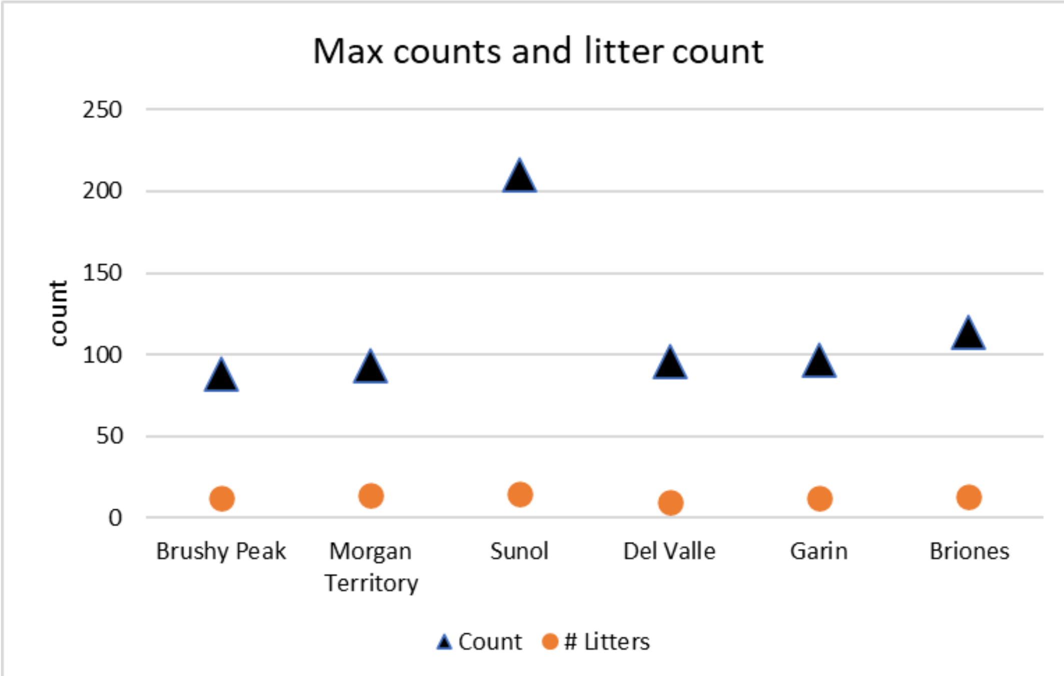

Figure 12.1: Maximum individual and litter counts for each sentinel site (May and June 2021).

To estimate the density of burrows and burrow clusters with attributes that showed if they were active, we conducted line transect surveys using distance sampling (Buckland *et al*. 2001) in the six sentinel sites (see Appendix H: Ground Squirrel Research Report). We walked north-south transects at 50-meter intervals, recording burrows and burrow clusters (burrows less than five meters apart; methods modeled after Townsend 2006 and Townsend and Zahler 2006). For each burrow and burrow cluster, we documented burrow number, burrow size, the presence of digging, tracks (consistent in size and shape with ground squirrels), scat (old or fresh, type), debris (presence in entrance), ground squirrel observation, and ground squirrel alarm calls (see Appendix H: Ground Squirrel Research Report, for method details).

Results indicated that at Morgan Territory (Mt. Diablo Range), Sunol (Mt. Hamilton), and Briones (East Bay Hills), more than 60% of burrows had fresh scat, while at the remainder of the sentinel sites—Brushy Peak (Mt. Diablo Range), Del Valle (Mt. Hamilton), and Garin (East Bay Hills)—less than 50% had fresh scat (see Appendix H: Ground Squirrel Research Report, Figure 5). Burrow attributes can indicate activity or inactivity; fresh scat, alarm calls, and the observation of a ground squirrel indicate likely active and, conversely, debris in an entrance may indicate inactivity. Burrows can persist on the landscape for variable periods of time depending on use, soil type, and soil moisture. Density estimates were reported for both burrows (single burrows) and burrow clusters (burrows clustered within five meters of one another).

Burrow density estimates/sq km (D) ranged from 6,852 at Brushy Peak (Mt. Diablo Range) to a high of 36,350 at Briones (East Bay Hills). Burrow cluster density estimates/sq km (DS) ranged from 3,405 (187–62,167; not included in Figure 12.3 due to the large confidence interval) at Brushy Peak and a high of 9,230 at Garin (East Bay Hills; Figures 12.2 and 12.3). The Brushy Peak density estimate's large confidence intervals can be remedied in future years by increasing the number of transects.

Although burrow density was lower in the Mt. Diablo Range subregion (6,852 at Brushy Peak and 10,590 at Morgan Territory) compared to the East Bay Hills and Mt. Hamilton subregions (range = 30,082–36,350 burrows/sq km), burrow-cluster-density estimates were similar to those in the other subregions. Burrows and burrow-cluster densities are measures that characterize past ground squirrel burrow activity and possible present use. Presumably, burrow density will decrease over time, with lower density or declining ground squirrel activity; the amount of time it takes for burrows to collapse varies. Therefore, burrow density alone does not necessarily indicate the presence of ground squirrels, nor does it necessarily correlate in "real time" with ground squirrel density. However, aspects of burrow density can support other measures, such as maximum counts. For example, increasing burrow density with concomitant "active" attributes (e.g., fresh scat, recent digging) can indicate increased ground squirrel activity and density. Burrow density with reported attributes (indicating active and inactive) and maximum counts can be used over time to understand if ground squirrel numbers at the sentinel sites are stable, decreasing, or increasing.

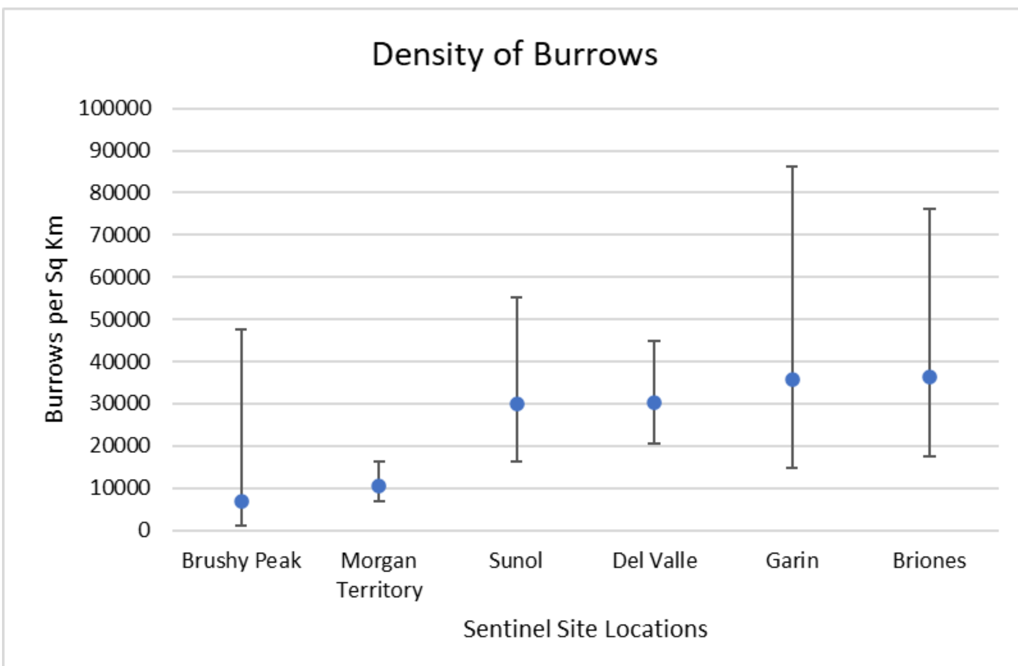

Figure 12.2: Density estimates (burrows/sq km±CI) for each sentinel site (May and June 2021).

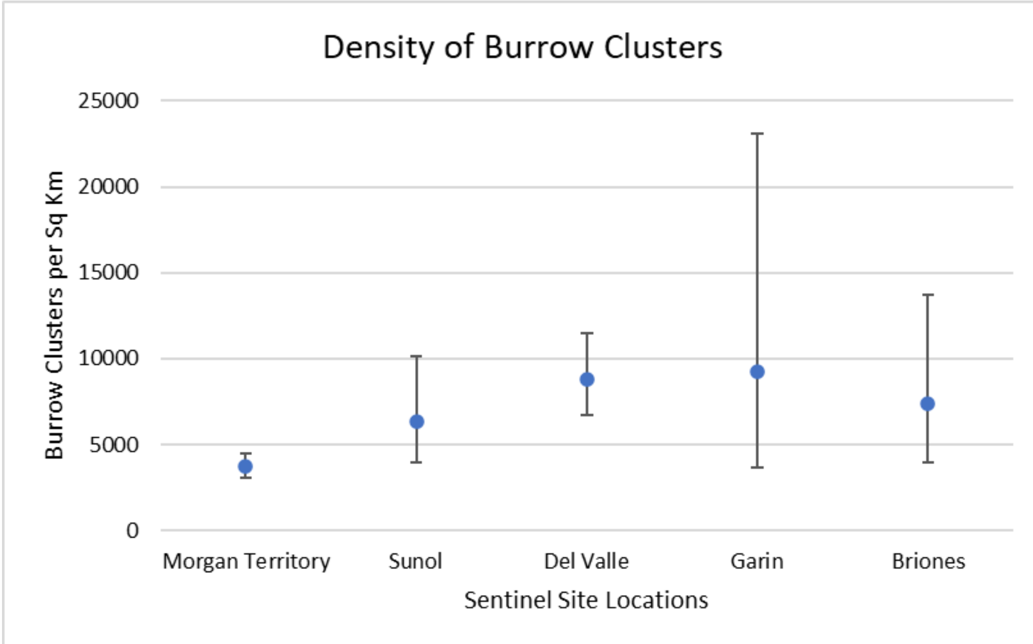

Figure 12.3: Density estimates (burrow cluster/sq km±CI) for each sentinel site (May and June 2021) except for Brushy Peak (not shown here; CI was too large to be meaningful).

Condition Goal: Stable or increasing maximum counts and burrow density estimates in all sentinel sites in each subregion over three-year intervals.

Condition Thresholds:

- *Good:* Ground squirrel counts and burrow density estimates are stable or increase for the majority of the sentinel sites and if there are decreases for one or both measures, they are not greater than 30%.
- *Caution:* Ground squirrel counts and burrow density estimates decrease by more than 30% in both sentinel sites in any one subregion in the area of focus.
- *Significant Concern:* Ground squirrel counts and burrow density estimates decrease by more than 50% in three or more of the six sentinel sites.

Stable or increasing maximum counts and burrow and burrow cluster density in the majority of sentinel sites with up to a 30% decrease in two or less of them. Natural fluctuations are expected. However, both sentinel sites in one subregion decreasing may indicate changing conditions. Marked decreases of 50% in more than three sentinel sites could indicate a more significant change.

Condition: Unknown (all subregions)

This first year can serve as a benchmark as these sites were chosen for their robust ground squirrel activity. The "good" condition threshold is based on trend, which cannot be determined until we have at least three subsequent years data.

Trend: Unknown (all subregions)

Additional years of data will provide trend information to determine if these sentinel sites remain stable.

Confidence: Moderate (all subregions)

Measurements in this first year were based on recent, reliable, and comprehensive survey data but the condition and trend could not be determined as this year is serving as benchmark for subsequent years.

Metric 3: Residual Dry Matter (RDM)[48],[49]

Rationale: Grassland habitat suitable to maintain a healthy ground squirrel population can be supported by mowing, burning, and grazing. California ground squirrels live in a spectrum of grassland conditions but are often found in grazed grasslands with low standing biomass. The absence of grazing can result in tall, dense grasses with high standing biomass which can be unsuitable habitat for grassland species, including ground squirrels.

Residual dry matter (RDM) monitoring developed by University of California scientists, is used by California land management agencies for assessing rangeland condition, protecting against erosion and adjusting stocking rates on grazed annual rangeland and associated savannas and woodlands. RDM is the dry, old herbaceous plant material remaining in fall, essentially mulch or litter left standing or on the ground at the beginning of a new growing season. It indicates the combined effects of the previous season's forage production, breakdown over summer, and its consumption by grazing animals of all types (Bartolome et al. 2006). Setting RDM targets is an important task in California range management.

RDM targets can be used to manage herbaceous biomass for special-status grassland animal species, such as the San Joaquin kit fox, badger, and burrowing owl. Because ground squirrels are thought to

[48] SFPUC may opt to use an alternate measure of vegetation suitability for the California ground squirrel on their lands for this metric.

[49] Residual dry matter (RDM) is the amount of old plant material left on the ground at the beginning of a new growing season. RDM indicates the previous season's use and can be used to describe the health or condition of annual rangelands (Harris et al. 2002).

prefer open areas with low, non-thatchy vegetation (Ricankova et al. 2006, Proulx et al. 2012, and Bylo et al. 2014), RDM data could, in theory, be used to assess which lands are consistent with their habitat preferences. Because RDM measures density rather than height and because the relationship between livestock and ground squirrels could be competitive in certain situations, particularly in less productive years (see also Fehmi et al. 2005; Cheng and Ritchie 2006; Proulx 2010 as cited in Bylo et al. 2014), this is an imperfect tool. However, these data are already collected over a significant portion of the study area, which may become useful if Metrics 1 and 2 show decline.

Current Baseline: RDM targets are often specified in Network partner agency monitoring plans and grazing licenses. Therefore, in theory, RDM targets and reporting could provide data useful for assessing habitat suitability. RDM targets were set and reported for Contra Costa Water District's (CCWD) San Joaquin HMUs. For these lands, Los Vaqueros Watershed RDMs were above target (i.e., less suitable for ground squirrels) in the five HMUs. H. T. Harvey & Associates (2017) indicated that RDMs were above target in all HMUs except portions of Corral Hollow. EBPRD sets RDM targets of 1000 lbs/acre. These targets are typically met on EBRPD lands. The extent of managed rangelands with reported grassland RDM monitoring results for Network partner agencies was not determined.

Condition Goal: A portion of managed grazed grasslands have prescribed RDMs that meet targets within an acceptable range for ground squirrels (generally, presumed to be less than 800 lbs. per ac).

Condition Thresholds:

- *Good:* Grazed grasslands with management plans in Network partner lands have RDMs compatible with ground squirrels and/or Rangeland Management Plans have RDMs set to be compatible with ground squirrels.
- *Caution:* Grassland management is insufficient to maintain acceptable RDMs for ground squirrels on more than 50% of grassland in any one subregion.
- *Significant Concern:* Grasslands in a significant portion (to be defined) of each subregion in the Network partner lands are not managed by adequate grazing, mowing, or burning.

These thresholds were predicated on the idea that at least some significant portion of grazed or otherwise managed grasslands should be maintained in a way compatible with ground squirrel habitat needs.

Condition: Unknown (all subregions)

We have not analyzed the information on RDM and ground squirrel occupancy on grazed grasslands.

Trend: Unknown (all subregions)

We have not analyzed information on RDM for grasslands over time.

Confidence: Low (all subregions)

Monitoring was not sufficiently recent, reliable, or comprehensive to assess condition.

OTHER METRICS CONSIDERED BUT NOT INCLUDED

Ground squirrel density estimates (low, moderate, and high) in occupied areas could provide a metric to convert density and area occupied into number of individuals. The advantage of this approach would be to estimate populations (see Townsend and Zahler 2005 for an example of this approach). The density estimate would assign a number of ground squirrels for a given unit of area; for example, published estimates of density include low = 11/ha, moderate = 40/ha, and high = 50/ha. This approach could then provide several metrics (presence, density, and population estimate) for a given area. For example, the desired condition would be present in at least 75% of the units in each subregion that supports grasslands, and at moderate density in at least 50% of the units in each subregion. Finally, population estimates could be derived from areas where size and density are known. This metric was not chosen because we lacked the data, funding, and time to complete it.

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

- RDM may not be the best tool for measuring habitat suitability for grassland wildlife species because: 1) it is designed to measure forage availability, not grassland height; 2) Typically, one RDM measurement is taken for an area ranging from 50–200 acres and therefore does not provide high resolution and; 3) A portion of Network partner lands are not grazed and therefore RDM targets are not collected or monitored in those areas so it would not be possible to measure their habitat suitability with this method.

- Surveys of ground squirrel abundance at sentinel sites have only been conducted for one year, 2021, which experienced below-average rainfall. Additional years of research are needed to capture years with more normal precipitation levels and to quantify how variation in precipitation and the onset of drought conditions might impact the local ground squirrel populations.

- Unprocessed images from camera efforts that have ground squirrels recorded and acoustic files from audiomoths need to be processed, collated, and used to update these metrics.

- Refine Metric 1 to assist with identifying ground squirrel distribution and abundance in suitable habitats.

PAST AND CURRENT MANAGEMENT

Several ongoing monitoring requirements limited to CCWD's Los Vaqueros Reservoir and Los Vaqueros Expansion mitigation lands require(d) prey assessment by estimating the percentage of active areas for San Joaquin kit fox prey species, including ground squirrels (potential and active burrows, *Mitigation and Monitoring and Habitat Management Plan for the Los Vaqueros Reservoir Expansion*). Monitored sites included the following in the Los Vaqueros Watershed (1998–2016), Mt. Diablo Range subregion: Marsh Creek (998 acres [ac hereafter]), Los Vaqueros (80 ac), Morgan Territory (329 ac), Altamont (651 ac), and Corral Hollow (3,021 ac). As part of this effort, a six-year dataset included 15 study plots showing mostly stable ground squirrel populations (Sterner 2007).

Smallwood (2014), who monitored ground squirrel burrow complexes at the Vasco Caves in different grazing regimes from 2006 to 2014, noted declines in both grazed and ungrazed areas.

As described previously, a study conducted in early summer 2021 on the areal extent of ground squirrel presence and abundance was undertaken to augment existing information about the species' current condition on EBRPD lands, and, in part, also to understand the possible impacts of climate change on this species. This sentinel site study evaluated two locations from each subregion for a total of six sites. As part of the study, sentinel sites were selected and methods for estimating abundance were used to establish baseline and current conditions of the ground squirrel for metrics (Townsend and Lenihan 2021); findings are presented in this chapter and in Appendix H, Ground Squirrel Research Report.

Post-fire monitoring (using camera traps and acoustic sensors) that began in November 2020 is collecting data on ground squirrels, however those data were not evaluated in time to be included in this analysis. Seasonal occupancy estimates will provide abundance estimates to compare over time for trends in burned and unburned lands (Los Vaqueros Watershed [CCWD], Morgan Territory and Round Valley [EBRPD]).

A range ecology grassland management and monitoring report based on 10 years of grassland botanical assessments and bird monitoring (Bartolome et al. 2011) was prepared for lands in the area of focus. RDM recommendations were not included as part of this assessment; range management recommendations focused on maintaining and enhancing native-plant and grassland-bird abundance, controlling invasive plant species, and understanding and managing the effects of grazing on native plants and grassland bird populations. The degree to which these recommendations are consistent with, rather than deleterious to, the presence of burrowing mammals was not assessed but could provide insight into how management recommendations may be promoting or inhibiting ground squirrel presence on the landscape as far as "grassland suitability" (see Potential Future Actions, following).

The majority of Network partner agency landowners prohibit the use of rodenticides in its grazing areas, watersheds and wildlands. However, private landowners may be using rodenticide on their properties.

POTENTIAL FUTURE ACTIONS

- Determine a method to measure current grassland health and suitability across the area of focus for wildlife species, such as the ground squirrel and monitor suitability through time.
- Aggregate ground squirrel research and surveys on Network partner lands into a document database to provide more information on ground squirrel distribution across the landscape through time.
- Use acoustic monitoring (e.g., AudioMoths) to include ground squirrel calls in addition to bird monitoring.
- Develop a database for Network partners to share presence/absence data and records (observations with location, date, time, and photograph if possible) to improve the specificity of ground squirrel presence data.
- Develop a public education program for neighboring landowners on the importance of ground squirrels in maintaining grassland health and biodiversity.

KEY LITERATURE AND DATA SOURCES

Literature

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PARTNER AGENCY DATA SOURCES

- East Bay Municipal Utility District (EBMUD), Mammal Database
- East Bay Regional Park District (EBRPD), Carnivore Research (Tilden-Sibley, Eastern Contra Costa County [ECCC], Sunol-Ohlone)
- Contra Costa Water District (CCWD), San Joaquin Kit Fox Monitoring (Habitat Management Units)
- California State Parks (CSP), Large Mammal Occupancy Study (Carnegie State Vehicular Recreation Area) and Felidae Conservation Fund Study (Mount Diablo State Park)

Other Data Sources:

- H. T. Harvey & Associates, *Los Vaqueros Reservoir Expansion Project Habitat Management Plan* (Annual Reports, 2016–2018)
- ICF International, *Contra Costa Water District Habitat Management Plan* (Annual Reports 2013–2015)
- iNaturalist (https://www.inaturalist.org)
- University of California, Berkeley, Museum of Vertebrate Zoology (MVZ) Mammal Collection (Arctos) (https://arctos.database.museum/SpecimenSearch.cfm)
- The Wildlife Project, *Los Vaqueros Project 2006 Annual San Joaquin Kit Fox Monitoring Report*

Additional details about all of these data sources are provided in in Appendix G, Data Assembly for Mammal Indicators.

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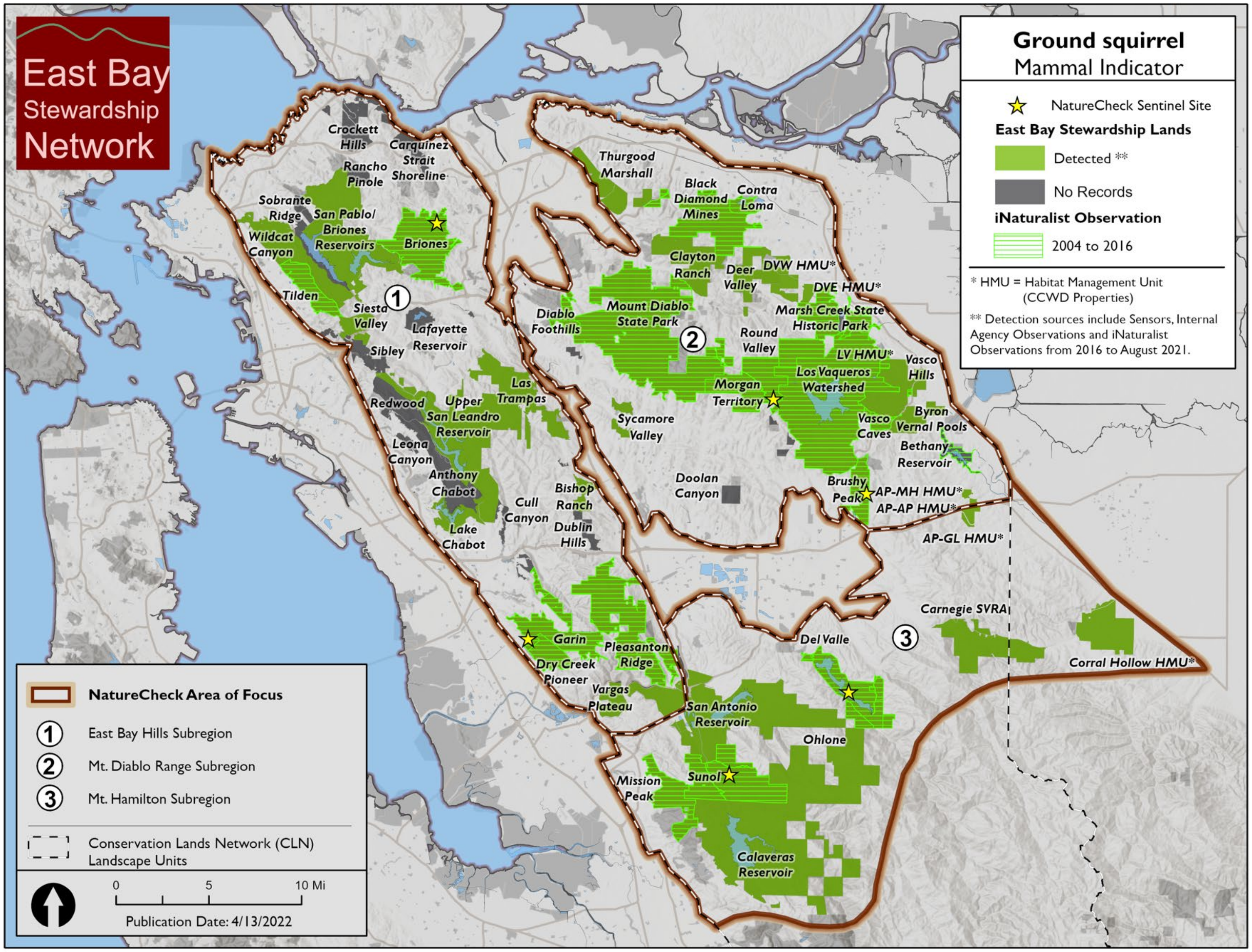


Figure 12.4. Network partner lands with California ground squirrel detections. Lands with no records shown in dark gray.

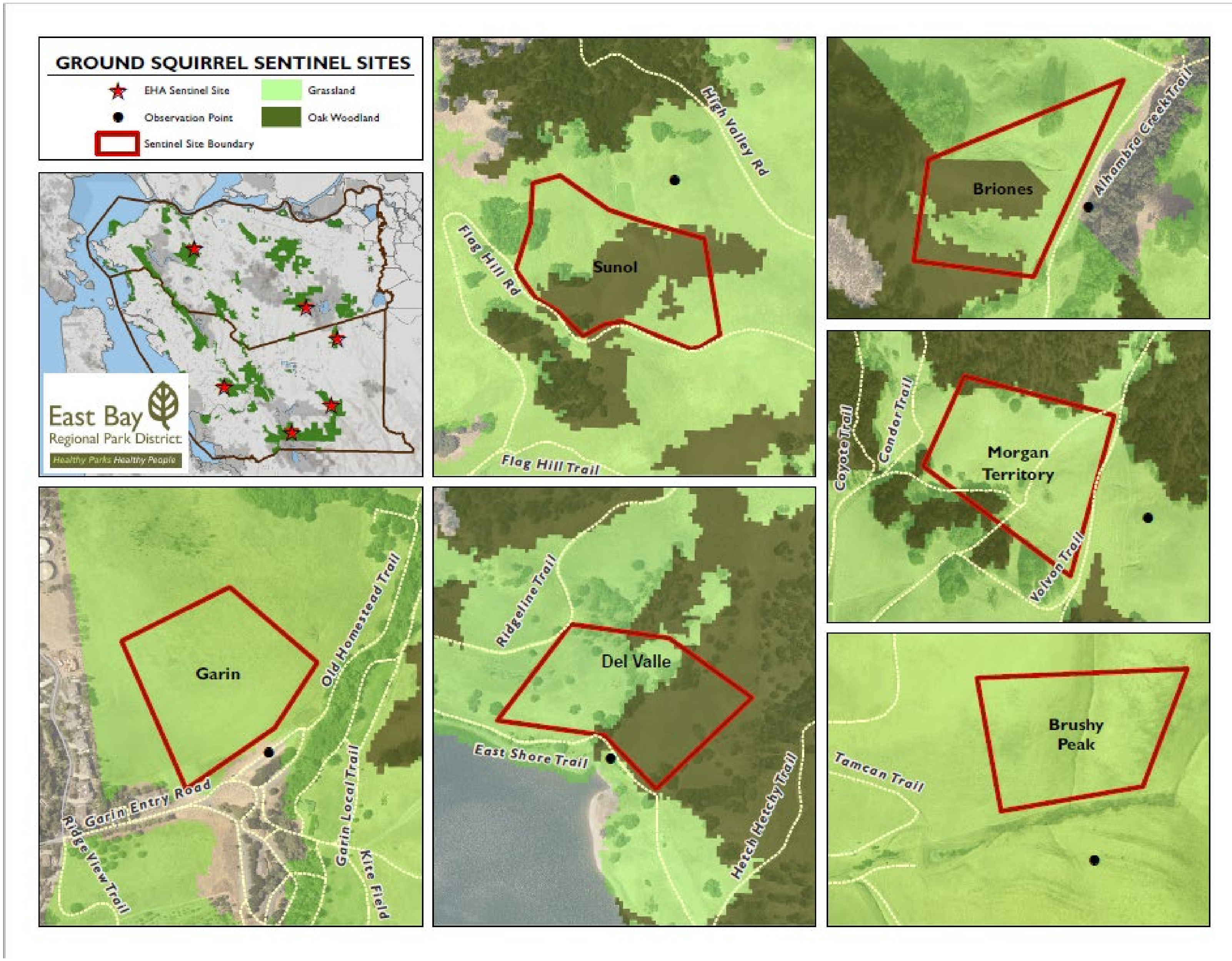


Figure 12.5 California ground squirrel sentinel sites for Metric 2

CHAPTER 13. DUSKY-FOOTED WOODRAT (*NEOTOMA FUSCIPES*)

EXECUTIVE SUMMARY

The dusky-footed woodrat (*Neotoma fuscipes* with the San Francisco subspecies, *Neotoma fuscipes annectans*, a California species of special concern) and its nests provide critical resources to members of both lower and upper trophic levels in forested and associated shrubland ecosystems. As ecosystem engineers, woodrats construct nests that provide shelter for numerous other taxa, including small rodents, lizards, snakes, insects, spiders, and other invertebrates. Additionally, this species is a key component in the food web for nocturnal forest-dwelling species. For these reasons, this mammal was chosen as an indicator for the health of forested and shrubland ecosystems in the East Bay Stewardship Network's (Network's) area of focus. (See map, Chapter 1.)

We used three metrics to evaluate this species' condition and trend within the three subregions in the area of focus for this project. These include woodrat and nest presence (Metric 1), detection rates and occupancy estimates (Metric 2) and nest density and percent active (Metric 3) to measure current condition. We analyzed these metrics using Network Partner data from monitored parks and EBMUD land units. These data came from monitoring sites in individual parks, reservoirs, recreation or management areas, and other open spaces, which we refer to as "Network partner lands" throughout this chapter. A description of data sources and methodology can be found in Chapter 9, Mammal Methods and Data Assembly.

Based on these data, we found that the overall condition is "caution" and the trend is "unchanging." However, it is important to note that we have very low confidence in these assessments due to a lack of data for the majority of our metrics. Based on Metric 1, the woodrat condition was considered "good" in the East Bay Hills subregion, of "significant concern" in the Mt. Diablo Range subregion, and "caution" in the Mt. Hamilton subregion; however, this determination was made with low confidence. Although the other two metrics were data-deficient, data for Metric 2 (detection rates and occupancy estimates) will be generated from current studies. Data for Metric 3 could likely be generated from ongoing surveys required during maintenance activities on Network partner lands.

A primary goal of the analysis was to provide a benchmark against which managers can measure future changes and understand the likely trajectory of this species. Baseline data and analysis can be used to identify projects that achieve multiple benefits for this species.

Given the constraint of using only existing and available data, the evaluation also identified areas where not enough is known to draw meaningful conclusions, as well as opportunities for future research and collaboration between land managers. Data gaps are described at the end of this chapter and may be areas to focus on for future work.

METRICS SUMMARY AT A GLANCE

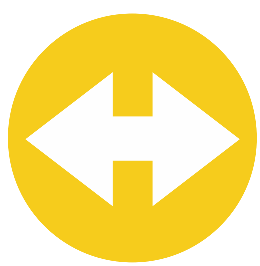
Table 13.1 summarizes the three metrics used in this NatureCheck ecological health assessment of the dusky-footed woodrat (hereafter referred to as "woodrat"). Each metric, along with how we arrived at its condition, trend, and confidence, is thoroughly described in the Metrics in Detail section later in this chapter. (See Chapter 1 for definitions and thresholds for condition, trend, and confidence; other terminology used throughout this chapter; how metrics are being used for each indicator; and other project methodology.)

Table 13.1. All woodrat metrics, with their respective condition, trend, and confidence for each subregion. Each metric is described in the Metrics in Detail section later in this chapter.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Metric 1: Woodrat and/or Nest–Woodrats and/or their nests are present in 50% of forested parks and/or land units in Network partner lands.			
Condition	Good	Significant Concern	Caution
Trend	Unknown	Unknown	Unchanging
Confidence	Low	Low	Low
Metric 2: Detection Rates and Occupancy Estimates–Woodrat abundance remains stable or increases in monitored forested units.			
Condition	Unknown	Unknown	Unknown
Trend	Unknown	Unknown	Unknown
Confidence	Low	Low	Low
Metric 3: Nest Density and Percent Active–Woodrat nest density and percent of active nests remain stable or increase in at least one monitored Network partner land area per subregion.			
Condition	Unknown	Unknown	Unknown
Trend	Unknown	Unknown	Unknown
Confidence	Low	Low	Low

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of the woodrat in the area of focus represented by the graphic below is based on the combined values of the individual metrics presented in Table 13.1. Each of these metrics is described in depth in the Metrics in Detail section of this chapter.



Condition: Caution (color: yellow)

Trend: Unchanging (symbol: horizontal arrow)

Confidence: Low (line around circle: none)

BACKGROUND

WHY IS THIS RESOURCE INCLUDED?

The San Francisco dusky-footed woodrat (*Neotoma fuscipes annectans*) is one of eleven recognized subspecies of the dusky-footed woodrat (*Neotoma fuscipes*) and is found throughout the San Francisco Peninsula and inland to the East Bay Hills (Matocq 2002). Considered a California species of special concern by CDFW, San Francisco dusky-footed woodrats and its nests provide critical resources to members of both lower and upper trophic levels in forested and shrubland ecosystems. They require moderate canopy with brushy understory. As ecosystem engineers, woodrats construct nests that provide shelter for numerous other taxa, including small rodents, lizards, snakes, and insects, spiders, and other invertebrates. These large terrestrial stick houses can last 20 or more years (Linsdale and Trevis 1951) and are easily detected. Additionally, this species is a key component in the food web for nocturnal forest-dwelling species such as the bobcat (*Lynx rufus*), gray fox (*Urocyon cinereoargenteus*), and owls. For these reasons, this mammal was chosen as an indicator for the health of forested and shrubland ecosystems in the Network's area of focus. (See map, Chapter 1.)

DESIRED CONDITION AND TREND

The desired condition is that at least 50% of forested units (land units and parks in the Network partner lands that support forests (see Intro Table 9.3) have at least one woodrat detection, with the desired trend being that a percentage of these forested units continues to meet or exceed this condition threshold. Also, that occupancy estimates from active camera studies show a stable or increasing trend from a baseline set in the first year. Finally, we would like to see woodrat nest density and percent active remain stable or increase in monitored areas (in at least one per subregion), as measured by protocol survey methods at established sentinel sites.

CURRENT CONDITION AND TREND

Condition: Caution

Trend: Unchanging

Confidence: Low

Woodrat and woodrat nest presence and distribution data for the 51 sq km of forests and 96.5 sq km of shrublands (habitat areas were determined using CLN 2.0 vegetation layer) within the area of focus used in this analysis came from the compiled Network partner agency records and published and unpublished woodrat nest studies described later in this chapter (also see Chapter 9, Tables 9.4 and 9.5b, and Appendix G, Data Assembly for Mammal Indicators). Based on these records, the woodrat was reported in the East Bay Hills subregion (Lafayette and San Pablo Reservoirs) and in the Mt. Hamilton subregion (Ohlone).

Supporting data included East Bay Municipal Utility District (EBMUD) presence and population density surveys from three reservoirs in the East Bay Hill subregion (Briones, San Pablo, and Upper San Leandro). These surveys consisted of detecting nests and determining the likelihood of activity as a proxy for population density. They found that both the number of nests and the number of active nests increased by 20% from 2002 to 2008.

Published woodrat nest densities (Shabel 2014) from the East Bay Hills subregion show similarities to those historically recorded. In this small study, conducted at Lake Chabot Regional Park, researchers found 167 woodrat nests in a 2.8 hectare (ha) (7-acre) study area. This equates to approximately 59 nests/ha, which is remarkably similar to the density of 57 nests/ha found in the late 1930s in the Berkeley Hills (Vestal 1938). As a point of comparison, higher nest densities have been reported in other parts of the Bay Area (not in the area of focus), with up to 92 nests/ha on the Stanford University campus (Bravo 2016) and 75 nests/ha in oak woodlands (Laudenslayer and Fargo 1997). Other reported nest densities are lower, especially in other habitats. For example, chaparral averaged four nests/ha and riparian habitat, 42 nests/ha; grasslands do not provide habitat for woodrats (Bravo 2016). High woodrat nest density in a given area may not necessarily indicate high woodrat population size, in part due to the incidence of unoccupied nests (Laudenslayer and Fargo 1997, Fargo and Laudenslayer 1999).

The current condition, trend, and confidence are the average of the condition, trend, and confidence for the woodrat in each subregion as shown in Table 13.2. The suite of metrics described in depth in the Metrics in Detail section of this chapter was combined to obtain this current condition and trend. These metrics are how we are measuring the difference between what is described in this section (i.e., how things are now) and the desired condition and trend in the preceding section (i.e., what we think "healthy" is for this indicator).

Table 13.2. Overall woodrat condition, trend, and confidence for each subregion in the area of focus.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Condition	Good	Significant Concern	Caution
Trend	Unknown	Unknown	Unchanging
Confidence	Low	Low	Low

STRESSORS

Several ecological and anthropogenic factors affect the health of this indicator. These include:

Historical Impacts: Loss of contiguous wooded areas with chapparal due to roads, trails, and fire control (fuels management) decreased available habitat and likely lowered the overall carrying capacity for woodrats. Unregulated and widespread use of rodenticides likely decreased abundance historically.

Fire Regime Change: Wildfires can destroy nest structures and the twigs and leaves used in the construction of those nests.

Pollution/Contaminants: Rodenticides are fatal to woodrats. Woodrats in areas adjacent to agriculture or suburban development might be more likely to encounter rodenticides on the landscape.

Direct Human Impacts: Habitats that support woodrat nests within the area of focus are disturbed by construction, fuel management, and other activities (e.g., road and trail infrastructure maintenance). For some regulated projects, mitigation for unavoidable disturbance to woodrat nests typically means relocating nests. This likely results in an unspecified amount of woodrat mortality due to increased exposure to predation (they no longer have a nest to return to, or if moved with their nest they are in an unfamiliar place) and potential competition with other woodrats in an unfamiliar range.

Habitat Disturbance/Conversion/Loss: Disturbance to forested and shrubland ecosystems due to rural and suburban development, including reduction and trail building, would likely reduce suitable woodrat nesting habitat and woodrat carrying capacity through permanent habitat loss, as well as habitat fragmentation.

Predation/Competition: Woodrats in areas adjacent to agriculture or suburban development might be more likely to encounter introduced predators like cats on the landscape.

CONDITION AND TRENDS ASSESSMENT

METRICS IN DETAIL

Presence/absence data for each unit (land unit or parks) on Network partner lands that supports forested and/or shrubland habitat could provide a simple way to calculate the proportion of units with suitable habitat that are occupied as a benchmark and determine current condition. Table 13.3 shows the acreage or area (sq km) of available suitable habitat for each subregion (see Chapter 9, Table 9.3), the number of areas that have that habitat per subregion, and the condition threshold (desired condition; see Table 13.3, Goal column). Presence/absence data may include records of woodrat nests (which may or may not be active) and/or woodrats (observation of an individual, an active woodrat nest, or camera trap photograph) in a given year or recent timeframe (the last three years, for example). We present recent Network partner agencies' records that we were able to compile for this effort, including camera studies (see Chapter 9, Table 9.5b and Appendix G: Data Assembly for Mammal Indicators).

*Table 13.3. The amount of forested and shrubland (scrub and chaparral) habitat, the to-be-determined number of units with a woodrat detection, and a condition threshold for "good" for the proportion of occupied land units and/or parks as a goal for each subregion in the area of focus.**

Subregion	Forest Acres (sq km)	Shrubland Scrub/Chaparral (sq km)	Units with Woodrat Detection/ Units Available	Goal (50%)
East Bay Hills	4,914 (19.9)	44.4	?/30	15/30
Mt. Hamilton	7,390 (29.9)	24.9	?/14	7/14
Mt. Diablo Range	243 (1.0)	27.3	?/7	4/7
Area of focus (Total)	12,547 (51)	96.5	?/51	26/51

*Only forested or shrubland parks or land units were included as candidates for determining woodrat presence.

Metric 1: Woodrat and/or Nest (Proportion Occupied)

Rationale: The presence of woodrats and/or their nests in forested habitats is a measure of ecosystem health. As a keystone species, woodrats provide prey for nocturnal predators, and their nests provide shelter for numerous taxa.

Condition Goal: Woodrats and/or their nests are present in 50% of forested parks and/or land units in Network partner lands.

Current Baseline: Camera records from monitored parks on Network partner lands were compiled, although some of the monitored sites lacked suitable habitat. The lack of records from Sibley Volcanic and Tilden may reflect that the cameras did not detect woodrats or that they were not recorded (identified during the image review process) because they were not a target species for the carnivore research studies from which the camera data was collected. As shown in Table 13.4, woodrats were detected in three of five (60%) monitored parks or land units in the East Bay Hills subregion. They were detected in EBMUD lands, but there were no records from Sibley Volcanic or Tilden[50]. Woodrats were detected in the Ohlone Wilderness in the Mt. Hamilton subregion but not detected in monitored parks in the Mt. Diablo Range subregion.

Table 13.4. Woodrat detection (1) and non-detection (0) for monitored park and land units and EBMUD lands units in the East Bay Hills. Numbers in parentheses represent total records for each Network partner agency land in each subregion within the area of focus (2012–2020; see Chapter 9, Table 9.5b).

Subregion	Agency	Monitored Network Lands[51]	Park Code	Woodrat Detections
East Bay Hills	EBMUD	EBMUD Property*	EBProp	1 (59)
East Bay Hills	EBMUD	Lafayette Reservoir*	LAFRES	1 (23)
East Bay Hills	EBRPD	Sibley Volcanic*	Sibley	0
East Bay Hills	EBMUD	San Pablo Reservoir*	SPRES	1 (1)
East Bay Hills	EBRPD	Tilden (Nature Area)*	Tilden	0
		% Units Occupied		***3/5 (60%)***
Mt. Diablo Range	CCWD	Altamont Subunit Altamont*	AP-AP HMU	0
Mt. Diablo Range	EBRPD	Clayton Ranch	CLRA	0
Mt. Diablo Range	CCWD	Deer Valley East Subunit Deer Valley	DVE HMU	0
Mt. Diablo Range	CCWD	Deer Valley West Subunit Deer Valley	DVW HMU	0
Mt. Diablo Range	CCWD	Los Vaqueros	LV HMU	0
Mt. Diablo Range	CCWD	Mountain House Subunit Altamont	AP-MH HMU	0
Mt. Diablo Range	EBRPD	Morgan Territory*	MOTE	0
Mt. Diablo Range	CSP	Mount Diablo State Park*	Mt. Diablo	0
Mt. Diablo Range	EBRPD	Round Valley	ROVA	0
		% Units Occupied		***0/9 (0%)***
Mt. Hamilton	CCWD	Corral Hollow HMU	CH HMU	0
Mt. Hamilton	CSP	Carnegie State Vehicular Recreation Area*	CSVRA	0
Mt. Hamilton	CCWD	Grant Line Subunit Altamont	AP-GL HMU	0
Mt. Hamilton	EBRPD	Ohlone Wilderness*	Ohlone	1 (61)
		% Units Occupied		***1/4 (25%)***
		Total Detections (all subregions)		***4/18***
		Proportion of the Total Study Area		***0.22***

*Forested habitat present for these parks or land units; units without asterisk have other habitats present.

Network partner agency abbreviations: CCWD = Contra Costa Water District, CSP = California State Parks, EBMUD = East Bay Municipal Utility District, EBRPD = East Bay Regional Park District

[51] See Table 14.3 for the amount of suitable habitat available.

Condition Thresholds:

- *Good:* Woodrat present in 50% of monitored[52] forested parks or land units within each subregion as documented in a three-year time period.[53]
- *Caution:* Woodrat present in less than 50% but more than 25% of monitored forested lands, or declining from baseline by 10% to 40%, in a three-year year period.
- *Significant Concern:* Woodrat present in less than 25% of monitored forested lands and/or declining from baseline by more than 40% from original baseline within a three-year period.

Woodrats are not present in all forested ecosystems, but where they are they can be locally abundant. While 50% of forested lands is an arbitrary number, it does represent a significant proportion of existing lands. While not all Network partner lands are monitored and the proportion that are monitored changes from year to year, this threshold is restricted to these lands.

Condition: Caution (average of all conditions below)

Good (East Bay Hills). Based on the aggregated records from the analysis, the East Bay Hills subregion had 60% of monitored parks or land units with detections, which exceeds the "good" threshold

Significant Concern (Mt. Diablo Range). Based on the aggregated records from the analysis, Mt. Diablo had 0% with detections from the monitored lands, which meets the "significant concern" threshold.

Caution (Mt. Hamilton). Based on the aggregated records from the analysis, Mt. Hamilton had 25% with detections, which meets the "caution" threshold.

Trend: Unchanging (average of all trends below)

Unchanging (Mt. Hamilton). The Mt. Hamilton subregion had several years in row of camera detections (2013–2018, see Appendix G, Data Assembly for Mammal Indicators, Table 4g.

Unknown (East Bay Hills, Mt. Diablo Range). Without a time series from consistently monitored lands, a trend could not be assessed.

Confidence: Low (all subregions)

We used the data (records) that were available to determine detections for this assessment but monitoring is not sufficiently comprehensive in terms of the amount of Network partner lands

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[52] Lands that are being monitored by camera traps or have been surveyed for woodrats and their nests.

[53] A baseline is established in Year 1 of data collection; three years (three data points) are required to establish a trend.

monitored. Additionally, it is unclear if woodrat were recorded from camera trapping images, which makes the data for this species potentially unreliable.

Metric 2: Detection Rates and Occupancy Estimates

Rationale: This metric is being used as a measure of ecological health because stable or increasing woodrat abundance indicates that the species has the resources it needs to persist and can therefore also support other species that rely upon it. This metric depends on camera trap detection rates (an intensity-of-use measure) and occupancy estimates (a surrogate for abundance) to measure trends.

Condition Goal: Woodrat abundance (detection rates and/or occupancy estimation) remains stable or increases in monitored forested units (as measured by camera trapping efforts).

Current Baseline: We cannot provide a baseline at this time; however, ongoing processing of existing and forthcoming camera images will provide the data we need to do so in the future. These data will represent Year 1 values for the following thresholds.

Condition Thresholds:

- *Good:* Woodrat abundance is stable or increasing in monitored forested Network partner lands in each subregion as established by detection rates (woodrat detections per 100 camera trap nights) and/or occupancy estimates (a reliable surrogate for abundance), evaluated in three-year cycles and because some fluctuations can be expected, declines less than 30% are acceptable (still in the "good" condition).
- *Caution:* Woodrat detection rates and/or occupancy estimates decline by more than 30% from the baseline (Year 1 values) over a three-year cycle.
- *Significant Concern:* Woodrat detection rates and/or occupancy estimates decline by more than 50% in any one year or season from baseline (Year 1 values), or after three years of a stable trend.

Monitoring trends in woodrat abundance is another measure to understand ecosystem health. Establishing a baseline in the first year of data collection can provide a benchmark against which to measure change. Detection rate (detections by unit of camera trap night effort) measures the intensity of use in the area monitored, and occupancy estimates (occupancy of a study area corrected by detection probability) can be used to see trends in abundance over time.

Condition: Unknown (all subregions)

The condition is unknown at this time due to a lack of data.

Trend: Unknown (all subregions)

The trend is unknown at this time due to a lack of data.

Confidence: Low (all subregions)

Our confidence is low because we have insufficient data to assess condition or trend.

Metric 3: Nest Density and Percent Active

Rationale: Woodrat nests are important for the numerous other species that use them for shelter and food. This can be measured by recording woodrat-nest density and determining the percent active (Table 13.5),[54] which provides additional data about local woodrat populations and their stability. As mentioned, woodrats are critical to forested ecosystem health in part as an important prey resource for nocturnal carnivores. Selected Network partner lands can be used as proxies for this metric within a given subregion because determining woodrat density and percent active for the entire area of focus is not feasible. However, monitoring smaller areas on an annual basis is an attainable goal.

Table 13.5. Example of standards for assessing active versus nonactive nests during surveys. (Source: EBMUD report, Neotoma fuscipes annectens*, 2008).*

	Nest Classification	Attributes for Each Category
1	**Active**	New nesting materials near or on nest, or fresh droppings present.
2	**Probably Active**	Nest in very good condition; clean openings to nest, or older droppings present.
3	**Maybe Active**	No signs of current activity, but in nest in good condition or with nest openings clear.
4	**Probably Not Active**	Nest in poor condition or with spider webs over nest.
5	**Not Active**	Nest broken down or nest openings closed or blocked.

Condition Goal: Woodrat nest density and percent of active nests remain stable or increase in at least one monitored Network partner land area per subregion.

Current Baseline: The current baseline is unknown for all subregions. A relatively recent monitoring effort conducted by EBMUD (EBMUD 2007, 2008) that surveyed presence and population density at three reservoirs (Briones, San Pablo, and Upper San Leandro) found that both the number of nests and number of active nests increased by 20% from 2002 to 2008. Another published study from the East Bay Hills subregion from Lake Chabot Regional Park (Shabel 2014) measured a woodrat nest density remarkably similar to that from a 1937 study in the Berkeley Hills (Vestal 1938) (see details in Current Condition and Trend section). These findings from the East Bay Hills subregion provide some support that woodrat nests are present and potentially stable or increasing, and based on one study, similar to historical densities. However, these studies are 14 and eight years old, respectively. The current baseline remains unknown. Recent data are needed from the three subregions to provide information about the contemporary condition and trend of this metric.

[54]See methods in EBMUD report (2007, 2008).

Condition Thresholds:

- *Good:* Woodrat nest density and percent active remain stable or increase in a three-year cycle from the baseline to establish trend in each subregion; because some fluctuations can be expected, declines of less than 30% are acceptable (still in the "good" condition).
- *Caution:* Woodrat nest density and percent active decrease by more than 30% in any *one* subregion in a three-year cycle from the baseline.
- *Significant Concern:* Woodrat nest density and percent active decrease by more than 30% in *two or more* subregions in a three-year cycle from the baseline.

Stable or increasing nest density and percent is a desired condition. Some fluctuation is expected. The 30% threshold for "caution" and "significant concern" was chosen to capture downward trends that may indicate environmental changes that are impacting the abundance and persistence of woodrats and their nests.

Condition: Unknown (all subregions)

Recent, reliable, and comprehensive monitoring data about nest density and percent active were not available to evaluate condition threshold or current condition.

Trend: Unknown (all subregions)

A time series of recent, reliable, and comprehensive nest density and percent active data was not available to evaluate trend.

Confidence: Low (all subregions)

Monitoring was not sufficiently recent or comprehensive to evaluate condition or trend.

OTHER METRICS CONSIDERED BUT NOT INCLUDED

No other metrics were considered beyond those noted in this chapter.

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

- Because the San Francisco dusky-footed woodrat is listed as a state species of special concern, potential impacts to this species are considered under CEQA review. In some instances, as a result of this review process, mitigation measures are designed to minimize impact to woodrats and their nests require pre-impact surveys for woodrat nests. Additionally, preliminary surveys conducted for the CEQA review process may include woodrat nest surveys. Results from CEQA woodrat nest surveys are not currently available from Network partners; centralizing access to these data would provide up-to-date information on woodrat nest detections for our metrics.

- Data collection methods on the presence or absence of woodrats and their nests should be standardized to supply date, location, and record type. These records could then be plotted and tallied on an annual basis to measure distribution and presence/absence, which would inform Metrics 1 and 3. Fuel reduction efforts and other ongoing maintenance work are also good sources for these data. Other sources include the Alameda whipsnake survey by-catch; however, these results would need to be sourced, aggregated, and tallied with location coordinates and date information.

- Comprehensive monitoring for this species and their nests has not been conducted within the area of focus. However, if nest location surveys, camera trapping detections, and multiyear monitoring (either specifically for woodrats or where they are detected as by-catch) could be compiled, there is likely enough information to establish (1) confirmed presence, (2) current distribution, and (3) multiyear camera trap detection rates to serve as a baseline against which to measure change over time (trends).

- Camera trapping surveys for which we had records appeared to be inconsistent in recording woodrat images. Including this species in current camera trapping studies and cataloging existing images will provide additional detection data that we can use in this assessment.

PAST AND CURRENT MANAGEMENT

As mentioned, EBMUD conducted San Francisco dusky-footed woodrat population density surveys at three reservoirs in the East Bay Hills subregion. Current woodrat management includes an East Bay Regional Park District (EBRPD) parkwide protocol outlining avoidance and minimization measures for projects that may impact this species (San Francisco Dusky-footed Woodrat Protocol for the East Bay Regional Park District, January 2019). This protocol was developed in coordination with the California Department of Fish and Wildlife.

Furthermore, EBRPD has an ongoing fuels management program that includes felling mature trees, removing understory vegetation by hand, masticating scrub, and burning brush piles. Reducing high-intensity fires may also support woodrat populations as wildfire may both directly kill woodrats as well as destroy their homes (Chew 1959).

POTENTIAL FUTURE ACTIONS

- Use the additional data sources described here to inform analysis of the three metrics included in this chapter. These sources potentially include fuel reduction activities and other permitted projects that require woodrat nest documentation, Alameda whipsnake survey by-catch data, and camera trap images from previous and ongoing studies.

- Establish sentinel sites to measure woodrat nest density and percent active (see Table 13.5) in each of the subregions. This would establish baseline conditions that could be resurveyed on an annual basis to gauge persistence and trend, providing information needed, in part, to address Metric 3.
- Standardize data collection on woodrat nest location (extant; not nests that are moved or destroyed).
- Use a seasonal occupancy analysis for camera trap data from current research efforts to establish a baseline occupancy estimation that could be used to determine trends. Use camera trap data to construct current distribution maps that would contribute to Metric 1.

KEY LITERATURE AND DATA SOURCES

Literature

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Partner Agency Data Sources

- East Bay Municipal Utility District (EBMUD), Mammal Database
- East Bay Regional Park District (EBRPD), Carnivore Research (Tilden-Sibley, Eastern Contra Costa County, Sunol-Ohlone)
- Contra Costa Water District (CCWD), San Joaquin Kit Fox Monitoring (Habitat Management Units)
- California State Parks (CSP), Large Mammal Occupancy Study (Carnegie State Vehicular Recreation Area) and Felidae Conservation Fund Study (Mount Diablo State Park)

Other Data Source:

University of California, Berkeley, Museum of Vertebrate Zoology (MVZ) Mammal Collection (Arctos)

Additional details about all of these data sources are provided in Appendix G, Data Assembly for Mammal Indicators.

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CHAPTER 14. BATS

EXECUTIVE SUMMARY

This chapter presents an evaluation of the current condition of a suite of bat species on lands owned and managed by East Bay Stewardship Network (Network) partner agencies. These species are good indicators of ecosystem health because the presence of the full suite of expected bat species, and their abundance, can provide information about the health of local insect populations and the availability of limited, critical habitat features.

We used three metrics to evaluate the condition and trend of a suite of bat species within the three subregions of the area of focus. (See map, Chapter 1.) These include species richness (Metric 1), seasonal call rates (Metric 2), and annual roost surveys (Metric 3). We analyzed these metrics using a variety of available data sources, a description of which can be found in Chapter 9. These data came from surveys done in individual parks, reservoirs, recreation or management areas, and other open spaces that we refer to as "Network partner lands" throughout this chapter.

Based on these data, we found that the overall condition is "caution" and the trend is "unchanging." All expected bat species have been documented across the AOF historically. The most recent dataset from 2017-2021 show declines in species richness in the Mt. Diablo and Mt. Hamilton subregions, but an increase in species richness in the East Bay Hills, when compared to historical data (pre-2017) (see Figure 14.2). We were able to collect data for Metrics 2 (call rates) and 3 (roost surveys) and the results are presented. Condition thresholds are predicated on trends in these metrics to determine if seasonal call rates are stable or increasing for a small number of locally and regionally common species, and if roost exit surveys conducted during the solstice each year show stable numbers for each roost. Because this was the first year, no determination of condition could be made for Metrics 2 or 3, but this year's data will serve as a benchmark.

A primary goal of the analysis was to provide a benchmark against which managers can measure future changes and understand the likely trajectory of these species. Baseline data and analysis can also be used to identify projects that achieve multiple benefits for bats.

Given the constraint of using only existing and available data, the evaluation also identified areas where not enough is known to draw meaningful conclusions, as well as opportunities for future research and collaboration between land managers. Gaps in our understanding include comprehensive bat monitoring efforts to provide standardized data for each subregion. Basic acoustic monitoring can provide species-detected lists (for Metric 1) and seasonal call rates (for Metric 2). A standard approach to this effort would provide an understanding of the distribution of bat species as well as their seasonal activity rates in a larger portion of the area of focus. These are described as data gaps at the end of this chapter and may be areas on which attention should focused in the future.

METRICS SUMMARY AT A GLANCE

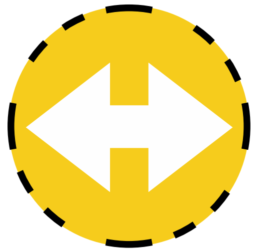
The table below summarizes the three metrics used in this NatureCheck ecological health assessment for bats. Each metric, along with how we arrived at its condition, trend, and confidence, is thoroughly described in the Metrics in Detail section later in this chapter. (See Chapter 1 for definitions and thresholds for condition, trend, and confidence; other terminology used throughout this chapter; how metrics are being used for each indicator; and other project methodology.)

Table 14.1. All bats metrics, with their respective condition, trend, and confidence for each subregion. Each metric is described in the Metrics in Detail section later in this document.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Metric 1: Species Richness–Maintained within the suite of expected species (excluding rare species) in each subregion to at least 80% of expected bat species (excluding rare ones).			
Condition	Caution	Caution	Caution
Trend	Improving	Unchanging	Declining
Confidence	High	High	High
Metric 2: Seasonal Call Rates–Stable and increasing trends for a few of the common species for each season or for selected seasons.			
Condition	Unknown	Unknown	Unknown
Trend	Unknown	Unknown	Unknown
Confidence	Low	Low	Low
Metric 3: Annual Summer Solstice Roost Surveys at Known Roosts (Exit Counts)–Counts remain stable for known roosts ("sentinel roosts") from each subregion.			
Condition	Unknown	Unknown	Unknown
Trend	Unknown	Unknown	Unknown
Confidence	Low	Low	Low

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of the suite of expected bat species in the area of focus represented by the graphic below is based on the combined values of the individual metrics presented in Table 14.1. Each of these metrics is described in depth in the Metrics in Detail section of this chapter.



Condition: Caution (color: yellow)

Trend: Unchanging (symbol: horizontal arrow)

Confidence: Moderate (line around circle: dashed)

BACKGROUND

WHY IS THIS RESOURCE INCLUDED?

The presence of the full suite of expected bat species, and their abundance, can provide information about the health of local insect populations and the availability of limited, critical habitat features. Of the 14 to 16 bat species expected in this area, the western red bat (*Lasiurus blossevillii*), the pallid bat (*Antrozous pallidus*), and Townsend's big-eared bat (*Corynorhinus townsendii*) are California species of special concern. Bat maternity roosts also receive some protection under the California Environmental Quality Act (CEQA).

Because bats use a variety of roosting sites, they can serve as an indirect measure of limited or patchy habitats, including riparian trees or forests with dense foliage and trees in various stages of decay, wood fall and snags, mines and caves, and rock outcrops. Bats with known roosting preferences can be used as proxies to understand which of these habitat features are available for other taxa that also depend on them. Bats are tied to freshwater sources, even if those sources are small pools of water or springs. Due to their diets, bats can be an indirect measure of insect diversity and abundance. Unfortunately, these insects are negatively affected by widely applied insecticides as well as numerous other stressors. A recent study in German nature reserves found that flying insect numbers may be plummeting by as much as 76% (Hallmann et al. 2017). Other studies show that as much as 40% of insect species are threatened with extinction worldwide, and that they are declining eight times faster than mammals, birds, and reptiles (Sanchez-Bayo and Wyckhuys 2019, Carrington 2019). Bats are highly mobile, widely distributed, and live longer than other similar-sized mammals, their presence (or absence) can also help indicate changes in these resources over time.

DESIRED CONDITION AND TREND

A healthy, intact ecosystem would support the full suite of expected bat species in each subregion each year. For select common bat species, stable or increasing abundance and activity levels (as measured through seasonal call rates) is maintained in each subregion for each season (fall and winter = migratory and hibernating; spring and summer = breeding and presence of roosting habitat). For select sentinel, or known, roosts, we would hope to see stable or increasing annual exit counts as measured by annual Summer Solstice Roost Surveys. The baseline exit counts for these has been set for six sentinel roosts surveyed for the June 2021 Summer Solstice Roost Survey (two in the East Bay Hills subregion, one in the Mt. Diablo Range subregion, and three in the Mt. Hamilton subregion; see Figure 14.1 at the end of this chapter for locations).

CURRENT CONDITION AND TREND

Condition: Caution

Trend: Unchanging

Confidence: Moderate

A table of expected bat species for the area of focus (see map, Chapter 1) was compiled from descriptions of each species' geographic range and from records from public sources including Arctos (Museum of Vertebrate Zoology [MVZ] Mammal Collection, University of California, Berkeley). Bat species records from Network partner agency survey data and reports (2004–2021) and the California Natural Diversity Database (CNDDB) (by county) were used to populate our documentation and, when possible, provide a date range for when the data was collected for each subregion. Network partner data came from a number of sources, such as the East Bay Regional Park District (EBRPD) bat surveys (2004–2015 and 2017–2021, see Figure 14.1 at the end of this chapter), the East Bay Municipal Utility District (EBMUD) mammal database (observations were recorded from 1995 to 2015 for the East Bay Hills), the Carnegie State Vehicular Recreation Area (CSVRA) (a 2014 report; Mt. Hamilton), and a Post-Fire Monitoring Study (acoustic files were collected in late 2020 to 2021; the classification was divided into two probability categories based on analysis: >75% likelihood, shown in black, and <75% likelihood, shown in red). Acoustic files below the 75% likelihood threshold require additional review to confirm the species; therefore, these findings should be considered preliminary.

Table 14.2: Expected bat species and documentation by subregion, 2004–2021. Data sources include the EBRPD bat survey data in two date ranges ("EBRPD 2004 - 2015" "EBRPD 2017- 2021"), EBMUD mammal database ("EBMUD 1995 -2015"), CNDDB query (by county, see below), Carnegie SVRA ("CSVRA 2014"), and Post-Fire Monitoring Study[55] (Mt. Diablo Range subregion only; included call identification with greater and less than 75% likelihood: "PF-2021 >75%", "PF-2021 <75%"). "Not Detected" indicates that were no bat records from these sources; for the Mt. Diablo subregion, PF<75% were excluded as a record.

Common Name	Scientific Name	Species Listing Status	Data Sources and Years Data Were Collected, by Subregion		
			East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Pallid bat*†	*Antrozous pallidus*	CSC	EBRPD 2004–2015, EBRPD 2017 - 2021, EBMUD 1995 - 2015	EBRPD 2004-2015, PF-2021 <75%	EBRPD 2004-2015, CSVRA 2014 EBRPD 2017 - 2021
Townsend's big-eared bat*†	*Corynorhinus townsendii*	CSC	Not Detected	Not Detected PF-2021 <75%	EBRPD 2004-2015, CSVRA
Big brown bat*	*Eptesicus fuscus*	None	EBRPD 2004-2015, EBRPD 2017- 2021, EBMUD 1995 - 2015	Not Detected PF-2021 <75%	EBRPD 2004-2015, EBRPD 2017- 2021
Red bat*†	*Lasiurus blossevillii*	CSC	EBRPD 2017 - 2021	Not Detected PF-2021 <75%	EBRPD 2017 - 2021, SJC
Hoary bat*†	*Lasiurus cinereus*	None	EBRPD 2004-2015, EBRPD 2017- 2021	PF-2021>75%	SJC
Silver-haired bat†	*Lasionycteris noctavigans*	None	EBRPD 2017 - 2021	PF-2021 <75%, AC	EBRPD 2017 - 2021
California myotis*	*Myotis californicus*	None	EBRPD 2004-2015, EBRPD 2017-2021, EBMUD 1995 - 2015	EBRPD 2017-2021, PF-2021 >75%	EBRPD 2017-2021, CSVRA 2014
Long-eared myotis*†	*Myotis evotis*	None	Not Detected	Not Detected	SCC, CSVRA 2014
Fringed myotis*†	*Myotis thysanodes*	None	Not Detected	Not Detected	*SCC*, CSVRA 2014
Long-legged myotis*†	*Myotis volans*	None	Not Detected	Not Detected	SCC

[55] On-going study being conducted by EBRPD

Common Name	Scientific Name	Species Listing Status	Data Sources and Years Data Were Collected, by Subregion		
			East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Yuma myotis*†	*Myotis yumanensis*	None	EBRPD 2017 - 2021	PF-2021 >75%, CCC	EBRPD 2017 – 2021, *SCC,* CSVRA 2014
Canyon bat*	*Parastrellus hesperus*	None	Not Detected	*EBRPD 2004-2015, PF-2021* >75%	EBRPD 2004-2015, EBRPD 2017 – 2021, CSVRA 2014
Mexican free-tailed bat*	*Tadarida brasiliensis*	None	EBRPD 2004-2015, EBRPD 2017 – 2021, EBMUD 1995 - 2015	EBRPD 2017 – 2021, PF-*2021* >75%	EBRPD 2004-2015, EBRPD 201-2021
Little brown myotis† (rare)	*Myotis lucifugas*	None	Not Detected	PF-2021 <75%, CCC	SJC
Small-footed myotis† (rare)	*Myotis ciliolabrum*	None	Not Detected	PF-2021 *>75%,* CCC	SJC
Big free-tailed bat† (very rare)	*Nyctinomops macrotis*	None	Not Detected	AC, CCC	Not Detected
Western mastiff bat[56] (rare)	*Eumops perotis*	CSC	Absent	PF-2021 >75%	SJ, SCC

*Arctos query (not included by subregion)

†CNDDB record, by counties included in the area of focus: AC = Alameda County, CCC = Contra Costa County, SCC = Santa Clara County, SJC = San Joaquin County

Abbreviations: C = Carnegie State Vehicular Recreation Area bat study (2014), CSC = California species of special concern

Color (probability): Black = >75% likelihood, red = <75% likelihood

The current condition, trend, and confidence are the average of the condition, trend, and confidence for bats in each subregion as shown in Table 14.3. The suite of metrics described in depth in the Metrics in Detail section of this chapter was combined to obtain this current condition and trend. These metrics are how we are measuring the difference between what is described in this section (i.e., how things are now) and the desired condition and trend in the preceding section (i.e., what we think “healthy” is for this indicator).

[56] The western mastiff bat is absent in Santa Clara County and not expected in the East Bay Hills subregion because it is not within this species’ range.

Table 14.3. Overall bats condition, trend, and confidence for each subregion in the area of focus.

	East Bay Hills	Mt. Diablo Range	Mt. Hamilton
Condition	Caution	Caution	Caution
Trend	Improving	Unchanging	Declining
Confidence	Moderate	Moderate	Moderate

STRESSORS

Several ecological and anthropogenic factors affect the health of this indicator. These include:

Historical Impacts: The removal of older buildings, mine closures, and bridges that served as bat roosts have impacted local bat populations.

Climate Change: Drought, which has occurred for multi-year periods over the past 10 years, can have deleterious effects on the insect populations that bats rely on for food. Climate change is likely to cause shifts in distribution of bat populations due to shifting prey (insect) populations and changes in local climate conditions at roost sites.

Fire Regime Change: Wildfires could be decreasing the availability of suitable tree- and snag-roosting habitat.

Disease: White-nose syndrome (WNS) is having a significantly negative effect on some bat species.

Pollution/Contaminants: Insecticides are used in a wide variety of circumstances, particularly in agricultural areas in areas adjacent to Network Partner Lands. Not only could this result in the loss of insect populations, these chemicals can also bioaccumulate in bats, with deleterious effects on their health.

Direct Human Impacts: Wind turbines can cause significant bat mortality (Smallwood and Bell 2020, Thompson et al. 2017, Arnet and Baerwald 2013, and Hayes 2013).

Habitat Disturbance/Conversion/Loss: Suitable roosting structures, such as bridges, buildings, trees, and other structures, are demolished impacting roosts and reducing availability. Fuel reduction could result in roost disturbance and loss of suitable roosting habitat. Increased urbanization creates more light pollution, which may disturb night roosts. Habitat disturbance has been shown to affect health of individual bats (Seltmann et al. 2017 – Habitat disturbance results in chronic stress and impaired health status in forest-dwelling paleotropical bats.)

CONDITION AND TRENDS ASSESSMENT

METRICS IN DETAIL

Data aggregated from Network partner agencies included the EBMUD mammal database, the EBRPD bat survey records (2004–2015, 2017–2021), and other sources listed in the Key Literature and Data Sources section at the end of this chapter. Combined, these were used to update previously aggregated species-richness data, the results of which are shown in Table 14.2.

Recent bat monitoring efforts in the Mt. Diablo Range subregion (EBRPD's Round Valley and Contra Costa Water District's [CCWD] Los Vaqueros Watershed) are capturing seasonal call rates (winter, spring, summer 2021), some of which are included here. The continuation of the effort and related analysis will establish baseline conditions against which to measure trends for Metric 2. Additional acoustic monitors to measure seasonal call rates are also planned for the East Bay Hills and Mt. Hamilton subregions.

In addition to these acoustic monitoring projects, in 2021, six roosting sites were chosen as sentinel sites, at which emergent counts were conducted: two in the East Bay Hills, one in the Mt. Diablo Range, and three in Mt. Hamilton. The emergent counts collected at these sites provide baselines (Figure 14.1). Emergent counts conducted in June 2021 at these sites will be repeated each year, using solstice exit surveys (Wisconsin Summer Bat Colony Monitoring Protocol; see Appendix I). The 2021 solstice exit survey results were compiled and will serve as the baseline for assessing condition and trend for this metric for each subregion over time.

Metric 1: Species Richness

Rationale: Bat species diversity indicates that the ecosystem is providing adequate and varied insect prey and a range of adequate roosting resources. Loss of even a few bat species could indicate the loss of a critical habitat feature or type of prey.

Condition Goal: Species richness within the suite of expected species (excluding rare species) is maintained (Table 14.2) in each subregion to at least 80% of expected bat species (excluding rare ones).

Current Baseline: Data aggregation from Network partners included the EBMUD mammal database and bat survey records from EBRPD (2004–2015 and 2017–2021) in particular. The aggregated bat records data for this effort updated species richness documentation (Table 14.2). Bat detection data were compiled from Network partners and the CNDDB.

EBRPD acoustic and emergent bat surveys were conducted at bat houses, roosts, and other locations on EBRPD lands (Figure 14.1, Table 14.2). From 2004 to 2015, EBRPD bat surveys recorded six species from five parks (Chabot, Cull Canyon, Garin, Redwood, and Sibley) in the East Bay Hills subregion, two species from three lands (Black Diamond Mines, Brushy Peak, and Contra Loma) in the Mt. Diablo Range subregion, and six species from four lands (Camp Arroyo, Del Valle, Mission Peak, and Sunol) in the Mt. Hamilton subregion. The pallid bat, a California species of special concern, was detected in all subregions, and the Townsend's big-eared bat, also a California species of special concern, was detected in the Mt. Hamilton subregion.

Between 2017 and 2021, 22 emergent and 21 ad hoc acoustic surveys were conducted on Network partner lands; nine species were detected in six parks in the East Bay Hills subregion, two species at Clayton Ranch in the Mt. Diablo Range subregion, and nine species from three parks in the Mt. Hamilton subregion (Figure 14.1, Table 14.4; Figure 14.1 shows survey locations and species detected from these surveys as well as the land units on which these surveys were conducted or where records were from). Emergent counts ranged from zero to 50 individuals in the East Bay Hills subregion and from 58 to 1,011 individuals in the Mt. Hamilton subregion. No emergent count results were available from the Mt. Diablo Range subregion.

Table 14.4: Results from bat surveys (EBRPD, 2017–2020; "acoustic" and "emergent" were counted as separate surveys). Shows counts of detections (1s) and non-detections (0s) for each species by survey.

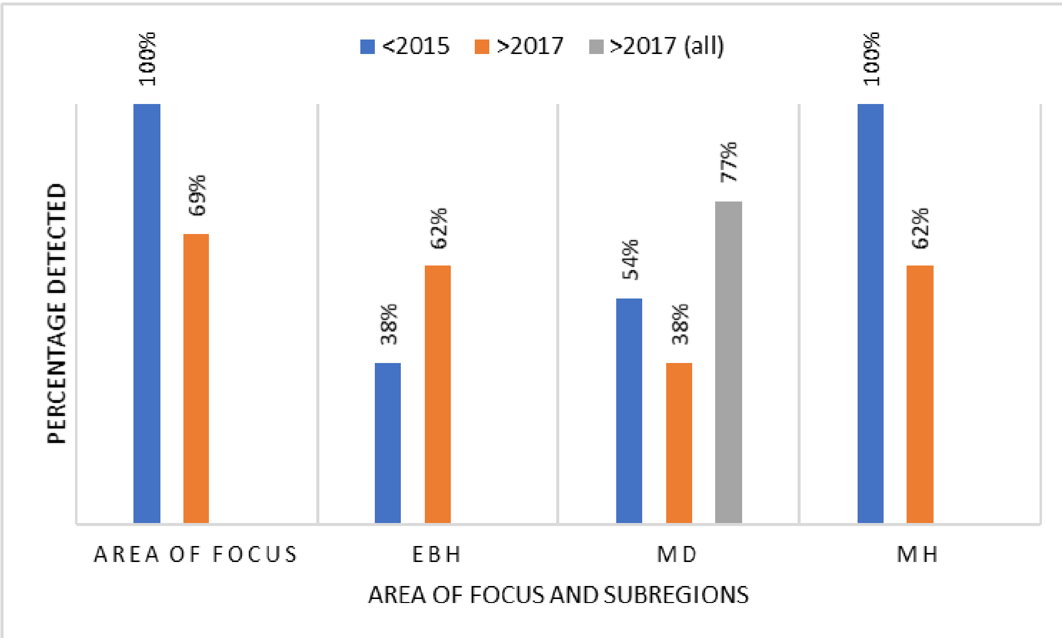
				Species Detections (Yes/No)									
Subregion	**No. Lands**	**No. Surveys**	**No. Sp.**	**MYSP**	**MFBA**	**YUMY**	**CAMY**	**BBBA**	**REBA**	**SHBA**	**HOBA**	**PABA**	**CABA**
East Bay Hills	**6**	**21**	**9**	**2**	**8**	**5**	**6**	**3**	**1**	**5**	**2**	**2**	**0**
Mt. Diablo Range	**1**	**2**	**2**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**
Mt. Hamilton	**3**	**20**	**9**	**10**	**10**	**6**	**6**	**4**	**2**	**2**	**0**	**2**	**1**
TOTAL	***10***	***43***	***10***	***12***	***19***	***11***	***13***	***7***	***3***	***7***	***2***	***4***	***1***

Bat species abbreviations: MYSP = *Myotis* sp., MFBA = Mexican free-tailed bat, YUMY = Yuma myotis, CAMY = California myotis, BBBA = big brown bat, REBA = red bat, SHBA = silver-haired bat, HOBA = hoary bat, PABA = pallid bat, and CABA = canyon bat.

Column abbreviations: No. Lands = Number of parks/land units that were surveyed, No. surveys = number of surveys conducted, No. sp. = number of species detected for each subregion.

We were able to determine the condition of this metric based on a variety of data sources from 2004 to 2021; therefore, it will serve as a reliable baseline (Figure 14.2). To assess the current condition using this metric, we calculated the percentage of species that were detected out of the expected species (i.e., excluding rare species) from Table 14.2 (see Figure 14.2). We divided these data into two timeframes: before 2015 and after 2017. The more recent data included results from EBRPD surveys (2017–2021; Table 14.4) and acoustic surveys for the Post-Fire Monitoring Study (2021) conducted in the Mt. Diablo Range subregion (see Metric 2 for methodology and other references for this study). The Post-Fire Monitoring Study detected 10 of the 13 expected species (five species with >75%

confidence and an additional five species with <75% confidence in species identification, based on acoustic classification from SonoBat bat call analysis software; see Table 14.2 and Figure 14.2). In addition to the 10 of 13 expected species, two rare species, *Myotis ciliolabrum* and *Eumops perotis*, were detected, as well as *Myotis lucifugus* (<75% likelihood and difficult to distinguish from other more common Myotis species, based on the sonogram; SonoBat software). This metric will be updated on an annual basis to assess condition and trend.



Subregion abbreviations: EBH = East Bay Hills, MD = Mt. Diablo Range, MH = Mt. Hamilton

Figure 14.2: The number of detected bat species as a percentage of the expected 13 species (not the rare ones; see Table 14.2) for the area of focus and subregions (EBH, MD, and MH). For species detected in 2017 and later, ">2017" (=orange bar) includes all species detected except the 5 species with less than a 75% likelihood in the Post-Fire Study (MD only). For the Mt. Diablo Range ("MD"), ">2017 (all)" (=gray bar) indicates all species detected.

Condition Thresholds:

- *Good:* 80% to 100% of the expected species (not those considered rare) are documented in the area of focus and in each subregion each year.
- *Caution:* The percentage of detected expected species is less than 80% and/or decreases by more than 20% (which represents a loss of three species in a single year in any one subregion).

- *Significant Concern:* Less than 25% of expected species occur within each subregion and/or the number of documented species decreases by more than 40% (the loss of five species) in any one subregion within a three-year period.

Intact ecosystems have most to all of their expected species in any given taxon—in this case, of the suite of expected bat species for the area of focus. Documenting the full complement of bats is a way to measure “intactness,” with intact ecosystems thought to be more stable and resilient to both anthropogenic and environmental perturbations. Additionally, an intact bat community indicates that the resources upon which this variety of species relies are also available. The “good” threshold (most to all species) measures intactness. Condition can be assessed through the stated percentage thresholds, and trends can be measured through changes in these percentages.

Condition: Caution (all subregions) The most recent data, 2017–2021 (Figure 14.5, orange bar), indicates that the area of focus and each subregion are below the 80% species detected threshold (“good”) and above the 25% threshold (“significant concern”), which places it/them in “caution” condition.

Trend: Unchanging (average of all trends below)

> **Improving** (East Bay Hills)
>
> **Declining** (Mt. Diablo Range, findings from >2017, excluding calls with <75% likelihood classification), or **Improving** (Mt. Diablo Range, including all species detected) (Note, the average of these gives an **Unchanging** trend)
>
> **Declining** (Mt. Hamilton)

Our trend analysis compared aggregated records of bat species detected from before 2015 to those detected from 2017 to 2021. The area of focus and the Mt. Hamilton subregion had 100% of expected species detected before 2015 (condition good). The species-detected percentages in the 2017–2021 date range showed declines, with the exception of the East Bay Hills subregion, which changed from 38% (before 2015) to 62% (2017–2021), showing an improving trend (Figure 14.2). However, for this subregion, both 38% and 62% were below the 80% threshold for good condition. The Mt. Diablo subregion had two trends: improving and declining. The trend was declining when considering only those species classified with a >75% confidence but improving when using all species detections (including calls classified with lower confidence [Figure 14.2, gray bar]).

Confidence: High (all subregions)

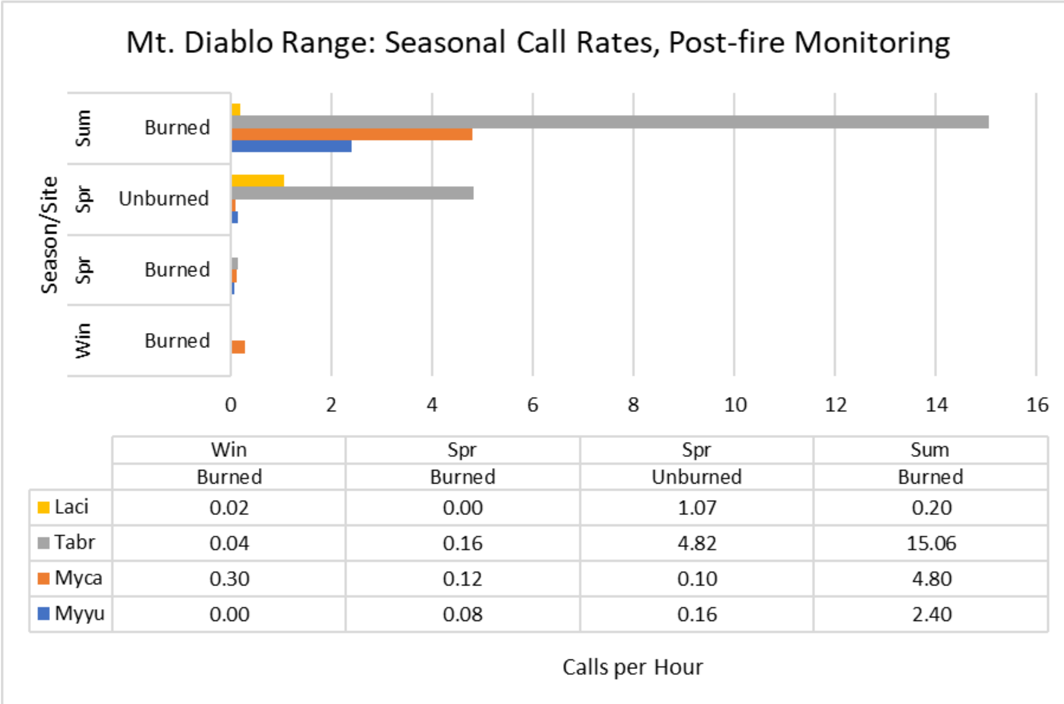
Data (detections) used for this metric were reliable, recent (in some cases) and comprehensive (covering several areas in each subregion) and represent a long time series; records from the recent past provided a time-series needed to determine trends for the area of focus and the subregions.

Metric 2: Seasonal Call Rates

Rationale: Stable abundance of common bat species over time indicates that their environment is providing necessary insect prey and roosting habitats. This can be measured by using call rates for the different species to assess seasonal abundance and to track trends over time.

Condition Goal: Stable and increasing seasonal call rate trends for a few of the common species (recommended species include *Myotis yumanensis*, *Tadarida brasiliensis*, and *Myotis californicus*) for each season or for selected seasons. Species appropriate for sampling site and subregion will be determined based on the findings from the acoustic monitoring. The chosen species should represent bats that are both common and widespread as well as those that are not common but are locally abundant. This way, common species that can represent larger regional and local trends can be selected.

Current Baseline: Seasonal activity rates were measured as "call rate per hour" for three sampling periods (winter, spring, and summer 2021) (Figure 14.2) for two monitoring sites in the Mt. Diablo subregion from the Post-Fire Monitoring Study (EBRPD study, on-going). Pettersson D500x acoustic bat monitors were set at burned and unburned sites for one- to two-week periods, recording five hours each night (2030 to 0130). The collected acoustic files were analyzed to identify species and number of calls per hour (SonoBat bat call analysis software) and data collection at these sites will continue for future comparisons. Seasonal call rates for Yuma myotis, California myotis, Mexican free-tailed, and silver-haired bats (Figure 14.3) were calculated as a benchmark against which to measure seasonal trends in subsequent years at these two sites for the Mt. Diablo subregion. Results from an additional study (G. Reyes, USGS) are pending for monitoring sites in all subregions. Once completed, this study will provide additional benchmarks from other sampling sites. From these studies, benchmarks will be determined the first year of collection and then averaged over three years for each study site.



	Win Burned	Spr Burned	Spr Unburned	Sum Burned
Laci	0.02	0.00	1.07	0.20
Tabr	0.04	0.16	4.82	15.06
Myca	0.30	0.12	0.10	4.80
Myyu	0.00	0.08	0.16	2.40

Bat species abbreviations: *Laci = silver-haired bat, Tabr = Mexican free-tailed bat, Myca = California myotis, and Myyu = Yuma myotis*

Figure 14.3: Seasonal call rates for four bat species in burned and unburned sites in 2021 for the Mt. Diablo Range subregion. (Sum = summer, Spr = spring, Win = winter)

Condition Thresholds:

- *Good:* Maintain current or increasing seasonal call rates in each subregion for each key (common) species over the course of three or more years. Small decreases of less than 20% are acceptable.
- *Caution:* Seasonal call rates for two or more common species decrease by 20% but not more than 50% in more than one season from the previous year.
- *Significant Concern:* Seasonal call rates for the majority of common species decrease by more than 50% in more than one season from the previous year.

Condition: Unknown (all subregions)

We are unable to assess condition due to the lack of a three-year time-series data set.

Trend: **Unknown** (all subregions)

No time series of seasonal call rates were available to assess condition and trend for this metric.

Confidence: Low (all subregions)

The activity call rates used for this metric were from two study sites in the Mt. Diablo subregion; these data were recent, reliable, and represent high-quality data. These data do not provide the three-year time series needed to indicate trend. The monitoring data was not comprehensive because call-rate data (a measure of activity) was only available for one subregion. Acoustic bat surveys are planned or underway for all subregions and will provide seasonal call rates to assess condition and trends over time.

Metric 3: Annual Summer Solstice Roost Surveys at Known Roosts (Exit Counts)

Rationale: Annual solstice exit surveys for known roosts provide a measure of roost stability because some roosts are considered critically important to bat populations. A downward trend in annual roost-site exit counts could indicate local bat number declines.

Condition Goal: Emergent counts from annual Summer Solstice Roost Surveys remain stable for known ("sentinel") roosts in each subregion.

Current Baseline: Sentinel roost sites were selected to establish a baseline emergent count following Summer Solstice Roost Survey methods (see Appendix I: Wisconsin Summer Bat Colony Monitoring). These include two sentinel roosts in the East Bay Hills subregion, one sentinel roost in the Mt. Diablo Range subregion, and three sentinel roosts in the Mt. Hamilton subregion (Figure 14.1). The exit survey results from these locations shown in Table 14.5 ranged from a low of three bats in the East Bay Hills subregion to a high of 954 in the Mt. Hamilton subregion. Ideally, in the future, we will be able to add an additional site for the Mt. Diablo Range subregion. Local trends will be determined by conducting annual exit counts at sentinel roosts (following protocols established for the Summer Solstice Roost Survey). This effort will also contribute to a nationwide effort for annual bat monitoring using a standardized survey protocol (G. Reyes, personal communication, May 2021).

Table 14.5: Results from Summer Solstice Roost Surveys (June 20–22, 2021) in each subregion in the area of focus (Year 1, baseline).

Subregion	Network Partner Land Area	Agency	Sentinel Site CODE	Site Name	Start Time	End Time	Duration	Bat Count
East Bay Hills	Redwood (Roberts RRA*)	EBRPD**	RD_1	Park Concession Res/Box	20:33	21:07	0:34	3
East Bay Hills	Redwood	EBRPD	RD_2	Piedmont Stables	20:10	21:07	0:57	64

Subregion	Network Partner Land Area	Agency	Sentinel Site CODE	Site Name	Start Time	End Time	Duration	Bat Count
Mt. Diablo Range	Black Diamond Mines	EBRPD	BD_1	Black Diamond Mines, Stope 11	20:28	21:44	1:16	40
Mt. Hamilton	Del Valle	EBRPD	DV_1	Oak Point Restroom	20:35	21:30	0:55	954
Mt. Hamilton	Del Valle	EBRPD	DV_2	Camp Arroyo Power Plant	20:33	21:15	0:42	143
Mt. Hamilton	Sunol	EBRPD	SN_1	High Valley Barn	20:03	21:30	1:27	112

*Roberts Regional Recreation Area

**East Bay Regional Park District

Condition Thresholds:

- *Good:* Sentinel roost colony sizes are maintained or increase from the baseline (Year 1, Table 14.5) over the course of three years; decreases in counts of up to 20% at individual sites and overall are acceptable.
- *Caution:* Sentinel roost colony sizes decrease by more than 20% but not more than 50% from the baseline (Year 1) over the course of three years.
- *Significant Concern:* Sentinel roost colony sizes decrease by more than 50% from the baseline (Year 1) over the course of five years.

Condition: Unknown (all subregions)

Summer Solstice Roost Surveys (2021) were conducted to establish baselines against which future trends can be measured.

Trend: Unknown (all subregions)

Time series for exit counts were not available to assess trends.

Confidence: Low (all subregions)

Monitoring data is recent, reliable, and somewhat comprehensive, and provides a benchmark upon which to measure trend. We have confidence in our recent data, but without multiple years of exit counts from the same roosts, we cannot assess condition, which is predicated on trends.

OTHER METRICS CONSIDERED BUT NOT INCLUDED

Recent bat mortality studies at the Altamont Wind Farm were identified as a possible data source (D. Johnston, D. Bell, and S. Smallwood have reports [personal communication, January 2020]) and could be used to create an additional metric. However, S. Smallwood and D. Johnston caution that methods for the Altamont wind-turbine fatality counts vary widely in how they report deaths per kilowatt hour. Additionally, data interpretation can be problematic because reduced mortality may be a function of fewer bats or may be because mitigation efforts to reduce bat death rates were successful. Furthermore, these data are biased toward Mexican free-tailed bats. However, wind energy permits will likely provide an ongoing source of bat information into the future. In addition to bat mortality rates due to wind turbines, data from the Altamount Pass on rates of bats per hour (a measure) could also potentially be used to understand historical trends (S. Smallwood, personal communication, January 2020).

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

- Trend and condition data are lacking for Metrics 2 and 3.
- Currently, no call rate data for the East Bay Hills and Mt. Hamilton subregions was available.
- There is currently only one emergent survey location in the Mt. Diablo subregion.
- There is likely little known about bat productivity with the AOF. Future work could identify maternity colonies and attempt to track reproductive rates over time.
- Currently have one year of post-fire monitoring for call rates. Continued monitoring could reveal how bat populations respond to fire.

PAST AND CURRENT MANAGEMENT

In addition to the acoustic survey results presented here, planned acoustic surveys will establish more baselines for these metrics as additional acoustic sensors in each subregion document species present and call rates.

The North American Bat Monitoring Program (NABat www.nabatmonitoring.org/) uses standardized protocols to gather data through acoustic surveys, summer roost counts, and winter hibernacula surveys. These data are used to measure local, regional, and range-wide changes in bat populations in the U.S., Canada, and Mexico to assess bat-species abundance at multiple spatial scales, see changes in species distribution, and provide regular analyses and reporting on the status of North American bats.

POTENTIAL FUTURE ACTIONS

- Work with Network partner agencies to identify bat data being collected and ways to share these data for metrics such as species detections.
- Consider increasing the number of acoustic monitors deployed in the area of focus to gain a better understanding of bat species richness and call rates.
- Maintain buildings, mines, and large trees and erecting proper bat boxes would help ensure the availability of suitable roosting habitat.
- Study the health of specific invertebrate populations that serve as important prey for specific bats in area of focus.

KEY LITERATURE AND DATA SOURCES

Literature

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Wisconsin Bat-Roost Monitoring Project. (n.d.). Wisconsin Bat Program, Bureau of Natural Heritage Conservation Species Management. http://wiatri.net/inventory/bats

PARTNER AGENCY DATA SOURCES

- East Bay Municipal Utility District (EBMUD), Mammal Database
- East Bay Regional Park District (EBRPD), Bat Survey Database (2004–2015, 2017–2021), Post-Fire Monitoring Study (2021)
- California State Parks (CSP), Carnegie State Vehicular Recreation Area, Miscellaneous Reports (2014)

Other Data Sources:

- California Department of Fish and Wildlife (CDFW), California Natural Diversity Database (CNDDB)

- University of California, Berkeley, Museum of Vertebrate Zoology (MVZ) Mammal Collection (Arctos)

Additional details about all of these data sources are provided in in Appendix G, Data Assembly for Mammal Indicators.

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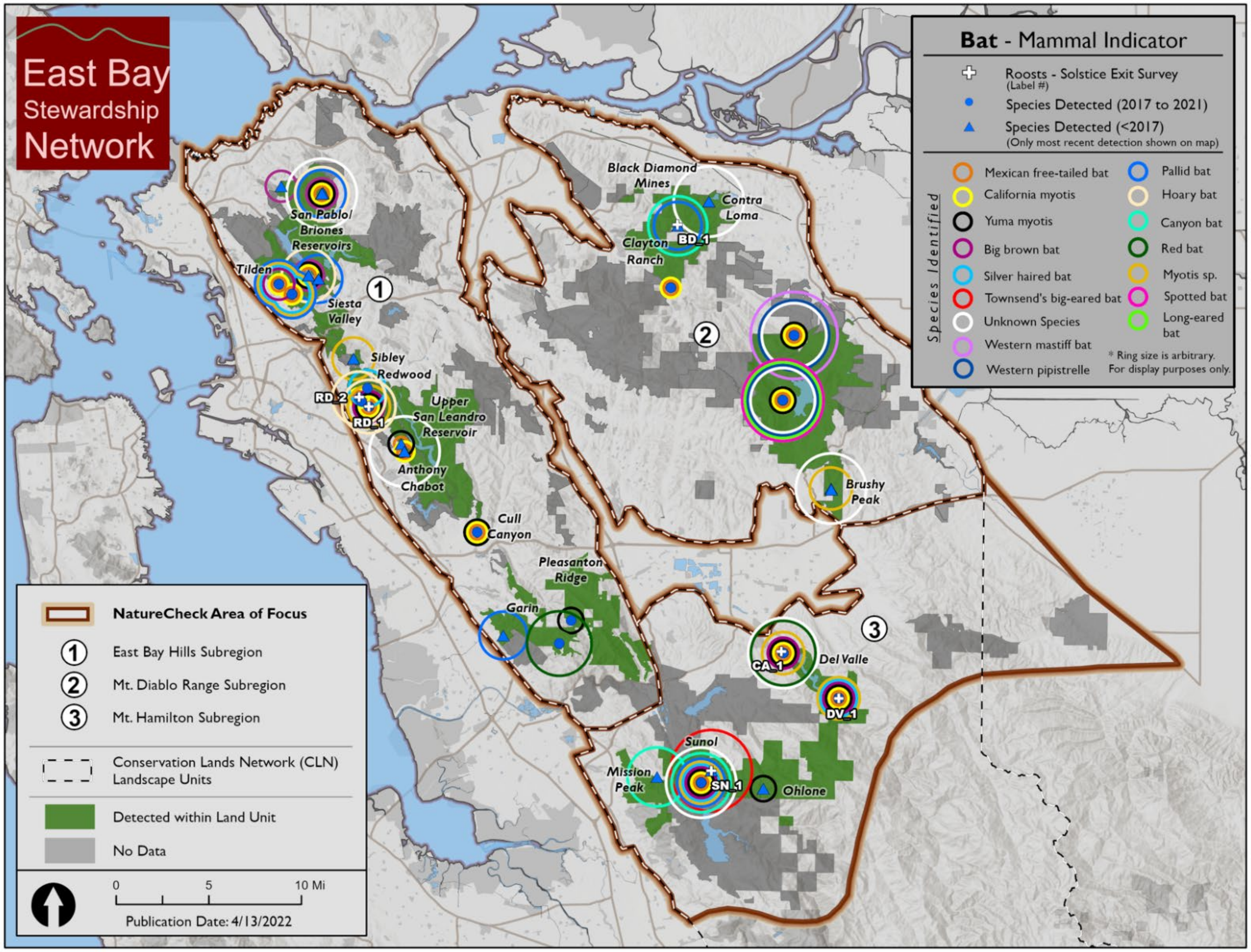

Fig 14.1: Bat species at EBRPD acoustic and emergent survey locations (2004 – 2015, 2017 – 2021), Post-Fire Monitoring Study (PF-2021) and EBMUD bat records and roost locations ("Solstice Exit Survey") (2021; Table 14.5). Land units (or parks) in green indicate Network partner agency land areas with bat species detections; dark gray areas indicate land units or parks without bat species survey data.