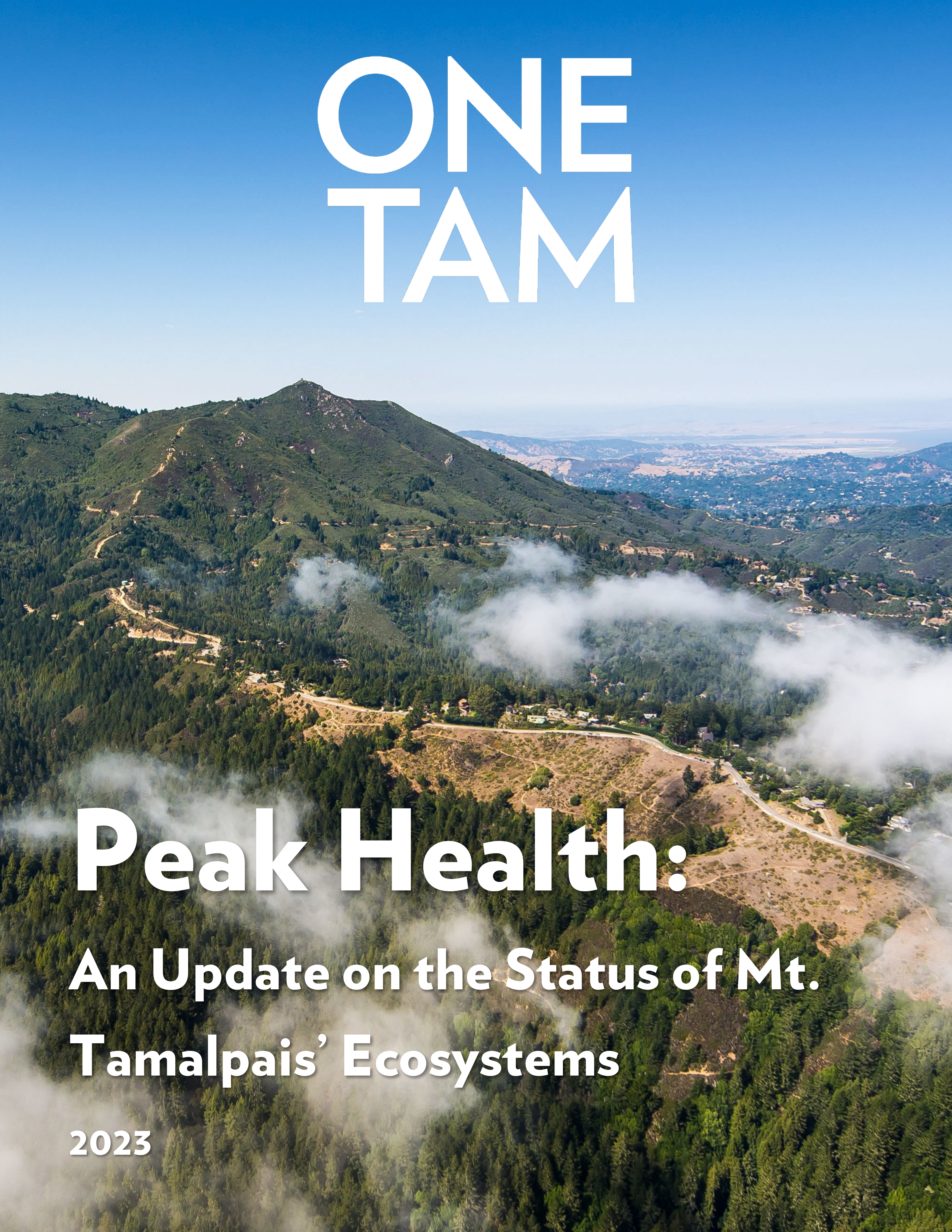

ONE TAM

Peak Health:

An Update on the Status of Mt. Tamalpais' Ecosystems

2023

ACKNOWLEDGEMENTS

Mt. Tamalpais, and all the lands currently managed by the One Tam partners, are Coast Miwok land.

In addition to the authors and contributors listed in each chapter, several others helped bring this project to fruition. We thank Lizzy Edson and Zac Stanley for their data and cartographic skills and for creating the tables, graphs, and maps used throughout this document; Susan Tasaki for her editorial work; and Michelle O'Herron for her writing, editing, and wrangling. Also, thanks to Yolanda Molette and Michela Gentile for their review and guidance, and to Janet Klein for her overall support.

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For individual chapters, please first cite the chapter's author(s) and title, followed by information on the full volume.

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EXECUTIVE SUMMARY

This report updates the 2016 *Measuring the Health of a Mountain: A Report on Mount Tamalpais' Natural Resources,* which represented an unprecedented collaboration among One Tam land managers, the Golden Gate National Parks Conservancy, and the larger scientific community. Anchored in a Western intellectual tradition, it uses the most current data and best expert judgement to understand the mountain's health.

There are many ways to evaluate something as complex as the health of a mountain, from the condition and trend of an individual species or entire communities to larger ecological processes or threats. We considered all of these aspects by identifying measurable elements (metrics) that say something about the health of important species or communities (health indicators). Combined in different ways, these indicators tell us about the health of broader communities, overall biodiversity, or climate resilience.

The 2016 report established important benchmarks and repeatable metrics that managers can use to see change across jurisdictional boundaries. It led to better resource management coordination and also revealed many new opportunities to collaboratively fill in important information gaps and to be better stewards of the mountain.

Some of those opportunities have been realized. A new countywide bat monitoring program and bee inventory within the One Tam area of focus (Figures 1.1 and 1.2)—both identified as key needs in the 2016 report—have been added to this update. The California giant salamander (*Dicamptodon ensatus*), another species listed as an important information gap in 2016, also now has its own chapter.

More broadly, a countywide vegetation map completed in 2021 provides a comprehensive representation of the mountain's plant life that was not available in 2016. The map and its underlying data allow us to see change over time and to manage these lands within a regional context in a way that was not possible before. Further, the 2023 Marin Regional Forest Health Strategy offers additional breadth and depth of analysis on important plant communities not included in this report.

The 2016 effort was as much a journey into deeper collaboration and relationship building as it was the creation of a report. Bringing together agency staff and regional experts, it fostered a greater spirit of trust and collaboration across disciplines and organizations. It also created a new way to bring in others who love this place and to engage new generations of curious minds.

In a world so full of wonderful things to study, we opted to pursue projects designed specifically to fill information gaps identified in the 2016 report. In doing so, we fostered a new community of interconnected community members and scientists.

WHAT HAVE WE LEARNED ABOUT MT. TAM’S HEALTH?

Mt. Tamalpais (Mt. Tam) is one of the most ecologically rich and beloved places in the San Francisco Bay Area. Part of the Golden Gate Biosphere Reserve, Pacific Flyway, and California Floristic Province, the mountain is a vital refuge for many threatened, endangered, and special-status species. It is also an important link in a much larger network of interconnected open spaces, including 195,000 acres of protected open space in Marin County.

The mountain’s ecosystems provide abundant ecological, economic, and social benefits to its visitors and neighbors. For example, the clean drinking water from its lakes and reservoirs, carbon sequestered in its grasslands, and natural beauty and solace of its forests all depend on the mountain’s overall health as well as that of the species that make up each of its interconnected ecosystems.

And yet, until 2016, we were not able to answer the question: How healthy is Mt. Tam? Thanks to our first health assessment, in 2016 we could say that the overall condition of the mountain’s ecosystems was cautionary but fairly stable. We saw similar results this time (Figure 1); however, measuring a trend between the overall condition for Mt. Tam between the two reports has been complicated by the addition of new indicators since 2016, an expanded geography, and a major new vegetation mapping effort that parses those communities differently than before. A look at the indicators that were combined to reach this overall condition (Table 1) reveals a complex story of improvement in some areas and decline in others. It shows that some species (e.g., the foothill yellow-legged frog [*Rana boylii*] and northwestern pond turtle [*Actinemys marmorata*], which have been the focus of restoration programs) have improved since 2016, while others (e.g., the coho salmon [*Oncorhynchus kisutch*]) continue to struggle despite the extraordinary efforts being made to save them.

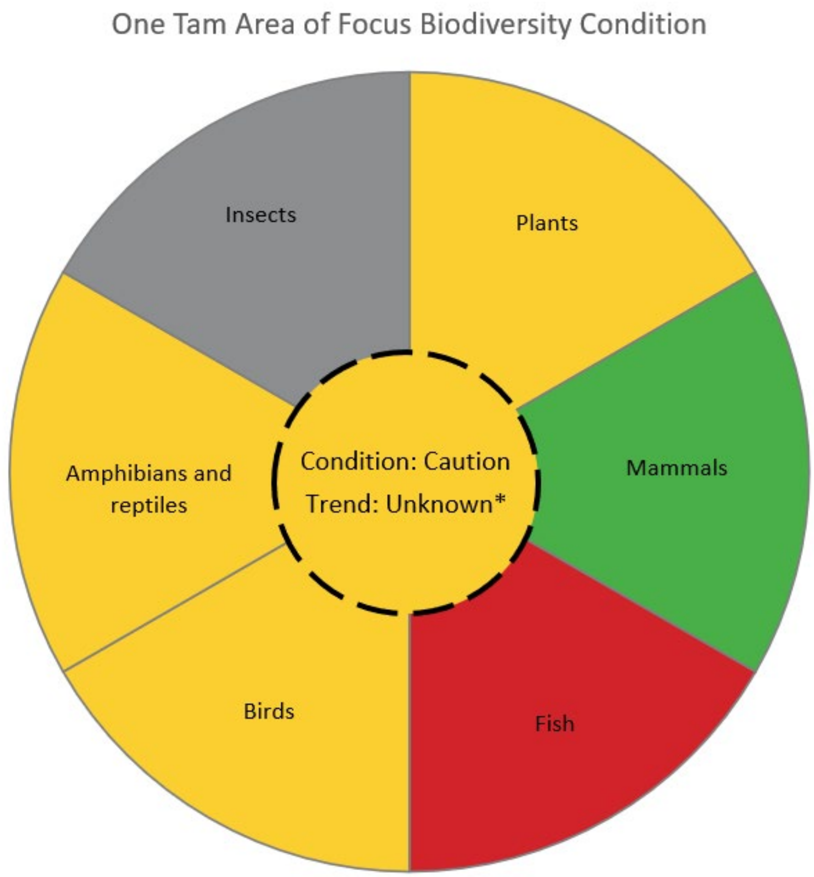

FIGURE 1 OVERALL CONDITION MT. TAM'S ECOLOGICAL HEALTH

**We did not establish a trend in the overall condition for Mt. Tam between 2016 and 2022 because of the addition of new indicators since 2016, an expanded geography, and a major new vegetation mapping effort that parses those communities differently than before. In addition, some indicators improved while others declined or did not see a change in condition.*

The colors of each part of Figure 1 represent the overall condition for each taxonomic group. Green = good, yellow = caution, red = significant concern, and gray = unknown. Refer to the legend on page 7 for further explanation.

Each chapter describes the individual health indicators that comprise each segment in greater detail. In brief, however, here is what we have observed.

VEGETATION

Some of Mt. Tam's plant communities are thriving, but most are suffering from the effects of climate change, invasive species, plant disease, and changed fire regimes. Ecologically important and iconic communities (e.g., maritime chaparral, shrublands, and open-canopy oak woodlands) are declining, while old-growth redwood (*Sequoia sempervirens*) and Sargent cypress (*Cupressus sargentii*) forests are in good condition and stable or improving. A notable exception is second-growth redwood forests, which are in caution condition with a declining trend.

WILDLIFE

Most of Mt. Tam's wildlife species and communities appear to be doing well, with stable or improving trends. We were able to add three new wildlife indicators to this update: bees, California giant salamanders, and bats. The health of bird communities overall is mixed; the Northern Spotted Owl (*Strix occidentalis caurina*) is doing well but the Osprey (*Pandion haliaetus*) is moving to a condition of significant concern. Additional years of Marin Wildlife Watch data have revealed that mammals are in good condition with a stable trend. The North American river otter (*Lontra canadensis*) continues its remarkable comeback. The California red-legged frog (*Rana draytonii*), foothill yellow-legged frog, and northwestern pond turtle have all benefited from restoration and restocking efforts. Yet, populations of coho salmon and steelhead trout (*Oncorhynchus mykiss*) are dangerously small and of great concern.

LANDSCAPE-SCALE MEASURES OF HEALTH

Considering the mountain's health by combining—or "rolling up"—its individual health indicators allows us to begin to explore how well ecological systems and landscape-level processes are functioning across the mountain as a whole. This approach provides land managers and scientists with another way to track the mountain's health. Based on this approach, shrubland, grassland, open-canopy oak woodland, and redwood forest ecological communities are all in cautionary condition.

Another way to look at overall health is by using models that provide a broader view of how climate change may affect different communities. Pepperwood Preserve scientists conducted a new analysis for this report to inform key hypotheses about potential climate impacts and to prioritize indicators for long-term vegetation monitoring on Mt. Tam. They modeled projected trends in vegetation distribution under future climate scenarios and used three different approaches. For example, they found that coast redwood communities are expected to shrink under all approaches. On the other hand, vegetation types adapted to hotter and more arid conditions such as chaparral are expected to expand toward a warming coast and lower elevations. Grasslands are projected to decline, though the impacts appear highly dependent upon future rainfall and thus are subject to significant uncertainty.

DATA GAPS

The condition of many other important indicators of Mt. Tam's ecological health—including invertebrates (other than bees), lichens, hardwood forests, riparian areas, and seeps and springs—remains largely unknown (see Chapters 11 and 25). However, as with 2016 indicators identified as needs that we have now included, we hope to add them to a future update. Additionally, specific information gaps about the indicators in each chapter of this report may continue to be strategically addressed. For example, in this update we have included new climate vulnerability information for each indicator.

WHERE DO WE GO FROM HERE?

Scientific research is an inherently iterative and cumulative process, and as our understanding of the state of the mountain's ecosystems evolves, this health evaluation will likewise grow and improve.

Our work will reveal new insights and provide opportunities for improving the condition of key resources. Restoration and stewardship can help bolster communities and species that are currently flagging. Meanwhile, factors beyond the control of One Tam land managers—e.g., climate change and ecological succession—may alter the landscape in ways we cannot yet fully predict.

As in 2016, this assessment is a critical step in both understanding how important aspects of the health of the mountain are faring and continuing to identify gaps in our current knowledge. Land management agencies can prioritize and incorporate these findings into ongoing resource work. They can also use them to help measure the results of their efforts and identify actions that may shift trends and the condition of health indicators. With the support and partnership of scientists, stakeholder groups, and individual community members, we can use this report to continue to be good stewards of this remarkable mountain.

TABLE 1 SUMMARY OF ALL ECOLOGICAL HEALTH INDICATORS AND THEIR 2022 CONDITION, TREND, AND CONFIDENCE SCORES

Ecological Health Indicator	2022 Condition, Trend, and Confidence*	
	Plants	
Coast Redwood Forests (Old-Growth)		**Condition:** Good **Trend:** Improving **Confidence:** Moderate
Coast Redwood Forests (Second-Growth)		**Condition:** Caution **Trend:** Declining **Confidence:** Moderate
Sargent Cypress Forests		**Condition:** Good **Trend:** No Change **Confidence:** High
Open-Canopy Oak Woodlands		**Condition:** Caution **Trend:** No Change **Confidence:** Moderate

Shrublands: Coastal Scrub and Chaparral		**Condition:** Caution **Trend:** Declining **Confidence:** Moderate
Maritime Chaparral Community Endemics		**Condition:** Significant Concern **Trend:** Declining **Confidence:** Moderate
Grasslands		**Condition:** Caution **Trend:** Unknown **Confidence:** Low
Serpentine Barren Community Endemics		**Condition:** Caution **Trend:** No Change **Confidence:** High
Ecological Health Indicator	**2022 Condition, Trend, and Confidence***	
	Wildlife	
Bees		**Condition:** Unknown **Trend:** Unknown **Confidence:** Low
Anadromous Fish (Coho Salmon, Lagunitas Creek)		**Condition:** Significant Concern **Trend:** No Change **Confidence:** High
Anadromous Fish (Coho Salmon, Redwood Creek)		**Condition:** Significant Concern **Trend:** Declining **Confidence:** Moderate
Anadromous Fish (Steelhead Trout)		**Condition:** Significant Concern **Trend:** No Change **Confidence:** Moderate
California Giant Salamander		**Condition:** Unknown **Trend:** Unknown **Confidence:** Low

California Red-Legged Frog		**Condition:** Good **Trend:** Improving **Confidence:** Moderate
Foothill Yellow-Legged Frog		**Condition:** Caution **Trend:** Improving **Confidence:** High
Northwestern Pond Turtle		**Condition:** Caution **Trend:** Improving **Confidence:** High
Birds (overall)		**Condition:** Caution **Trend:** No Change **Confidence:** High
Northern Spotted Owl		**Condition:** Good **Trend:** No Change **Confidence:** High
Osprey		**Condition:** Significant Concern **Trend:** Declining **Confidence:** Moderate
Bats		**Condition:** Good **Trend:** No Change **Confidence:** Moderate
Mammals (overall)		**Condition:** Good **Trend:** No Change **Confidence:** Moderate
North American River Otter		**Condition:** Good **Trend:** Improving **Confidence:** Moderate

**See the glossary for definitions and Chapter 2 for the overall methodology used to derive the scores. These conditions and trends represent what we believe to be each indicator's current state, which may or may not be the* *same as it was in 2016. Each chapter describes changes since 2016 as well as the approach and data sources used to assess each ecological health indicator.*

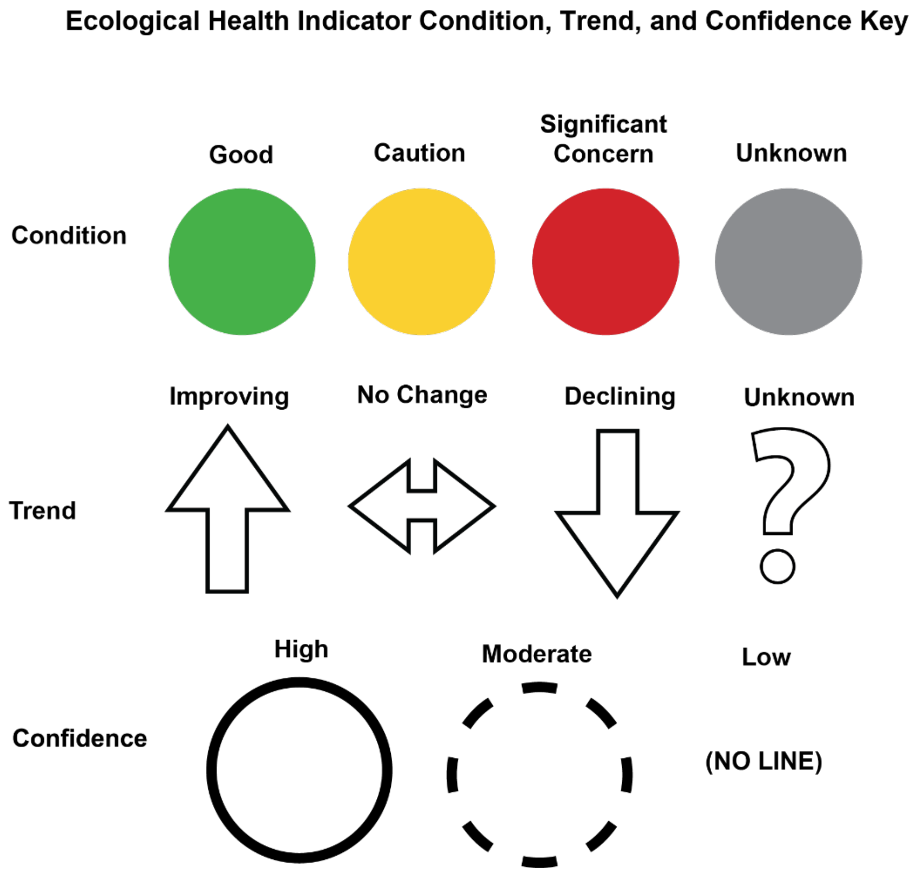

FIGURE 2 SYMBOLOGY USED SHOW OVERALL CONDITION, TREND, AND CONFIDENCE OF EACH INDICATOR

GLOSSARY OF TERMS

General Terminology	
Area of Focus	Sections of Mt. Tam included in the scope of this ecological health analysis (Figure 1.1).
Condition	Current state of a metric or of the indicator as whole, based on an average of the condition of its metrics. Conditions are **good, caution, significant concern,** or **unknown** (if insufficient information is available). Thresholds for changes in condition category are set on a case-by-case basis.
Condition Goal	The desired, measurable state for each *metric* against which monitoring data are compared.
Confidence	The degree of certainty with which the condition and trend are assessed. • **High:** Measurements are based on recent, reliable, and suitably comprehensive monitoring. • **Moderate:** Monitoring data lack some aspect of being recent, reliable, or comprehensive; however, measurements are also based on recent expert or scientist observation. • **Low:** Monitoring is not sufficiently recent, reliable, or comprehensive, but either some supporting data exist, or measurements are also based on expert or scientific opinion.
Desired Condition(s)	The qualitative goal for the overall *indicator*; the threshold or state it should be in to be considered healthy; often identified as a recovery target for rare/listed species.
Indicator	The species, community, or physical process (e.g., stream flow/water quantity) that provides an essential ecological function or is indicative 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, strongly correlated with overall condition, sensitive to stressors, and an early warning of potential problems.
Metric	How an aspect of an indicator is assessed or measured.
One Tam Partners	One Tam is made up of four agencies and one nonprofit organization: California State Parks, Marin County Parks, Marin Water, the National Park Service (including Golden Gate National Recreation Area and Muir Woods National Monument), and the Golden Gate National Parks Conservancy (Parks Conservancy).
Overall Condition	The combined current state of the indicator, based on the totality of its metrics.
Stressors	Elements that challenge the integrity of ecosystems and the quality of the environment; may be natural environmental factors or may result from the activities of humans. Some stressors exert a relatively local influence, while others are regional or global in scale.

Trend	Change in condition as determined by comparing current versus previous measures. A 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. • **No Change:** The condition is unchanging. • **Declining:** The condition is deteriorating/getting worse. • **Unknown:** Not enough information is available to state a trend.
Agency Acronyms	
CDFW	California Department of Fish and Wildlife
NOAA/NMFS	National Oceanic and Atmospheric Administration/National Marine Fisheries Service
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

CHAPTER 1. INTRODUCTION

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WHY DO AN ECOLOGICAL HEALTH ASSESSMENT?

Teeming with an incredible diversity of life, Mt. Tamalpais (Mt. Tam) is among the region's greatest natural treasures. Located in one of 36 internationally recognized biodiversity hotspots (the California Floristic Province and the Golden Gate Biosphere Reserve), the mountain's complex terrain and its location between the sea and inland San Francisco Bay Area support a remarkably diverse array of microclimates and habitats. These, in turn, sustain a stunning variety of plants and animals, some of which are found nowhere else on Earth.

Despite its ecological richness and protected status under three governmental agencies and one water district, the mountain faces threats, among them, invasive species, forest pathogens, altered wildfire regimes, and climate change. The public agencies that manage its land today (Figure 1.1) and the communities that love it all have a role to play in helping to keep the mountain healthy and vibrant.

However, to do so, we must first try to answer important questions: What do we know about species and ecological community health? How can we observe and measure change? What are the gaps in our understanding of these resources and the physical and ecological drivers affecting them? And how do we use this information to inform management decisions, better align the work of One Tam partners around critical needs, and inspire public support?

In spring 2016, One Tam partners joined with experts from around the San Francisco Bay Area to answer these questions. For the first time, inventory and monitoring efforts, surveys, and research that revealed facets of the mountain's health across multiple jurisdictional boundaries were brought together. This combined knowledge was used to develop metrics to measure the health of key ecological indicators and to assess data gaps and potential next steps to improve the state of our understanding.

WHERE WE ARE NOW

As the first iteration of this project, the 2016 report set baselines against which change could be measured over time. And indeed, in this 2022 update, we have seen both improvements and declines. Each chapter describes in detail what we are seeing for each indicator and how those results should be interpreted. (We also recognize that for some species or communities, five years between evaluations may not be enough to detect changes.)

Further, the 2016 report helped reshape an early list of proposed One Tam projects and programs, ensuring that they were focused where work was most needed. Several new projects were started to fill important data gaps, including a county-wide vegetation map, bat monitoring program, and forest health assessment. Within the area of focus, there are now invasive plant species early detection and rapid response programs, bee monitoring, a new joint monitoring effort for grassland birds, and more.

As a result, this update includes three new indicators that were identified as important data gaps in the original survey: bats, bees, and the California giant salamander (*Dicamptodon ensatus*). It has updated and more comprehensive data on the current and future impacts of climate change. Condensed summaries of the information presented here are available at onetam.org/peak-health.

GEOGRAPHIC SCOPE

The One Tam area of focus--nearly 53,000 acres--occupies the heart of a nearly contiguous, expansive network of protected lands comprising roughly 147,000 acres, or 44%, of Marin County. Lands within in this larger network are managed by a number of entities: the four One Tam partner agencies; individual cities, homeowners, and agricultural operations; and nonprofit groups, including Slide Ranch, Audubon Canyon Ranch, and the San Francisco Zen Center. (Figures 1.1 and 1.2).

However, this report covers only ecosystems on public lands within the area of focus. It encompasses the entirety of Marin Water lands as well as lands managed by Mount Tamalpais State Park, Muir Woods National Monument and the Golden Gate National Recreation Area (including some of the northern lands managed by Point Reyes National Seashore), and a number of Marin County Parks open space preserves. Lands managed by individual cities, homeowners, or other organizations are not included in the analyses in this report.

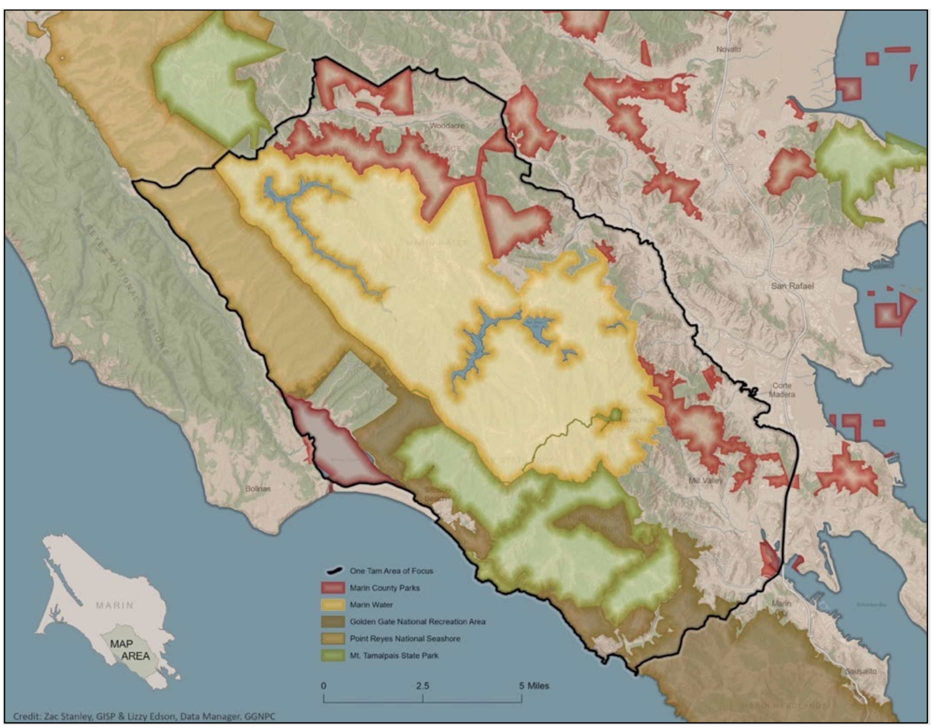

FIGURE 1.1 THE ONE TAM AREA OF FOCUS

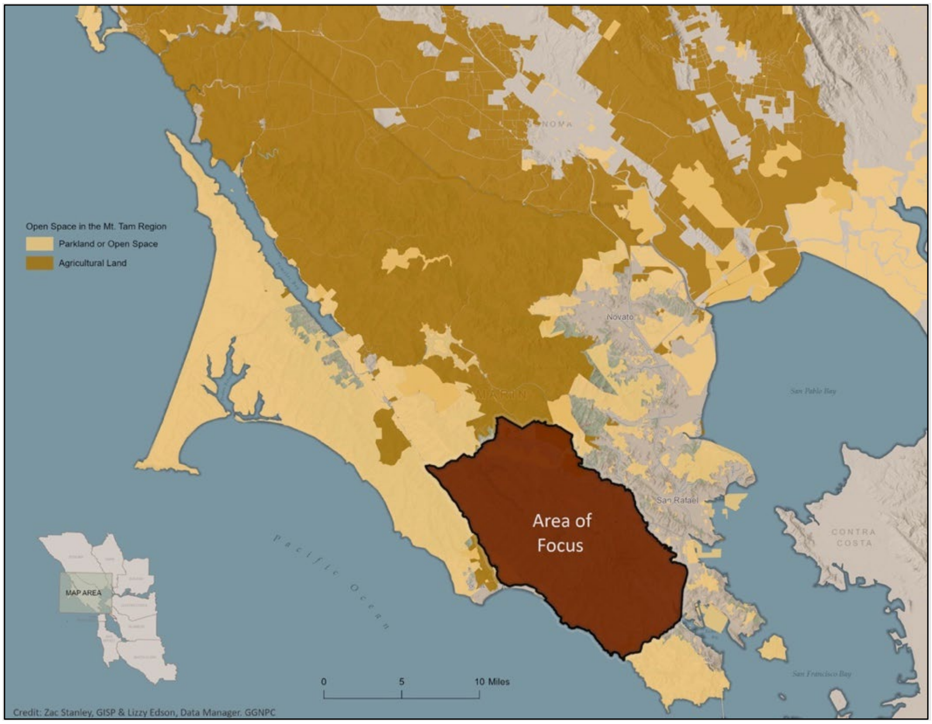

FIGURE 1.2 THE ONE TAM AREA OF FOCUS WITHIN THE REGIONAL NETWORK OF OPEN SPACES AND AGRICULTURAL AREAS

THE HUMAN CONNECTION TO ECOLOGICAL HEALTH

Marin County is a part of the ancestral territory of the Federated Indians of Graton Rancheria (Coast Miwok and Southern Pomo people), a federally recognized tribal nation. However, the way these lands are managed has changed dramatically since Europeans arrived (Gibson, 2012; Spitz, 2012). As one of Marin's most dramatic landmarks, Mt. Tam has also been a major focal point for local community activism and stewardship. Today, One Tam agencies and the Parks Conservancy work both independently and in partnership to offer new pathways for community members to support the mountain's health. The following section summarizes some of the challenges and opportunities of a few key aspects of this work: stewardship, recreation, and community science.

STEWARDSHIP AND RECREATION

Mt. Tam is nationally renowned for the wide variety of recreational opportunities it offers. In particular, its extensive trail network facilitates exploration of its myriad natural and cultural resources and scenic wonders. Visitor surveys by Marin County Parks (2015) and Marin Water (Alta 2014, currently being updated) showed that hiking, walking, and cycling are the primary reasons people visit local parks and open spaces, immediately followed by access to nature and views.

Indeed, public parks and open-space preserves are the main way most people connect with nature and take advantage of its wide range of both mental and physical health benefits (Frumkin, 2001). This was made particularly clear during the COVID-19 pandemic, when more visitors than ever sought respite in local parks (Heckert & Bristowe, 2021). However, it also became evident that access to nature is not equitably distributed. For example, many of Mt. Tam's trailheads and other recreational amenities are hard to access without a car. Efforts are underway to improve inclusive access, and this is likely to continue to be an important priority going forward. Additionally, One Tam partners have deepened their commitment to connecting with a wide range of diverse communities and ensuring that all feel welcome.

One Tam partners, both individually and collectively, have a long history of offering community science, stewardship, and environmental-education programming. And it's making a difference. Community members are pitching in, volunteering for habitat restoration and trail improvement projects as well as patrols that help promote proper trail use and etiquette and reduce conflicts between user groups. For example, a docent program for the foothill yellow-legged frog (*Rana boylii*) has improved breeding conditions for this threatened species. Volunteers have also played a part in a wide range of projects, from processing millions of wildlife camera images to pulling countless tons of weeds. Indeed, volunteerism has become a kind of recreational activity in its own right—an important part of stewarding the mountain.

Supporting visitation and community engagement opportunities are the cornerstones of what One Tam land managers do. However, they must balance these agendas with protecting and improving the mountain's ecological resources. Despite the many benefits that recreation has, when not well managed, it can negatively affect the mountain's ecological health as well as the experience of its visitors. Thus, each agency uses science-based planning (e.g., roads, trails, and biodiversity management plans) to facilitate recreation that is compatible with their respective missions and resource-protection responsibilities.

Generally, negative recreational impacts include wildlife habitat fragmentation; soil compaction and erosion; vegetation trampling, loss, and composition changes; and the introduction and spread of non-native plants. Non-designated—aka "social"—trails also act as vectors for non-native, invasive species, the spread of which is of high concern (van Winkle, 2014) given their potential to permeate and change already stressed vegetation communities. Poorly designed and sited trails are also an issue (Marion & Leung, 2001). Well-loved for more than a century, Mt. Tam's trail systems were largely inherited by modern-day land managers from historic ranch, hunting, and military access roads, railroad rights of way, and informal trails that developed over many years of use. Many of these routes were not created with sustainable alignment, resource protection, or facilitating the best experience in mind. Adding to these challenges, decades of deferred maintenance have affected both the mountain's trails and their adjacent resources.

In the literature review by Larson et al. (2016) on the effects of recreation on wildlife, most studies found at least one effect, and most effects were negative. This correlates with decreases in species abundance and activity levels (Garber & Burger, 1995), which cause wildlife to flee or avoid otherwise suitable habitat (Taylor & Knight, 2003) or alter species composition and behavior (Ikuta & Blumstein, 2003). Studies have also documented how recreational activities alter the ways carnivores use protected areas (George & Crooks, 2006; Reed & Merenlender, 2011), and how the presence of dogs affects mammal abundance and behavior near trails (Lenth et al., 2008). Unfortunately, few recreational-impact studies provide suggestions for practical management actions—e.g., fencing and signage, buffers, docent programs, or education and outreach to specific user groups to minimize observed issues (Larson et al., 2016).

We do not have a clear idea of the mountain's annual visitation levels and how it may be changing over time, partly because the mountain has four separate land management agencies and because of the required time and expense of visitor surveys. However, data are becoming available through the ongoing Marin Wildlife Watch project, cell phone and sports-tracking apps, and academic research currently underway. Under the One Tam initiative, agency managers are now finding ways to share this information as it comes in and use it to inform management decisions.

Recreational use data can also be looked at in relation to other resource monitoring to determine potential impacts as well as figure out ways to mitigate them. Drawing conclusions from nuances in animal behavior can be tricky, however, and we must consider the full picture of what these data snapshots tell us. For example, we will need to determine if minor shifts in behavioral or diurnal use patterns actually result in concerning decreases in species abundance and distribution.

The mountain's land management agencies have a core responsibility to both proactively plan visitor access and minimize recreation's potential impacts. Indeed, One Tam land managers have all made significant improvements in reducing erosion, developing sustainable routes, and improving the way people move through the landscape. One Tam's Early Detection Rapid Response program finds and treats invasive plants before they can become established. Each agency also has its own invasive plant program and offers many opportunities for volunteers to participate and pull weeds. Crews work constantly to create more-sustainable trail alignments and address erosion and social trails; National Park Service and California State Parks trail projects in the Redwood Creek Watershed are one example.

Over the years, a range of preferences and beliefs about the kinds of recreation that should be allowed, and where and when recreation should happen, have surfaced. In addressing these issues, the agencies recognize that appropriately planned visitor access can and does improve both the visitor experience and the mountain's long-term sustainability.

THE ROLE OF COMMUNITY SCIENCE

Understanding the health of Mt. Tam is a complex, ambitious endeavor. Community science (aka citizen science and participatory science) assists us with this; its collaborative approach involves both professionals and members of the public in the process of collecting, analyzing, and interpreting data. Community science also supports our understanding of Mt. Tam's health through a variety of activities that aim to address ecological data gaps; implement long-term monitoring; provide formal and informal science education; and promote curiosity, connection, and participation to a wide range of audiences.

Within the One Tam partnership, successful community science efforts depend on building connections to the land and among participants, often while thoughtfully deploying new technologies to scale up data-collection efforts. For example, the iNaturalist platform has grown nearly exponentially since the early 2010s; projects such as the City Nature Challenge have spurred some of this growth. This flexible data platform allows some annotation and the transfer of data to other databases (e.g., Calflora). It also functions as a social network, facilitating constructive dialogue and community formation in the digital world as well as on the mountain.

One Tam community science will continue to build on successes already achieved by our partner organizations. Indeed, several chapters in this report benefited from the imagination, skill, and dedication of community science volunteers, interns, and staff. For example, Marin Water's Turtle Observers program has both provided key insights into the health of the western pond turtle (*Actinemys marmorata*) at Lake Lagunitas and inspired children and adults to volunteer. The 2012 botanical resurvey of Alice Eastwood's transects, also led by Marin Water, demonstrated the importance of historical data and the power of building a community of participants.

In the 2016 edition of Peak Health, terrestrial mammals were identified as a data gap, and early data showed the promise of deploying camera traps (an emerging technology) throughout Mt. Tam. Since then, Marin Wildlife Watch (formerly the Marin Wildlife Picture Index Project) volunteers have cataloged millions of images, adopting multiple iterations of ever-improving software to accomplish this task. Another priority—invertebrate conservation—has surfaced since 2016. Thanks largely to the collaboration between academic and agency partners and hundreds of hours from community science volunteers, we now have an inventory of bees in this region. Finally, community science has been identified as an important approach to address data gaps for other indicators (see chapters on the California giant salamander and mountain-wide floristic diversity).

The future of community science holds much promise as One Tam deepens its community connections; builds scientific capacity among community members; facilitates the intergenerational transfer of naturalist knowledge; and, most importantly, promotes awe and curiosity in a place like nowhere else on Earth: Mt. Tam.

ECOLOGICAL SETTING

GEOLOGY

The mountain and surrounding region have a complex geologic history. Most of the underlying substrates predate the formation of the San Andreas Fault. These include silica-rich, sedimentary Franciscan chert, formed from shells of marine plankton; serpentine soils derived from ultramafic (igneous) rocks that metamorphosed under high pressure; and sedimentary sandstones, among others (Blake et al., 2000).

This geological mix has been further shaped by topographic complexity, climatic history, vegetation, ecosystem processes, erosion, and significant geologic events that have taken place over very long periods of time. Understanding the resultant diversity and patchy distribution of soil types is critical to understanding Mt. Tam's extraordinary levels of biodiversity. They explain the high levels of plant diversity and structural heterogeneity, as well as the wide range of species found in vegetation patches (Davies et al., 2005; Pickett & Cadenasso, 1995; Tuomisto et al., 1995).

The mountain's array of serpentine soils—a product of California's state rock, serpentinite—is a good example. The chemical composition of these soils, which are characterized by elevated heavy-metal concentrations, can vary widely both within and between patches. They also typically have a low calcium-to-magnesium ratio, which limits the availability of soil nutrients to plants (reviewed in Barbour et al., 2007). Thus, the resulting soils have decreased productivity and can appear inhospitable. Remarkably, some native plant species have evolved to tolerate these unique soils; many of Mt. Tam's rare species are restricted to serpentine areas. The juxtaposition of low-productivity serpentine soils in a matrix of non-serpentine soils results in a habitat heterogeneity that contributes to the incredible biodiversity of this landscape (Figure 1.3).

BIODIVERSITY

The Bay Area's natural richness and variety are due in large part to the region's Mediterranean climate, topographic complexity, and coastal influence, which together foster high levels of biodiversity.

Located on San Francisco's doorstep, Mt. Tam is a critical link in a larger network of open spaces (Figure 1.2), and a refuge for many species that are otherwise constrained by increased development and other stressors (see the Ecological Stressors section). The mountain is also home to several endemic plant species, including the Mt. Tamalpais thistle (*Cirsium hydrophilum* var. *vaseyi*) and Mt. Tamalpais manzanita (*Arctostaphylos montana* ssp. *montana*). In addition to its remarkable ecological value, Mt. Tam's biodiversity provides a number of essential ecosystem services, including high-quality drinking water, erosion control, and clean air, and offers diverse natural landscapes for recreation and tourism (LCA, 2009).

The combination of Mt. Tam's varied topography and its location near the coast in an important marine upwelling and convergence zone creates a confounding array of microclimates in a relatively small geographic region. The One Tam area of focus extends from sea level to more than 2,500 feet in elevation, and then back down to the San Francisco Bay to the east. Seasonal differences in climate are affected by these changes in elevation and topography. There are also dramatic differences between the coastal (ocean-facing) and interior (bay-facing) aspects of the mountain.

As previously discussed, the mountain's wide range of soils create niches for unique plant communities and the wildlife that depends upon them. The area of focus's nearly 53,000 acres host 10 times the number of native plant species per acre as are found in Yosemite National Park, which is almost 20 times as large. Furthermore, Marin County is located along the Pacific Flyway (a major bird migration corridor), which represents the range limit for species such as the Northern Spotted Owl (*Strix occidentalis caurina*).

This report's species lists (Appendices 2–9) represent the current and best available information compiled by One Tam partner agencies. Assembled using a combination of each agency's existing lists, they incorporate inventory and monitoring work by agency staff, as well as other efforts (e.g., the Christmas Bird Count, agency bioblitzes, and surveys by the California Native Plant Society). Only verified sightings are included; species that had not been reported since 1970 are not on the lists. A caveat: Certain taxonomic categories are currently missing or under-represented, and the lists' coverage does not always extend to the entire area of focus. This is primarily due to a lack of inventories for certain taxonomic groups and the limitations of accepting only expert-verified sightings.

Based on these data, Mt. Tam's native species diversity currently encompass more than 250 animals, 50-plus of which are federal and/or state listed as threatened, endangered, sensitive, or rare (Figure 1.3 and Appendices 5–9). Mt. Tam is also home to more than 1,000 known plant species, several of which are only found on the mountain and 40-plus of which are listed as federal or state threatened, endangered, or rare (Figure 1.3 and Appendices 2 and 3). Roughly 40% of the total plant species on Mt. Tam are non-native (see Non-native Species section). Sixty-five native plant and 12 animal species are believed to have been extirpated from the mountain (see Appendix 4 and Chapter 12).

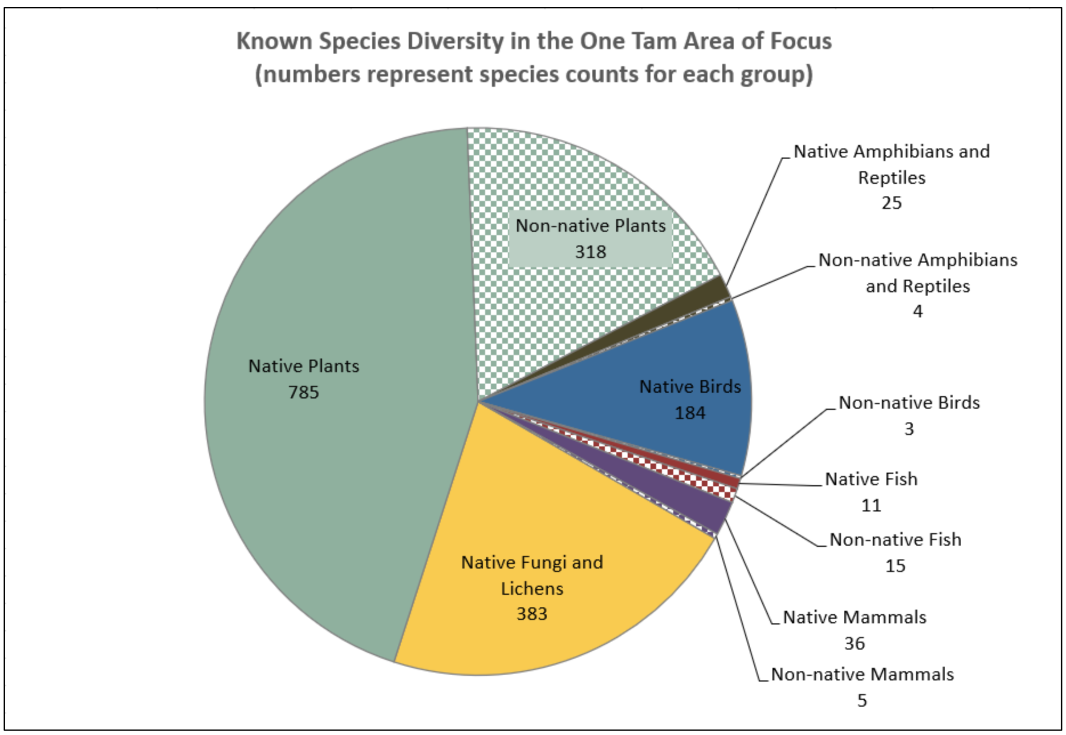

FIGURE 1.3 KNOWN SPECIES DIVERSITY, ONE TAM AREA OF FOCUS

ECOLOGICAL STRESSORS

While Mt. Tam's plants and wildlife generally occupy protected open spaces, the health of the mountain's ecosystems is threatened by global climate change; altered fire regimes; invasive, non-native plants and animals; habitat fragmentation; plant diseases; noise, light, and air pollution; and other human-caused impacts. These ecological stressors negatively affect the size, range, and reproductive capacity of plants and wildlife and may directly result in habitat loss and degradation. Interactions among these stressors (e.g., between climate change and fire frequency, or between fire and plant diseases) further compound these effects and make managing the landscape much more challenging.

A summary of some key stressors affecting the health of Mt. Tam follows.

CLIMATE CHANGE

Due to its elevation and proximity to the coast, Mt. Tam could serve as a cool refuge for plant and animal species contending with climate change and its associated fluctuations in temperature, precipitation, fog, and soil moisture. Although climate change models show a range of potential future scenarios for Marin County and the San Francisco Bay Area, some common trends have emerged. Because there is greater uncertainty in projecting precipitation than there is for temperature, we summarize results for two climate change models with comparable temperature increases but different rainfall projections: Warm/Wet and Warm/Dry. These include models provided in the California Fourth Climate Change Assessment for the San Francisco Bay Area Region (Ackerly et al., 2018; Pierce et al., 2018). The summaries that follow include projected primary impacts on temperature and precipitation under these scenarios, and secondary impacts on hydrology, fire hazards, and ecosystems overall for the One Tam area of focus.

Temperature: Between 1950 and 2005, average temperatures across the Bay Area rose by 1.7°F (0.95°C). Both winter and summer temperatures are predicted to continue rising under future climate change scenarios. Temperature projections spanning potential Warm/Wet and Warm/Dry conditions under the business-as-usual emissions scenario (referred to as RCP 8.5) used throughout this report show potential increases in annual temperatures for the One Tam focus area ranging from approximately 3.4°F (1.9°C) by mid-century to 6.0°F (3.4°C) by the end of the century (Pierce et al., 2018). Projected impacts on annual maximum (summer) temperatures and annual minimum (winter) temperatures are summarized in Table 1.1.

Precipitation: Future precipitation projections for the One Tam area of focus are more uncertain than those for temperature. Historically (1950–2005), annual rainfall has been highly variable, with a range of 57.6 inches (146.3 cm) between the wettest and driest years. Future climate change projections suggest even more seasonal and interannual variability. For the area of focus, projected annual precipitation change ranges from approximately 9% less to 20% more by mid-century, and 2% to 30% more by the end of the century (Pierce et al., 2018). This increased variability suggests two things: Peak rainfall events, generated by “atmospheric rivers,” may cause floods, and alternatively, more frequent and intense droughts could affect Mt. Tam’s streams, wetlands, and vegetation communities. Models also suggest that the timing of rainfall may shift to a narrower winter window, with the potential for earlier onset of warmer and drier spring conditions (Micheli et al., 2016).

TABLE 1.1 PROJECTED FUTURE TEMPERATURES AND PRECIPITATION COMPARED TO 1961–1990 FOR BOTH WARM/WET AND WARM/DRY SCENARIOS

			Projected Temperature (°F) or Precipitation (%) Change			
		Historical Average	**CNRM-CM5 Model (Warm/Wet)**		**MIROC5 Model (Warm/Dry)**	
Variable	**Units**	**1961–1990**	**2035–2064**	**2070–2099**	**2035–2064**	**2070–2099**
Precipitation Change	inches/year	38.5	20%	30%	- 8.6%	2.4%
Minimum Winter Temperatures	°F	45.5	3.4	6.6	3.2	5.5
Maximum Summer Temperatures	°F	67.5	3.2	6.1	3.6	5.7

Fog: Fog is an important source of moisture and cooler temperatures on the mountain, particularly during spring and summer. It could also potentially mitigate climate impacts by reducing incoming solar radiation and providing water during the dry season. A fog frequency map shows the historic patterns of fog across Mt. Tam (Torregrosa et al., 2016). However, there is significant uncertainty as to the potential impacts of climate change on fog in the Bay Area.

The sole dynamic simulation model for coastal fog in California shows a potential long-term trend of a 12% to 20% reduction from 1900 to 2070, with significant uncertainty (Ackerly et al., 2018; O’Brien et al., 2013). A previous 2010 study estimated that the amount of fog along California's coast has fallen 33% over the past 100 years (Johnstone & Dawson, 2010). In both cases, the authors are not confident this speaks to a long-term trend; ongoing monitoring is needed to inform these projections. With less fog and higher temperatures, fog-dependent plant communities on Mt. Tam—e.g., coast redwood (*Sequoia sempervirens*) forests and maritime chaparral—could become drought-stressed.

Soil Moisture: Rising temperatures are making Marin County more arid. Even under higher future rainfall scenarios, hotter temperatures will increase evapotranspiration and essentially reduce available soil moisture. This difference between potential and actual evapotranspiration—known as climatic water deficit—is a good indicator of drought stress (Flint et al., 2013). Climatic water deficit is one of the key variables used to project climate stressors on vegetation (Thorne et al., 2017), fire probability (Moritz et al., 2012; Mann et al., 2016; Park et al., 2021), and water demand for irrigation (Micheli et al., 2016). Potential increased climatic water deficits are on the order of 3 inches of equivalent rainfall for the One Tam focus area by mid-century (Micheli et al., 2016).

Wildfire Hazards: Between 2000 and 2020, approximately 127 acres of the area of focus burned (CalFire, 2020). While many of Mt. Tam's ecosystems are fire-adapted, successful fire suppression policies have led to a significant accumulation of fuels (vegetation capable of feeding a wildfire). Warmer, drier conditions combined with fuel accumulation are increasing the chances of wildfire in Marin County. California's Fourth Climate Change Assessment projects that Mt. Tam will have an end-of-century wildfire probability increase of approximately 10% compared to historical conditions (Westerling, 2018); alternative methods suggest an increase on the order of 15% over 30 years consequent to the combined effect of projected climate change and land use (Krawchuk & Moritz, 2011; Mann et al., 2016).

Recent fire seasons in neighboring Sonoma County have demonstrated the ways warmer and drier weather combined with accumulated fuels can generate extreme wildfire hazards. "Fire weather," a condition characterized by low humidity and high wind, may also become more frequent over time. Significant fire-mitigation efforts, with a focus on fuels reduction, are underway, with the potential for direct and indirect impacts on watershed function and biodiversity. Resumption of controlled fire, where feasible, may be considered part of a climate-adaptation strategy.

Sea Level Rise and Coastal Erosion: Based on a business-as-usual emissions scenario (RCP 8.5), a recently published sea-level rise model (Griggs & Reguero, 2021) estimates that the average (or 50th percentile) will range from 13 cm in 2030 to 75 cm by 2100. Changes in sea level have potentially significant impacts on coastal areas as well as estuarine and freshwater systems farther inland in the area of focus. When combined with periodic El Niño events driven by seasonally elevated water levels, sea level rise is estimated to create up to 30% larger winter wave energy, a key driver of coastal vulnerability in coming decades (Barnard et al., 2015).

Plant and Animal Community Change: Changes in temperature, precipitation, fog, and soil moisture may make future conditions inhospitable for certain plant species, or even entire communities. The term "climate exposure" can be used to describe the estimated combined impact of climate stressors on local vegetation (Thorne et al., 2017). Both the Warm/Wet and Warm/Dry models project that Mt. Tam's higher-elevation areas will experience lower climate exposure and its western portion will undergo higher climate exposure by the end of the century. In the long term, climate change is expected to alter the basic physical conditions under which native plant communities on Mt. Tam have evolved, with climate exposure forcing a shift in both composition and distribution. These shifts may be facilitated by short-term (episodic) disturbances such as fires, droughts, floods, and pest outbreaks, all of which are becoming more frequent. Vegetation's sensitivity to climate change is heterogeneous and complex, but models for Marin County suggest an expansion of climate conditions suitable for more drought-tolerant species and communities, including coastal sage scrub and chamise chaparral, as climatic water deficit increases (Ackerly et al., 2012; Micheli et al., 2016; Thorne et al., 2017).

The effects of climate change on animals are similarly varied and challenging to predict, and few studies have focused on how it will affect Bay Area's wildlife (Ackerly et al., 2018). However, changes in vegetation communities, which will undoubtedly have consequences for the wildlife that depends upon them, may ripple up and down trophic levels. One Tam's long-term Marin Wildlife Watch camera-monitoring project is expected to be a valuable resource as we work to understand variations in wildlife occupancy (a metric of presence) over time. It is anticipated that wildlife that requires cool, wet conditions may be at greatest risk. Warmer temperatures may also change movement patterns, and rising sea levels will likely affect coastal, bay, and lower floodplain habitats in the area of focus. Changing ocean conditions may also impact species such as the endangered coho salmon (*Oncorhynchus kisutch*) and the threatened steelhead trout (*O. mykiss*), which spend part of their lives in Mt. Tam's streams and part at sea. Known or predicted effects of climate change of concern for specific plant and wildlife species or communities are described in this report's respective chapters.

ALTERED FIRE REGIMES

European colonization, the removal of Coast Miwok people from their traditional lands, and the deliberate curtailing of the use of fire for Tribal land stewardship have dramatically altered the region's natural fire regimes. This has been compounded by modern fire suppression efforts that began in the 1930s (GGNPC 2023b; Nelson, 2023). Consequently, it has been more than 70 years since Mt. Tam experienced a large, stand-replacing fire. Excluding fire has had significant negative impacts to the mountain's cultural and natural resources, and it is important to work toward increased collaboration with Tribal representatives to plan and implement prescribed burns informed by Traditional Ecological Knowledge (Nelson, 2023).

While fire suppression is important to protect local air quality and nearby property, plant communities on Mt. Tam are naturally dynamic and largely mediated by fire cycles (LCA, 2009). The elimination of fire has resulted, in part, in the succession of grasslands to shrublands, shrublands to woodlands, and woodlands dominated by Douglas-fir (*Pseudotsuga menziesii*). Fire suppression also has implications for the regeneration of fire-dependent species such as Sargent cypress (*Cupressus sargentii*) and Marin manzanita (*Arctostaphylos virgata)*. There are many questions about how the seed banks of these and other fire-dependent species will respond to future fires—or the lack thereof—on Mt. Tam. More detail on the effects a lack of fire is having on these communities may be found in this report's respective chapters.

In addition to these direct impacts, changed fire regimes and fire suppression are interacting with other ecological stressors on Mt. Tam in a variety of ways. Increased fuel loads caused by forests impacted by Sudden Oak Death may in turn increase the intensity of any fires that do occur. Large fires burn hotly and can kill significant numbers of trees over a wide area. This both releases nutrients into the soil and increases the amount of light reaching the ground, which can be exploited by non-native, invasive plants (LCA, 2009).

On Mt. Tam, climate change is expected to increase fire frequencies on the order of 20% under projected climate scenarios (Micheli et al., 2016). However, underlying factors can combine in ways that make specific effects difficult to predict. In general, drier and warmer conditions are more favorable to wildfires.

At present, state-wide fire management policies require suppression of all unplanned wildland fires. In Marin County, the number of wildland fires—both accidentally and deliberately ignited—has trended upward over the last several decades, but the total area burned per decade has declined (CDFFP, 2015).

This is largely due to more-effective fire suppression efforts. So, while models predict more intense fires, current suppression policies continue to maintain the fire regime in an altered state. This will likely lead to infrequent, but large and intense, wildland fires that will burn many acres despite efforts to control them.

NON-NATIVE, INVASIVE SPECIES

A plant or animal that has been introduced—either intentionally or not—to a new region is considered non-native, but not necessarily invasive. Invasive species display particular characteristics—e.g., fast growth, abundant offspring, and rapid maturation—that, when combined with a lack of natural predators and diseases that help control them in their native environment, allow them to rapidly grow and spread, frequently displacing native species.

Non-native, invasive species in Marin County come in myriad forms, including water molds, plants, invertebrates, fish, amphibians, birds, and mammals. The major threats posed by invasive species include changes in fire frequency or intensity, groundwater depletion, changes to soil chemistry, competition with native species, and a loss of native species diversity (LCA, 2009).

NON-NATIVE, INVASIVE PLANTS

While all natural areas on Mt. Tam face some degree of threat from invasive plant species, soil type, moisture level, and shade make some areas more resistant than others to invasion. Furthermore, small, patchy habitats have more gaps for invasive species to take hold, as well as more edges that may be exposed to invasion. Larger, more intact habitat patches and more remote parts of the mountain, on the other hand, may have fewer pathways—i.e., roads, trails, or human development corridors—for invasive-species dispersion.

The higher winter temperatures, longer and warmer growing seasons, and more frequent drought or storms predicted under future climate change scenarios may affect native ecosystems adapted to existing conditions by reducing resiliency and increasing the risk of spreading invasive plants (Frey et al., 2015).

Currently, about 30% of the known plant species on Mt. Tam are non-native (Figure 1.4). Of those, around 65 are priority species targeted for early detection, mapping, and control by the One Tam Conservation Management Program (Tables 1.2A and B).

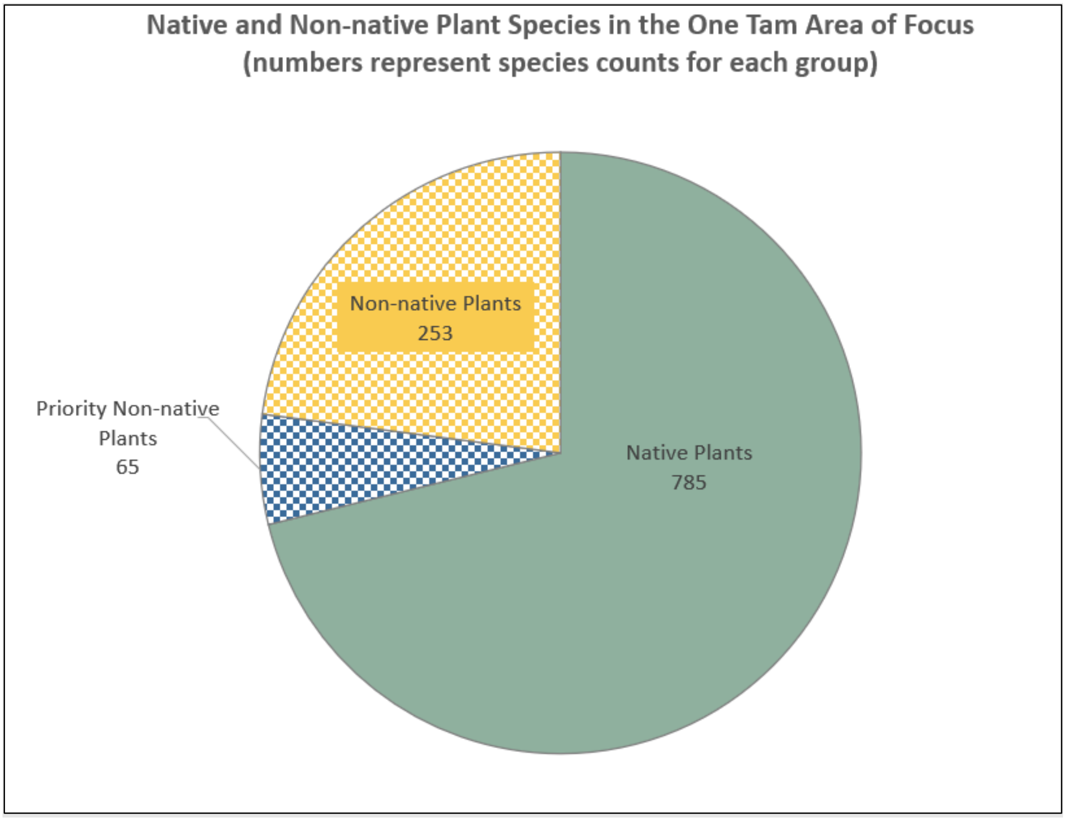

FIGURE 1.4 KNOWN NUMBERS OF NATIVE AND NON-NATIVE PLANT SPECIES IN THE ONE TAM AREA OF FOCUS

Although the highest-priority species are not currently widespread in Marin County or on Mt. Tam, they have demonstrated a capacity to harm to ecosystems in other regions or adjacent counties. Because suitable habitat for these species is found on Mt. Tam, it is critical that we find and manage incipient populations in their early stages. In 2020, the One Tam Conservation Management Program reviewed 10 years of invasive-plant data to prioritize control projects across the mountain. As of 2023, approximately 90% of the patches of the highest-priority species are being treated annually. One Tam partners continue to review local detections of widespread invasive plants for mountain-wide containment and control.

Other non-native, invasive species that are widespread in the county and/or on Mt. Tam are closely controlled by the mountain's land management agencies via existing vegetation programs using staff and volunteer support. These species may become high priorities for removal when found in small amounts far from source populations.

It is important to note that not every species included in Tables 1.2A and B is managed by every agency to the same degree. Additionally, some of invasive plant species not on this list are managed by partner agencies outside of the One Tam partnership.

TABLE 1.2, A & B PRIORITY 1 AND PRIORITY 2 TARGETED NON-NATIVE, INVASIVE PLANT SPECIES IN THE ONE TAM AREA OF FOCUS

Priority 1 Invasive Plant Species	
Scientific Name	**Common Name**
Aegilops triuncialis	Barbed goatgrass
Ailanthus altissima	Tree of heaven
Albizia lophantha	Plume acacia
Arctotheca calendula	Capeweed
Brachypodium sylvaticum	Slender false brome
Bromus tectorum	Cheatgrass
Buddleja davidii	Butterfly bush
Carex pendula	Hanging sedge
Carthamus lanatus	Wooly distaff thistle
Centaurea calcitrapa	Purple star thistle
Clematis vitalba	Old man's beard
Cytisus striatus	Portuguese broom
Dittrichia graveolens	Stinkwort
Dittrichia viscosa	False yellowhead
Elymus caput-medusae	Medusahead
Fallopia japonica	Japanese knotweed
Hypericum grandifolium	Canary Island St. John's wort
Iris pseudacorus	Horticultural iris
Maytenus boaria	Mayten
Sesbania punicea	Rattlebox
Solanum aviculare	New Zealand nightshade
Sorghum halepense	Johnsongrass
Stipa manicata	Andean tussockgrass
Stipa miliacea	Smilo grass
Stipa tenuissima	Mexican feathergrass
Ulex europaeus	Common gorse

Priority 2 Invasive Plant Species	
Scientific Name	**Common Name**
Acacia melanoxylon	Blackwood acacia
Ageratina adenophora	Thoroughwort
Arctotheca prostrata	Prostrate cape weed
Calendula arvensis	Field marigold
Centaurea solstitialis	Yellow star thistle
Cortaderia jubata	Jubata grass
Cortaderia selloana	Pampas grass
Cotoneaster franchetii	Francheti cotoneaster
Cotoneaster lacteus	Milkflower cotoneaster
Cotoneaster pannosus	Silverleaf cotoneaster
Crataegus monogyna	Hawthorn
Cytisus scoparius	Scotch broom
Delairea odorata	Cape ivy
Digitalis purpurea	Foxglove
Dipsacus fullonum	Fullers' teasel
Ehrharta erecta	Panic veldtgrass
Eucalyptus globulus	Blue gum
Euphorbia oblongata	Eggleaf spurge
Festuca arundinacea	Reed fescue
Foeniculum vulgare	Sweet fennel
Genista monspessulana	French broom
Hedera canariensis	Algerian ivy
Hedera helix	English ivy
Helichrysum petiolare	Licorice plant
Hypericum perforatum	Common St. John's wort
Ilex aquifolium	Holly
Lathyrus latifolius	Everlasting pea
Leucanthemum vulgare	Oxeye daisy
Ligustrum lucidum	Glossy privet
Pennisetum clandestinum	Kikuyu grass
Phalaris aquatica	Harding grass
Pittosporum crassifolium	Stiffleaf cheesewood
Pyracantha angustifolia	Narrowleaf firethorn

Scientific Name	Common Name
Romulea rosea var. *australis*	Rosy sand crocus
Rubus armeniacus	Himalayan blackberry
Rytidosperma caespitosum	Tufted wallaby grass
Rytidosperma penicillatum	Purple wallaby grass
Spartium junceum	Spanish broom
Tradescantia fluminensis	Small-leaf spiderwort

NON-NATIVE PLANT PATHOGENS

Sudden Oak Death (SOD), caused by the introduced pathogen *Phytophthora ramorum*, was first documented in the United States on Marin Water and California State Parks lands in Marin County in 1995 (Garbelotto & Rizzo, 2005). During the years since, this pathogen has killed tens of thousands of trees on Mt. Tam. Vegetation mapping done in 2004, 2009, and 2014 (AIS, 2015) tracked the rapid spread of the disease across Marin Water lands. The 2014 update found that 84% of forested vegetation types were affected by SOD, although the degree of impact varied by species composition of the forest and by woodland canopy characteristics (AIS, 2015).

The SOD mortality rate exceeds 80% for tanoak (*Notholithocarpus densiflorus*), the loss of which has transformed thousands of acres where this species was once dominant in the canopy. Mapping done in 2018 as part of the Marin Regional Forest Health Strategy shows 98% of the remaining 36 acres of tanoak-dominated forest with significant canopy mortality (GGNPC, 2023a). Mortality rates are lower but still significant among the coast live oak (*Quercus agrifolia)* and California black oak (*Q. kelloggii*). Dozens of other native tree and shrub species also experience damage and/or lower levels of mortality. The white oak, including valley oak (*Q. lobata*) and Oregon oak (*Q. garryana*), are not affected (APHIS, 2022).

In addition to causing dramatic changes in habitat structure, dying and dead trees increase fuel loads. The effects of the loss of oak trees on species dependent on them for food and shelter (e.g., dusky-footed woodrat [*Neotoma fuscipes*], Acorn Woodpecker [*Melanerpes formicivorus*]) are not yet known (Cunniffe et al., 2016). Oaks and other hardwood species affected by SOD are an important and culturally significant forest type for the Coast Miwok people, providing food, medicine, and other cultural materials. Reducing barriers to Indigenous stewardship practices in Marin County could have restorative effects for hardwood forests and woodlands (Nelson, 2023)

Several other disease-causing forest pathogens have either been observed on the mountain or have a high likelihood of invading in the near future. In particular, cinnamon fungus (*Phytophthora cinnamomi*) is deadly to Pacific madrone (*Arbutus menziesii*) and some species of manzanita. This pathogen is known to occur in Marin County, including several locations on Mt. Tam (T. Swiecki, personal communication). According to data developed by the Marin Regional Forest Health Strategy, 26% (280 acres) of madrone forest on Mt. Tam is experiencing moderate canopy mortality, which could be linked to impacts from *Phytophthora* species (GGNPC, 2023a). Although *P. cinnamomi* spreads more slowly than *P. ramorum*, it has a much broader range of host species and the potential to kill a wider variety of species (Sims et al., 2016).

These other pathogens have many of the same ecosystem effects as SOD, including changes in species composition and ecosystem functions, loss of wildlife food sources, changes in fire frequency or intensity, decreased water quality due to increased erosion, and increased opportunities for weed invasion in newly open areas (LCA, 2009).

NON-NATIVE, INVASIVE ANIMALS

Non-native, invasive animals compete with native species for food, shelter, and nest or den sites. Some of them also prey directly on native species. There are more than 20 known non-native animal species on Mt. Tam (Figure 1.5). Species of particular concern include:

- The American bullfrog (*Lithobates catesbeianus*) competes with and preys upon other amphibian species, including the federally threatened California red-legged frog (*Rana draytonii*) as well as the foothill yellow-legged frog (*R. boylii*), a federal and state species of concern.
- The signal crayfish (*Pacifastacus leniusculus*) preys upon the juvenile foothill yellow-legged frog.
- The red-eared slider (*Trachemys scripta elegans*) and other non-native turtles compete with and prey upon native aquatic wildlife.
- The wild turkey (*Meleagris gallopavo*) eats seeds, invertebrates, small vertebrates, and other food needed by native species, and its foraging damages native vegetation and causes soil disturbance and erosion.
- Domestic and feral cats (*Felis catus*) prey on native birds, rodents, and reptiles.

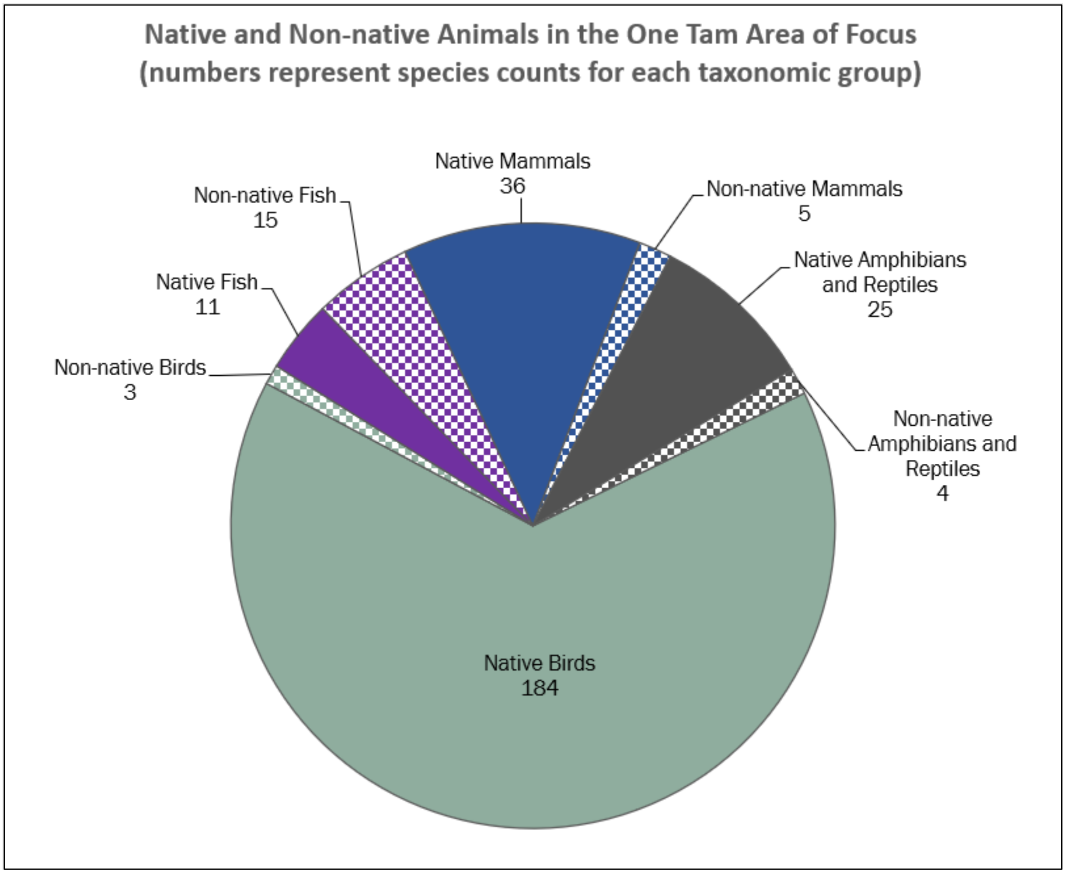

FIGURE 1.5 NUMBERS OF NATIVE AND NON-NATIVE ANIMAL SPECIES, ONE TAM AREA OF FOCUS

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CHAPTER 2. THE HEALTH ASSESSMENT PROCESS AND METHODS

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DEFINING THE ECOLOGICAL HEALTH OF A MOUNTAIN

Something as complex as ecological health cannot be easily or simply defined. And, although the definition can be science-based, there is always an element of subjectivity. For this project, we elected to consider the overall health of Mt. Tam through the lenses of processes, resiliency, and diversity rather than specific qualitative or quantitative goals.

Even though each of the mountain's four primary land management agencies have different missions, policies, and regulations, they have a shared mandate: to preserve biodiversity, maintain and maximize natural processes, and keep a diverse array of vegetation communities healthy in the face of environmental change. Based on these common purposes, we chose to define "ecological health" as follows:

- Mt. Tam's ecosystems are resilient, able to function/recover despite disturbances, changes, or shocks.
- The full complement of plants, animals, and other life forms are present; can reproduce; and are able to find food, shelter, and water as long as climate conditions allow them to persist.
- Natural processes occur in a manner and frequency considered "normal," based either on historical evidence or their ability to maintain ecological functions and adapt under changing climate conditions.

THE HEALTH ASSESSMENT PROCESS

Determining how to measure the health of the mountain's resources has required a collaborative, iterative, and multidisciplinary approach.

First, we created an initial list of health "indicators" (e.g., habitats, species) that spoke to some aspect of the overall definition of health. We then filtered these through several criteria (e.g., sufficient available data) to determine if they could be used for this project. For each remaining indicator, subject-matter experts developed a set of "metrics" that could be used to measure the health of that indicator over time. Their analyses of these metrics were then reviewed by other subject-matter experts. This provided the basis for the original 2016 document, *Measuring the Health of a Mountain: A Report on*

Mount Tamalpais' Natural Resources. (This process is described in greater detail in subsequent sections.)

This report updates that 2016 effort and considers changes to the mountain's health.

Fortunately, the original report provided a solid foundation on which to base this update, so we did not have to repeat the original lengthy and involved process. Rather, subject-matter experts—some of whom contributed to the 2016 report, some who were new to the project—reviewed and updated each chapter based on their latest data and field observations.

Using what we have learned since 2016, this update refines our original choices and adds new material. For example, we have new data on the expected effects of climate change as well as what we can learn from crowd-sourced data such as iNaturalist. In some cases, no data had been collected, leading to a decision to drop a metric for a particular indicator. In others, new data have allowed us to add indicators that we could not include in 2016 (e.g., bats, bees, and the California giant salamander [*Dicamptodon ensatus*]). A new, countywide vegetation map became available in 2018, providing a much more detailed and comprehensive view of the mountain's plant communities. While this allowed for a better analysis of their health, it also complicated measuring change over time against the old data (and assumptions made in the absence of data for some areas). Likewise, a corollary forest health strategy completed in 2023 offers opportunities to align this project with its much more in-depth dive into those communities.

Ultimately, what we learned is that as nature is dynamic and adaptable, so must be any effort to measure its health over time.

2016: WHERE IT BEGAN

The initial process was led by the Health of Mt. Tam's Natural Resources Advisory Committee, which consisted of a team of natural resources staff and ecologists from the One Tam partner agencies, Parks Conservancy, and Point Blue Conservation Science.

Advisory Committee members began by contacting others around the country who had conducted similar ecological health assessment efforts.[1] These individuals were asked about project goals, process, scope, and scale; selecting health metrics; defining and quantifying ecological health; and how their work had been received by various audiences. Their guidance was invaluable and helped shape our own process and resulting communication tools.

In particular, they emphasized setting up a structured and well-organized framework for engaging subject-matter experts; choosing indicators that were ecologically meaningful and measurable; basing the initial report on existing data; and creating scientifically based, clear, and engaging public

[1] These included the National Park Service, Chicago Wilderness Alliance, Conservation Lands Network, San Francisco Estuary Partnership, and the San Francisco Bay Area Wetlands Ecosystems Goals Project.

communications tools that could distill significant complexity and nuance in a way that accurately represents the status of the chosen ecosystem health indicators.

The Advisory Committee ultimately elected to follow a methodology similar to that used by the National Park Service for its Natural Resource Condition Assessments (NRCAs). Like NRCAs, the 2016 report relied on existing information to assess trends and conditions, confidence levels, stressors/threats, and critical information gaps. The depth and breadth of the resulting assessments reflected the varying levels of data and expert opinion on each indicator available at the time.

For the first time, this project allowed the mountain's four land management agencies to collect and synthesize all of this existing information and set baselines against which to measure and track change. The report also summarized potential future research, monitoring, or management actions that could help support each ecological health indicator. (It is important to note that, while One Tam agency partners may use its findings to help inform management decisions, the 2016 report is not an official management document.)

SELECTING INDICATORS

Not every biological community type, plant, or animal species on Mt. Tam was included in this health assessment process. Good indicators are measurable, have low amounts of data "noise," and reveal other aspects of ecosystem health.

The Advisory Committee initially constructed a comprehensive list of the mountain's taxonomic groups and plant and animal communities that could be considered as health indicators (see Appendix 1). One or more important factors from the following list drove the selection of indicators that were ultimately put forth for consideration:

- It was present in the One Tam area of focus (Figure 1.1).
- It had existing information and/or expert opinion to draw upon to determine its condition or trends.
- It was useful in some meaningful way (e.g., an indicator of biological integrity and biodiversity, natural disturbance regimes, or habitat quality).
- It was a threatened, endangered, or rare species that, if lost, would have an impact on the mountain's health by the above definitions.
- It was especially iconic or charismatic, could be used to build public affinity and interest, and/or to help gauge the health of the mountain by the above definitions.

ENGAGING THE BROADER SCIENTIFIC COMMUNITY

A thorough assessment of existing information, data, and reports about the preliminary indicators selected by the Advisory Committee was undertaken. These were then distilled into summary worksheets that included, to the extent possible: a preliminary assessment of the condition and trend of that indicator, our confidence level in the assessment, a rationale for choosing the species or community, a description of the resource and its significance to the health of Mt. Tam, current and desired condition, proposed goals and metrics by which to measure condition and trend, key ecological stressors, existing information sources (e.g., research data, monitoring, restoration projects, etc.), known information gaps, and future planned and desired management actions.

Twenty-two of these worksheets were used as the basis for a day-long workshop, which was attended by approximately 40 natural resource staff scientists from all five One Tam partners as well as from Point Blue Conservation Science, the National Park Service Inventory and Monitoring Program, and Point Reyes National Seashore. Participants were broken into facilitated, taxonomically based groups to review existing information, discuss the current state of agency knowledge and data sources, identify information gaps, and provide feedback on the list of proposed indicators, metrics, and condition and trends assessments. Their feedback was then reviewed by the Advisory Committee and used to revise the summary worksheets.

Two additional scientist workshops were held later. One focused solely on potential bird species and guilds as indicators of health, ecological stressors, and landscape-scale processes. The other brought together 60 local and agency scientists to consider the remaining (non-bird) indicators. Attendees were asked to review and make recommendations on the worksheet summaries' metrics, goals, and condition and trend statements; discuss existing data; share their expert opinions; and identify missing information.

Workshop participants relied upon a wide array of background materials, including agency reports and data sets, published papers, and gray literature. However, where data were scarce or nonexistent, they were asked to use their best professional judgment to try to make a statement about goals, conditions, and trends for the proposed indicators. They also identified data gaps and areas of uncertainty as well as further research or monitoring needed to fill those gaps.

As a result of these discussions and the feedback gathered at the workshops, a subset of the initially proposed indicators was selected. These indicators were not only deemed good representatives of the health of Mt. Tam, but they also had sufficient information or opinion consensus to set metrics and assess condition and trends. These indicators are included in this report.

METHODS

The information presented in this report is not a comprehensive analysis of Mt. Tam's resources, but rather, a methodical assessment of existing information and expert opinion on those selected as good ecological health indicators. Grounded in the realities of land management, it centers on the partner agencies' overarching environmental goals and the resources they are currently monitoring, measuring, and reporting on over time.

Every indicator has its own chapter, and each describes the project's methodology and logic, a format that was used for the original 2016 effort as well. This approach was also used to create a more in-depth guide to this process (O'Herron & Farrell, 2019).

Each chapter in this report follows the same general format:

UPDATE AT A GLANCE

New to this 2022 update, this section summarizes changes in the condition, trend, and confidence measurements for each indicator, plus includes bulleted highlights of new findings or important changes since 2016.

Condition, Trend, and Confidence:

The specific ways condition, trend, and confidence were assessed for a particular indicator and its metrics can be found within each chapter. However, the overall approach is as follows:

- An overall condition of good, caution, significant concern, or unknown was assigned to each indicator; the determination was based on an average of the condition of all the combined individual metrics. As defined here, the condition reflects how a given resource is doing within the limited geography of the One Tam area of focus and therefore, may be different from official federal or state designations of threatened, endangered, or special concern that span a broader geography.
- An overall trend of improving, no change, declining, or unknown was similarly assigned, based on the average trend of all the combined individual metrics. Each trend assessment reflected what was determined to be a reasonable time scale upon which to measure change, depending on the species or community in question.
- A confidence level of high, moderate, or low was assigned based on the quality, quantity, and recency of available data and the degree of best professional judgement (if required) to make the condition and trend assessments.

To provide a quick visual overview of how an indicator may have changed, each chapter shows the overall condition, trend, and confidence for both 2016 and 2022 using the following circle/arrow symbology (Figure 2.1).

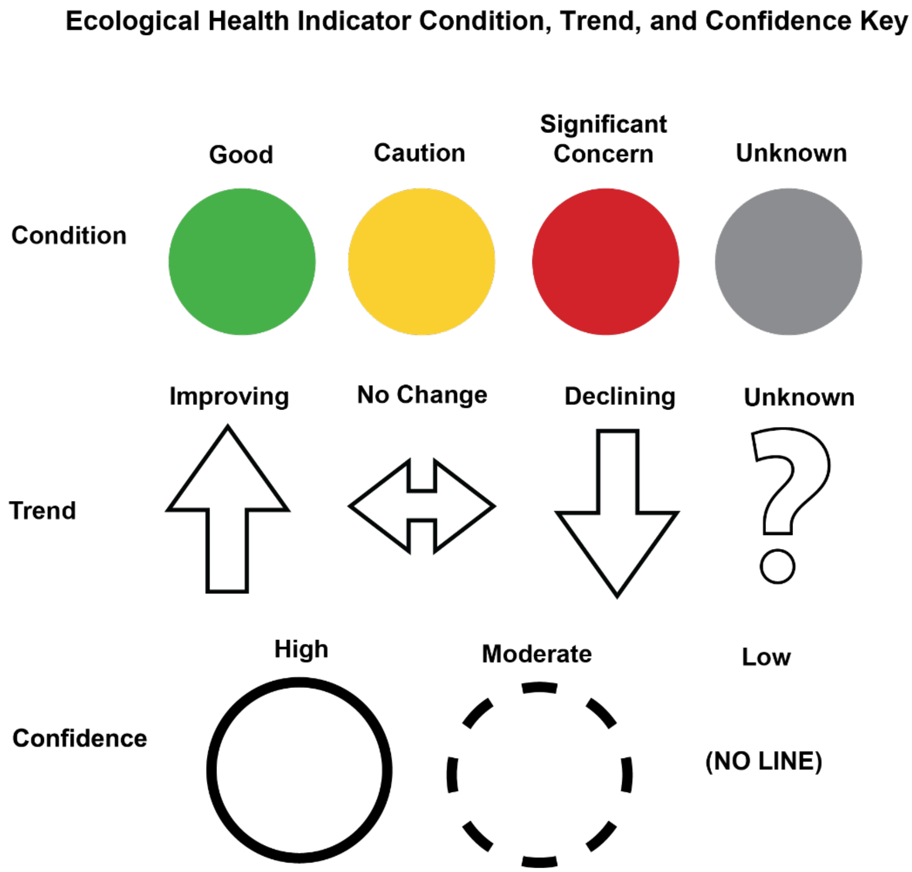

FIGURE 2.1 SYMBOLOGY USED SHOW OVERALL CONDITION, TREND, AND CONFIDENCE OF EACH INDICATOR

The indicator's metrics and their condition, trend, and confidence are then presented in tabular format in each chapter.

The overall condition, trend, and confidence in the circle/arrow graphic was derived by averaging the scores of these metrics as follows. Each condition, trend, and confidence level described with one word had a corresponding numerical score.

Condition

- Good = 100
- Caution = 50
- Significant Concern = 0
- Unknown = no score

Trend

- Improving = 100
- Unchanging = 50
- Declining = 0
- Unknown = no score

Confidence

- High = 100
- Moderate = 50
- Low = 0

Scores were combined using a simple (unweighted) average calculated by adding the scores for condition, trend, and confidence and dividing by the number of metrics used. (To avoid unfairly/inaccurately lowering the overall average, “unknowns” are not scored or included.) The resulting average condition, trend, and confidence score equaled the indicator’s overall condition, trend, and confidence as a whole, as shown in Table 2.1.

TABLE 2.1 RANGE OF AVERAGE SCORES ASSOCIATED WITH EACH OVERALL CONDITION, TREND, AND CONFIDENCE LEVEL

Average Score of All Metrics Combined	Condition	Trend	Confidence
100–76	Good	Improving	High
26–75	Caution	Unchanging	Moderate
0–25	Significant Concern	Declining	Low

Figure 2.2 illustrates a hypothetical example of how each metric’s condition, trend, and confidence was scored and then how those scores were used to calculate the averages for the indicator as a whole. For visual simplicity, only the condition calculation is called out with arrows; however, the process is the same for calculating overall trend and confidence as well.

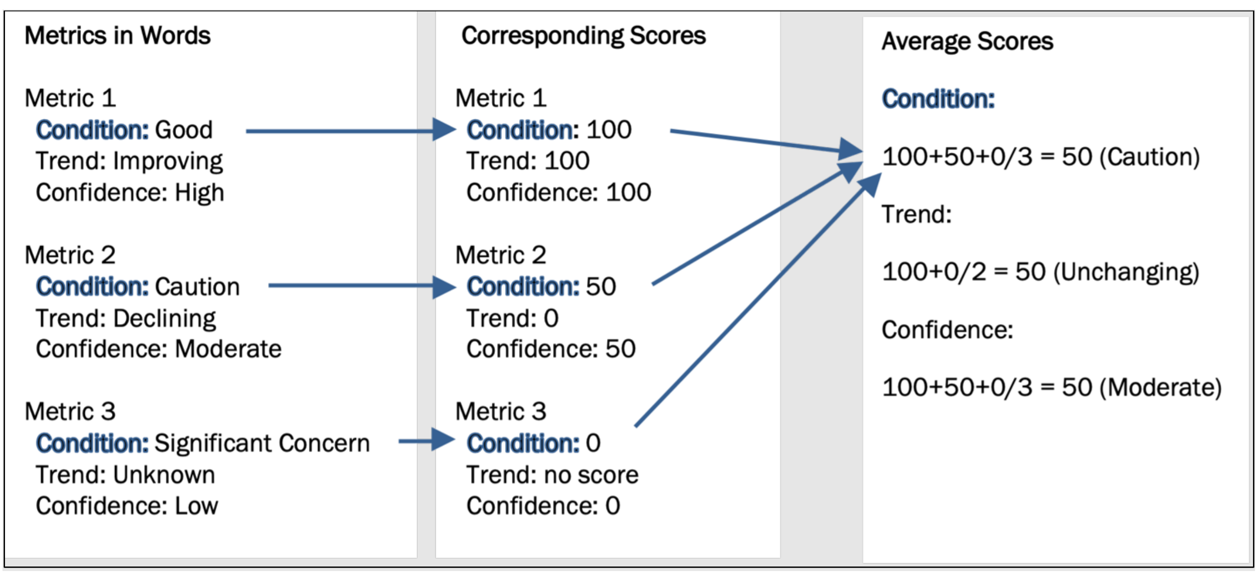

FIGURE 2.2 AN EXAMPLE OF HOW METRICS ARE SCORED AND AVERAGED TO ARRIVE AT THE OVERALL CONDITION, TREND, AND CONFIDENCE FOR EACH INDICATOR

INTRODUCTORY SECTION

Why Is This an Important Indicator?

A summary of the resource's significance and why it was chosen as an indicator of the health of Mt. Tam.

Current Condition and Trend

Historical and currently known condition, extent, and/or population size for this indicator.

Desired Condition and Trend

Qualities land managers and other experts consider necessary for a particular indicator to maintain its ecological function(s), and the threshold or state it should be in to be considered healthy.

> Note: Some of the vegetation community chapters set condition goals using specific acreages. While acreage is a useful measure of habitat patch size and overall extent, it is not always possible to maintain a set number in the face of climate change and ecological succession, which are beyond the scope of current land management efforts. In some cases, maintaining a diversity of habitats and/or ecological functions is a more realistic goal.

The metrics attempt to measure the difference between the Current Condition and Trend and the Desired Condition and Trend.

Stressors

Summaries of the ways various ecological and/or human-induced stressors are affecting the indicator's health.

CONDITION AND TREND ASSESSMENT SECTION

A high-level summary of the metrics used to measure the health of each overall indicator, including a baseline (set using information at hand in 2016), condition goals, thresholds for moving from one condition status to another, and current condition, trend, and confidence level.

Each metric indicates the difference between the Current Condition and the Condition Goal.

Condition: The current condition of the metric. Thresholds for when a resource goes from one condition category to another are set on a case-by-case basis; an example of how to set thresholds might be:

- **Good:** The condition goal is 75%–100% met.
- **Caution:** The condition goal is 26%–74% met.
- **Significant Concern:** The condition goal is 0%–25% met.

- **Unknown:** Not enough information is available to determine condition.

Trend: Change in the condition of the metric, based on current versus previous measure(s), independent of status (e.g., a resource may be declining but still be in good condition).

- **Improving:** Its condition is getting better.
- **No Change:** Its condition is unchanging.
- **Declining:** Its condition is deteriorating/getting worse.
- **Unknown:** Not enough information to state a trend.

Confidence: Amount of certainty with 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, measurement is also based on recent expert or scientist observation.
- **Low:** While monitoring is not sufficiently recent, reliable, or comprehensive, either some supporting data exists, or the measurement is also based on expert or scientific opinion.

SUPPORTING DATA, OBSERVATIONS, RESEARCH, AND MANAGEMENT SECTION

This section starts with a list of indicator-specific monitoring, inventory, or research programs, Geographic Information Systems (GIS) analyses, or other sources that serve as supporting data for condition and trends assessments.

Data Gaps

Identifying data gaps that need to be filled was an important aspect of this effort. If a metric had a data gap that was likely to be addressed in the near term, it was included and filled out to the best of the author's ability.

Past and Current Management, Restoration, Monitoring, and Research Efforts

A summary of stewardship and management activities of varying scales that have been underway for decades within the One Tam area of focus. This update calls out aspects that are new since the 2016 report. By no means a comprehensive list, it is intended to provide a sense of the type and scale of work that has been undertaken to monitor, protect, and restore the health indicators included in this document.

Future Actionable Items

A preliminary summary of actionable needs identified by agency and other local scientists. These are actions not currently funded through agency programs that will be further evaluated and prioritized for future funding and implementation outside of this health assessment process. These may include:

- Inventorying and monitoring to track priority indicator metrics, increase our understanding, and improve our ability to monitor the health of Mt. Tam's biological resources.
- Existing program support.
- Addressing critical questions and helping inform resource management.

SOURCES SECTION

A list of references cited, important supporting materials, authors, and agency staff and other subject-matter experts who participated in workshops and/or provided a technical review of the chapter.

SOURCES

REFERENCES CITED

O'Herron, M., & Farrell, S. (2019). *Ecological health assessments process guide*. Golden Gate National Parks Conservancy. https://tinyurl.com/y3j7bmhe

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CHAPTER 3. VEGETATION HEALTH INDICATORS SUMMARY

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OVERVIEW

The mountain's plant communities and their arrangement on the landscape (Figure 3.2) are the foundations of ecosystem health. Rare plants—important elements of biodiversity in their own right—also play a role in indicating the health of particular ecosystems. Both vegetation communities and individual rare plant populations may show the effects of stressors, including alterations to natural disturbance regimes (e.g., grazing, fire), climate change, and invasion by non-native species.

Mt. Tam hosts a rich array of native plants (Figure 3.1; Table 3.1; Appendices 2 and 3). However, not every plant community type or rare plant species is included in this health assessment process. Good indicators are easily measured, have low data "noise," and often reveal some other aspect of ecosystem health. With this in mind, we chose certain plant species and community types to serve as suites of indicators for this project.

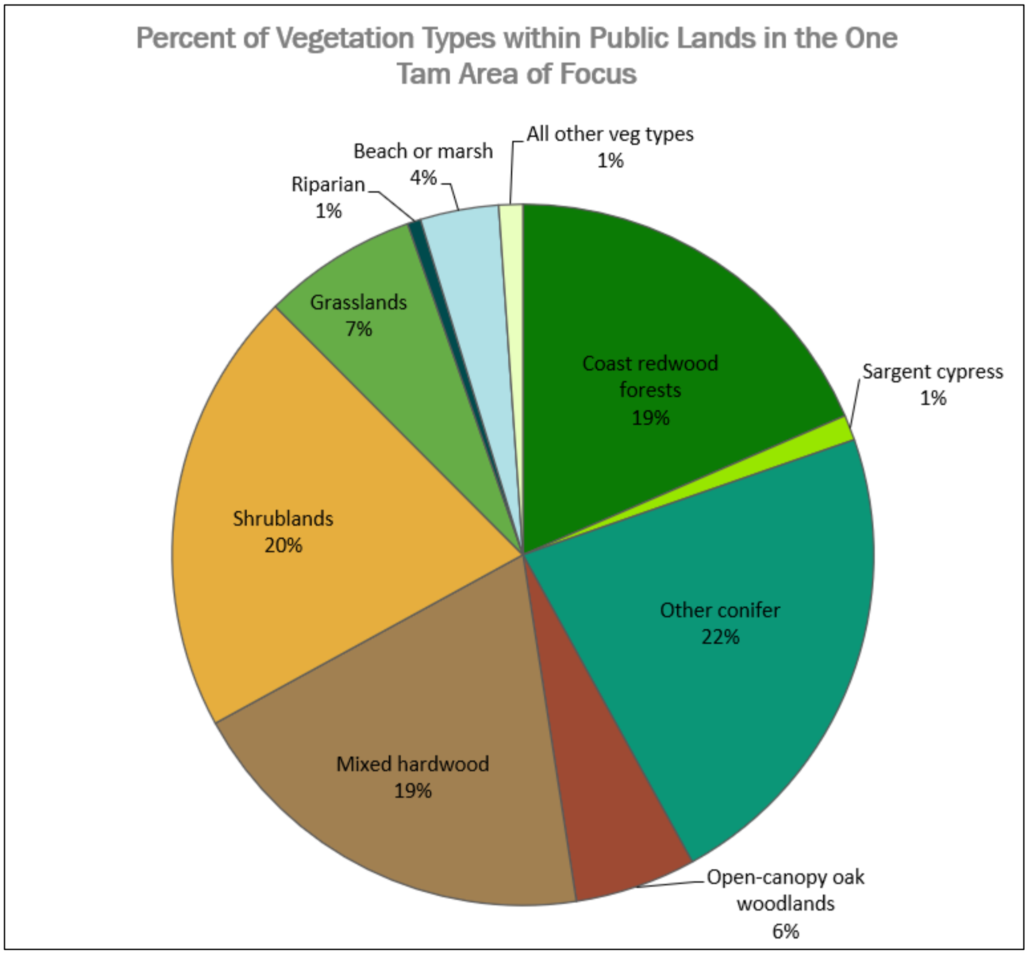


FIGURE 3.1 PERCENTAGE OF VEGETATION TYPES, ONE TAM AREA OF FOCUS

TABLE 3.1 ACRES OF VEGETATION TYPES MANAGED BY ONE TAM PARTNER AGENCIES

Community Type	Total Acres
Coast Redwood Forests	7,091
Sargent Cypress	451
Other Conifer	8,592
Open-Canopy Oak Woodlands	1,594
Mixed Hardwood	7,478
Shrublands (Coastal Scrub and Chaparral)	7,817
Grasslands	2,737
Riparian	238
Beach or Marsh	1,428
All Other Vegetation Types	426
Urban or Developed	113

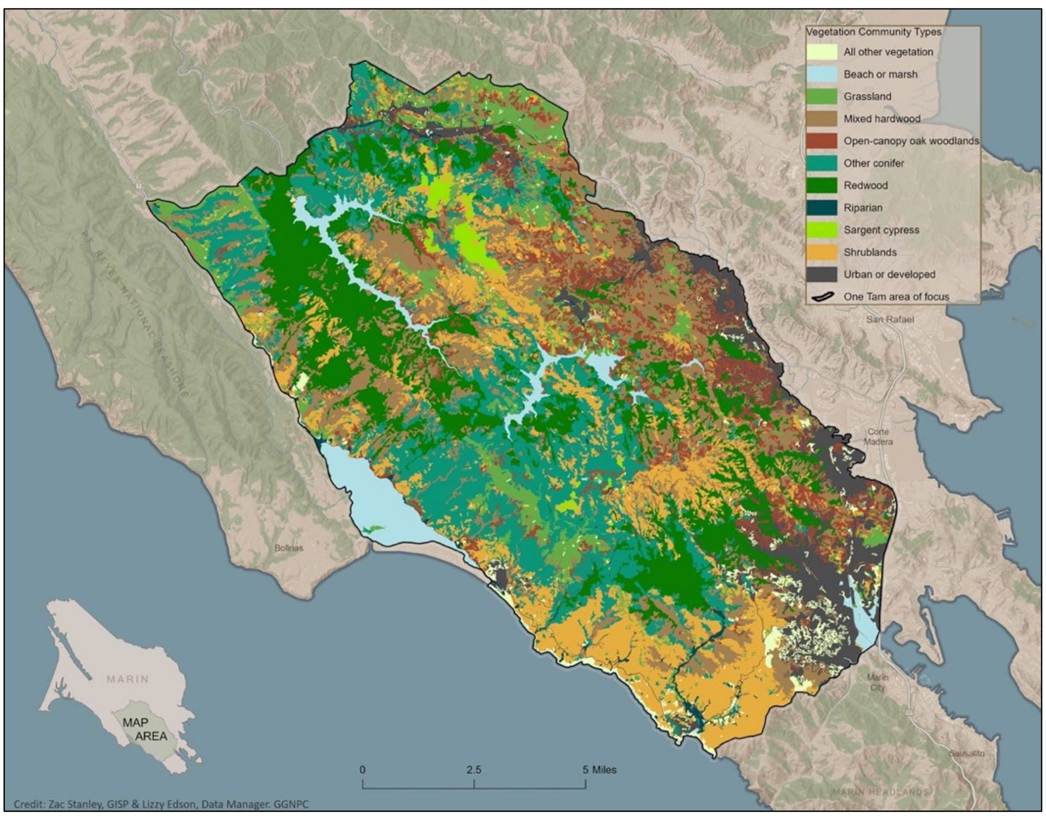


FIGURE 3.2 VEGETATION COMMUNITIES AND HYDROLOGY, ONE TAM AREA OF FOCUS

UPDATED INDICATORS

The condition, trend, and confidence assessments of all the vegetation indicators from the 2016 report described here have been updated in this version. None were added or removed.

The chapter summaries that follow include a circle, an arrow, and a line icon that summarize overall condition, trend, and confidence, respectively (Figure 3.3). These results were derived by averaging the scores of metrics used to evaluate the health of each. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are used to evaluate the health of each indicator, and other project methodology details.)

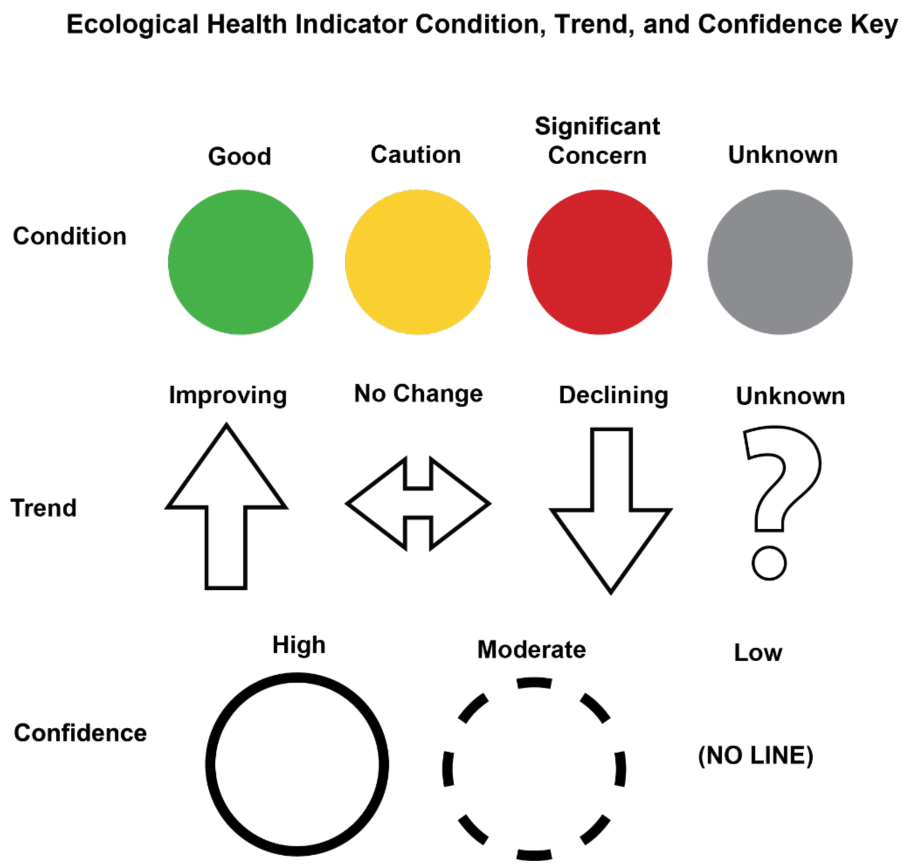
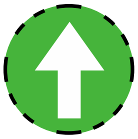


FIGURE 3.3 SYMBOLOGY USED TO SHOW OVERALL CONDITION, TREND, AND CONFIDENCE OF EACH INDICATOR

COAST REDWOOD FORESTS (CHAPTER 4)

Old-growth Forest



Condition: Good
Trend: Improving
Confidence: Moderate

Second-growth Forest

Condition: Caution
Trend: Declining
Confidence: Moderate

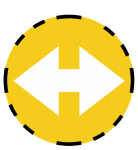
Iconic **coast redwood forests** (*Sequoia sempervirens*) are experiencing changes due to Sudden Oak Death (SOD), climate change and invasion by non-native species. The One Tam area of focus has a small amount of old-growth coast redwoods, but the majority are second-growth, having been logged at some point in the past. We have observed no detectable change in redwood forest health in the One Tam area of focus since the 2016 report, and the impact of SOD on the tanoak (*Notholithocarpus densiflorus*) midstory appears to be slowing. Thanks to the 2018 Marin Countywide Fine Scale Vegetation Map (GGNPC et al., 2021), we now have a complete picture of where redwood stands are found throughout the county, as well as a suite of data that will allow us to assess coast redwood forest health and inform forest management into the future. Note: The geographic scale of this analysis was changed to reflect the expanded One Tam area of focus. Redwood stands on Bolinas Ridge (National Park Service land) and at Roy's Redwoods Preserve and French Ranch (Marin County Parks preserves) are now included.

SARGENT CYPRESS (CHAPTER 5)

Condition: Good
Trend: No Change
Confidence: High

Sargent cypress (*Cupressus sargentii*), particularly the pygmy forest along San Geronimo Ridge, is a rare vegetation type that hosts several California Native Plant Society–listed and locally rare plant species. Unlike many of the other communities chosen as indicators, Sargent cypress appears to be relatively disease- and weed-free, and may expand its range in the face of stressors that negatively affect other dominant plant species. Sargent cypress plant communities are typically stable for decades, then experience a complete reset after a high-intensity fire. There have been no fires in Sargent cypress habitats in the One Tam area of focus since the 2016 report, and so, as expected, they have experienced no major changes. Our confidence in this assessment has increased since 2016, however, because invasive species presence was field-assessed in 2022. While the condition and trend of the metrics have not changed overall, new observations and additional management guidance have been included in this updated chapter.

OPEN-CANOPY OAK WOODLANDS (CHAPTER 6)



Condition: Caution
Trend: No Change
Confidence: Moderate

Mt. Tam's stately **open-canopy oak woodlands**, which serve as habitat for numerous plants and animals, exhibit tremendous biodiversity. They have also been impacted by Douglas-fir (*Pseudotsuga menziesii*) encroachment as a result of alterations in natural disturbance regimes and by the invasion of non-native plants, particularly French broom (*Genisa monspessulana*). In addition, oak woodlands are losing large numbers of trees to SOD. While the condition of oak woodlands went from declining in 2016 to no change in 2022, it is important to note that mapping techniques and extent changed between the two analyses such that it is difficult to compare results across years. However, this chapter's new baselines will provide a more accurate way to measure change over time going forward.

SHRUBLANDS: COASTAL SCRUB AND CHAPARRAL (CHAPTER 7)

Condition: Caution
Trend: Declining
Confidence: Moderate

Shrubland communities on Mt. Tam are of two general types: **Coastal scrub** areas are primarily dominated by soft-leaved, woody, drought-deciduous or evergreen shrubs such as California sagebrush (*Artemesia californica*) and coyote brush (*Baccharis pilularis*). **Chaparral** cover is dominated by drought- and fire-tolerant, hard-leaved, woody evergreen species such as manzanitas. Declines in condition and trend from what we knew in 2016 to our best current understanding in 2022 should be viewed with the understanding that in each of the two years, we measured slightly different things in two of the metrics. However, this does not account for all of the differences in condition and trend between the two analyses. The condition of shrublands in the area of focus has been reduced from good in 2016 to caution in 2022 because new data and analyses indicate a higher level of threat and a greater loss of shrublands extent than was previously known. Numerous lines of evidence reveal that shrublands are losing acreage to forest succession due to fire suppression, and more shrubland acres than were previously known are occupied by invasive plants.

MARITIME CHAPARRAL COMMUNITY ENDEMICS (CHAPTER 8)

Condition: Significant Concern
Trend: Declining
Confidence: Moderate

Maritime chaparral, which is associated with several special-status species, is found on Mt. Tam's marine-influenced lower elevations. No significant changes in the metrics used for this indicator have been detected since 2016. National Park Service staff conducted surveys to monitor rare chaparral endemics in 2017 and 2020, but these surveys did not encompass all known populations. Consequently, we have a lower confidence in our current condition and trend assessment than we did in 2016.

GRASSLANDS (CHAPTER 9)

Condition: Caution
Trend: Unknown
Confidence: Low

Mt. Tam's iconic, sweeping **grasslands** serve as habitat for numerous plants and animals, and contain tremendous biodiversity. They have also been affected by ecological succession as a result of alterations in natural disturbance regimes and by the invasion of non-native plants. The state's native grasslands are at 1% of their historical extent, and Mt. Tam preserves some of the best examples of remnant grassland ecosystems in the region (Noss & Peters, 1995). The 2018 Fine Scale Vegetation Map provided new information on grassland extent and composition to support this chapter update. Notably, it documented significantly fewer acres of grassland than were included on earlier maps. A change in geographic boundaries for the One Tam area of focus also changed grassland extent. Differences in this map and previous efforts meant that we had to establish a new baseline from which a trend may be inferred in the future.

SERPENTINE BARREN ENDEMICS (CHAPTER 10)

Condition: Caution
Trend: No Change
Confidence: High

The majority of Mt. Tam's rare plants fall into a few community types, and particular suites of species were chosen to indicate the status of those communities. Approximately half the rare plants—by both number of taxa and number of populations—are serpentine endemics. Rare plants within the **serpentine barrens** plant community were sorted into "relatively common" and "relatively uncommon" to measure both biodiversity and the health of open-canopy serpentine types. New data on barren occupancy and species abundance from the One Tam Serpentine Endemic Occupancy Project (initiated in 2016) are now available and have been used to inform this update. This allows us to set baselines, condition goals, and condition and trend thresholds for each metric, something that was not possible in 2016. The changes in each metric are described in more detail in the Condition and Trend Assessment section of this chapter.

EXTIRPATED SPECIES

Another way to examine ecosystem health is to consider species that are no longer present, and to try to understand the factors that contributed to their loss. The current list of likely extirpated plant species (see Appendix 4) includes native species historically found within the One Tam area of focus. However, these species have not been seen in more than 50 years and/or have not been found in searches of their last known locations. Note that this list contains many species that require fire to germinate; while they may be present in the seedbank, they are not observable and therefore, are effectively presumed absent. The longer these species go without fire, the higher the likelihood that their seeds will not be viable even if a fire does occur.

Historical presence was established primarily through comparing the One Tam species list with *Marin Flora: Manual of the Flowering Plants and Ferns of Marin County, California* (Howell, 1970). Taxa indicated as growing on Mt. Tam in that book but not listed as present on the current species list were compared against herbarium records (CCH, 2016) and recent observations included in online databases (Calflora, 2016; NPSpecies, 2016). Additional staff and local expert knowledge were used to document known locations and/or extirpations in order to add or remove species from the list.

Over time, One Tam agency staff, which continues to survey for species thought to be extirpated from the mountain, have removed several from the list. It will be necessary to have additional botanical experts verify herbarium specimens upon which some otherwise unsubstantiated records are based to ensure that a species' presence is not based on misidentification or taxonomic changes.

Extirpated species lists, compelling and dramatic examples of changes that have taken place in the recent past, indicate the trajectory of plant species on Mt. Tam. For example, some potentially extirpated plants may have disappeared from the aboveground flora due to lack of fire, or may appear to be shifting their range northward and westward (away from the mountain and toward the coast), possibly as a result of climate change.

MANAGEMENT AND MONITORING

Mt. Tam's land management agencies strive to preserve biodiversity and functioning ecosystems, and to do so in the face of a changing environment that is largely beyond their control. Because nature is not static, preserving things exactly as they are is neither a realistic nor desirable goal.

For example, vegetation succession, an ongoing natural process, is also affected by landscape-scale processes such as wildfire and the land management policies of individual agencies. Consequently, while maintaining a certain number of acres of a particular vegetation community over a large landscape might not be the management target of a particular agency, monitoring shifts in acreages over short periods of time can be useful to help managers understand how ecosystems and their functions might be changing.

OVERARCHING VEGETATION MANAGEMENT AND MONITORING EFFORTS

Following are descriptions of several large-scale programs that manage or track plant communities and species on Mt. Tam. Past and current management, monitoring, restoration, and other efforts that support only specific plant communities are summarized in each respective chapter.

Weed Monitoring, Surveying, and Management: Guided by a prioritized list of invasive plant species, One Tam staff and partner agencies survey roads, trails, facilities, and disturbed sites year-round, (primarily, March through September) through the Early Detection Rapid Response program. Survey areas are further prioritized based on levels of human use (which increases the potential for invasive-species introductions) and habitat health. Work groups survey all roads and trails every three years. National Park Service surveys began in 2008, and other land managers launched similar programs in subsequent years. The One Tam staff began its own program in 2016, with a goal to increase surveys and add capacity to partner agency efforts.

Invasive plant species are placed into one of two categories: highest priority and local detections. "Highest priority" species are new to the mountain, have very low distribution, or likely occur on nearby lands; these species are mapped at all size classes. "Local detections" are priority weeds with wide distribution. For both categories, the mapping interpatch distance is 20 meters. Surveyors record data on patch size, number of individuals, phenology, and percent cover. Early detection and treatment of new infestations help mitigate their impacts and reduce the costs of invasive plant management.

Large-scale Weed Management Program: One Tam partner agencies commit significant resources to mapping, monitoring, and managing invasive vegetation on their respective lands. Volunteer-based efforts to control invasive plants include regular drop-in days for adults and families, school groups (from elementary to college-age students), and special volunteer events (e.g., Muir Woods Earth Day) that bring hundreds of volunteers to the mountain every year. Full-time and seasonal staff and interns are dedicated to providing volunteer management and leading these stewardship activities.

In addition, many staff also work directly in the field, controlling, mapping, researching, and monitoring invasive plant populations and past control efforts. In 2012, National Park Service and California State Parks staff launched a comprehensive watershed-wide approach to controlling targeted invasive plants in the Redwood Creek Watershed; this approach increased efficiencies and ensured the management of priority weeds across jurisdictional boundaries.

All agencies invest significant resources in staff-supervised, contractor-based vegetation management to both control and map targeted invasive-plant populations. Special fuels-reduction projects on partner lands are implemented by contractors with the dual purpose of fuels management (keeping fuelbreaks free of broom and other weedy vegetation) and resource enhancement.

Rare Plant Monitoring: Mt. Tam supports more than 40 rare, threatened, and endangered plant species. Data are available for many of these species through field surveys conducted by One Tam land managers and partners, including the Marin Chapter of the California Native Plant Society. The scale of each monitoring program varies based upon staff and volunteer resources. For example, National Park Service staff monitor rare plants annually (individual populations are visited once every three to five years), and during the past 10 years, Marin Water staff re-inventoried its rare plant populations and updated its data on the more than 400 individual patches on watershed lands.

INDICATOR ANALYSIS METHODOLOGY

VEGETATION COMMUNITY MAPPING AND ANALYSIS

Since the release of the first edition of this report, One Tam sponsored the creation of the 2018 Fine Scale Vegetation Map, which adheres to the National Vegetation Classification System and uses 2018 high-resolution lidar data (GGNPC et al, 2021). The map products include a “lifeform” layer divided into 27 classes and a higher-resolution set of 107 vegetation classes mapped in units of one acre or less.

Methods used to produce this vegetation layer combined machine learning and expert knowledge to validate data and correct for errors, resulting in an estimated overall accuracy of 77% for the fine-scale vegetation map and 95% for the lifeform map. To facilitate regional strategies across jurisdictions, the map and the methods used to create it align with new data for neighboring counties. This comprehensive dataset contains attributes relevant to forest health that apply to all forest stands, including areas of standing dead vegetation and canopy gaps that formed between 2010 and 2019.

The 2018 Fine Scale Vegetation Map gives land managers an important resource, one they can use to inform climate adaptation planning for vegetation communities and ecosystem health. This high-resolution map can be combined with modeled data on climate exposure (Thorne et al., 2017) and wildfire probabilities (Moritz et al., 2012; Mann et al., 2016) mapped at a relatively coarse scale to locate general areas with high or low risk of fire- and climate-change impacts. Combining these data sources provides a hypothesis about vegetation change that can be used to inform monitoring, fuels treatments, or habitat restoration.

To better understand vegetation communities, we clipped the 2018 Fine Scale Vegetation Map to provide three different coverages: the whole One Tam area of focus; combined public lands coverage within the One Tam Area of focus; and, at the finest resolution, individual agency lands within the area of focus. It should be noted that clipping the vegetation map to any individual agency results in a bit of data "noise" due to varying degrees of boundary-layer accuracy, particularly where two or more boundaries intersect or align.

Regardless of the coverage of the clipped vegetation layers, however, our process was the same: the planar acreage was recalculated for each vegetation polygon using U.S. survey acres, and the vegetation map column, "Fine Scale Map Class in '18," was used to roll up vegetation polygons into the following broader community types:

- Redwood
- Sargent cypress
- Other conifer
- Open-canopy oak woodlands
- Mixed hardwoods
- Shrublands
- Grasslands
- Riparian
- All other vegetation types
- Beach or marsh
- Urban or developed

We then derived the overall extent of various vegetation types and canopy-level metrics for each of the plant-community indicators. These specific analyses are described in more detail in each chapter.

The 2018 Fine Scale Vegetation Map represents a huge step forward in our ability to understand the current state of the mountain's plant communities, track changes in them over time, and coordinate monitoring and management with other land managers. Contrast this with the 2016 version of this report, which relied on six different vegetation maps created at different scales and at different times. Those data sets, which are still referenced in the chapters that follow, included:

- The 1994 National Park Service Vegetation Map encompassed all of Golden Gate National Recreation Area, parts of Point Reyes National Seashore, and all of Mount Tamalpais State Park (Schirokauer et al., 2003).

- The 2004, 2009, and 2014 Marin Water Vegetation Maps covered all of the watershed lands. Only Marin Water had time-series maps (2004, 2009, 2014) that could be used to detect changes over time. All data from the 2004 and 2009 maps were summarized in the report for the 2014 mapping project (Evens et al., 2006; AIS, 2015).

- The 2008 Marin County Parks-Marin County Open Space District Vegetation Map included all of the agency's preserves (AIS, 2008).

That being said, using a new map assembled in a new way did create challenges in comparing 2016 assessments with those we are now able to make. In some cases, it was impossible to compare the two Peak Health reports, and new baselines were set based on the new data. This is described in detail for each applicable metric where it applies in the chapters that follow.

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CHAPTER 4. COAST REDWOOD (*SEQUOIA SEMPERVIRENS*) FORESTS

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

2016 OLD-GROWTH FOREST

Condition: Good

Trend: Improving

Confidence: High

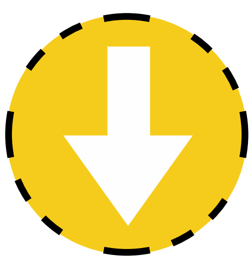
2022 OLD-GROWTH FOREST

Condition: Good

Trend: Improving

Confidence: Moderate

2016 SECOND-GROWTH FOREST

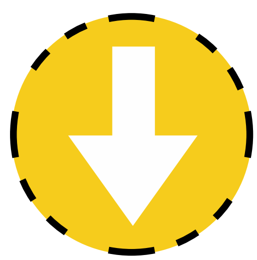


Condition: Caution

Trend: Declining

Confidence: Moderate

2022 SECOND-GROWTH FOREST



Condition: Caution

Trend: Declining

Confidence: Moderate

FIGURE 4.1 CONDITION, TREND, AND CONFIDENCE FOR COAST REDWOOD FORESTS, ONE TAM AREA OF FOCUS

We have not observed any detectable change in redwood forest health in the One Tam area of focus since the 2016 report. Sudden Oak Death (SOD) impacts to the tanoak (*Notholithocarpus densiflorus*) midstory appear to be slowing. The 2018 Marin Countywide Fine Scale Vegetation Map (GGNPC et al., 2021) provides a complete picture of where redwood stands are found throughout the county, as well as a suite of data that will allow us to assess redwood forest health and inform management into the future.

Other highlights since 2016 include:

- The geographic scale of this analysis was changed to reflect the expanded One Tam area of focus. Redwood stands on Bolinas Ridge (National Park Service land) and at Roy's Redwoods Preserve and French Ranch (Marin County Parks preserves) are now included.
- No metrics were added or removed. However, new data from the 2018 Fine Scale Vegetation Map provide opportunities to describe redwood forests at a landscape scale and to begin to connect remote-sensing data with on-the-ground ecological conditions.

METRICS SUMMARY

Metrics in Table 4.1 were used to assess coast redwood forest health. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 4.1. Each metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 4.1 ALL COAST REDWOOD FOREST METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1: Forest structure and demography with old-growth characteristics, or moving toward old-growth characteristics		
	2016	**2022**
Condition	**Old-growth:** Good **Second-growth:** Significant Concern	**Old-growth:** Good **Second-growth:** Significant Concern
Trend	**Old-growth:** Improving **Second-growth:** Declining	**Old-growth:** Improving **Second-growth:** No Change
Confidence	**Old-growth:** High **Second-growth:** Moderate	**Old-growth:** Moderate **Second-growth:** Moderate

Metric 2: Mid-canopy structure		
	2016	**2022**
Condition	**Old-growth:** Caution **Second-growth:** Caution	**Old-growth:** Caution **Second-growth:** Caution
Trend	**Old-growth:** Unknown **Second-growth:** Declining	**Old-growth:** Unknown **Second-growth:** Declining
Confidence	**Old-growth:** High **Second-growth:** High	**Old-growth:** Moderate **Second-growth:** Moderate
Metric 3: Targeted non-native, invasive species cover		
	2016	**2022**
Condition	Good	Good
Trend	**Muir Woods:** Unknown **Second-growth:** Declining	**Muir Woods:** No Change **Second-growth:** No Change
Confidence	Moderate	High

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

Coast redwood trees are the epitome of resiliency. Among the tallest in the world, individual redwoods may live as long as 2,000 years. Thick bark and an ability to rapidly resprout enable established adult trees to survive most wildfires, and their seedlings thrive in the mineral-rich soil left behind by fires and floods (Lorimer et al., 2009). High levels of tannins make the redwood resistant to insect and fungal infestations. Acidic soil conditions, thick duff layers, and dense shade also make redwood-dominated stands relatively resistant to non-native plant invasion. However, despite their overall resilience, historical logging practices diminished the extent and density of old-growth redwood stands and altered forest conditions overall. As a result, coast redwood forests are on the International Union for Conservation of Nature Red List as “endangered” (Farjon & Schmid, 2013).

Coast redwood forests in the One Tam area of focus are significant cultural resources for the Coast Miwok. Trees are used for tools and construction, and associated species (e.g., tanoak and hazelnut) serve as important food plants (GGNPC, 2023).

Mt. Tam’s coast redwood forests also provide important habitat for a number of mammals and birds, including the state- and federally threatened Northern Spotted Owl (*Strix occidentalis caurina*).

Endangered coho salmon (*Oncorhynchus kisutch*) and threatened steelhead trout *(O. mykiss*) also live in the Redwood Creek Watershed.

These forests store more standing carbon than any other kind in California (Van Pelt et al., 2016). Redwood foliage "harvests" fog, and the accumulated water drips slowly down to the soil, increasing total precipitation within stands and creating a separate microclimate below the canopy (Dawson, 1998). Redwood growth rates have increased significantly in recent decades (Sillett et al., 2015), but their future trajectory is unknown as California becomes functionally more arid with climate change (Johnstone & Dawson, 2010; Fernández et al., 2015). As such, the redwood may serve as an indicator of climate change, particularly changes in precipitation and summer fog (Micheli et al., 2016). A sudden decline in such a long-lived and resilient species would signify changes on a scale likely to be detrimental to other vegetation communities as well.

Redwood forest communities are good indicators of the effects of forest management practices, wildfire regimes, and disease processes. Coast redwood trees sprout prolifically from stumps, and many of the mountain's second-growth redwood stands have higher redwood tree densities than old-growth areas as a result of turn-of-the-century logging (Noss, 2000). In the absence of wildfire or active management, fast-growing species such as Douglas-fir (*Pseudotsuga menziesii*) and tanoak have become more abundant. High densities of tanoak in second-growth redwood stands in the moister regions of the One Tam area of focus reflect this history. Redwood forest communities are also being impacted by SOD (caused by the pathogen *Phytophthora ramorum*), which rapidly kills tanoak trees and other coast redwood forest understory species. Since the 1990s, SOD has been responsible for wide-spread cycles of tanoak dieback and resprouting in One Tam area of focus redwood forests, as well as in mixed hardwood forests across the region (Cunliffe et al., 2016).

Finally, these forests are good barometers of ecological health because understory conditions in heavily visited redwood forests can also be indicative of recreational pressures. Soils in redwood forest systems are sensitive to compaction by human foot traffic, which can damage both redwood tree roots and other plants that grow on the forest floor (Voigt, 2016).

CURRENT CONDITION AND TREND

Towering stands of old-growth coast redwoods once stretched across fog-shrouded hills and valleys from southwestern Oregon to the Big Sur Coast of Central California. Less than 5% of this original old-growth redwood forest remains, although second-growth forests persist over much of the historical range (Fox, 1989). Coast redwood forests occupy 11,265 acres in Marin County (Figure 4.2). Within the One Tam area of focus, coast redwood forests cover 7,091 acres.

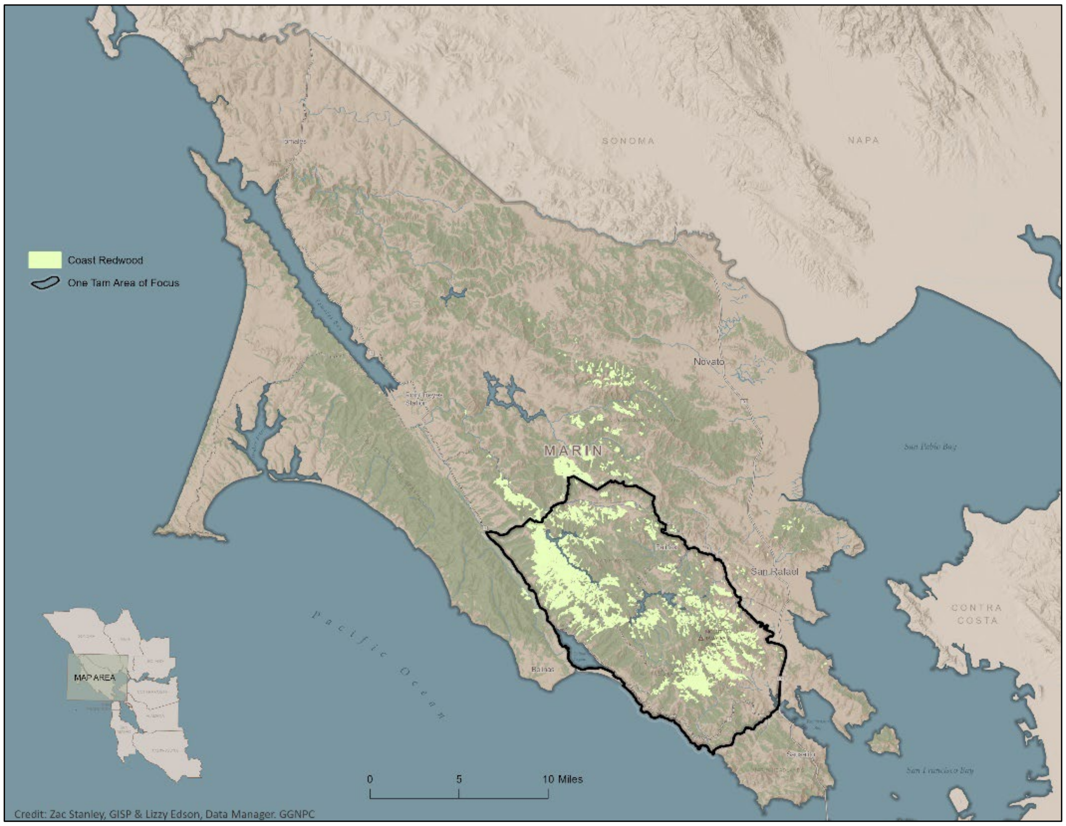


FIGURE 4.2 DISTRIBUTION OF COAST REDWOOD FORESTS, MARIN COUNTY (GGNPC ET AL., 2021)

The vast majority of the mountain's redwood forests have a varied history of commercial logging prior to gaining protections within the current network of public lands. Less than 15% of redwood stands within the One Tam area of focus were protected from logging and can be considered "old-growth." These include stands at Muir Woods National Monument, Steep Ravine and Fern Creek (Mount Tamalpais State Park), and Roy's Redwoods Preserve (Marin County Parks), among other locations. One Tam land management agencies have more-detailed field measurements for Muir Woods than many other redwood stands, which is why it was considered separately in parts of the 2016 analysis. In general, old-growth conditions represent a desirable state for redwood stands, given their complex habitat structure and other ecological conditions that make them more resilient to wildfire and other stressors.

Although specific characteristics will vary based on site conditions, old-growth coast redwood forests include (Van Pelt et al., 2016, unless otherwise noted):

- A multilayered, multi-aged canopy dominated by coast redwoods.
- A well-developed midstory with shade-tolerant species, including tanoak, California bay laurel (*Umbellularia californica*), and Douglas-fir.
- An understory with both shrub and herbaceous components.

- Large-diameter trees (100 cm diameter at breast height [dbh] or more), with large horizontal branches, cavities, broken limbs, and burn scars.
- Standing snags/deadwood and large, very slowly decaying wood (nurse logs) on the ground.
- Approximately 50 to 100 overstory trees per hectare (ha) (Lorimer et al., 2009).
- Riparian/alluvial systems and associated midstory trees that include bigleaf maple (*Acer macrophyllum*) and alder species (*Alnus* spp.) in valley-bottom sites.

In Marin County, trees found in a more diverse redwood forest understory often include bigleaf maple, tanoak, Douglas-fir, California nutmeg (*Torreya californica*), and California bay laurel (Buck-Diaz et al., 2021). Most redwood stands in the area of focus are considered second-growth. These stands exhibit greatly simplified structure, with an absence of larger trees in the canopy, a less diverse understory, and high densities of small-diameter trees. The potential for second-growth stands to achieve old-growth characteristics (e.g., a more developed understory and complex habitat structure) in the near term is largely driven by site conditions such as tree density and presence of other woody species. Some of Mt. Tam's second-growth stands have clusters of large-diameter trees that were inaccessible or otherwise undesirable for logging. In general, though, these second-growth stands vary widely in their characteristics and in the degree to which they have recovered from the effects of logging due to varying site conditions and the amount of time that has passed since they were last logged.

DESIRED CONDITION AND TREND

The desired condition for **old-growth** redwood forests is a complex species composition and multi-aged, multi-storied stands; coarse woody debris; tree cavities; and other nesting structures such as large limbs.

In **second-growth** forests, the desired condition is evidence that a stand is on a trajectory toward developing old-growth characteristics. This includes a reduction in the total stem density (trees per unit area) over time as well as the development of large-diameter trees and a multistoried stand structure (Lorimer et al., 2009). Maintaining the existing extent of redwood forests in the One Tam area of focus is considered highly desirable because of their habitat value for Northern Spotted Owls and coho salmon, their ability to store carbon and other greenhouse gases (Cobb et al., 2017), and their iconic value.

Historical Impacts: See the discussion of logging impacts in previous sections.

Invasive Species Impacts: Deep shade created by the redwood overstory prevents many invasive species from impacting these forests. However, some—notably, panic veldtgrass (*Ehrharta erecta*)—can persist in the redwood understory and disrupt native biodiversity.

Climate Vulnerability: Models generally forecast warmer temperatures and uncertain precipitation patterns for coastal California over the next 15 years, with the southern extent of the redwood range experiencing more warming than the north (Fernández et al., 2015). The impact these predicted climate changes will have on redwood forest health is complex, given that redwoods have shown increased growth with climate changes and higher atmospheric $C0_2$ (Sillett et al., 2015). However, the more frequent and longer droughts predicted with climate change may stress redwoods and associated understory species, and smaller redwood forest understory plants may be more vulnerable to increasingly arid summers (Fernández et al., 2015; Johnstone & Dawson, 2010; Micheli et al., 2016; Ackerly et al., 2018).

The fate of Marin County's redwood forests may very much depend on whether climate change produces overall wetter or drier conditions. Bay Area redwoods occupy relatively low climate-water-deficit zones, but as water deficits increase, some populations currently near the drier edge of the range could end up in unsuitable conditions. Long-lived trees like redwoods may achieve equilibrium with new conditions too slowly to acclimate to climate change (Ackerly et al., 2015). A statewide model of climate exposure suggests that about 45% of redwood forests in the One Tam area of focus are in a "high exposure" category and thus may not be able to adapt (Thorne et al., 2017; GGNPC et al., 2021).

Fog decreased by approximately one-third from 1950 to 2010 (Johnstone and Dawson, 2010), but predicting future fog patterns is complicated (Ackerly et al., 2018). Because redwoods can get 30% to 40% or more of their water from fog and low clouds during the dry season, reduced fog frequency, particularly in the summer, could lower their ability to thrive, especially if precipitation also declines (Johnstone & Dawson, 2010; Torregrosa et al., 2020; Limm et al., 2009).

With respect to the potential impacts of climate change on wildfires, redwoods are projected to be relatively resilient, even in the face of high fire severity (Simler et al., 2018). A study of canopy burn severity and resprouting is currently underway in the redwood forests that burned in Big Basin State Park (Santa Cruz County) during the 2020 CZU Lightning Complex Fire. Results may help managers understand how Coast Redwood resilience to high-severity fire is influenced by pre-fire landcover and management.

Fire Regime Change: The length of time between fires in Marin County has increased fourfold since 1859, and most redwood stands have not burned for 70 years (Dawson, 2022). Fire suppression and absence of cultural burning have resulted in a buildup of fuels, particularly in second-growth stands. This has affected forest structure and diversity as well as decreased the redwood's wildfire resilience.

Disease: Since its onset in 1995, SOD has taken a heavy toll on tanoaks within the One Tam area of focus and elsewhere on the Central California coast. Where there are a high number of affected trees, a redwood stand's structure can be altered (Maloney et al., 2005; McPherson et al., 2010; Ramage & O'Hara, 2010). Tanoaks are among the most shade-tolerant hardwoods in coastal California, and one of the few species that thrives in the dense shade of the redwood overstory. They are an important structural component of redwood forests and, as acorn producers, are also important for wildlife and a culturally significant species for local Indigenous people (Noss, 2000; Tempel et al., 2005; GGNPC, 2023). As late as 1990, the tanoak was the most abundant tree on Mt. Tam and the most numerous in many redwood stands (Parker, 1990). The prevalence of tanoak in the mountain's second-growth stands was due at least in part to fire suppression, which would have killed small trees (Brown & Baxter, 2003).

In addition to extensive canopy gaps left by dead trees, SOD damages the structural integrity of diseased trees; infected tanoaks rapidly collapse and decay. This decreases standing snags, and only temporarily increases the presence of larger logs on the ground. Remnant tanoak stumps quickly resprout, producing high densities of brush, which in turn become diseased, collapse, and resprout again. As a result, gaps between redwood trees fill in with brush, and fine fuels (lightweight, small-diameter material such as twigs and leaves) increase over the short-term. However, evidence suggests that fuels decrease over the long-term as the disease progresses (Forrestel et al., 2015). For example, evidence from wildfires in Big Sur redwood forests found an increase in redwood mortality in areas where SOD had recently killed trees, but not in areas where the disease had progressed (Metz et al., 2013).

Direct Human Impacts: Recreational use of redwood forests, both on- and off-trail, leads to soil compaction and disruption of understory biodiversity and species abundance (Voigt, 2016).

CONDITION AND TREND ASSESSMENT

METRICS

METRIC 1: FOREST STUCTURE AND DEMOGRAPHY WITH OLD-GROWTH CHARACTERISTICS OR MOVING TOWARD OLD-GROWTH CHARACTERISTICS

Baseline: The One Tam area of focus is located near the center of the geographic distribution of coastal redwoods. Old-growth redwood forest structure and demographics are available throughout the entire redwood range. Stand structure within Muir Woods most closely resembles those in southern redwood reference stands characterized as part of the Redwoods and Climate Change Initiative (RCCI). The RCCI is a research program led by Save the Redwoods League and Humboldt State University aimed at understanding the relationship between climate and redwoods, with long-term study plots spanning the state.

A 2014 Muir Woods forest structure study revealed a live-tree density per ha of 430 ± 31 individuals, with approximately 24% of trees >100 cm dbh (Table 4.2A). In 2015, University of California, Davis, researchers characterized stand structure in second-growth redwood forests with tanoak mid-story on Marin Water lands as a part of an ongoing carbon- and water-yield study. This study revealed live-tree density per ha of 2,144 individuals, with approximately 0.7% of trees with diameters >100 cm dbh (Table 4.2B).

TABLE 4.2A MEAN LIVE TREE DENSITY PER 17.95 M RADIUS PLOT, MUIR WOODS NATIONAL MONUMENT (STEERS ET AL., 2014)

Size Class (dbh in cm)	Mean Live Tree Density (*n*=9)	Standard Error
Sapling	73.7	26.8
5–10	9.8	1.7
10–15	5.2	5.2
15–20	3.6	1
20–25	2.6	0.7
25–30	1.7	0.4
30–35	1.7	1.3
35–40	1.2	0.3
40–45	1.4	0.4
45–50	0.8	0.4
50–75	2.6	0.3
75–100	2.6	0.6
100–150	5.1	0.9
150–1200	2.8	1.1
>200	2.8	0.9
Total Trees Per Plot (Excluding Saplings)	**43.9**	**3.1**
Estimated Trees Per Ha	**430**	
Percent With Dbh >100 Cm	**24**	

TABLE 4.2B MEAN LIVE TREE DENSITY PER HA IN REDWOOD STANDS ON MARIN WATER LANDS (COBB ET AL., 2017)[2]

Size Class (dbh in cm)	Mean Live Tree Density Per Hectare (*n*=40)		
	Redwood	**Tanoak**	**Total**
0–20	159	1,646.5	1,805.5
20–40	67	103.5	170.5
40–60	49.5	32	81.5
60–80	44	2.5	46.5
80–100	21	2.5	23.5
100–120	9	0.5	9.5
120–140	4.5	0.5	5
140–160	0.5	0	0.5
160–180	0.5	0	0.5
180–200	0	0	0
200–220	0.5	0	0.5
220–	0.5	0	0.5
Total trees per ha	**356**	**1,788**	**2,144**
% with dbh >100 cm			**0.007**

Condition Goal: Tree density (of all species) at or moving toward RCCI southern redwood forest reference conditions of 460 ±70 trees per ha, with approximately 18% of trees >100 cm in diameter (Van Pelt et al., 2016)

Condition Thresholds:

- **Good:** Tree density within one standard deviation of southern redwood forest (RCCI) reference conditions: 460 ±70 trees per ha, with approximately 18% of trees >100 cm in diameter.
- **Caution:** More than one standard deviation difference from southern redwood forest (RCCI) reference conditions (Van Pelt et al., 2016).

[2] Table derived from data provided directly by the lead author.

- **Significant Concern:** More than two standard deviation differences from southern redwood forest (RCCI) reference conditions (Van Pelt et al., 2016).

Current Condition:

Old-Growth Stands:

2016: Good (Note: This metric was assessed only for Muir Woods in 2016.)

The estimated live-tree density per ha of 430 ±31 individuals, with approximately 24% of trees with diameters >100 cm dbh, fell within one standard deviation of RCCI reference sites.

2022: Good

No new data have been collected for this metric, but it is reasonable to assume that Muir Woods trees currently have a density and size-class distribution similar to what they had in 2016. Fieldwork is needed to assess density and size-class distribution of other old-growth stands.

Second-growth Stands:

2016: Significant Concern

The estimated live-tree density per ha of 2,144 individuals, with approximately 0.7% of trees with diameters >100 cm dbh, was more than two standard deviations away from old-growth conditions in southern reference sites.

2022: Significant Concern

Another round of data collection in 2019 on Marin Water experimental plots (redwood stands with tanoak midstory) confirms that untreated stands are still in the significant concern category (Quiroga et al., 2023). Importantly, treatments did decrease stand density and increase tree diameters (quadratic mean diameter). However, these treatments are not planned at a scale large enough to upgrade the condition of second-growth stands throughout the area of focus. In addition, more fieldwork is needed to assess second-growth stand density and size-class distribution on lands other than those managed by Marin Water.

Trend:

Old-growth Stands:

2016: Improving (Note: This trend was assessed only for Muir Woods in 2016.)

Wood production was observed to have increased in recent decades in a 777-year-old redwood in Cathedral Grove, which is consistent with range-wide observations of a redwood growth surge in old-growth forests throughout coastal California (Sillett et al., 2015).

2022: Improving

Canopy density increased in 95% of redwood stands in Muir Woods from 2010 to 2019 (GGNPC et al., 2021).

Second-growth Stands:

2016: Declining

Twenty years into the SOD disease process, a persistent thicket of tanoak shoots had developed in the redwood understory, and continual re-infestation by *P. ramorum* prevented these shoots from developing into midstory level trees (Table 4.2B). This trend was captured in the 2009 and 2014 updates to the Marin Water vegetation map as an increase in hardwood density (stems per ha), much of which was attributed to the proliferation of tanoak sprouts (Table 4.3). In 2016, the overall trajectory was away from, rather than toward, old-growth conditions.

2022: No Change

As noted, fieldwork is needed to assess tree density and diameter in second-growth stands outside of Marin Water study plots. Redwood canopy density increased from 2010 to 2019 in 84% of stands of all age and size classes; 80% of stands showing a density loss were in the 0–2.5% loss category (Figure 4.3). (GGNPC et al., 2021). However, SOD continues to impact the tanoak midstory. With one measure of this metric improving (canopy density), but the other (SOD impacts on the midstory) remaining of concern at about the same level as in 2016, we selected a trend of no change for this metric.

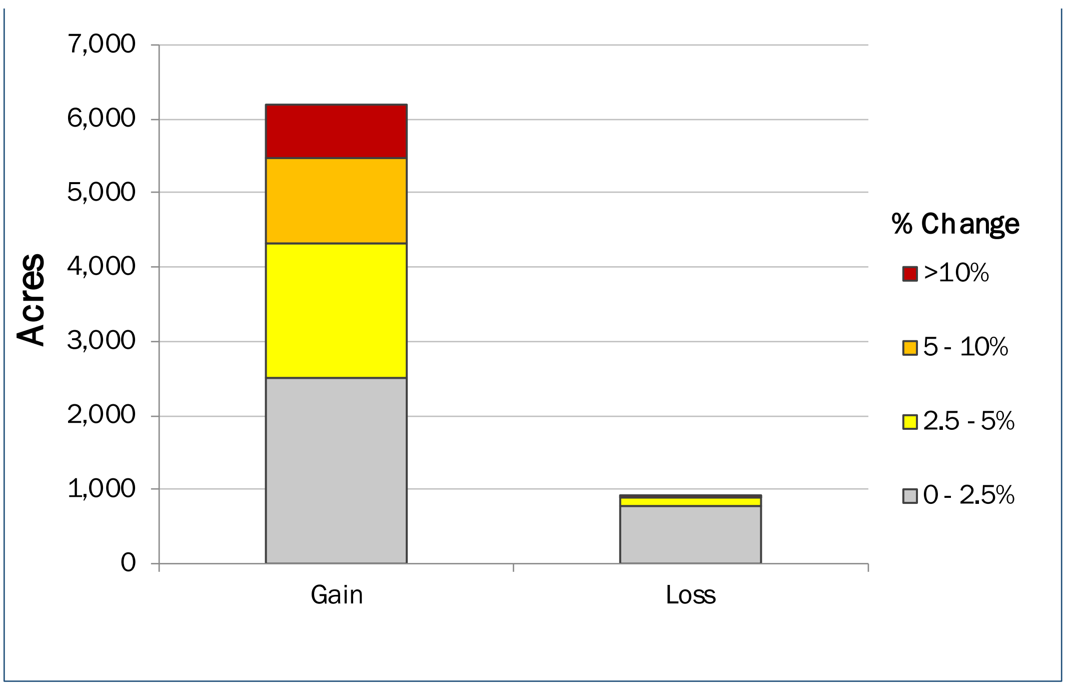


FIGURE 4.3. CHANGE IN CANOPY DENSITY FROM 2010 IN 2019 IN ALL REDWOOD STANDS (GGNPC ET AL., 2021)

Confidence:

Old-growth Stands:

2016: High

Our confidence was high for Muir Woods because of the availability of data collected following rigorous, documented protocols and because plots were distributed throughout the forest.

2022: Moderate

Now that we are looking at old-growth beyond Muir Woods, we need more fieldwork on other old-growth stands to assess this metric more confidently.

Second-growth Stands:

2016: Moderate

Our confidence was moderate for second-growth stands because—although available data came from rigorous, documented protocols—sample plots were concentrated in just two regions in a single jurisdiction within the One Tam area of focus. Such limited sampling may not have been sufficient to capture the range of regional variation.

2022: Moderate

We need more fieldwork on second-growth stands other than Marin Water stands to assess this metric more confidently.

TABLE 4.3 CHANGES IN HARDWOOD DENSITY IN FORESTED STANDS WITH TANOAK AS A CURRENT OR RECENT CO-DOMINANT CANOPY SPECIES ON MARIN WATER LANDS, 2009–2014 (AIS, 2015)

	Percent Change; Numbers for Each Vegetation Type Are in Acres							
Vegetation Types	**-5%**	**0**	**5%**	**10%**	**15%**	**20%**	**25%**	**30%**
Tanoak/California Bay/Canyon Oak Mixed Forest	8.5	147.8	12.2					
Madrone/California Bay/Tanoak	74.2	494.1	15.7					0.6
California Bay/Tanoak		47.5	15.6					
Tanoak Alliance								
Redwood/Tanoak		5.5		8.2				

	Percent Change; Numbers for Each Vegetation Type Are in Acres							
Vegetation Types	**-5%**	**0**	**5%**	**10%**	**15%**	**20%**	**25%**	**30%**
Redwood/Douglas-Fir (Mixed Hardwoods)	2.8	864.7	495.8	93	26.3			
Redwood/Upland Mixed Hardwoods	12.1	629.2	417.9	109.6				
Redwood/Riparian	3.7	338.3	21.7	4.5				
Douglas-Fir (Mixed Hardwoods)	18.6	3006	42.9	1.1	0.2			3.7
Douglas-Fir/Tanoak		47.1						
Total Acres:	**119.7**	**5,580.1**	**1,021.8**	**216.4**	**26.6**	**0**	**0**	**4.3**

METRIC 2: MID-CANOPY STRUCTURE

Baseline: Desirable old-growth conditions include the presence of a well-developed midstory canopy of shade-tolerant native trees that grow underneath towering redwoods. In alluvial sites such as Muir Woods, midstories may support bigleaf maple, alder, and willow in addition to tanoak, bay, and Douglas-fir. Midslope and ridgetop sites with a history of logging and fire suppression tend to develop midstory canopies dominated by tanoak (Van Pelt et al., 2016). This is indeed the situation in much of the One Tam area of focus. As late as 1990, tanoaks were the most abundant tree on Mt. Tam (Parker, 1990). Prior to the arrival of SOD in 1995, most of the mountain's second-growth redwood stands supported a multilayered tree canopy.

Condition Goal: Persistence of a multilayered stand structure dominated by native tree species.

Condition Thresholds:

- **Good:** Presence of native tree species in the mid-canopy in 90% of redwood forest stands.
- **Caution:** Presence of native tree species in the mid-canopy in 70% to 90% of redwood forest stands.
- **Significant Concern:** Presence of native tree species in the mid-canopy in <70% of redwood forest stands.

Current Condition:

Old-growth Stands:

2016: Caution (Note: This condition was assessed only for Muir Woods in 2016.)

Swiecki & Bernhardt (2006) monitored disease progression in a plot network that included Muir Woods sites. They reported a steady increase in SOD both in terms of new infections and declining tanoak health. For example, the rate of new infections in tanoak was more than 5% per year between 2000 and 2004. Over the same time, infected trees died at an annual rate of 8.2% per year. For Douglas-fir and coast redwood forests, it seemed that recovery of forest structure lost to the disease was relatively slow (Forrestel et al., 2015). However, the losses were restricted to susceptible species, and other midstory and understory species, including California bay and bigleaf maple, remained present (Steers et al., 2014). Thus, while *P. ramorum* was reorganizing species composition, shifting trophic structure, and at least temporarily reducing coast redwood forest mid-canopy cover, it seemed unlikely to cause a major shift in forest type (Folke et al., 2004).

2022: Caution

Because the 2018 Fine Scale Vegetation Map data (GGNPC et al., 2021) is at the alliance level, it does not provide direct information on native species presence within each redwood stand. However, the redwood stand structural classification indicates that most stands in Muir Woods have high vertical structure and <25% relative hardwood cover. High vertical structure can indicate stands of mixed age, a mix of redwoods and hardwoods, or canopy gaps. Relative hardwood cover is the percent of hardwood trees in a stand as viewed from above. In Muir Woods, 95% of the redwood acreage is classified as <25% relative hardwood cover, with an average and standard deviation of 5% ±10%. Fieldwork is needed to confirm the relationship between the 2018 Fire Scale Vegetation Map data and on-the-ground conditions (GGNPC, 2023).

Second-growth Stands:

2016: Caution

Extensive tanoak mortality had occurred since SOD first appeared in 1995. In many stands, the capacity of tanoaks to contribute to forest structure and wildlife food and habitat had been functionally lost (Ramage & O'Hara, 2010; Ramage et al., 2011; Ramage et al., 2012; see also citations in Stressors section). Marin Water field surveys and aerial mapping showed large declines in both canopy health and the total extent of redwood stands with a well-developed midstory (Figure 4.4). Between 2004 and 2014, more than 15% of redwood stands had lost tanoaks as a co-dominate species and were reclassified as a simpler vegetation type (Table 4.4).

2022: Caution

As discussed previously, no new data have been collected to directly assess this metric, but land managers continue to observe SOD in many forest types. Redwood stands (both old-growth and second growth combined) across the area of focus generally have high vertical structure (Figure 4.4) and low relative hardwood cover (Table 4.4). Fieldwork that connects on-the-ground conditions with the 2018 Fine Scale Vegetation Map's structural classifications will help us better assess this metric.

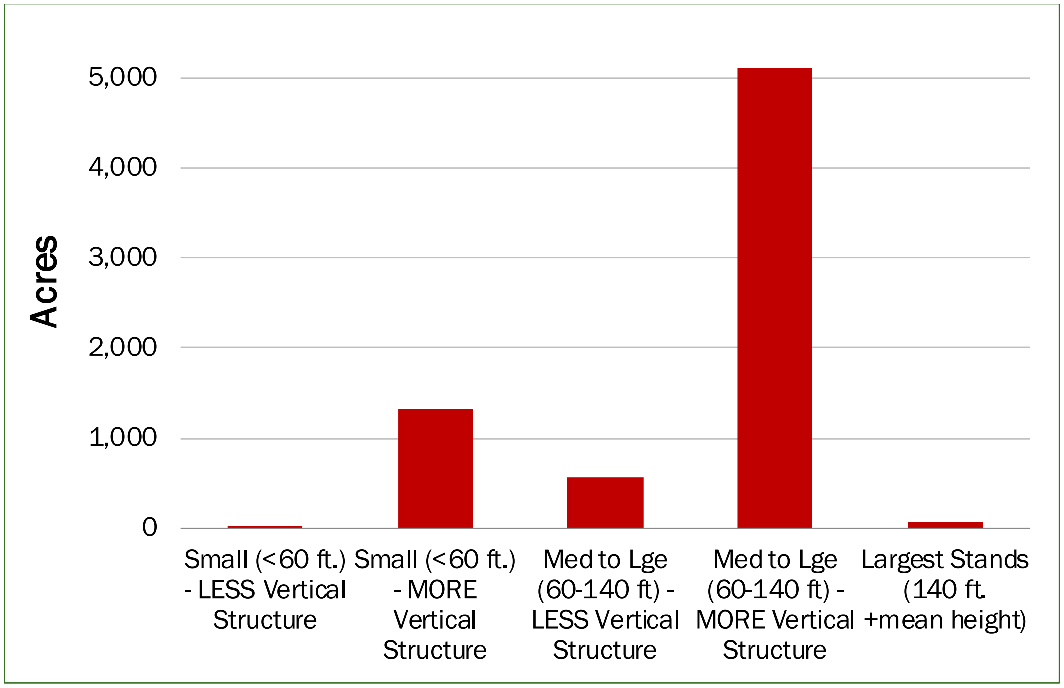


FIGURE 4.4. REDWOOD STRUCTURAL CLASSIFICATION BY ACREAGE (GGNPC ET AL., 2021)

TABLE 4.4. ACRES OF REDWOOD STANDS CATEGORIZED BY RELATIVE PERCENT HARDWOOD COVER, ONE TAM AREA OF FOCUS (GGNPC ET AL., 2021).

Relative Percent Hardwood Cover	
Category	**Acres**
≤25% Relative Hardwood	6,316
26%–60% Relative Hardwood	733
>60% Relative Hardwood	43

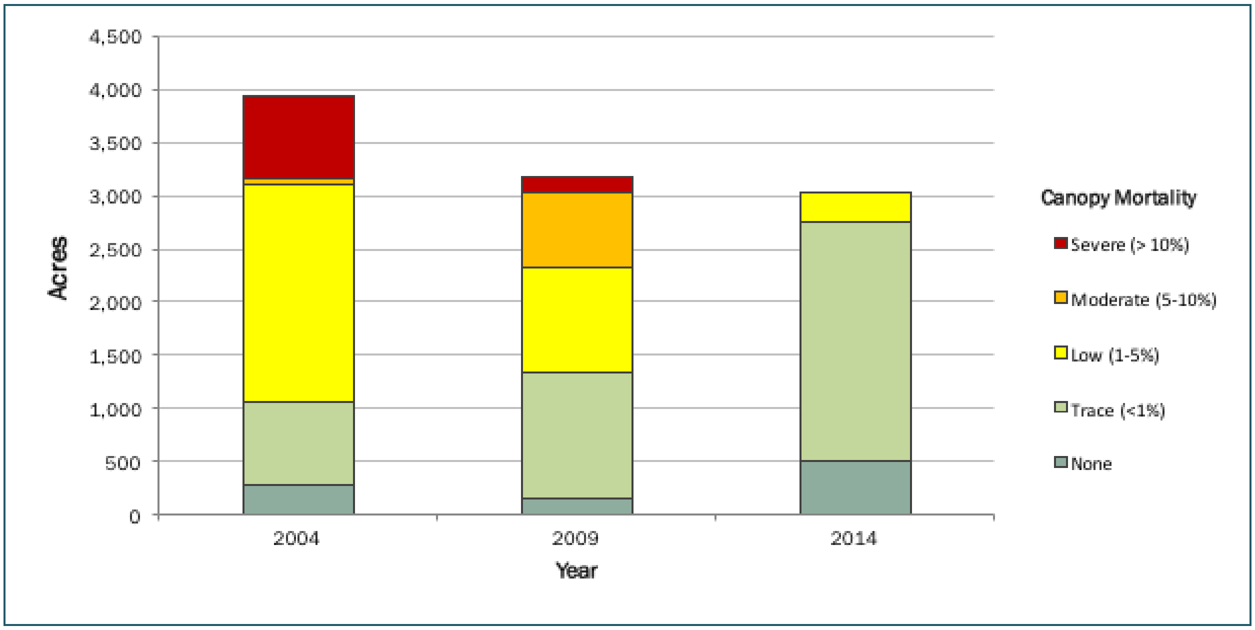


FIGURE 4.5 CHANGES IN HARDWOOD CANOPY MORTALITY AND TOTAL ACRES OF MIXED REDWOOD STANDS, MARIN WATER (AIS, 2015)

TABLE 4.5 CHANGES IN TOTAL ACRES OF FOREST STANDS WITH TANOAK CO-DOMINANCE, MARIN WATER (AIS, 2015)

Description	2004	2009	2014	% Change 2004–2014
Redwood/Tanoak	152	14	14	-91
Redwood/Douglas-Fir (Mixed Hardwoods)	1,520	1,520	1,483	-2.4
Redwood/Upland Mixed Hardwoods	1,537	1,273	1,169	-23.9
Redwood/Riparian	368	368	368	-
Total Acres:	**3,577**	**3,175**	**3,033**	**-15.20%**

Trend:

Old-growth Stands:

2016: Unknown for Muir Woods

We had no available data to assess a trend in 2016.

2022: Unknown

We cannot assess a trend until more data are collected, or until future vegetation mapping provides information to assess stands' relative hardwood cover change over time.

Second-growth Stands:

2016: Declining

Time-series stand composition data were available for redwood stands on Marin Water lands and revealed a notable simplification of stand structure where tanoaks had dropped out of the canopy or midstory layer. Approximately 15% of redwood/hardwood-dominated stands experienced significant declines in their tanoak component between 2004 and 2014. Recruitment of other native trees into the canopy appeared to be limited.

2022: Declining

Change in relative percent hardwood and conifer cover of all redwood stands (old-growth and second growth combined) between 2014 and 2018 is available for Marin County Parks and Marin Water lands, which together contain 63.5% of the redwood stands in the area of focus. For these stands, 97.2% showed no change in relative hardwood cover, 2.7% showed a 5% decrease in relative hardwood cover, and 0.1% showed a 10% decrease. None showed an increase in relative percent hardwood cover. Overall, this decline appears to be slowing down compared to the change between 2004 and 2014 noted on Marin Water lands. Future versions of the 2018 Fine Scale Vegetation Map will allow us to track changes in relative hardwood and conifer cover over time across the area of focus.

Confidence:

Old-growth Stands:

2016: High (Muir Woods only)

Available data were from the early 2000s, so our confidence in the condition analysis was high.

2022: Moderate

Because we have no new data with which to assess this metric, we remain moderately confident in the condition analysis.

Second-growth Stands:

2016: High

Although data were from comparisons between 2004, 2009, and 2014 vegetation maps for Marin Water lands only (AIS, 2015), tanoak decline had been extensively documented on Mt. Tam and regionally, and the situation on Marin Water lands was presumed to be representative of other second-growth stands in the One Tam area of focus.

2022: Moderate

Because we have no new data with which to directly assess this metric, we assessed it indirectly and are moderately confident in the condition analysis.

METRIC 3: TARGETED NON-NATIVE, INVASIVE SPECIES COVER

Baseline: Because of the shade they create, closed-canopy redwood stands are invaded by a limited range of non-native, invasive plant species; their acidic soil conditions may further slow the establishment of potential invaders. Field observations indicate that most invasive species in redwood communities exist at the periphery, along roads and trails where there are canopy gaps and disturbance is highest.

French and Scotch broom (*Genista monspessulana* and *Cytisus scoparius*, respectively), panic veldtgrass, Cape-ivy (*Delairea odorata*), English ivy (*Hedera helix*), cotoneaster (*Cotoneaster* spp.), and old man's beard (*Clematis vitalba*) were introduced to Mt. Tam from other parts of the world over the last century. Panic veldtgrass is the invasive species of greatest concern in old-growth forests such as Muir Woods.

As these species are relatively recent arrivals, the historic baseline is zero acres of redwood forests in which these invasive species are present.

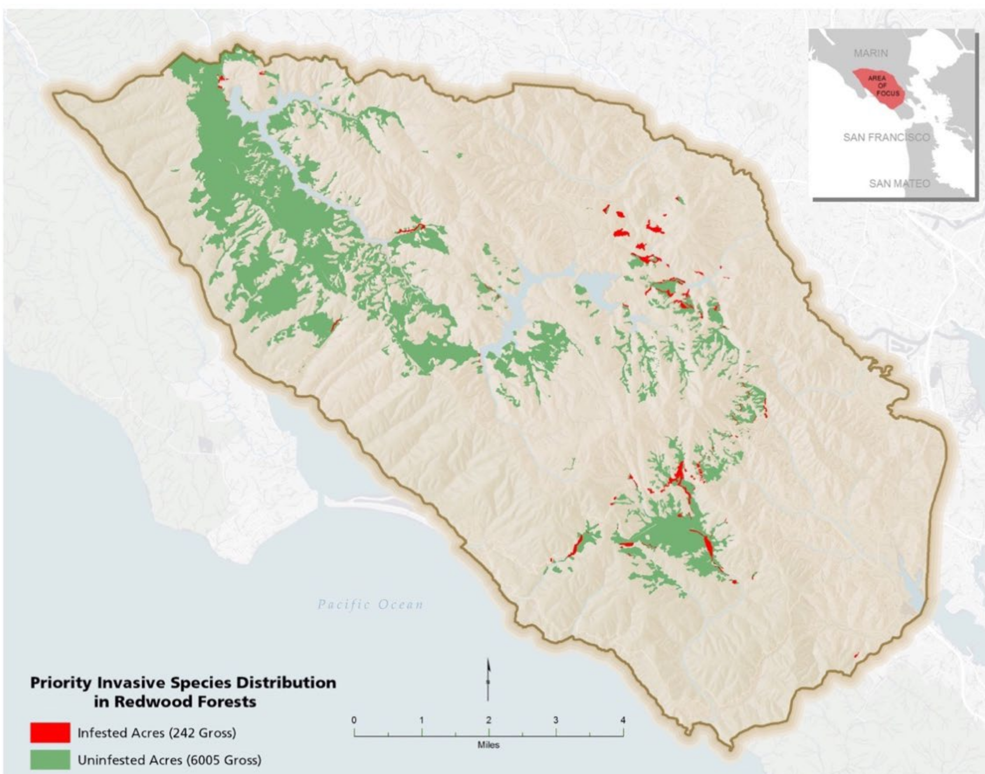


FIGURE 4.6 INVASIVE SPECIES DISTRIBUTION IN REDWOOD FORESTS, ONE TAM AREA OF FOCUS, 2014 (CALFLORA, 2016)

Condition Goal: Maintain 7,091 acres at or below maintenance levels for target weed species.

Note: The acreage for this condition goal and the thresholds below has been changed from 2016 because the One Tam area of focus has been expanded since then. Also, in this metric, we decided not to split the condition, trend, and confidence assessments into old- and second growth because condition thresholds are the same for both stands.

Condition Thresholds:

- **Good:** More than 90% (6,382 acres) of redwood stands are at or below maintenance levels for targeted priority invasive species.
- **Caution:** Between 80% (5,673 acres) and 90% of redwood stands are at or below maintenance levels for targeted priority invasive species.
- **Significant Concern:** Less than 80% of redwood stands at or below maintenance levels for targeted priority invasive species.

Current Condition:

2016: Good

Available data from all agencies showed approximately 4.7% of all redwood acres were affected by target priority invasive species.

2022: Good

Despite increased surveys since 2016, available data from all One Tam partner agencies indicate that only approximately 4.5% of redwood stands are affected by target weed species. Although it seems that target weed species are not increasing their footprint in redwood habitat, some areas have not been surveyed. So, while the actual number of acres with priority weeds is likely somewhat higher than 4.5%, we believe it is still within the threshold for a good condition.

Trend:

2016: Unknown for Muir Woods due to lack of prior data; declining for second-growth stands.

Although weed invasion was progressing more slowly in redwood forests than in many other vegetation types, it was nonetheless a growing concern. Golden Gate National Recreation Area's Natural Resource Condition Assessment identified weeds found in Muir Woods and other redwood stands after 1987, as well as evidence of spatial expansion of species already present (NPS, 2019). At the same time, active weed management in Muir Woods had also increased. It was unclear from the available data whether declines achieved through weed management in some locations or with some species offset the noted expansion.

For broom species, Marin Water time-series data accounted for management actions, but found that brooms within second-growth redwoods on Marin Water lands increased from 119 48.1 to 135 acres between 2009 and 2014 (Williams, 2014; AIS, 2015).

2022: No Change

That priority weeds have not increased in redwood ecosystems is a testament to the large investment by One Tam partners and the Redwood Creek Watershed Collaborative (discussed later) in invasive species surveys and treatment.

Confidence:

2016: Moderate

All One Tam partners maintained invasive species records that included spatial distribution, percent cover estimates, and management history information. However, mapping efforts and protocols were not uniform across jurisdictions (NPS, 2019) and the integration of these data was incomplete.

2022: High

Target weed species mapping efforts have increased, with multiple surveys per year in some priority areas. Since 2016, the One Tam Conservation Management Team has invested in improving weed data collection protocols and data management systems, giving us increased confidence in this metric for this update.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

Aerial Surveys and Mapping:

- National Park Service 1994 vegetation map (Schirokauer et al., 2003).
- Marin Water vegetation maps from 2004, 2009, and 2014 (AIS, 2015).
- Marin Water broom mapping from 2003, 2010, and 2013 (unpublished data).
- Marin Water 2014 photo interpretation of SOD affected forest stands (AIS, 2015).
- Marin County Parks 2008 vegetation map (AIS, 2008).
- One Tam early detection and invasive plant mapping (Calflora, 2016, 2022).
- Larry Fox and Joe Saltenberger old-growth redwood data (Fox & Saltenberger, 2011).
- 2018 Fine Scale Vegetation Map (GGNPC et al., 2021).

ACREAGE CALCULATIONS

Old-growth acreage was derived from a GIS data set, Old-growth Redwoods, Marin Public Lands (Fox & Saltenberger, 2011), provided by Save the Redwoods League. The layer was clipped to Redwood Alliances listed in Table 4.6 within Muir Woods National Monument and Mount Tamalpais State Park boundaries.

Updated acreages for redwood stands in 2022 analyses came from the 2018 Fine Scale Vegetation Map (GGNPC et al., 2021), clipped to One Tam partner agency boundaries within the area of focus.

See Chapter 2, Indicator Analysis Methodology, for additional information on the overall methodology used for vegetation community analyses.

*TABLE 4.6 METHODS USED TO CALCULATE THE AMOUNT OF COAST REDWOOD FOREST WITHOUT SOD AND WITHOUT INVASIVE SPECIES (AIS, 2015)**

Indicator Plant Community	Vegetation Types Included	Metrics	How Derived
Coast Redwood Forest	• Coastal redwood • Redwood (pure) • Redwood/tanoak-redwood-Douglas-fir (mixed hardwoods) • Redwood/chinquapin • Redwood/California bay • Redwood/upland mixed hardwoods • Redwood/riparian	Acres without SOD (canopy involvement)	Summed acreage of oak woodland polygons with attribute SOD*=0
		Acres without targeted invasive species	2003 drive-by survey* for broom, 2010 draft vegmgmt_polys_9_3*, 2013 broom re-map*

**Marin Water lands only.*

INFORMATION GAPS

Presence of Complex/Old-growth Habitat Structure. Quantifying habitat structure, including measuring and mapping coarse woody debris, tree cavities, and nesting platforms, is needed to inform Metric 1.

Field Assessments of Old-growth and Second-growth Stands. Additional fieldwork is needed to connect 2018 Fine Scale Vegetation Map data (e.g., structural classifications) to on-the-ground conditions. This would not only improve assessments of redwood health, but it would also identify areas for potential treatments to improve resilience and/or facilitate the transition of second-growth stands toward old-growth characteristics and ecosystem function. As noted throughout this chapter, stands outside of Muir Woods and SOD-impacted Marin Water lands have not been studied in detail with regard to trees per ha, diameter, and midstory composition.

Logging History Study: Developing a detailed logging history for Marin County from the mid-19th to the mid-20th century would inform land managers and others of past logging operations and their continuing legacy on the landscape.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Visitor Use Impacts: Marin County Parks completed a survey and trails planning document for Roy's Redwoods Preserve to understand and better channel visitor circulation and reduce social trails. This will protect and improve the old-growth forest vegetation community while enhancing the visitor experience. CEQA compliance is in development and will be available for public review in 2023.

Habitat Improvements: At Muir Woods, 350 linear feet of asphalt trail was removed at the top of the creek bank in Cathedral Grove in 2019. Riprap removal and large wood debris (LWD) installation from Redwood Creek in the upper half of Muir Woods substantially increased coho salmon habitat. By 2022, the total area of suitable winter habitat per 100 m more than quadrupled in the project area, and LWD density approximately quadrupled as well. As noted previously, redwood forests provide valuable shade and large woody debris required for coho salmon habitat, but only when other instream conditions are also suitable.

Redwood Creek Collaborative: This watershed-focused partnership (National Park Service, California State Parks, and the Parks Conservancy) continues to prioritize Muir Woods non-native species management and exclusion using a watershed-based strategy. The valley floor and riparian corridor are surveyed multiple times annually and weed removal efforts are at a maintenance level. Containment strategies have been implemented across the watershed to limit weed invasion pressure on Muir Woods. Ongoing efforts aim to eradicate highly invasive old man's beard and Cape-ivy.

SOD Impact Management: In 2020, as part of its Biological Fire and Fuels Integrated Plan implementation and based on Resilient Forest Project research (Cobb et al., 2017), Marin Water conducted treatments within another ~25+ acres of SOD-infected second-growth redwood stands. This research aimed to identify ways to improve forest function and strengthen areas with high levels of SOD-related hardwood mortality. Multiple partner agencies have implemented best management practices designed to minimize the potential importation or spread of invasive *Phytophthora* species.

Past Work

Following are some of the stewardship and management activities undertaken over the years to monitor, protect, and restore this health indicator.

OLD-GROWTH

- **Muir Woods and Steep Ravine:**
  - Ongoing, systematic invasive plant mapping and management on varying scales at Muir Woods has been carried out for more than three decades.

    - In 2012, the Early Detection Rapid Response (EDRR) program was expanded through National Park Service-supported crews working Redwood Creek Watershed-wide.
    - Beginning in 2016, EDRR work in Steep Ravine was initiated through the One Tam partnership.
- **Muir Woods:**
    - Installed more than 14,000 native plants to revitalize disturbed and compacted redwood understory habitat.
    - Converted asphalt trails to raised boardwalks to reduce compaction and guide visitor access.
    - Established boot-washing stations to reduce the risk of *Phytophthora* spread.
    - Conducted an inventory to assess canopy health and species richness.
    - Reduced the entrance parking lot size and converted part of it to a plaza.
    - Improved Hillside Trail by raising it above the fragile redwood root system.
    - Collected Lidar data to create topographic, stream channel, and tree-canopy maps of Muir Woods and Kent Canyon, which will help track changes to the forest over time.

SECOND-GROWTH

- **Invasive Plant Management and Mapping:** Regular invasive-plant EDRR surveys were carried out along roads and trails that border and traverse redwood habitat (all One Tam partner agencies).

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as a part of the development of this report. These are actions not currently funded through agency programs and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

- Break ground on the Roy's Redwoods Restoration project (Marin County Parks) to protect old-growth stands and improve visitor experiences. Anticipated in 2023.
- Conduct fieldwork to establish the relationship between redwood seral stages (e.g., old-growth and second-growth) and Lidar measurements (e.g., stand height and vertical structure) to better understand the health of these forests and identify management opportunities.
- Identify second-growth stands in arrested succession (i.e., not progressing toward old-growth conditions) and prioritize potential treatment areas to facilitate this progression.

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ADDITIONAL REFERENCE MATERIAL OF INTEREST

One Tam Forest Health Web Map

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CHAPTER 5. SARGENT CYPRESS (*HESPEROCYPARIS SARGENTII*) FORESTS

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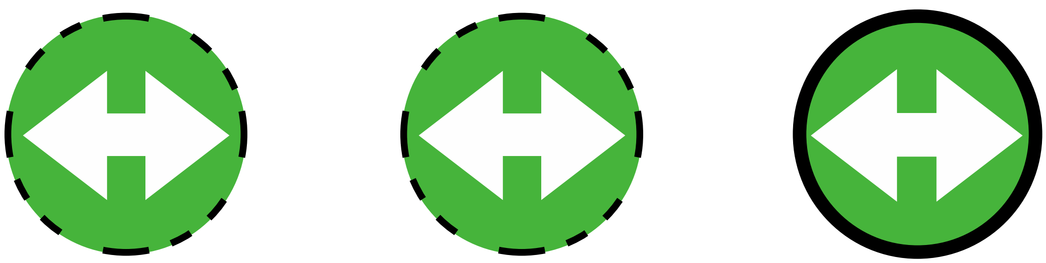
UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

2016 | 2022

2016: ALL FOUR ORIGINAL METRICS	2016: METRICS 2 AND 3 COMBINED*	2022: THREE METRICS



Condition: Good	**Condition:** Good	**Condition:** Good
Trend: No Change	**Trend:** No Change	**Trend:** No Change
Confidence: Moderate	**Confidence:** Moderate	**Confidence:** High

FIGURE 5.1 CONDITION, TREND, AND CONFIDENCE FOR SARGENT CYPRESS, ONE TAM AREA OF FOCUS

**Four metrics were used to evaluate Sargent cypress health in 2016 (left circle), but in 2022, Metric 2 was combined with Metric 3 because they assessed the same process: the ability of Sargent cypress to regenerate after fire, which may decline over time.*

Sargent cypress plant communities are typically stable for decades, then experience a complete reset after a high-intensity fire. There have been no fires in Sargent cypress habitats in the One Tam area of focus since the 2016 report, and so, as expected, they have experienced no major changes. Other items of note for this chapter include:

- When comparing 2018 maps to earlier versions, the geographic extent of this plant community has not changed.
- The original metrics remain appropriate to gauge the condition of the system.
- The condition and trend of the metrics have not changed overall; however, new observations and additional management guidance have been included in this chapter.
- The confidence level of this assessment has increased since 2016 because presence of invasive species was field-assessed in 2022.

METRICS SUMMARY

Metrics in Table 5.1 were used to assess Sargent cypress vegetation communities. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 5.1. Each metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 5.1 ALL SARGENT CYPRESS METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1: Acres (total and distribution)		
	2016	**2022**
Condition	Good	Good
Trend	No Change	No Change
Confidence	High	High
Metric 2: Recruitment of new trees at least at replacement level following fire events		
	2016	**2022**
Condition	Unknown	N/A. This metric was merged with Metric 3 in 2022.
Trend	Unknown	
Confidence	Low	
Metric 3: Time since last wildfire		
	2016	**2022**
Condition	Good	Good
Trend	No Change	No Change

Confidence	High	High
Metric 4: Targeted non-native, invasive species cover		
	2016	**2022**
Condition	Good	Good
Trend	Unknown	No Change
Confidence	Moderate	High

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

Two vegetation types are considered in this chapter: those where Sargent cypress is a solo dominant species and those where it is co-dominant with shrubs. The California Department of Fish and Wildlife classifies both types as sensitive natural communities (California Department of Fish and Wildlife, 2022) requiring consideration in pre-project environmental reviews. Sargent cypress trees are only found in the California Floristic Province (Bartel, 2012) and are considered broad serpentine endemics, with more than 85% of occurrences on these kinds of soils (Safford & Miller, 2020).

Sargent cypress communities are good indicators of a departure from historic fire-return intervals, which have been estimated at between 30 and 90 years for California's closed-cone conifer forests (Van de Water & Safford, 2011). Although fires typically kill standing Sargent cypress trees, they also help open the trees' cones and create the bare ground needed for seed germination (Esser, 1994). Sargent cypress stands typically recruit new trees in this way, making fire a key factor in their long-term persistence.

However, wildfire return intervals that are either too short or too long can negatively impact these communities (International Union for Conservation of Nature, 2016). Too-frequent fires can threaten recruitment because Sargent cypress trees need several years to mature and produce sufficient cones to create an adequate seedbank. On the other hand, because fire is needed for new trees to germinate and establish, too much time between fires results in stands with little to no recruitment of new trees. Research has shown that post-fire seedling density goes down as the stands age, suggesting that the amount of viable seed declines with the age of the stand (Ne'eman et al., 1999). This presents management challenges. While most forested habitats on Mt. Tam persist with low-intensity fire that can be replicated by prescribed burning or mechanical thinning, Sargent cypress communities have a different fire regime. For operational reasons, prescribed fires are typically low to moderate intensity. Due to stand structure and density, Sargent cypress communities typically burn at high intensity. Furthermore, mechanical work will not stimulate Sargent cypress cones to open nor provide the bare mineral soil the seeds need to establish.

These communities are considered an indicator of ecological health because, unlike many of the other vegetation communities chosen as indicators for the health of Mt. Tam, they appear to be relatively disease- and weed-free. A combination of deep shade found in dense, even-aged stands and the harsh growing conditions of serpentine soils make these communities relatively resistant to weed invasion. However, exceptions may be found in disturbed areas near roads, trails, and fuelbreaks, which can create a point of entry for some invasive species (Leonard Charles & Associates, 1995). Due to a variety of historic and ecological factors, many ecosystems in California are susceptible to the ongoing effects of non-native species invasion; however, Sargent cypress forests have not shown such vulnerability to date.

CURRENT CONDITION AND TREND

The One Tam area of focus includes all Sargent cypress habitat in Marin County (451 acres), all of which is found on Marin Water- and Marin County Parks-managed lands (GGNPC et al., 2021a). One quarter of these stands are dominated by only Sargent cypress trees, and the balance are Sargent cypress/shrub co-dominated, primarily with Mt. Tam manzanita (*Arctostaphylos montana* ssp. *montana,* a California Native Plant Society/California Rare Plant Rank 1B species, “Plants rare, threatened, or endangered in California and elsewhere”). The understory of these communities can be quite sparse, but includes native species such as irises (*Iris* spp.), Fremont’s star lily (*Toxicoscordion fremontii*), and sedges (*Carex* spp.). Also found are rare plants such as Marin County navarretia (*Navarretia rosulata*) and serpentine reed grass (*Calamagrostis ophiditis*). Sargent cypress communities also provide habitat for large ground-cone (*Kopsiopsis strobilacea*) and pleated gentian (*Gentiana affinis* var. *ovata*), which are locally rare.

In addition to the extensive stands of these two types found on San Geronimo Ridge (known as the “pygmy forest”), smaller patches of taller Sargent-cypress stands are found on the south side of Mt. Tam. This area did not burn in the 1945 fire (Figure 5.2), meaning these stands last burned in 1923 or earlier (Dawson, 2021). However, it is not possible to tease out the relative impacts of geology, microclimate, and fire history on the taller stands on the southern side of Mt. Tam using available data.

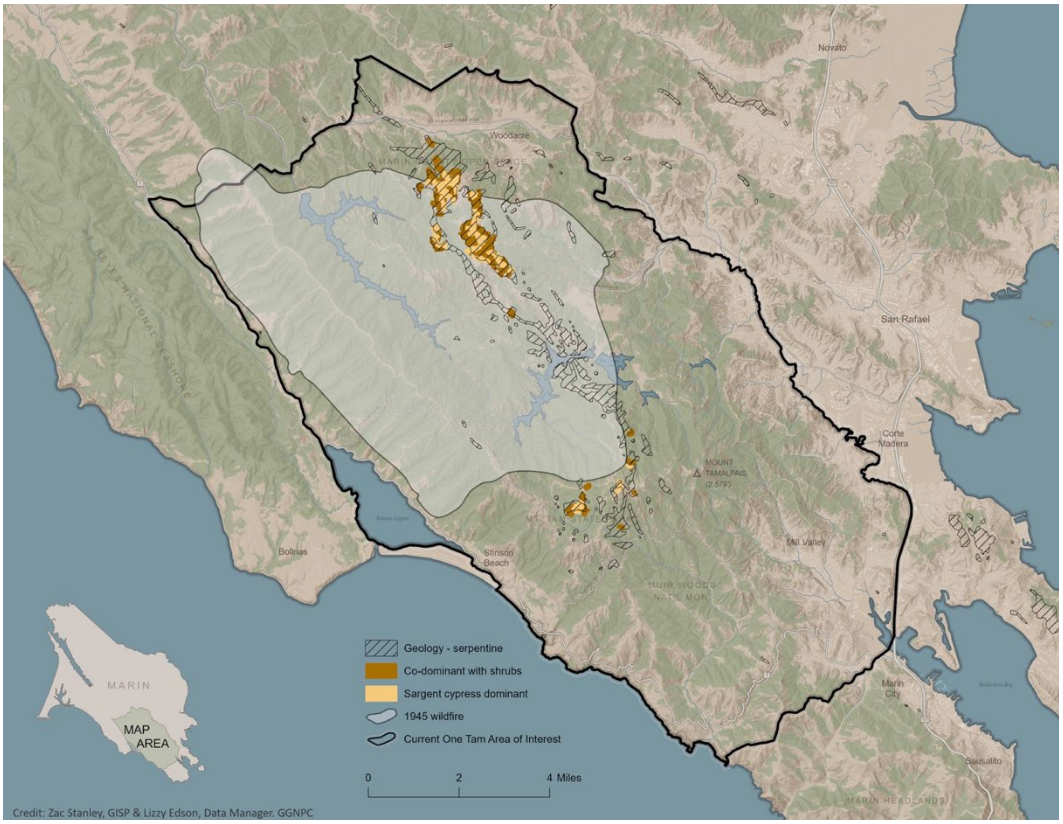


FIGURE 5.2 SARGENT CYPRESS VEGETATION TYPES, ONE TAM AREA OF FOCUS

Earlier vegetation mapping efforts (Aerial Information Systems, 2008 & 2015) found nearly the same acreage as data collected in 2018 to create the Marin Countywide Fine Scale Vegetation Map (GGNPC et al., 2021a): 434 acres (a change of 4%). Given some differences in classification and mapping between the two projects, this cannot be assumed to represent a change on the ground. Rather, it is within the range of variation to be expected from mapping-methodology differences. The 2016 Peak Health report presented a total acreage of 366 acres, a result of selecting a smaller area of focus (i.e., it did not include all Sargent cypress stands) and utilizing a different analysis technique.

The prevalence of standing dead trees in Sargent cypress stands is similar to other forests of Marin: 95% of stands have less than 2% canopy mortality (GGNPC et al., 2021a). Stands on Mt. Tam have an even-aged appearance, a lack of visible canopy disease, and a low abundance of non-native species. The several Sargent cypress stands visited during a 2004 vegetation mapping had a very low non-native species presence (Evens, Kentner & Klein, 2006). Several of these locations were revisited in 2022 and were found to be largely free of introduced species, with no location having more than 1% cover.

However, common weedy species were seen in a nearby location that had been recently treated as part of regular fire-road system maintenance. One location where the road passes through a Sargent cypress stand had an extensive patch of scarlet pimpernel (*Lysimachia arvensis*), a common garden weed. Common introduced annual grasses were also found sporadically along the roadside in this area.

DESIRED CONDITION AND TREND

- Sargent cypress community acreage remains stable.
- Species richness or structural diversity remains stable.
- Natural recruitment of Sargent cypress.
- Minimal presence of invasive species.

STRESSORS

Climate Vulnerability: A statewide model estimates that existing Sargent cypress communities will likely experience low to moderate stress, or exposure, due to climate variations projected by mid-century (Thorne et al., 2017). This level of exposure may be due to the location of these stands along ridge lines within the core of the One Tam area of focus, which can buffer the impacts of increased temperatures (GGNPC et al., 2021a). However, the rapidly changing climate is affecting fire regimes, which, as discussed elsewhere, are very important to these communities. Even with these observed and projected changes, the fire regime is expected to be within the range of conditions in which Sargent cypress stands could persist in the coming decades (Ne'eman et al., 1999). Climate change may also impact this habitat by influencing pests and disease. Although these have not been significant factors in Sargent cypress decline, in other habitats, a changing climate has resulted in trees becoming more vulnerable to pests and pathogens that previously had little impact on them (Kurz et al., 2008; Linnakoski et al., 2012). Finally, because these communities derive some of their moisture through fog drip, if the decrease in fog seen on the California coast continues (Johnstone & Dawson, 2010), we may expect reduced carrying capacity/live tree density. This could trigger a negative feedback loop of more open forest structures that allow soils to dry more readily and a greater light availability that facilitates increased invasion of introduced plants.

Fire Regime Change: Sargent cypress trees have an estimated life span of 300 years in the absence of disease or fire (Lanner, 1999). Cones, produced on trees that are five to seven years old, need two years to mature. Fire plays a critical role in new tree recruitment by stimulating cones to disperse seeds and creating the bare soil conditions Sargent cypress seedlings need to establish. Consequently, even-aged stands dating from the last wildfire event are the norm for this species. A wildfire return interval of less than 20 years can damage young trees before they are able to sufficiently restock the seed bank; an interval that is too great (100+ years) can lead to a stand's decline as viability of the seed bank declines before a wildfire creates the conditions ideal for stand regeneration (Ne'eman et al., 1999).

Direct Human Impacts: Roads, trails, and fuelbreaks facilitate the introduction and spread of non-native, invasive species unwittingly dispersed by equipment or people (staff and visitors). They also create sunny openings and disturbances in the otherwise closed-canopy, high-shade conditions, which allow existing or newly introduced weeds to expand their presence.

Habitat Disturbance/Conversion/Loss: While Sargent cypress communities can be invaded by Douglas-fir (*Pseudotsuga menziesii*), this is not currently happening on Mt. Tam. None of the stands visited in 2022 had more than 3.5% Douglas-fir cover.

Other Stressors: Dense clusters of mistletoe (*Phoradendron bolleanum/pauciflorum*) often form on bushy Sargent cypress trees in Marin County (International Union for Conservation of Nature, 2016). It is unknown if this is detrimental to the trees or simply a result of stand age.

CONDITION AND TREND ASSESSMENT

METRICS

METRIC 1: ACRES (TOTAL AND DISTRIBUTION)

Baseline: The 2016 version of this report included approximately 366 acres of Sargent cypress because its area of focus was smaller and the method for calculating acreage was different. Using current methodologies, it would have been approximately 434 (GGNPC et al., 2021b). This includes stands that were classified as pure Sargent cypress, as Sargent cypress alliance, and as co-dominant Sargent cypress and Mt. Tam manzanita. The current calculation uses the entire acreage of vegetation types that include Sargent cypress, even though some of these stands have significant areas dominated by shrubs.

The current Marin Countywide Fine Scale Vegetation Map (GGNPC et al., 2021a) includes 451 acres classified as Sargent cypress vegetation types. The classification, which has changed a bit since the earlier mapping efforts, is now split between two types: Sargent cypress–dominated (106 acres) and Sargent cypress along with two serpentine specialist shrubs: Jepson's ceanothus (*Ceanothus jepsonii*) and Mt. Tam manzanita (*Arctostaphylos montana* ssp. *montana*) (345 acres).

Condition Goal: Maintain Sargent cypress communities at the same acreage and spatial extent as shown in the 2004 vegetation survey (GGNPC et al., 2021b).

Condition Thresholds:

- **Good:** Greater than 95% of the acres of Sargent cypress communities remain as shown on the 2004 map.

- **Caution:** Between 80% and 95% of the acres of Sargent cypress communities remain as shown on the 2004 map, or the loss of one or more patches.
- **Significant Concern:** Less than 80% of the acres of Sargent cypress communities remain as shown on the 2004 map, or the loss of multiple patches.

Current Condition:

2016: Good

The total acreage of Sargent cypress communities in the One Tam area of focus constituted a condition of good.

2022: Good

The mapped extent of Sargent cypress communities in the One Tam area of focus is greater than 95% of that mapped in 2016, and there has been no loss of patches.

Trend:

2016: No Change

Data from the 2014 update to the Marin Water vegetation map indicated that there had not been a change in acreage of greater than 10% over the previous 10 years (Aerial Information Systems, 2015), which would be the threshold for changing this trend to improving or declining.

2022: No Change

Within the current area of focus, the extent is 451 acres. In 2022, Marin Water staff visited several stands that had changed from or to Sargent cypress vegetation types between 2018 and previous mapping efforts. However, these areas do not appear to have had an actual change in vegetation type. Rather, they were either misclassified in the previous mapping or were vegetation types that are difficult to classify, such as transition zones with a few Sargent cypress trees and a number of other tree species present.

Confidence:

2016: High

Vegetation maps from 2014 (Aerial Information Systems, 2015) showed approximately the same extent of Sargent cypress as was seen in 2004. This, combined with field observations of little to no change in the extent of these communities, warranted a high level of confidence.

2022: High

The 2018 Marin Countywide Fine Scale Vegetation Map Accuracy Assessment (Tukman Geospatial et al., 2021) process involved visiting one Sargent cypress stand that was found to be mapped correctly, as well as forest stands of many other types, none of which had been incorrectly mapped as Sargent cypress.

METRIC 2: TIME SINCE LAST WILDFIRE

Baseline: Significant wildfires affecting hundreds to thousands of acres occurred on Mt. Tam in 1881, 1891, 1923, 1929, and 1945. A regional policy of aggressive wildfire suppression and fuels management combined with improved fire response capabilities has greatly reduced the spatial extent of wildfires (Panorama Environmental, 2019). The ability of Sargent cypress to regenerate post-fire may start to decline after 100 fire-free years (Ne'eman et al., 1999). Most of the Sargent cypress stands on Mt. Tam burned in both the 1923 and the 1945 fires, and the current high density reflects their robust regeneration after the 22-year interval between those fires.

Condition Goal: At least 80% of Sargent cypress habitat in the One Tam area of focus has experienced a fire within the last 100 years, with at least 20 years between fires. Based on available science, this represents a slight shift in the specific thresholds compared to 2016, but the concept is unchanged. In the 2016 report, this metric was separated into two separate metrics: Metric 2, which looked at regeneration rates and Metric 3, which considered the time interval between fires. Interval between fires is important because the ability to regenerate post-fire is believed to decline over time. Because Metrics 2 and 3 were essentially looking at only slightly different facets of the same ecological dynamic, they have been combined here.

Condition Thresholds:

- **Good:** Less than 30% of Sargent cypress habitat in the One Tam area of focus has been fire-free for more than 100 years, or has experienced two fires within a 20-year period.
- **Caution:** 30% to 50% of Sargent cypress habitat in the One Tam area of focus has been fire-free for more than 100 years, or has experienced two fires within a 20-year period.
- **Significant Concern:** Greater than 50% of Sargent cypress habitat in the One Tam area of focus has been fire-free for the last 100 years, or has experienced two fires within a 20-year period.

Current Condition:

2016: Good

Approximately 70% of Mt. Tam's Sargent cypress habitat burned in 1945. Less than 25% is estimated to be older than 135 years (Leonard Charles & Associates, 1995).

2022: Good

A new fire history study (Dawson, 2021) allows us to be more precise in our estimates of fire history, but finds the same result. We estimate that in the last 100 years, 89% of Sargent cypress acreage has burned.

Trend:

2016: No Change

2022: No Change

Seventy-four acres (or 16%) of Sargent cypress habitat last burned in 1923. Based on available data, we know that stands that have been fire-free for 95 years have fewer viable seeds than younger stands, but apparently that is still sufficient for stand replacement (Ne'eman et al., 1999). We do not have data indicating that a stand that last burned more than 100 years ago will not persist, but available data suggests concern. By the end of 2023, 27% of Sargent Cypress acreage will have remained fire-free for at least 100 years, approaching the threshold for changing the condition status.

Confidence:

2016: High

The spatial distribution of existing Sargent cypress stands was cross-referenced with Mt. Tam fire maps developed using a combination of historical records and ground surveys of burn scars and residual charcoal (Leonard Charles & Associates, 1995).

2022: High

Our knowledge of the extent of historical fires is approximate and generally does not include small fires. However, existing data's level of accuracy is sufficient for landscape-scale assessments such as this.

METRIC 3: TARGETED NON-NATIVE, INVASIVE SPECIES COVER

Baseline: Because serpentine soils provide challenging growing conditions, a limited number of species are able to invade them. In Sargent cypress stands, dense shade may further limit potential invasions. Field observations indicate that most non-native, invasive species in Sargent cypress communities exist at the periphery, along roads and trails where shade is low and disturbance is highest (Marin Water, unpublished data).

Condition Goal: Sargent cypress stands are weed-free.

Condition Thresholds:

- **Good:** Less than 1% of the Sargent cypress–dominated areas have non-native, invasive plant cover. The introduced plants that *are* found in the Sargent cypress–dominated areas are known to be unable to thrive in dense shade on serpentine soils, and remain on the margins such as sunny roadsides.

- **Caution:** Between 1% and 5% of the Sargent cypress–dominated area is non-native, invasive plants. Alternately, introduced plants are not surveyed for in Sargent cypress–dominated areas, or the invasive potential of those species found is unknown.
- **Significant Concern:** Greater than 5% of the Sargent cypress–dominated area is non-native, invasive plants. Introduced plants found in the Sargent cypress–dominated areas are known to include at least one species capable of thriving in dense shade on serpentine soils.

Current Condition:

2016: Good

The 13 Sargent cypress plots included in the Marin Water 2004 map averaged 0.6% invasive plant species cover (13 plots, one with 2% and one with 6%). All were species found in open, disturbed habitats (scarlet pimpernel [*Lysimachia arvensis*], oatgrass [*Avena barbata*], silver hairgrass [*Aira caryophyllea*], soft chess [*Bromus hordeaceus*], and ripgut [*Bromus diandrus*]).

2022: Good

Early-detection and rapid response surveys conducted on the road and trail network show several different introduced plants in the vicinity, all of which are open-habitat annuals. In addition, when seven of the 13 plots were visited in 2022, they were found to have maintained an average of less than 1% cover of introduced species—again, open-habitat annuals.

Trend:

2016: Unknown

There was no repeat relevé data. However, based on field observations, the level of invasive-species infestation in Sargent cypress communities seemed to be stable. During rare-plant surveys in 2016, One Tam staff surveyed five serpentine barrens bounded by Sargent Cypress woodlands. Target invasive species for those surveys include purple false brome [*Brachypodium distachyon*] and barbed goatgrass [*Aegilops triuncialis*]. *B. didstachyon w*as recorded in or adjacent to four of five barrens; in one instance, *B. distachyon* cover exceeded 1% when grasslands or roadsides were also adjacent to the survey area. Cover remained less than 1% in serpentine soils, including barrens and adjacent Sargent cypress woodlands.

2022: No Change

Several relevé survey sites were revisited and the level of invasive species was found to be consistent with 2004 levels. However, existing data suggest that we can expect an increase in introduced plant cover after the next fire. All of the introduced species found in the vicinity of Sargent cypress stands in early-detection surveys thrive in disturbed open habitats, which will be ubiquitous after the next large fire. Regular monitoring will be required to determine if this is a transient early-succession stage or presents meaningful competition to the establishment of Sargent cypress or co-dominant shrubs.

Confidence:

2016: Moderate

Data from measurements made in 2005 within the majority of Sargent cypress areas supported staff observations that communities are largely weed-free.

2022: High; multiple sites were revisited in 2022 to assess current status, addressing a data gap identified in the 2016 report.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

- Marin Water's original 2004 vegetation map, which was updated in 2009 and 2014 to track the progression of Sudden Oak Death tree disease (GGNPC et al., 2021b).
- Marin County Parks 2008 vegetation map, created with a methodology similar to that used by Marin Water (Aerial Information Systems, 2008).
- Marin Countywide Fine Scale Vegetation Map, 2018.

ACREAGE CALCULATIONS

TABLE 5.2 METHODS AND DATA USED TO CALCULATE ACREAGES OF SARGENT CYPRESS COMMUNITIES

Indicator Plant Community	Vegetation Types Included	Metrics	How Derived
Sargent Cypress Communities	• Sargent cypress alliance • Sargent cypress/Jepson's ceanothus/Mt. Tamalpais manzanita	Acres (total and distribution)	Total acreage of all Sargent cypress types

INFORMATION GAP

Impact of Fire in the Current Climate: In the decades after the next large fire, the fine-scale vegetation map should be periodically redone to assess the fire's impact on the extent and regeneration of Sargent cypress communities.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Vegetation Mapping: The Marin Countywide Fine Scale Vegetation Map was completed. Derivative products and processes include county-wide Lidar, stand-level analysis of canopy gaps, expanded fire history, and a county-wide Marin Regional Forest Health Strategy interagency assessment (ongoing).

Invasive Species Early Detection Monitoring: The One Tam field staff began conducting regular Early Detection Rapid Response surveys of all roads and trails, facilitating quick action on any new invasive plants that are found. This includes a consensus list of Priority 1 and Priority 2 species that all agencies have committed to managing.

Resurveys: Following up on a data gap identified in the 2016 report, several of the 2004 relevés in Sargent cypress communities were revisited to assess the presence of introduced plants.

Past Work

Below is an example of the previous stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Mapping and Inventories: Periodic vegetation community mapping and ongoing early detection and rapid response (Marin Water), which has been expanded since 2016 (see above).

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists during the development of this report. These actions are not currently funded through agency programs and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Manage fire-dependent communities by:

- Avoid placing new roads through Sargent cypress habitat. This protects the habitat from fragmentation and limits potential weed seed reservoirs along the periphery of the intact habitat.

- Avoid projects that mechanically thin the canopy of Sargent cypress stands whenever possible. This protects the habitat from weed invasion and permits the fire intensity needed for seed dispersal. Consider placing fuel reduction projects outside of this ecosystem; these projects are better suited to other forest types, all of which historically had a more open stand structure and lower fire intensity than Sargent cypress communities.

- Use the One Tam Resource Advisor (a position on wildfires that advises fire personnel on natural and cultural resource protection) working group to think about how to prepare for advising fire personnel when a wildfire may burn this ecosystem. Consider nearby values that are at risk (communities, infrastructure) and how these might be protected while allowing the Sargent cypress habitat to burn.
- Use best practices to reduce the chance of spreading and introducing weed seeds or pathogens. This includes asking staff and visitors to ensure all gear, equipment, and clothing is free of plant parts and soil before coming to Mt. Tam. It could also include pre-project surveys and treatment for invasives, for example before roadside brushing which can easily spread a small infestation.
- Support community and agency efforts to educate the public on the role of fire in ecosystems and the value of community fire-readiness.
- Expect and prepare for post-fire management which may be resource intensive. Currently, the presence of invasive species is much higher than it was in 1945, the last time most of Mt. Tam burned. After the next wildfire, we should expect an explosion of the invasive species that today are at low levels. It will take significant management resources to monitor and, as needed reduce, the impact of these plants to the indicators in this report.
- Work with university and other researchers to better understand how climate change may alter the response of Sargent cypress communities and other ecosystems after the next wildfire.

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ADDITIONAL REFERENCE MATERIAL OF INTEREST

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CHAPTER 6. OPEN-CANOPY OAK WOODLANDS

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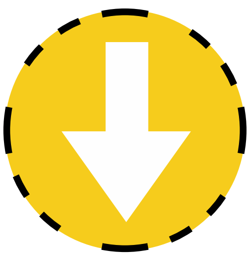
UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

2016

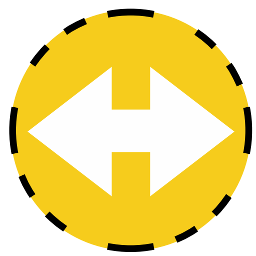


Condition: Caution

Trend: Declining

Confidence: Moderate

2022



Condition: Caution

Trend: No Change

Confidence: Moderate

FIGURE 6.1 CONDITION, TREND, AND CONFIDENCE FOR OPEN-CANOPY OAK WOODLANDS IN THE ONE TAM AREA OF FOCUS

The 2018 Marin Countywide Fine Scale Vegetation Map (GGNPC et al., 2021a) is the product of Marin County’s first simultaneous, multiagency vegetation mapping effort to use a single consistent methodology across multiple jurisdictions. The quality and consistency of these data make the new map a foundational resource for calculating current baseline acreages of open-canopy oak woodlands (also referred to as oak woodlands in this chapter) within the One Tam area of focus. Data analyses for the 2016 report combined decades-old images, mapping methodologies, and plant classifications with more recently mapped areas. Comparisons against the older, inconsistent vegetation map data were challenging. Looking ahead, future comparisons against the 2018 Fine Scale Vegetation Map should have greater accuracy and confidence levels.

The scale of this analysis includes an additional 67 acres of oak woodlands to the north that are part of the expanded One Tam area of focus (Edson et al., 2016). It also includes all partner agency lands within the area of focus; previously, we used the available subset of Marin Water data as a representative sample. Some trend comparisons are therefore based on comparing the current status of *all* oak woodlands with the status of the smaller subset monitored in the past.

Even with the additional 67 acres, we found that the current area of oak woodlands is 560 acres, or 26% less than was calculated in 2016. Despite the challenge of making accurate comparisons to older datasets, the observed impacts of Sudden Oak Death (SOD) and Douglas-fir (*Pseudotsuga menziesii*) encroachment give us high confidence that the overall acreage of oak woodlands is declining.

Based on the 2018 Fine Scale Vegetation Map (GGNPC et al., 2021a), metric-acreage thresholds have been updated to reflect a new baseline of 1,594 total acres; percentages for thresholds did not change. This means that historical declines will not be reflected in future comparisons due to the low accuracy and confidence that would result from incorporating older data. However, we do have a moderate level of confidence that declines in oak woodland condition and extent did occur prior to the new baseline.

Unlike the previous five years, hardwood canopy cover losses are largely absent from oak woodlands during the current analysis period. Nonetheless, the effects of past losses remain evident on the landscape. In addition, even though the recent rate of decline in the area of focus is low, it may still be greater than that seen in the broader region. On the other hand, most oak woodlands appear to have high hardwood cover (not necessarily all oaks) and may be approaching or providing closed-canopy conditions despite past declines.

Almost half of oak woodlands are affected by priority non-native, invasive species that have the potential to substantially alter their habitat function and value. Not only is the weed-impacted proportion of oak woodland habitat high, but it has also been increasing for decades, most recently by about 35% over the previous five-year period.

Similarly, 40% of all oak woodlands in the area of focus are impacted by canopy-piercing Douglas-fir. Whereas the previous assessment reported an apparently stable level based on Marin Water data (a jurisdiction in which some Douglas-fir management was taking place), we now see double the affected area when compared to data from less than five years ago. We are not sure if this is due to increased sensitivity in mapping technique or because understory Douglas-fir finally grew tall enough to pierce the hardwood canopies that previously obscured them.

METRICS SUMMARY

Metrics in Table 6.1 were used to assess the health of oak woodland plant communities. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 6.1. Each metric is described in the Condition and Trends Assessment section later in this chapter. (See Chapter

2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 6.1 ALL OPEN-CANOPY OAK WOODLAND METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1: Hardwood canopy cover		
	2016	**2022**
Condition	Caution	Good
Trend	Declining	Improving
Confidence	Moderate	Moderate
Metric 2: Acres without priority invasive plant species		
	2016	**2022**
Condition	Significant concern	Significant concern
Trend	Declining	Declining
Confidence	Moderate	Moderate
Metric 3: Acres without canopy-piercing Douglas-fir		
	2016	**2022**
Condition	Caution	Significant concern
Trend	No change	Declining
Confidence	Moderate	Moderate

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

Open-canopy oak woodlands on Mt. Tam have many tree species in common with mixed hardwood forests. However, by definition, they are dominated by one or more species of long-lived, acorn-producing trees from the genus *Quercus*, with overall canopy cover generally ranging between 10%

and 60% (Sawyer et al., 2009). The patchier, more open canopy creates a unique habitat structure for both herbaceous plants and wildlife. Understory species also include a distinct and more varied array of grasses, sedges, and forbs than closed-canopy forests (Evens et al., 2006). The herbaceous species richness of this community is on par with grasslands and oaks sustain animals from oak moths (*Phryganidia californica*) to mule deer *(Odocoileus hemionus*). California's oak woodlands support more than 2,000 species of plants, 300 species of vertebrates, and 5,000 species of invertebrates, more than any other habitat type in the state (Allen-Diaz et al., 2007).

This discussion focuses on stands dominated by coast live oak (*Q. agrifolia*), valley oak (*Q. lobata*), Oregon white oak (*Q. garryana* var. *garryana*), and/or black oak (*Q. kelloggii*). The most common co-occurring tree species include bay laurel (*Umbellularia californica*), madrone (*Arbutus menziesii*), and tanoak (*Notholithocarpus densiflorus*). Stands dominated by interior live oak (*Q. wislizeni*), canyon live oak (*Q. chrysolepis*), Shreve's oak (*Q. parvula* var. *shrevei*), or leather oak (*Q. durata*) are excluded because their overall structure is more similar to shrublands or closed-canopy mixed hardwood forest. Stands dominated by blue oak (*Q. douglasii*), the only other open-canopy oak woodland type in the county, are excluded because they occur outside the One Tam area of focus. While some oak woodland stands within the area of focus have canopy cover greater than 60%, putting them outside our typical definition of open-canopy woodlands, we included all stands of coast live, valley, Oregon white, and black oak in our analyses.

Most open-canopy oak woodland alliances within the county, even those of limited extent, are globally secure due to greater representation outside of Marin. However, valley oak woodlands are globally vulnerable (rank G3; CNDDB, 2023), meaning there are only 21 to 100 occurrences and/or 2,590 to 12,950 hectares in the world. Oregon white oak woodlands are vulnerable within California but are globally secure, as their distribution extends from Marin County into Oregon, Washington, and British Columbia (CNPS, 2022). Blue oak and valley oak woodlands are restricted to California, whereas coast live oak and black oak woodland distributions extend north and/or south into adjacent areas of the Pacific coast.

As of 2003, more than 70% of California's oak woodlands were under private ownership (Allen-Diaz et al., 2007), making conservation of these community types on public lands a high priority. In the San Francisco Bay Area, the *Conservation Lands Network 2.0 Report* (BAOSCa, 2019) focuses on a network of lands that support ecological integrity and watershed functions to ensure resilience to environmental disturbance. It assigns rarity ranks to most oak woodland vegetation types, spotlighting their priority for protection and stewardship. Due to significant losses, valley oak woodlands were given the highest rarity rank (1) throughout the Bay Area, with an accompanying goal of protecting 90% of the remaining acres. Within the Marin Coast Range (which includes Mt. Tam), blue oak, coast live oak, and Oregon white oak were assigned a rarity rank of 2, indicating that these vegetation types are locally rare or critical to conservation and warrant a 75% regional protection target (BAOSCb, 2019). While these targets have not been met, and only 35% of Marin County's oak woodlands are on publicly protected lands, the One Tam area of focus provides protection for 10% of the county's coast live oaks—a significant contribution toward the target amount. Oak woodlands on private lands in

Marin County are not accounted for here but may be protected by conservation easements. The Conserved Area Explorer[3] shows 46.6k acres of easements in Marin (CNRA, 2021), these are primarily in the county's northern mainland, which comprises only about 100 acres of oak woodland.

Mt. Tam's land management agencies highlight oak woodlands as important areas for conservation management. At Mount Tamalpais State Park, natural resource goals for mixed hardwood forests, including open-canopy oak woodlands, specify a diverse assemblage of native species, among them, those that are rare, threatened, and endangered. Resource management aims to improve stand structure, regeneration, and resilience, and to exclude targeted and highly invasive species. Marin County Parks' *Vegetation and Biodiversity Management Plan* (May & Associates, 2015) considers all oak woodland alliances (other than coast live oak) as sensitive vegetation communities due to rarity rankings and/or regional scarcity; its stated intent is to protect, enhance, and/or expand these habitats. Marin Water's *Biodiversity, Fire, and Fuels Integrated Plan* (Panorama Environmental, 2019) outlines actions to improve wildfire resiliency, reestablish desired stand structure, and enhance ecosystem function in diseased forest and woodland habitat. The plan lists oak woodland as a "special habitat" and highlights the impacts of SOD on coast live oak and black oak communities. Planned actions include improving grasslands and oak woodlands within the Ecosystem Restoration Zone through weed management and prescribed burning.

On Mt. Tam, open-canopy oak woodlands can be used as an indicator of forest disease, fire regimes, and habitat quality for several oak-dependent birds (Rizzo et al., 2003; Holmes et al., 2008; Cocking et al., 2015). Lace lichen (*Ramalina menziesii*), California's state lichen, primarily grows in open-canopy oak woodlands and is a good indicator of air quality (Sharnoff, 2014).

CURRENT CONDITION AND TREND

The One Tam area of focus supports approximately 1,594 acres of open-canopy oak woodlands (Figure 6.2), which cover 4% of the publicly managed open space land in this geography (see Chapter 3, Table 3.1) and about 8% of all open-canopy oak woodlands in Marin County. Within the area of focus, oak woodlands are most abundant in the Bon Tempe/Lake Lagunitas and Cascade Canyon Preserve areas near the town of Fairfax.

[3] The Conserved Areas Explorer developed by the CA Nature team at the California Natural Resources Agency is an online web map that allows users to visualize areas currently considered conserved for the 30x30 initiative using the California Protected Areas Database, U.S. Protected Areas Database, California Conservation Easement Database, and the California Marine Protected Areas networks.

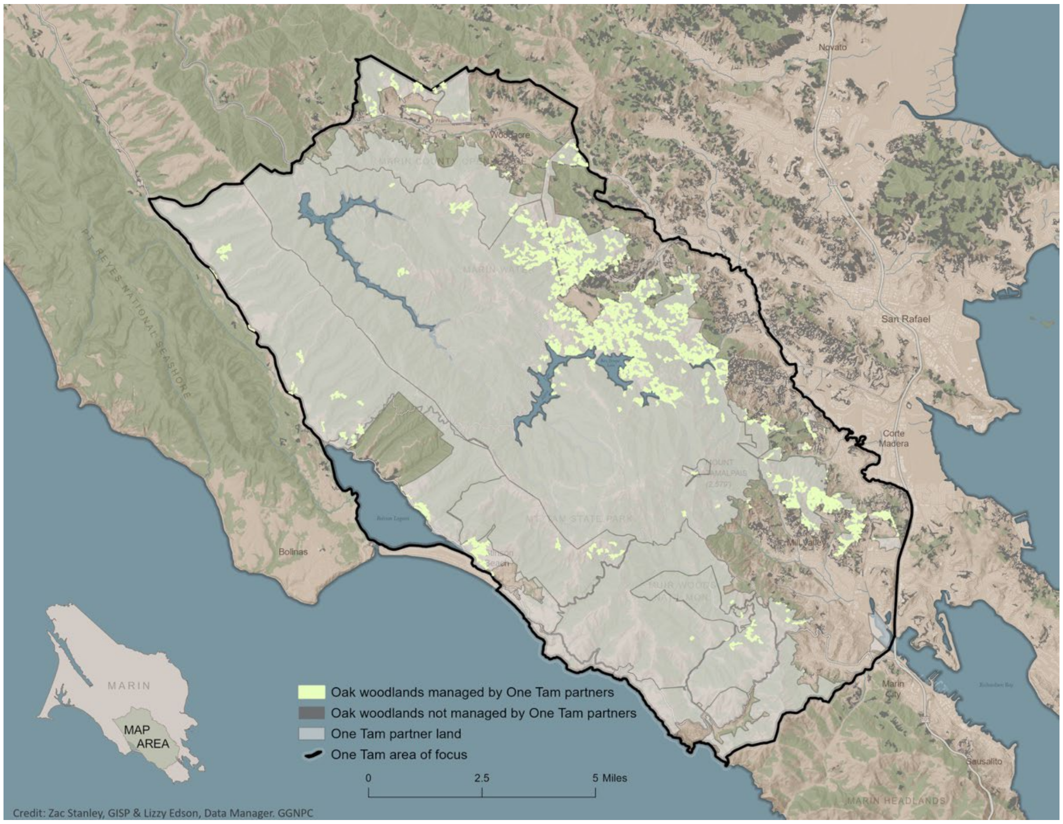


FIGURE 6.2 OAK WOODLANDS, ONE TAM AREA OF FOCUS, 2022

Previously, the desired condition within the One Tam area of focus called for maintenance of the full spatial extent at 2,154 acres (Edson et al., 2016). However, 684 of those acres were in areas where the most recent spatial data came from a vegetation map based on 1994 imagery (Shirokauer et al., 2003), which was considered too unreliable for comparison. When the 1994 data is excluded, the 2014 acreage of oak woodland comparable to the current map is 1,526 acres and equates to 4% of the former area of focus (1,594 acres is 4% of the current area of focus). Historical mapping techniques were neither as accurate nor as consistent as current efforts. Because we now have relatively accurate mapping conducted consistently across the entire county, the total acres of oak woodland from the most recent vegetation mapping effort (GGNPC et al., 2021a) will be used as new baseline to use for future comparisons.

At 73%, coast live oak is the county's most abundant type of open-canopy oak woodland; this is reflected within the One Tam area of focus, where it accounts for 91% of open-canopy oak woodland acres (Figure 6.3). Black oak woodlands, which account for 1%, are least abundant; of the 219 acres countywide, 28% are found within the area of focus. Black oaks are more commonly encountered as part of a mix of tree species but sometimes form stands of sufficient density to be classified as black oak communities. Blue oak woodlands are also quite limited in the county, comprising only 4% of oak woodlands. Blue oak woodlands do not occur within the area of focus, but one-third of the 839 acres in the county can be found on protected lands in Rush Creek Open Space Preserve, which is managed by Marin County Parks.

Mt. Tam is also home to 25 acres of valley oak woodlands, a plant community restricted to California and considered threatened as well as high priority for inventory and conservation (CDFW, 2023). In addition, Mt. Tam has the southernmost patch of Oregon oak-California fescue (*Festuca californica*) association. Both valley oak and Oregon oak are better represented at the county level, differences that are likely a function of topography and climate; blue oaks are more common in hotter, drier sites and valley oak, in seasonally moist flats.

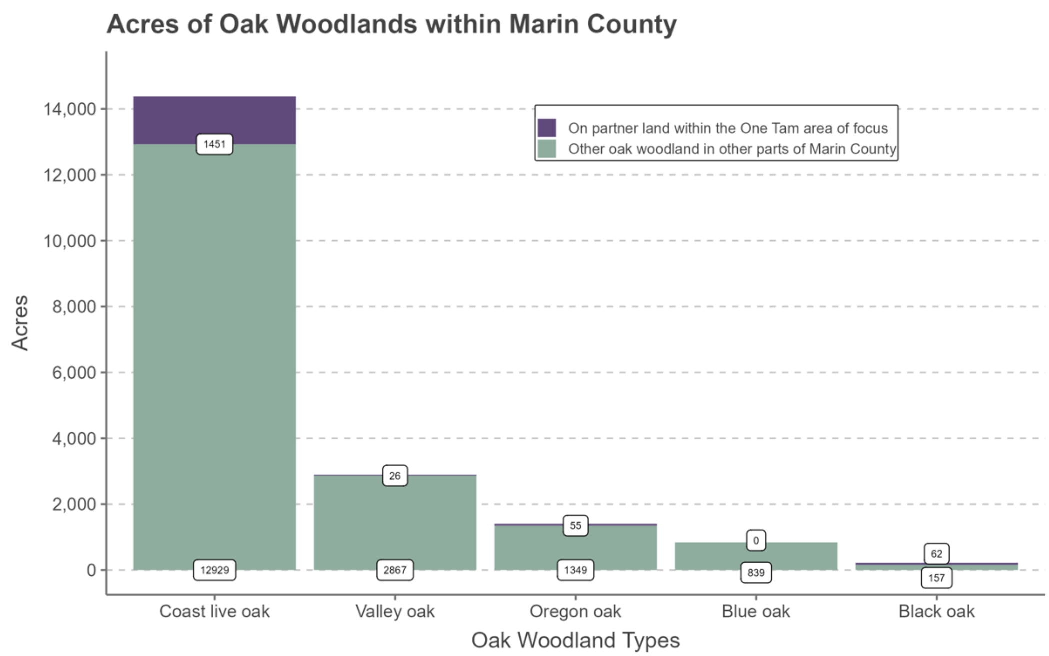


FIGURE 6.3 RELATIONSHIP OF OAK WOODLAND TYPES, ONE TAM AREA OF FOCUS AND MARIN COUNTY

DESIRED CONDITION AND TREND

The desired conditions for open-canopy oak woodlands in the One Tam area of focus are maintenance of the full spatial extent of this vegetation type (1,594 acres in 2018), the persistence of discontinuous canopy dominated by trees from the genus *Quercus*, and discontinuous shrub and herbaceous layers dominated by native species. Good examples of this type can be found in the Bon Tempe/Lake Lagunitas area and in the Cascade Canyon Preserve.

Invasive Species Impacts: French broom (*Genista monspessulana*) is the invasive plant species with the greatest negative impact on oak woodlands in the One Tam area of focus. This woody shrub invades the understory, forming dense monoculture stands that substantially reduce habitat function and value and support much lower levels of biodiversity than is available in oak woodlands with uninvaded understories. Similarly, invasive grasses are a persistent and pervasive threat to many herbaceous plant communities, and oak woodland understory communities are no exception.

The goldspotted oak borer (*Agrilus coxalis*), a beetle native to Arizona, has recently become invasive in California and is causing oak mortality in the southern part of the state. It is currently found in Riverside, Orange, Los Angeles, and San Bernardino Counties. Goldspotted oak borer infestations are known to cause mortality in mature coast live oak, canyon live oak, and California black oak. If it were to spread to northern California's oak woodlands, it could pose a serious threat to Marin's limited stands of black oak as well as the foundational habitat and ecosystem functions of the region's expansive coast live oak woodlands (UCCE, 2017).

Climate Vulnerability: A statewide climate-exposure model shows a wide range of variability in the "Warm/Wet" and "Warm/Dry" futures along the eastern portion of the One Tam area of focus where most oak woodlands occur (GGNPC, 2021a; Thorne et al., 2017). How these predicted climate changes will impact the health of each plant species depends on its adaptive capacity related to fire, mode and level of recruitment, and seed longevity (Thorne et al., 2016). Low levels of acorn longevity in the soil reduce the adaptive capacity of oak species. Both the "Warm/Wet" and "Warm/Dry" futures are likely to increase SOD's prevalence and its effects on coast live oak and black oak types.

Fire Regime Change: Historically, wildfires in north coast oak woodlands could be described as being high frequency and of limited intensity. Crown fires were relatively rare, and mature oaks typically survived. Wildfires maintained an open-canopy structure, limited the development of a shrub layer, and prevented the establishment of Douglas-fir (Holmes et al., 2008), which can quickly overtop oak canopies and leave dead oaks in the understory. More than a century of fire suppression on Mt. Tam has shifted some areas from oak woodland to Douglas-fir conifer forest, changed oak woodland stand structure, and increased fuel loads. This, in turn, increases the associated risks of high-intensity wildfires with the potential to kill mature oaks. Fuel loads are also increasing due to SOD-related tree mortality as well as invasion by perennial weeds like French broom (Panorama Environmental, 2019).

Disease: Oaks in the red oak group, including coast live oak and black oak, are susceptible to SOD, a disease caused by the plant pathogen *Phytophthora ramorum*. A 2014 survey found that SOD occurred in more than 90% of open-canopy oak woodlands on Marin Water lands (AIS, 2015). Excessive tree loss creates canopy gaps; reduces wildlife food sources; may reduce gene flow and genetic diversity within impacted species; and can, at least temporarily, increase the potential for more severe fires around affected trees (Rizzo et al., 2003).

Another *Phytophthora* species, *P. quercina*, has had an impact on valley oak in restoration planting elsewhere in California (Chitambar, 2016). While its potential for introduction to Marin County is low, planting using acorns or nursery-grown stock, best management practices, and testing will prevent restoration sites from becoming vectors for disease.

Pollution/Contaminants: Open-canopy oak woodlands are highly sensitive to the effects of nitrogen deposition (BAOSC, 2011). Nitrogen increases can drive non-native annual grass invasion with the associated impacts of thatch buildup, loss of native species, and reductions in biodiversity within otherwise uniquely diverse herbaceous understories. A report on National Park Service units in the area analyzed exposure and sensitivity to calculate risk; Muir Woods, the park unit closest and most relevant to the area of focus, scored "moderate" (Sullivan et al., 2011).

Direct Human Impacts: Fuelbreak and fuel-management-zone construction and maintenance primarily affect standing dead oaks but also prioritize the removal of small, lower limbs from living oak trees growing near community interfaces or along strategic access routes. Gas- and power-line maintenance activities sometimes include full removal of mature trees that threaten infrastructure.

Habitat Disturbance/Conversion/Loss: Thousands of years of the deliberate use of fire by Indigenous populations kept less fire-tolerant species such as Douglas-fir out of large areas of woodlands that are now dominated by oaks. On Mt. Tam, the more recent fire regime of very infrequent fires has allowed Douglas-fir to recruit into these oak-dominated woodlands. Douglas-firs that grow taller than the oak canopy reduce oak growth and vigor, may eventually lead to oak mortality, and lower adult oak tree densities (Cocking et al., 2015). Understory grasslands may be lost as natural succession shifts open-canopy to closed-canopy oak woodlands. Some may further convert to bay laurel-dominated stands, a process facilitated by SOD that lives in bay trees but causes mortality in some oak species (BAOSC, 2011). Conversely, if enough mature trees are lost and recruitment is insufficient, open-canopy oak woodland stands could convert to grasslands or shrublands, with a corresponding shift in biodiversity as oak-related microhabitats are lost. Historically, California oaks have been cleared for intensive agriculture, rangeland, and urban or residential development, work that eliminated them from much of their former range (Bernhardt & Sweicki, 2001).

Predation/Competition: In the past, mountain lions and wolves preyed on deer in greater numbers. The practices of Indigenous groups may have further contributed to reductions in deer densities. Absent pre-colonial levels of predation, hunting, and land management, deer densities are likely elevated compared to historical numbers. Ample evidence supports the hypothesis that high densities of ungulate browsers result in elevated browsing pressure on broadleaf tree seedlings and young saplings, leading to a depressed rate of new tree recruitment (Beschta, 2005; Ripple & Beschta, 2008). Similarly, prescribed livestock grazing or browsing can negatively affect tree seedlings.

A common perception is that oaks are not recruiting in sufficient numbers to sustain populations, but empirical evidence for this across all oak species is sparse. Many species-specific factors have been proposed for the apparent recruitment failure (Garrison et al., 2002; Tyler et al., 2006). Some evidence indicates that browsing pressure from deer and rodents is depressing seedling survival (Tyler et al., 2002; Ripple & Beschta, 2007; Kuhn, 2010; Davis et al., 2011).

CONDITION AND TREND ASSESSMENT

METRICS AND GOALS

METRIC 1: HARDWOOD CANOPY COVER

Baseline: *P. ramorum*, the pathogen that causes SOD, was unknown in Marin County prior to 1995 (Rizzo et al., 2003). It is now so well established in the One Tam area of focus that eradication is unlikely. The accelerated decline and death of tanoaks, coast live oaks, and black oaks in Marin County are also likely to continue into the foreseeable future (Cunniffe et al., 2016). Between 2004 and 2014, detectable signs of canopy disease increased dramatically in Marin Water's oak woodlands, with similar observations made by resource staff on other agency lands (Edson et al., 2016). Canopy mortality (standing dead trees) continues to be prevalent in coast live oak and black oak woodlands (Figure 6.4), with approximately one-third of each type in the One Tam area of focus exhibiting 1% to 5% standing dead trees. In contrast, Oregon white oak and valley oak types, which are unaffected by SOD, have less than 5% of their overall acreage affected and no patches with greater than 2% mortality.

The prevalence of coast live oak woodlands is reflected in the 34% of overall oak woodland acreage with some degree of canopy mortality, a marked decrease from Marin Water's oak woodlands' 90% canopy-level mortality in 2014. While various factors may be contributing to the apparent decrease in mortality levels (see further discussion under "current condition" section, below), the effects of SOD on the landscape and within oak woodlands remains severe. Between 2009 and 2014, nearly 370 acres (40%) of Marin Water's oak woodland habitat experienced hardwood cover decreases of 5% to 25% (Table 6.2). The Marin Water 2014 vegetation map indicated that nearly 78 acres (or 8%) of oak woodland vegetation types had less than 25% hardwood cover (GGNPC et al., 2021b; Table 6.3). Despite the recent period (2014-2018) showing little hardwood decline (Figure 6.5; Table 6.3), we expect the apparent respite is the result of temporary weather patterns or new methods of data categorization. Loss of oaks is likely to continue, putting areas of high hardwood loss at risk of converting to grassland or shrubland habitat types, or hardwood forest without a dominant oak component.

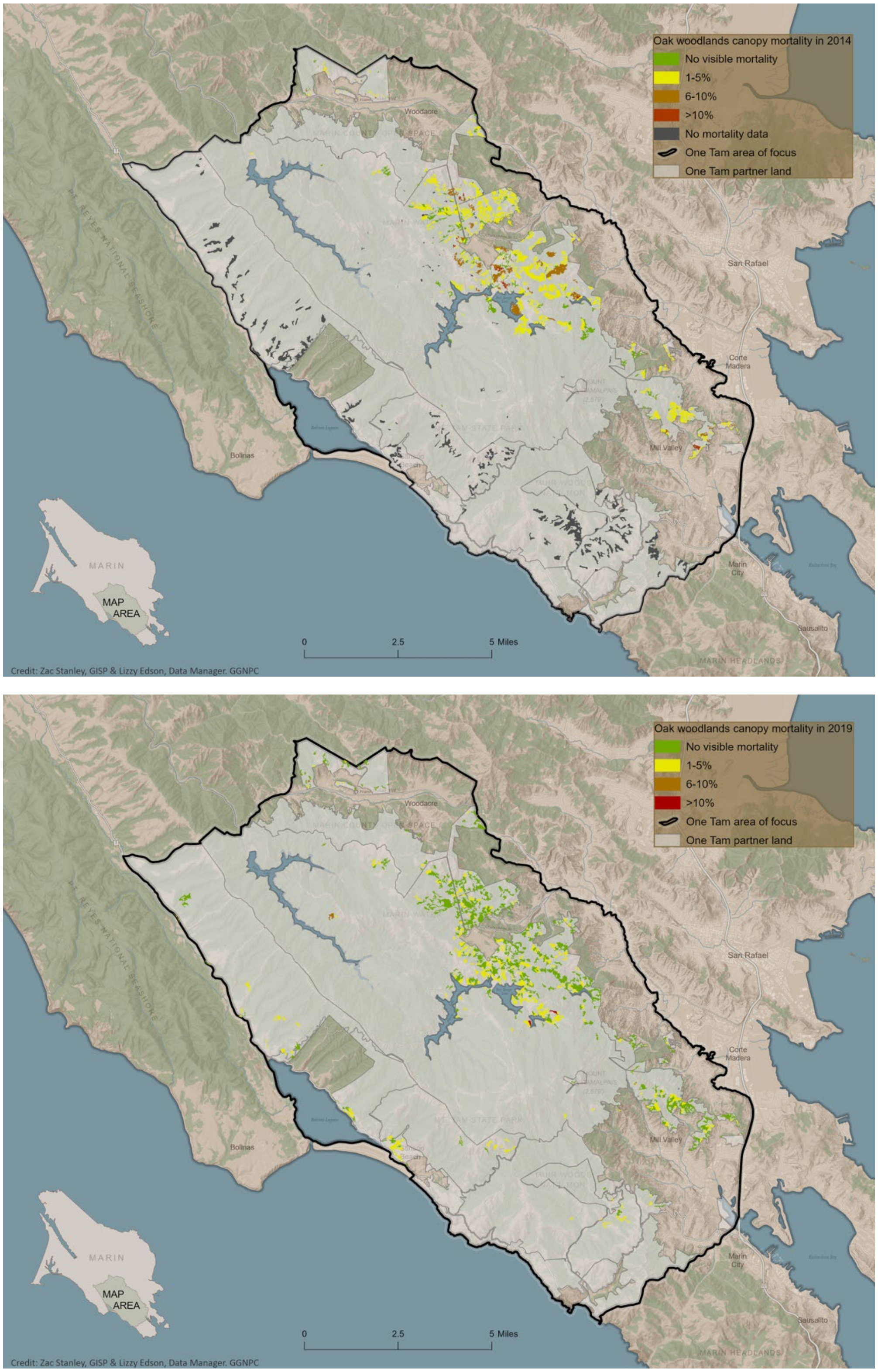


FIGURE 6.4 CANOPY MORTALITY IN OAK WOODLANDS, ONE TAM AREA OF FOCUS, 2014 (TOP)–2019 (BOTTOM) (GGNPC ET AL., 2021A)

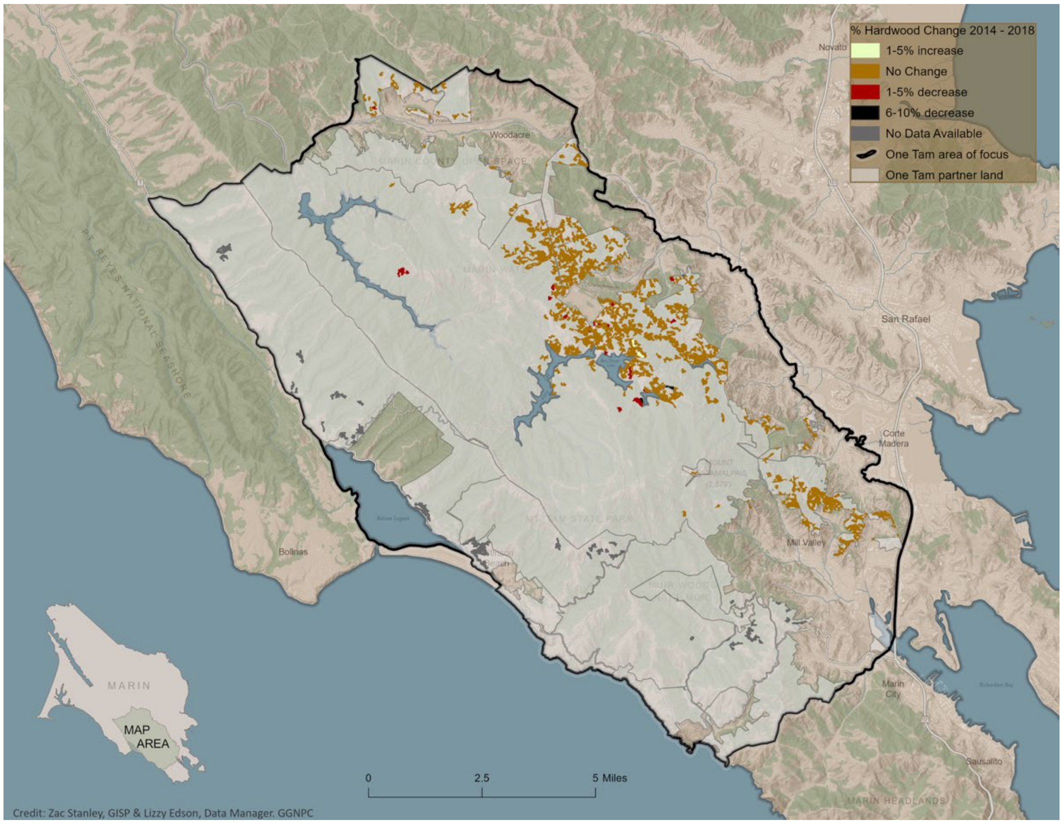


FIGURE 6.5 CHANGE IN HARDWOOD COVER IN OAK WOODLANDS, ONE TAM AREA OF FOCUS, 2014–2018 (GGNPC ET AL., 2021A)

TABLE 6.2 ACREAGE CHANGE, OAK WOODLAND HARDWOOD COVER, ONE TAM AREA OF FOCUS, 2009–2014 AND 2014–2018 (GGNPC ET AL., 2021B & 2021A)

	Change in Hardwood Cover (2009–2014; 2014–2018)							
Vegetation Type	% Increasing (+5% to +10%)		% Decreasing (-5% to -25%)		% Stable		Total Acres	
	2014	2018	2014	2018	2014	2018	2014	2018
Black oak	0	0	8.8	4.3	91.2	95.7	5.7	62.3
Coast live oak	1	0.3	40.3	2.7	58.7	85.5	907.7	1,450.7
Oregon oak	0	0.1	41.9	0	56.5	99.9	6.2	55.4
Valley oak	0	0	0	0	100	100	10	25.5
Interior live oak (excluded from the 2018 analysis)	0	N/A	0	N/A	100	N/A	24.5	N/A

Note: Changes shown for the period 2009-2014 are for Marin Water lands only, whereas 2014–2018 change represents a larger area that includes Marin County Parks parcels in addition to the Marin Water areas previously assessed.

TABLE 6.3 PERCENT OF ACRES IN HARDWOOD CANOPY COVER CLASSES IN OAK WOODLANDS, 2014 COMPARED TO 2018 (GGNPC ET AL., 2021B)

Vegetation Type	0%–2%		2%–10%		11%–25%		26%–40%		41%–60%		>60%		Total Acres	
	2014	2018	2014	2018	2014	2018	2014	2018	2014	2018	2014	2018	2014	2018
Black oak	0	0	0	0	0	0.7	0	2.2	8.8	0	91.2	97.8	5.7	62.3
Coast live oak	0	0	0.6	0	5.4	0.7	2.5	4.3	24.3	26.1	67.2	68.9	907.7	1,450.7
Oregon oak	0	0	0	0	0	0	0	0	0	4.4	100	95.6	5.5	55.4
Valley oak	0	0	0	0	0	0	0	10.3	0	23.3	100	66.3	10	25.5
Interior live oak (excluded from the 2018 analysis)	6.5	N/A	87.8	N/A	0	N/A	0	N/A	3.3	N/A	2.4	N/A	24.5	N/A

Note: Changes shown for the period 2009-2014 are for Marin Water lands only, whereas 2014–2018 change represents a larger area that includes Marin County Parks parcels in addition to the Marin Water areas previously assessed.

Condition Goal: Maintain approximately 1,590 acres of oak woodland with more than 25% hardwood canopy cover. This updated goal is based on oak woodland acres from the 2018 Fine Scale Vegetation Map (GGNPC et al., 2021a), which used consistent methodologies to simultaneously map Marin County vegetation. The previous goal, 2,150 acres, was based on multiple mapping efforts with varying methodologies and levels of accuracy.

Condition Thresholds:

The following thresholds have been updated to reflect the new baseline goal of 1,590 total acres, but the proportions remain the same as the 2016 assessment.

- **Good:** More than 1,435 acres (90%) of oak woodland with hardwood cover >25%; acreage with a >5% decline in hardwood cover of <5% (80 acres) over five years.
- **Caution:** 1,120–1,434 acres (70% to 90%) of oak woodland with hardwood cover >25%; acreage with a >5% decline in hardwood cover of between 5% and 10% (80–160 acres) over five years.
- **Significant Concern:** Fewer than 1,120 acres (70%) of oak woodland with hardwood cover >25%; acreage with a >10% decline in hardwood cover of >10% (160 acres) over five years.

Current Condition:

2016: Caution

Marin Water's 2014 vegetation map indicated that nearly 92% of oak woodland vegetation types had more than 25% hardwood cover (Table 6.3; GGNPC et al., 2021b). Assuming this was representative of other, non-Marin Water oak woodlands within the One Tam area of focus, 1,980 total acres of oak woodland were estimated to have a hardwood cover of less than 25%, which was above the good threshold.

2022: Good

The 2018 Fine Scale Vegetation Map (GGNPC et al., 2021a) shows that there are 1,594 acres of oak woodlands in the area of focus, 99% of which have at least 25% hardwood cover (Table 6.3). Only nine acres fall below the 25% threshold, indicating that the condition of hardwood cover is good.

However, 73% of oak woodlands have hardwood cover greater than 60%, leaving just 418 acres of what we consider to be open-canopy woodlands. When compared to closed-canopy hardwood forests, the open-canopy acres are even fewer (just under 370) when the additional canopy cover of conifers in these stands is taken into consideration. Furthermore, we have insufficient data to conclude how much of the hardwood cover comprises oak species as opposed to other hardwoods (e.g., bay laurel or madrone) that may be increasing as adjacent oaks are lost to SOD. The high cover of hardwoods in oak stands highlights the need for data on species richness and function of closed-canopy vs. open-canopy oak stands to fully assess their health. Analyzing bird and mammal data by canopy cover in oak-dominated habitats may also help determine whether the 60% cutoff is ecologically meaningful.

Trend:

2016: Declining

The percent cover of hardwoods declined by more than 5% across nearly 370 acres (40%) of Marin Water oak woodland habitat in five years (2009–2014; Table 6.2). Assuming this was representative of other oak woodlands within the One Tam area of focus, the total number of oak woodland acres with hardwood canopy cover declines higher than 5% was estimated to be 800 acres. Only 1% of oak woodlands had hardwood increases over >5%, and the remaining 60% appeared to have stable hardwood cover (increase or decrease of 5%) (Table 6.2).

2022: Improving

Recent data show that mortality and hardwood decline leveled off during the 2014–2018 period (Table 6.2), with approximately 33% of oak woodland acreage showing any canopy mortality (Figure 6.4), down from more than 90% in 2014. For all oak woodland types combined, less than 3% of the area shows a decrease in hardwood cover, down from 40% in 2014 (Table 6.2). This could be a function of fluctuating weather patterns driving SOD prevalence, with lower rainfall during drought years (Figure 6.6) reducing sporulation; the lower rate of tanoak die-off (see Chapter 4, Coast Redwood Forests) supports this theory. Alternatively, fewer canopy trees may be vulnerable to SOD infection, which seems unlikely given the stability of oak woodland acreage and increases in canopy cover over the measurement interval. New data categorization methods also account for some portion of the change by grouping trace levels of mortality (<0.5%) into the “no mortality” acreage.

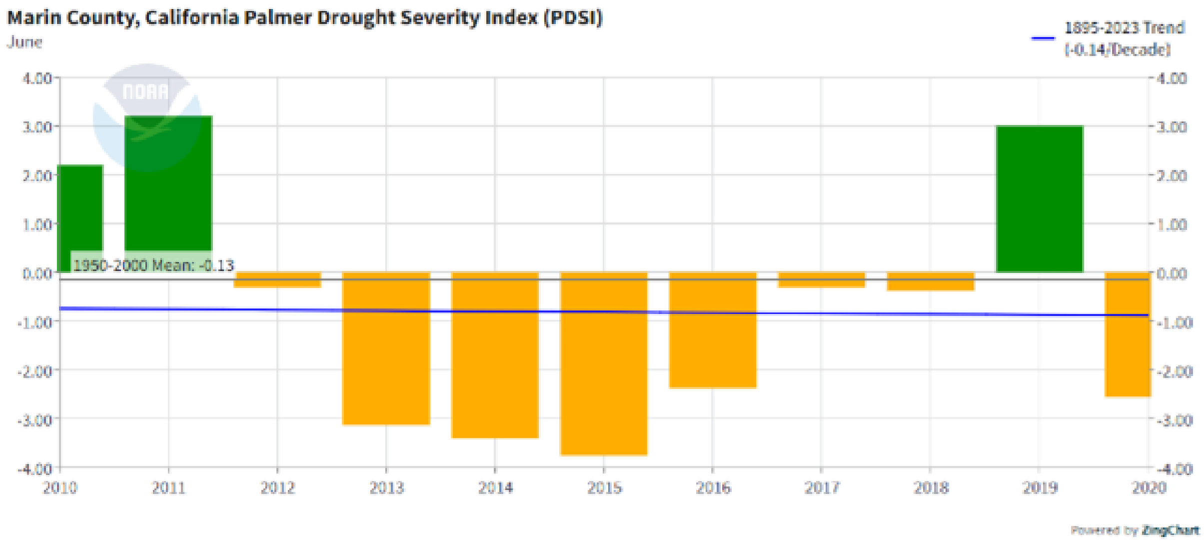


FIGURE 6.6 PALMER DROUGHT SEVERITY INDEX FOR MARIN COUNTY, 2010–2020 (NCEI, 2023)

Confidence:

2016: Moderate

Marin Water's oak woodlands comprised 41% of that habitat type in the One Tam area of focus, and their decline was presumed to be representative of the situation on lands managed by other agencies. However, those data were lacking.

2022: Moderate

As previously noted, changes in mapping techniques and comparison areas reduce our general confidence in trend determination. However, we have relatively high confidence in the quality of mortality and hardwood-cover data and the level at which these are represented on all One Tam partner agency lands in the area of focus. This new dataset covers 100% of Mt. Tam's oak woodlands when measuring 2018 mortality and hardwood-cover attributes, and 90% of oak woodlands when measuring hardwood decline from 2014 to 2018. We therefore have moderate confidence in comparing the results from these two assessment periods.

METRIC 2: ACRES WITHOUT PRIORITY INVASIVE SPECIES

Baseline: French broom and Scotch broom (*Cytisus scoparius*) as well as other invasive plant species—e.g., panic veldt grass (*Ehrharta erecta*), cape ivy (*Delairea odorata*), and cotoneaster (*Cotoneaster* spp.)—were introduced to Mt. Tam during the 20th century. Because they are relatively recent arrivals, the historical baseline is zero acres of open-canopy oak woodlands where these invasive species are present. Healthy open-canopy oak woodlands do not have target invasive species, and broom reduction in oak woodlands has been a high priority on One Tam partner agency lands. To date, at least 746 weed-infested acres of oak woodlands have been identified in the area of focus.

Condition Goal:

- High-priority invasive plant species at <5% cover in oak woodland habitat.

Condition Thresholds:

- **Good:** More than 1,435 acres of open-canopy oak woodlands (90%) with <5% invasive species cover.
- **Caution:** 1,275 to 1,434 acres (80% to 90%) of open-canopy oak woodlands with <5% invasive species cover.
- **Significant Concern:** Fewer than 1,275 acres (80%) of open-canopy oak woodlands with <5% invasive species cover.

Current Condition:

2016: Significant Concern

Available data from all One Tam partner agencies showed that 545 acres (25% at the time of assessment) of open-canopy oak woodlands were affected by target invasive species. Percent cover data were incomplete. However, review of records available for a single species within a single jurisdiction (French broom in Marin Water's oak woodlands) indicated that the threshold for caution had been exceeded.

2022: Significant Concern

Available data from all One Tam partner agencies show that nearly half (47%, or 746 acres) of open-canopy oak woodlands are affected by target invasive species (Figure 6.7). Percent cover data remain incomplete, inconsistent, and difficult to compile, especially across multiple jurisdictions. However, a rough analysis of both Marin County Parks and Marin Water data reveals that both agencies' broom populations have more than 10% cover in one-third of the area, making it likely that more than 20% of Mt Tam's oak woodlands have high (>5%) weed cover.

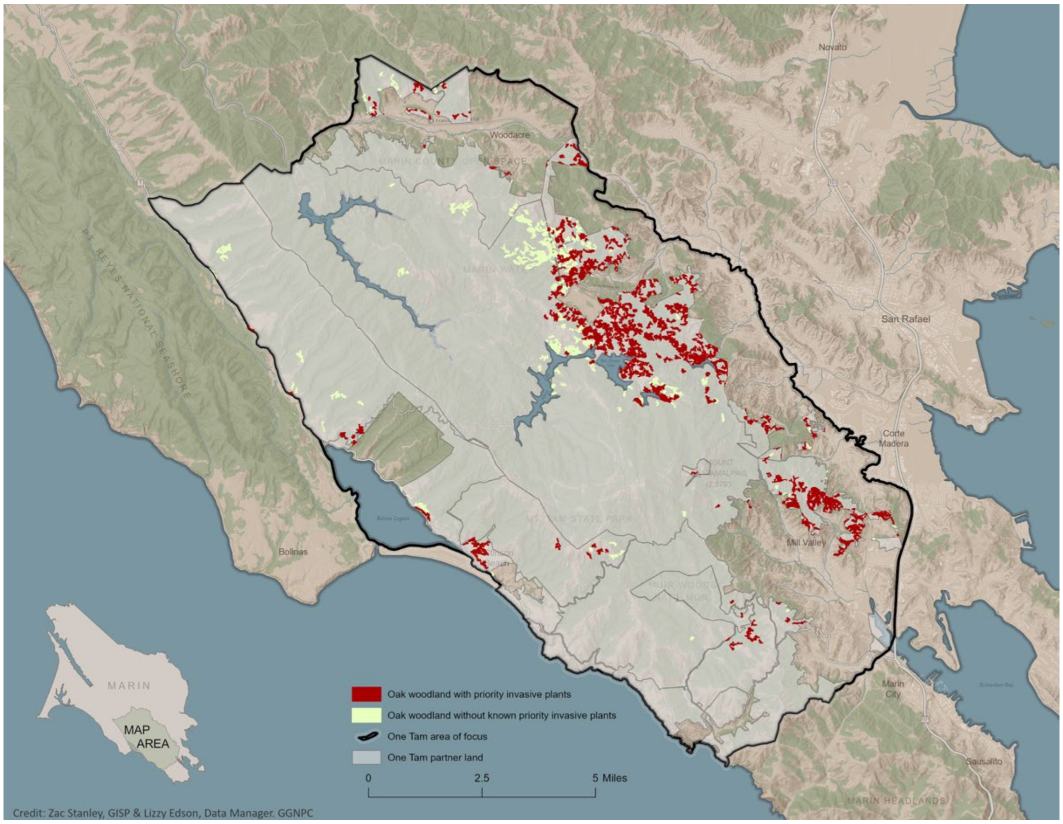


FIGURE 6.7 INVASIVE SPECIES DISTRIBUTION IN OAK WOODLANDS, ONE TAM AREA OF FOCUS, 2022 (CALFLORA, 2016)

Trend:

2016: Declining

Available data from all One Tam partners indicated that the spatial extent and percent cover of invasive species in oak woodlands had continued to increase. Time series data for a single species within a single jurisdiction were presumed to be representative.

2022: Declining

Seventeen acres of weed-infested oak woodland were found within the 67 acres of newly incorporated oak woodland in the vicinity of San Geronimo Valley. Therefore, invaded oak woodlands increased by 34% (184 acres) within the previously assessed area, due to either weed expansion or documentation of previously unmapped weed populations. Available information from all One Tam partner agencies indicates the overall spatial extent and percent cover of invasive species in oak woodlands continues to increase despite targeted projects and efforts to reduce small areas of limited, high-priority species, and even some efforts to take on larger areas of more widespread priority species like French broom.

Confidence:

2016: Moderate

All One Tam partners maintain invasive species records that include spatial distribution, percent cover estimates, and management history information. However, mapping efforts and protocols were not uniform across agencies at the time of the assessment, and integration of these datasets was incomplete.

2022: Moderate

Mapping remains incomplete and inconsistent, although integration has improved somewhat because some partner agencies are now using the Calflora platform to track weed extent and/or management data. Countywide fine-scale mapping efforts are not able to detect understory weeds, inconspicuous species, or small invaded areas, which means that accurate weed mapping generally remains a high-effort, ground-based task. Areas, species, time intervals, and protocols differ across partner agencies as they each endeavor to prioritize and achieve their respective individual mapping goals.

METRIC 3: ACRES WITHOUT CANOPY-PIERCING DOUGLAS-FIR

Baseline: When Douglas-fir becomes established in the canopy above hardwoods, open-canopy oak woodland patches transition to the higher canopy closure of mixed conifer-hardwood forest or conifer-dominated stands that have lower habitat value for certain bird and plant species (Cocking et al., 2015). The best available data estimated the pre-2016 total baseline at approximately 100 acres of open-canopy oak woodlands with canopy-piercing Douglas-fir.

Condition Goal: Maintain 90% (1,435 acres) of current oak woodlands without canopy-piercing Douglas-fir. The current goal is based on oak woodland acres from the 2018 Fine Scale Vegetation Map (GGNPC et al., 2021a).

Condition Thresholds:

The following thresholds have been updated to reflect the new baseline acreage goal of 1,590 total acres, but the proportions remain the same as the 2016 assessment.

- **Good:** More than 1,435 acres (90%) of open-canopy oak woodlands without canopy-piercing Douglas-fir.
- **Caution:** 1,116 to 1,434 acres (70% to 90%) of open-canopy oak woodlands without canopy-piercing Douglas-fir.
- **Significant Concern:** Fewer than 1,116 acres (70%) of open-canopy oak woodlands without canopy-piercing Douglas-fir.

Current Condition:

2016: Caution

The vegetation maps for Marin County Parks and Marin Water current at the time of assessment documented 260 acres of oak woodlands with canopy-piercing Douglas-fir, or approximately 19% of the combined oak woodlands in these two jurisdictions. Extrapolating to the entire One Tam area of focus, approximately 400 acres of oak woodlands may have had Douglas-fir in the canopy.

2022: Significant Concern

Based on 2018 aerial imagery, the vegetation map documents 460 acres of oak woodlands with canopy-piercing Douglas-fir for Marin County Parks and Marin Water lands in the previously analyzed area of focus. This represents approximately 34% of the combined oak woodlands within these two jurisdictions. In the entire One Tam area of focus, the vegetation map shows 632 acres (40%) of oak woodlands with Douglas-fir in the canopy (Figure 6.8); 272 acres have <5% conifer cover in the canopy. The remaining 360 acres (57%) have 5% to 25% conifer cover and are likely to pose a greater challenge for management to reduce Douglas-fir cover.

As previously mentioned, the updated area of focus incorporates 67 newly included acres of open-canopy oak woodland in the vicinity of San Geronimo Valley. Of these, 44 acres (66%) are affected by Douglas-fir, leaving only 34% unaffected in these northern areas. This is a much lower proportion than the 60% unaffected we see overall within the area of focus. In the westernmost 109 acres of oak woodlands (within National Park Service jurisdiction), only 16% remain unaffected by overstory Douglas-fir.

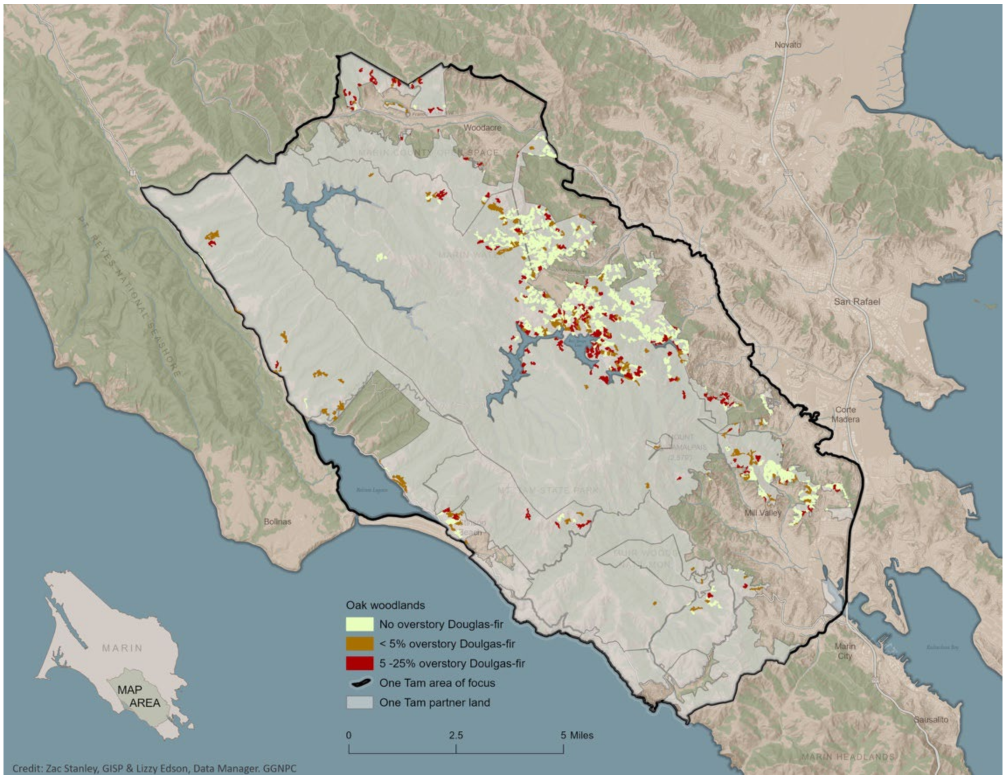


FIGURE 6.8 DOUGLAS-FIR IN OAK WOODLANDS, ONE TAM AREA OF FOCUS, 2018 (GGNPC ET AL., 2021A)

Trend:

2016: No Change

Marin Water time series data indicated that the spatial extent of canopy-level Douglas-fir in oak woodlands was unchanged between 2004 and 2014. Conditions on Marin Water lands were presumed to be representative of or slightly better than those of the area of focus as a whole because Marin Water was thinning Douglas-fir saplings in select oak woodland patches while other jurisdictions were not.

2022: Declining

It appears that Marin Water's 10-year trend of stability from 2004-2014 did not hold for the subsequent four-year period. 2014 data for Marin Water and Marin County Parks showed 260 acres with canopy-piercing Douglas-fir within the previous area of focus. 2018 data show the acreage is 460 in that same area. When looking across the entire One Tam area of focus, only 60% of oak woodlands contain no Douglas-fir; whereas, in 2014 within a slightly smaller area of analysis, 81% were unaffected. This uptick in Douglas-fir impact is happening despite increased efforts by various land managers to address its expansion into sensitive habitats.

Confidence:

2016: Moderate

Data from Marin Water and Marin County Parks' vegetation maps represented 66% of oak woodlands in the One Tam area of focus. National Park Service and California State Parks did not have similar data, but conditions were thought to be similar.

2022: Moderate

It is possible that some of the change can be attributed to differences in mapping techniques, particularly given the notable shift from the 10-year trend recorded for Marin Water lands from 2004-2014. Therefore, we do not have high confidence in the trend for this metric, although the condition is valid.

SUPPORTING DATA, OBSERVATIONS, RESEARCH, AND MANAGEMENT

Data sources for acreages listed under the above metrics:

Aerial Surveys and Mapping:

- Standardized 2004–2014 County Parks/Marin Water vegetation map (GGNPC et al., 2021b).
- 2018 Marin County Fine Scale Vegetation Map (GGNPC et al., 2021a).
- Marin Water broom mapping from 2010 draft vegmgmt_polys_9_3, and 2013 and 2018 broom remapping.
- Marin Water 2015 photo interpretation of SOD-affected forest stands (AIS, 2015).
- Marin Water, Marin County Parks, California State Parks, and National Park Service weed records from both the Calflora database and internal records.

ACREAGE CALCULATIONS

TABLE 6.4 METHODS AND DATA USED TO CALCULATE ACREAGES OF SOD, DOUGLAS-FIR, AND BROOM

Indicator Plant Community	Analysis/ Report Year	Vegetation Types Included	Metrics	How Derived
Open-canopy oak woodlands	2016	• Black oak alliance • Coast live oak (CLO) alliance • CLO/grass-poison oak; CLO–riparian • CLO–Douglas-fir	Acres without SOD (canopy involvement)	Summed acreage of oak woodland polygons with attribute SOD*=0.
			Acres without broom or other targeted	2003 drive-by survey* for broom, 2010 draft vegmgmt_polys_9_3*, 2013 broom re-map*.

Indicator Plant Community	Analysis/ Report Year	Vegetation Types Included	Metrics	How Derived
		• Oregon oak alliance • Valley oak riparian mapping unit • Interior live oak (ILO) alliance • Interior live oak-Eastwood manzanita • Coastal open-canopy oak woodland	priority invasive species	
			Acres without canopy-piercing Douglas-fir	Summed acreage of oak woodland polygons with Marin Water attribute ConDensity >0; Marin County Parks ConDen >0.
Open-canopy oak woodlands	2022	• Coast live oak alliance • Oregon white oak alliance • Valley oak alliance • Black oak alliance	Hardwood canopy cover	**For Figure 6.4 Canopy Mortality:** Calculated acreage of 2017 area of focus (AOF) oak woodland alliance polygons with attribute STANDING_DEAD_19 in each of the following four classes, summed separately: 0, 1–4, 5–9, ≥10. **For trend assessment and Table 6.2:** Summed acreage of 2017 AOF oak woodland alliance polygons with attribute HDW_CHANGE_14_18 >0 (increasing), 0 (stable), <0 (decreasing), and -9999 (no data). Trend assessment data was only available for Marin Water and Marin County Park areas, which represent more than 90% of oak woodlands on One Tam partner agency lands in the 2017 AOF. **For condition assessment, Figure 6.5 Change in Hardwood Cover, and Table 6.3:** Summed acreage of 2017 AOF oak woodland alliance polygons with attribute HDW_COVER_18 in the following six classes: <2, 2–10, 11–25, 26–40, 41–60, ≥61. **To discuss proportion of oak woodlands in higher canopy cover**

Indicator Plant Community	Analysis/ Report Year	Vegetation Types Included	Metrics	How Derived
				conditions (i.e., those closer to "closed-canopy" oak woodlands but still included in this assessment): Summed acreage of 2017 AOF oak woodland alliance polygons with attribute HDW_COVER_18 >60.
			Acres without broom or other targeted priority invasive species	Dissolved all 2017 AOF partner agency invasive plant polygons into a single layer. Clipped dissolved weed layer to 2017 AOF oak woodland alliance polygons. Recalculated acreages. Selected "oaks with weeds" polys within the 2014 AOF; summed acres. Inverted selection and summed acres to determine conditions within just the newly included areas of the 2017 AOF.
			Acres without canopy-piercing Douglas-fir	Split 2017 AOF oak woodland alliance polygons by partner agency. Recalculated acreages. Summed acreage of oak polygons with attribute CON_COVER_ >0 for full 2017 AOF. Selected oak polygons on Marin Water and Marin County Parks lands intersecting the 2014 AOF and summed those with CON_COVER_>0 for purpose of back comparison against 2016 report totals. Summed inverted selection of Marin County Parks oaks with CON_COVER_ >0 in 2014 AOF to determine conditions within just the newly included areas of the 2017 AOF.

**Marin Water data only.*

See Chapter 2, Indicator Analysis Methodology section, for additional information about the overall methodology used for vegetation community analyses.

INFORMATION GAPS

Species Richness: Some measure of the diversity of native species present has been identified as an important metric for open-canopy oak woodlands. The goal would then be to maintain species richness at the reference condition. No progress has been made to fill this gap. As discussed previously, species richness data can help address questions about the effect of canopy closure on habitat value.

Age Structure of Native Trees: This important metric would be useful in determining whether new trees are being recruited at a rate sufficient to maintain the total acres and structural integrity of open-canopy oak woodlands over time. A stable age structure follows a reverse J-curve frequency distribution, with abundant seedlings and fewer individuals of successively older ages. Acorn production and seedling recruitment tend to be periodic, and survival from sapling to adult is a key transition. While some data may be available to support this assessment, currently, there is not enough information to make any statement about condition or trend for the One Tam area of focus or the region. California OakWatch—a joint participatory science project of the California Native Plant Society and the Global Consortium for the Conservation of Oaks—tracks oak recruitment via iNaturalist observations (iNaturalist, 2023). Local volunteers could be recruited to this project to gather data on Mt. Tam and all lands in Marin, contributing to the larger body of knowledge on oak recruitment. Partnering with the California OakWatch iNaturalist project could be a low-investment way to have observers who could record where oaks are reproducing successfully.

Function and Value of Open- vs. Closed-canopy Oak Woodlands: If a particular range of canopy cover (e.g., 25% to 60%) could be linked to desirable qualities such as high species richness and unique function or habitat value, it would provide support for management aimed at achieving those qualities. This is particularly true if there are human-related barriers to natural processes (e.g., fire) that would otherwise help maintain those levels. Increased information about functions and values could also inform threshold levels for concern. Bird-guild or camera-trap data could help answer questions about the relationship between canopy cover and habitat value by compiling and comparing data on species diversity, richness, or actions and interactions detected within different canopy closure ranges.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Planning:

- Marin Water identified oak woodlands and grasslands as priority habitat types in its Biodiversity, Fire, and Fuels Integrated Plan (Panorama Environmental, 2019) and outlined monitoring and management work in these habitats.

- Marin County Parks began implementation of its Vegetation and Biodiversity Management Plan (May & Associates, 2015). The plan summarizes the status of several preserves and work needed, as well as areas of priority oak woodlands.

- One Tam published the Marin Regional Forest Health Strategy (GGNPC, 2023) outlining actions required to manage forest types, including open-canopy oak woodlands. Priority work includes Douglas-fir removal and SOD inoculum load reduction.

Restoration:

- An FY21 Marin Water annual report shows 139 acres of Douglas-fir thinning and 230 acres of broom removal in oak woodlands and grasslands (combined). Marin Water annually controls broom and Douglas-fir in several hundred acres of oak woodland.

- Marin County Parks staff and contractors have been managing broom for decades in many areas, including some oak woodlands. They perform succession management by cutting encroaching Douglas-fir saplings and pine trees in some areas, with additional conifer and broom removal done by volunteers during restoration workdays. These efforts were sporadic and not well-documented in the past but have increased with additional staffing since 2011. Marin County Parks currently has 183 acres of broom under long-term management in oak woodlands.

- In 2022, Marin County Parks expanded its defensible space fuel reduction work at the community interface on the eastern edge of Baltimore Canyon Preserve to target invading broom, Douglas-fir, and mayten (*Maytenus boaria*) in 47 acres of oak and bay woodlands. An additional 80 acres of oak woodlands that had initially been the focus of broom removal for fuels reduction between 2011 and 2014 have been maintained through long-term broom-removal efforts, 2015 to the present.

Monitoring:

- 2018 Fine Scale Vegetation Map completed, as detailed elsewhere in this chapter.

- Five-year broom remapped in 2018, showing reduced rate of spread (Marin Water).

- Invasive plant species early-detection mapping and monitoring (Marin Water, National Park Service, Marin County Parks).

Past Work

Following are some of the previous stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Restoration:

- Succession management through volunteer restoration workdays to pull broom and cut encroaching Douglas-fir saplings in some areas, with additional conifer removal done by staff and contractors (Marin County Parks).
- Wide Area Fuel Load Reduction project at Pine Point, a joint project with Youth2Work; removed Douglas-fir and non-native pine invading oak woodlands and grasslands and replaced Douglas-fir with native SOD-resistant oaks to meet both ecosystem and fuels reduction goals (Marin Water).

Monitoring:

- Aerial photo monitoring and interpretation of vegetation communities repeated every five years to determine SOD distribution and impact (Marin Water).
- Invasive plant species early detection mapping and monitoring (Marin Water, National Park Service, Marin County Parks).

Outreach: Partnership with the University of California Cooperative Extension on public outreach to build awareness of SOD spread, impacts, and risk-reduction measures.

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as a part of the development of this report. These actions are not currently funded through agency programs and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Existing Program Support:

- **Targeted Non-native, Invasive Plant Species Control:** Develop and implement a mountain-wide targeted program to remove invasive plant species known to have impacts on open-canopy oak woodland species richness and structure, including panic veldt grass, cape ivy, cotoneasters, and brooms.

  Management: Implement oak woodlands actions in the Marin Regional Forest Health Strategy. Identify “superspreader” (SOD inoculum reservoir bay laurel trees) and remove within 10m of susceptible oak trees (Kozanitas et al., 2022). This should be prioritized during extended drought periods, when bay laurels showing signs of infection can be targeted as reservoirs. Any trees within 10m of susceptible oaks can be removed before a warm, wet spring allows them to jump-start a new wave of infection. Resprouts are often heavily browsed by deer, and it takes approximately five to ten years for them to become tall enough to rain infection on adjacent oaks. If accessible via trails, bay resprouts are also an easy target for volunteers.

Fuel Load Reduction, Roads, and Trails-related Management: Restore open-canopy oak woodland habitat by strategically expanding Wide Area Fuel Load Reduction projects, which often include the removal of target invasive species such as acacia, eucalyptus, broom, and small-diameter Douglas-fir.

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CHAPTER 7. SHRUBLANDS: COASTAL SCRUB AND CHAPARRAL

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

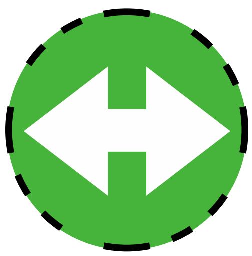
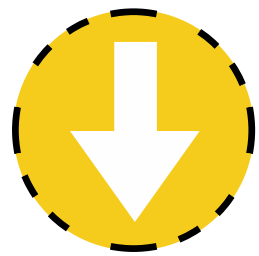
2016	2022
	
Condition: Good	**Condition:** Caution
Trend: No Change	**Trend:** Declining
Confidence: Moderate	**Confidence:** Moderate

FIGURE 7.1 CONDITION, TREND, AND CONFIDENCE FOR SHRUBLANDS, ONE TAM AREA OF FOCUS

The declines in condition and trend from what we knew in 2016 to our best current understanding in 2022 should be viewed with the understanding that in each of the two years, we measured slightly different things. Specifically, we have replaced what was Metric 3 in the 2016 report—"Acres without canopy-piercing Douglas-fir," which was meant to measure forest encroachment into shrublands—with the more general "Total acres." This change was necessary because our primary tool, the new 2018 Marin Countywide Fine Scale Vegetation Map (GGNPC et al., 2021), does not estimate shrublands conifer cover. Also, while total acres may be compared over time to determine shrublands' net loss or gain, looking at acres with Douglas-fir measures loss to forest but does not capture acres gained by shrublands expansion elsewhere.

However, not all of the differences in condition and trend between the two analyses are due to using different metrics. The condition of shrublands in the area of focus has been reduced from good in 2016 to caution in 2022 because new data and analyses indicate a higher level of threat and a greater loss of shrublands extent than was previously known. Numerous lines of evidence reveal that shrublands are losing acreage to forest succession due to fire suppression, and more shrublands acres are occupied by invasive plants than were previously known.

Differences in time series, classification, and mapping methodologies lower our confidence in trends derived from comparisons between the older vegetation maps and the new countywide map. For example, the 2016 version of this report utilized vegetation maps based on aerial imagery collected in 2014 for Marin Water (Aerial Information Systems, 2015), 2008 for Marin County Parks (Aerial Information Systems, 2008), and 1994 for the National Park Service and California State Parks (Shirokauer et al., 2003). In this chapter, we utilize the 2018 Fine Scale Vegetation Map (GGNPC et al., 2021) as a new baseline that can be used to measure changes in vegetation-acreage metrics from this point forward.

The 2018 countywide map provided an analysis standard for vegetation composition, structure, and distribution among the One Tam partner agencies that did not exist in 2016, when the partners were using different mapping methodologies. We have high confidence that this countywide map, which is current as of 2018 when the aerial imagery used to create the map was acquired, establishes an accurate and uniform baseline for vegetation community status across the One Tam area of focus.

A second significant change in this version is the recalibration of Metric 2 condition thresholds. The original thresholds were established as ≥ or <5,500 acres, whereas the new thresholds are Good: ≥5,200 acres and Caution: <5,200 acres. We reset the condition thresholds downward to be closer to the status in 2018, since the true status in 2016 is ambiguous.

METRICS SUMMARY

Metrics in Table 7.1 were used to assess the health of shrublands plant communities. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 7.1. Each metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 7.1 ALL SHRUBLANDS METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1: Core areas		
	2016	**2022**
Condition	Good	Caution
Trend	Unknown	No Change
Confidence	Low	Moderate
Metric 2: Acres without priority invasive plant species		
	2016	**2022**
Condition	Good	Caution
Trend	Declining	Unknown
Confidence	Moderate	Moderate
Metric 3: Total acres		
	2016	**2022**
Condition	N/A	Caution
Trend	N/A	Declining
Confidence	N/A	Moderate

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

Shrublands, also known as scrub or brush, are plant communities dominated by multi-stemmed woody plants typically <6 m tall. Shrublands extent and structure are often dynamically mediated by disturbances such as herbivory, fire, or salt spray. In Marin County, the two main shrublands divisions are chaparral and coastal scrub.

Chaparral—the most widespread and characteristic type of California shrublands—is dominated by sclerophyllous (hard-leaved) evergreen shrubs such as chamise, manzanita, and some ceanothus species. These drought-tolerant plants are adapted to the steep slopes; shallow, rocky soils; hot, dry summers; and wet winters of the Coast Ranges. Chaparral species are adapted to periodic stand-replacing fires with return intervals of between 20 and 100 years. Persistent soil seed banks readily germinate after a fire, and some species resprout from thick root burls. Serpentine chaparrals are open, low-growing shrublands associated with the harsh conditions presented by serpentine soils (see Chapter 10). On Mt. Tam, chaparral tends to occupy elevations above 400 meters—the average altitude of the summer marine inversion layer (Johnstone & Dawson, 2010)—in which summers are hotter and drier, winters are colder, and uplift brings more precipitation. Maritime chaparral, which occurs on poorly developed soils at lower elevations in the fog belt, is a notable exception (Sawyer et al., 2009).

Coastal scrub is dominated by relatively soft-stemmed, woody shrubs that thrive in the narrow zone of maritime climate along the California coast. Coyote brush (*Baccharis pilularis*), an evergreen shrub, is characteristic of the northern division of coastal scrub (Ford & Hayes, 2007) that predominates on Mt. Tam. Coastal scrub is typically found on well-developed soils below 400 meters, where summer fog is frequent. Maritime influence in this zone ameliorates summer drought stress, moderates seasonal temperature extremes, and exposes vegetation to salt-laden air masses. In hotter, drier settings, drought-deciduous species such as California sagebrush (*Artemisia californica*) and sticky monkeyflower (*Mimulus aurantiacus*) are favored. In cooler, wetter settings, winter-deciduous species such as brambles (*Rubus* spp.) and hazelnut (*Corylus cornuta*) tend to predominate. In the absence of grazing and fire, coyote brush frequently invades grasslands, and stands of coastal scrub can be mid-successional or persistent (Heady et al., 1988).

Mt. Tam's shrublands may be seen as indicators of successional processes, disturbance, and wildlife habitat quality. For example, the preservation of large blocks of coastal scrub and chaparral is critical to the long-term viability of many bird species (California Partners in Flight, 2004). Intact shrublands are fairly resistant to plant invasions, in part due to the high densities of small herbivores that shelter and forage in the understory (Lambrinos, 2002). However, disturbances that create openings can be exploited by invasive plants (D'Antonio, 1993).

CURRENT CONDITION AND TREND

There are approximately 7,817 acres of shrublands—or 20% of the One Tam area of focus—with 4,113 acres of coastal scrub, 3,539 acres of chaparral (including 351 acres of maritime chaparral and 749 acres of serpentine chaparral), and 165 acres of unclassified shrublands. (Figures 3.2 and 7.2).

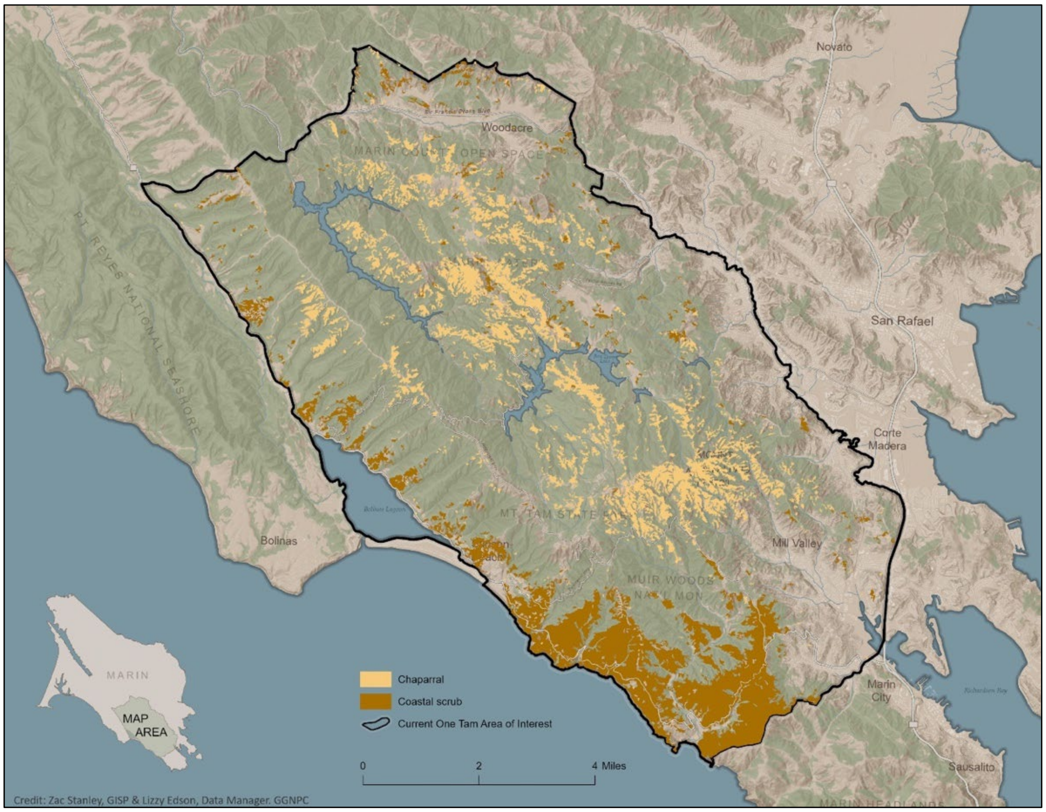


FIGURE 7.2 CHAPARRAL AND COASTAL SCRUB, ONE TAM AREA OF FOCUS

DESIRED CONDITION AND TREND

The desired condition for the One Tam area of focus is the persistence of large, weed-free blocks of shrublands vegetation that provide habitat for plant and wildlife species sensitive to fragmentation. As forested habitats have replaced shrublands in many locations over the past century of fire exclusion, preservation of shrublands acreage along forest edges has become even more desirable.

STRESSORS

Invasive Species Impacts: The dense canopy created by mature chaparral makes it resistant to invasion by non-native plant species (Dickens & Allen, 2014). While large, intact patches of coastal scrub are also resilient to invasion, coastal scrub is generally less dense than chaparral, making it more vulnerable, especially in gaps and along patch edges. Key invaders of coastal scrub on Mt. Tam include licorice plant (*Helichrysum petiolare*), thoroughwort (*Ageratina adenophora*), jubata grass (*Cortaderia jubata*), broom species (*Cytisus, Genista, Spartium*), Cape ivy (*Delairea odorata*), and Monterey pine (*Pinus radiata*).

Climate Vulnerability: A statewide model estimates that coastal scrub and chaparral will likely experience low to moderate climate exposure throughout mid- to end of the century (Thorne et al., 2017), and a Bay Area model forecasted a spatial reduction in coniferous and evergreen broadleaf forests and increases in oak woodlands, shrublands, and grasslands in most future climate scenarios (Ackerly et al., 2012). A hotter, dryer future would generally favor expansion of chaparral communities. However, even chaparral species with vascular systems highly resistant to drought-induced cavitation are vulnerable to prolonged droughts due to their shallow rooting depth (Paddock et al., 2013). Thus, altered precipitation patterns could have negative impacts on some of the more rare, non-resprouting manzanitas and ceanothus, such as the Mt. Tamalpais manzanita (*Arctostaphylos montana* ssp. *montana*) and the Point Reyes ceanothus (*C. gloriosus* var. *exaltatus*). Coastal scrub composition may shift dramatically with changes in maritime temperature and precipitation.

Fire Regime Change: Fire-adapted chaparral and coastal scrub communities may be replaced by hardwood or coniferous forest if fire exclusion alters the natural fire-return interval (Cornwell et al., 2012; Keeley, 2005; Callaway & Davis, 1993). Chaparral is somewhat more resilient to such senescence risk due to its long-lived seedbanks, which may sprout even after a century-long fire interval (Zedler, 1995). And although mechanical tree removal can rescue mature chaparral species from overshading, it does not provide the heat shock or chemical cues that seeds of many chaparral species require to break their dormancy and germinate (Keeley, 1991).

Disease: Sudden Oak Death (SOD), caused by the water mold *Phytophthora ramorum*, has devastated tanoak and coast live oak populations (see Chapter 6), but it also damages or kills many native shrub species. Recently, other introduced *Phytophthora*s have emerged in California as harmful wildland plant pathogens. These water molds thrive in nurseries and can be inadvertently introduced via restoration plantings. In 2015, the federally watchlisted species *P. tentaculata* was found in wildland plantings in Alameda and Santa Clara Counties. Elsewhere in California, infestations of *P. cinnamomi, P. cambivora, and P. cactorum* have decimated stands of rare and endangered manzanita and ceanothus species, and have had severe impacts on other native species, including madrone (*Arbutus menziesii*) and coffeeberry (*Frangula californica*).

Direct Human Impacts: Large blocks of shrublands are resilient to invasions and other threats from edge effects, but become more vulnerable when fragmented by roads, trails, fuelbreaks, and other disturbance pathways (Lambrinos, 2002; Kemper et al., 1999).

Habitat Disturbance/Conversion/Loss: In the absence of fire, Douglas-fir invades many different kinds of plant communities, including coastal scrub (Chase et al., 2005) and chaparral (Horton et al., 1999). Shade-intolerant scrub and chaparral species are vulnerable to the shading concomitant with conifer invasion.

CONDITION AND TREND ASSESSMENT

METRICS

METRIC 1: CORE AREAS

Baseline: As of 2018, 33 blocks of contiguous native-shrub-dominated vegetation >30 acres had been mapped in the One Tam area of focus, for a total of >5,100 acres (GGNPC et al., 2021). Of that total, 1,689 acres were chaparral and 3,415 acres were coastal scrub. We consider this to be a robust baseline against which to compare future mapping results These core areas (Figure 7.3) comprise 65% of shrublands in the One Tam area of focus, providing habitat for shrublands plants, birds, and other wildlife sensitive to edge effects, fragmentation, and invasion.

Condition Goal: Maintain core areas of shrub-dominated vegetation at >30 acres in size.

Condition Thresholds:

- **Good:** At least 5,200 total acres of native shrublands in patches that are ≥30 acres.
- **Caution:** Fewer than 4,500–5,200 acres of native shrublands in patches that are ≥30 acres.
- **Significant Concern:** Fewer than 4,500 acres of shrublands in patches that are ≥30 acres.

Current Condition:

2016: Good

Forty >30-acre blocks of native-shrub-dominated vegetation were mapped in the One Tam area of focus, for a total of >5,500 acres.

2022: Caution

The estimated number and acreage of core areas has been reduced since 2016. There are seven fewer large blocks of shrublands and 400 fewer acres in the current vegetation map than in the 2016 analysis. This discrepancy may be due to methodological differences between the 2018 Fine Scale Vegetation Map (GGNPC et al., 2021) and older maps, and/or to actual shrublands loss to forest encroachment. (Shrublands-to-forest succession has been well documented in Marin County over the past half-century [Startin, 2022; Hsu et al., 2012; Chase et al., 2005].) We have revised the condition thresholds for good and caution downward from 5,500 acres in 2016 to 5,200 acres for this report because we are resetting the baseline closer to the status in 2018. We also acknowledge that some shrublands blocks are likely to have been reduced in extent by forest succession since the 1994 National Park Service and California State Parks vegetation maps were produced.

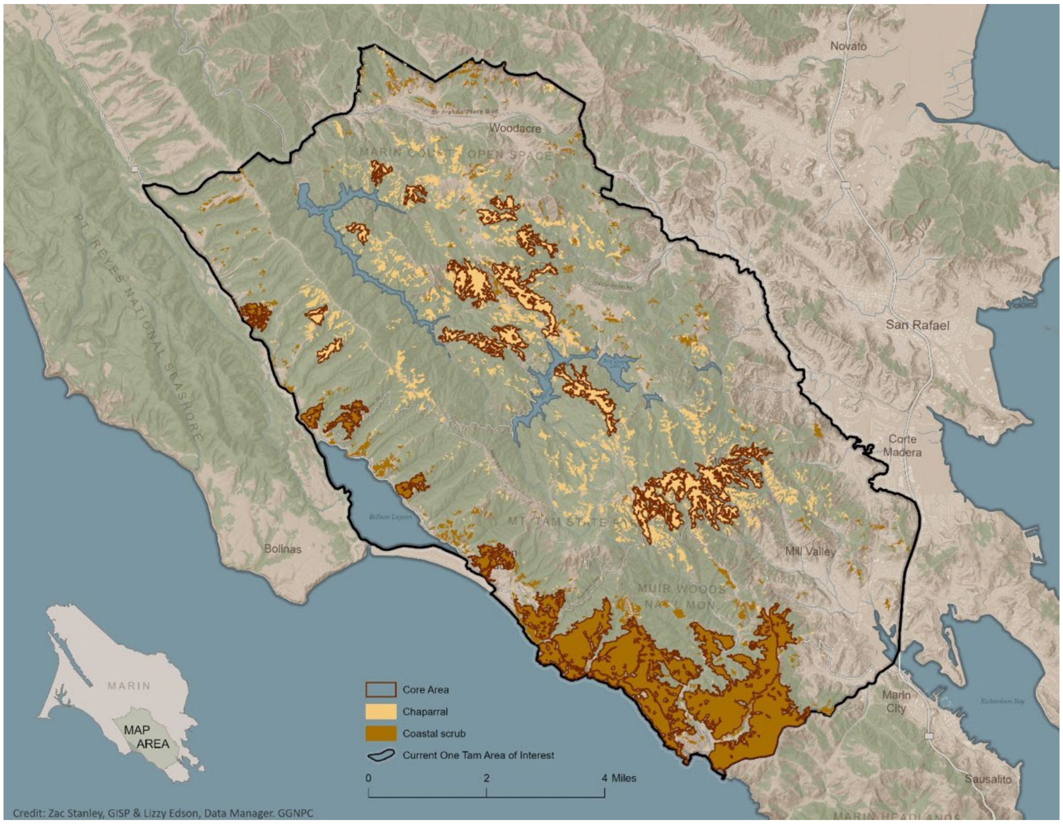


FIGURE 7.3 CORE CHAPARRAL AND COASTAL SCRUB LOCATIONS, ONE TAM AREA OF FOCUS

Trend:

2016: Unknown

A reduction of ±10% in total acreage in core areas of ≥30 contiguous acres over a five-year period was determined necessary to indicate a change. However, there were insufficient data to establish a trend.

2022: No Change

The exact rate of change in core areas is unknown, but it is unlikely to have exceeded ±10% over five years. A study from Bolinas Ridge showed a 51% loss of shrublands-to-forest succession over 70 years, which is a rate of about 4% every five years.

Confidence:

2016: Low

Time-series vegetation maps from Marin Water (Aerial Information Systems, 2015) showed that overall, shrublands were stable. Although similar time-series data were not available for Marin County Parks, National Park Service, or California State Parks, the trend was considered likely to be similar. However, confidence regarding core patch sizes was low. The National Park Service 1994 vegetation map was used to identify core areas in these jurisdictions, but the underlying data had not been updated since the map was originally produced. Active Marin Water and Marin County Parks fuelbreak expansion and trail realignment programs also had the potential to fragment shrub patches at a scale that was not discernable in landscape-level mapping.

2022: Moderate

The 2018 Fine Scale Vegetation Map (GGNPC et al., 2021) establishes a reliable baseline for core shrublands patches, but—due to disparate time series, classifications, and mapping methodologies—does not support direct comparison with earlier vegetation maps used by the One Tam partner agencies. While several studies indicate that forests are slowly encroaching on shrublands in some locations on Mt. Tam, the rate of succession across the area of focus is unknown.

METRIC 2: ACRES WITHOUT PRIORITY INVASIVE PLANT SPECIES

Baseline: Invasive species threaten shrublands composition, structure, and function. Key invaders of coastal scrub in the One Tam area of focus include licorice plant, thoroughwort, jubata grass, broom species, Cape ivy, and Monterey pine. Field observations indicate that most non-native, invasive species in shrublands communities exist at the periphery; at the wildland-urban interface; along roads, trails, and fuelbreaks; or where the canopy has been otherwise disturbed.

Condition Goal: Native shrublands with <5% cover of high-priority invasive plant species.

Condition Thresholds:

- **Good:** 90% or more of native shrublands acres are free of priority invasive plants or have <5% cover of priority invasive plants.
- **Caution:** 80%–90% of native shrublands acres are free of priority invasive plants or have <5% cover of priority invasive plants.
- **Significant Concern:** Less than 80% of native shrublands acres are free of priority invasive plants or have <5% cover of priority invasive plants.

Current Condition:

2016: Good

Data from Marin Water (Williams, 2014; Panorama Environmental, 2019) showed that the most abundant invasive species, French broom (*Genista monspessulana*) and Scotch broom (*Cytisus* *scoparius*), were present in <4% of Marin Water shrublands (116 acres), and that other weeds were present in lower amounts.

2022: Caution

Mapping data from all four partner agencies show that priority invasive plants occupy 1,124 gross acres of shrublands in the One Tam area of focus, or 14% of total shrublands acres (Figure 7.4). The majority of infested acres occur in coastal scrub vegetation rather than chaparral. Net infested acres were not calculated for this report, but, because many of the largest mapped patches have sparse cover of priority invasives (<5%), they certainly comprise significantly <14% of shrublands.

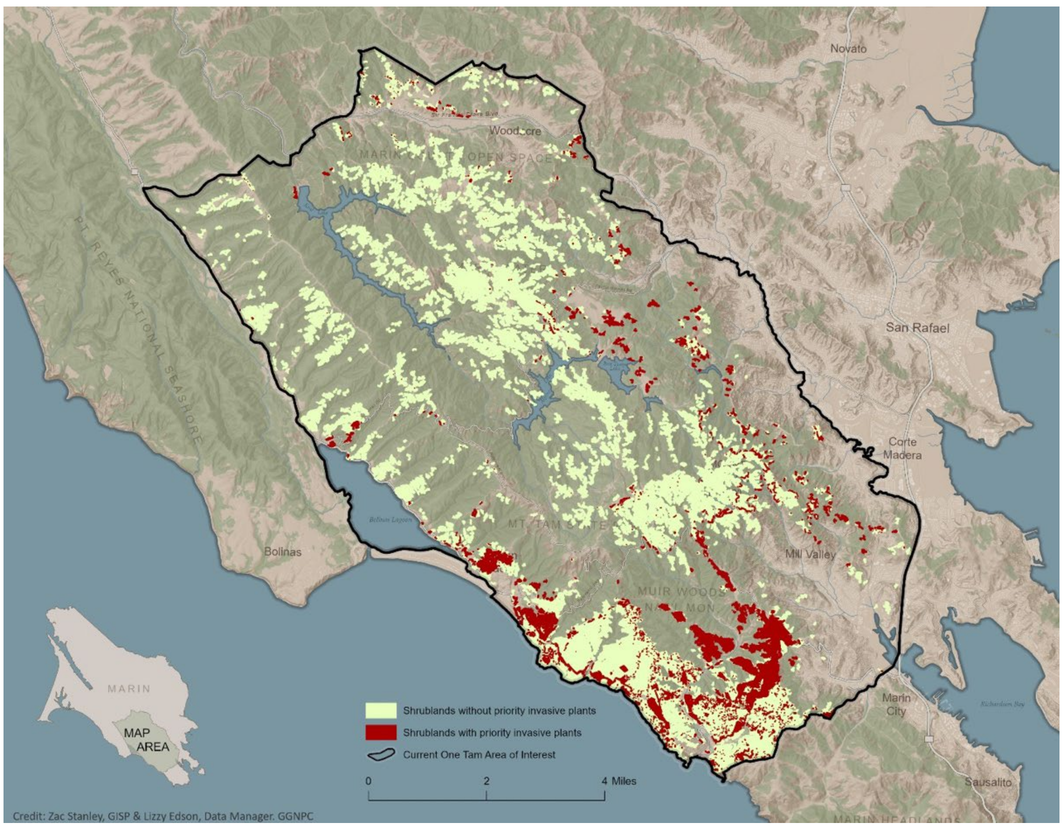


FIGURE 7.4 SHRUBLANDS PATCHES OCCUPIED BY PRIORITY INVASIVE PLANT SPECIES

Trend:

2016: Declining

Despite an active weed-management program, the acreage of Marin Water shrublands infested by French broom increased by 9%, or 9.5 acres, between 2009 and 2013. It should be noted that these results were based on visual population estimates over large areas and likely had a high error rate. Nonetheless, it is clear that French broom has steadily expanded across Mt. Tam since the mid-20th century. A trend of declining with moderate confidence was based on observed increases of broom on Marin Water lands and an assumption of similar impacts on the other partner lands.

2022: Unknown

The 2018 Fine Scale Vegetation Map (GGNPC et al., 2021) establishes a reliable baseline for shrublands extent but—due to disparate time series, classifications, and mapping methodologies—does not support direct comparison to earlier vegetation maps used by partner agencies. One Tam partner agencies now share the Calflora Weed Manager database and use similar mapping protocols, which should improve time-series comparisons in the future.

Confidence:

2016: Moderate

Weed maps on Marin Water lands were consistently updated once every five years. While management and surveillance did not systematically cover all shrublands on National Park Service and California State Park lands, large areas are visible from the extensive road and trail network and were considered to be relatively free of dense infestations of invasive species.

2022: Moderate

All One Tam partner agencies' weed control and early detection programs now provide relatively comprehensive surveillance and mapping cover throughout most of the area of focus, and the countywide vegetation map and shared Calflora Weed Manager database also enable comprehensive status assessments across the area of focus. However, while our confidence in the current status of invasive plants is relatively high, our confidence in trend detection is relatively low.

METRIC 3: TOTAL ACRES

Baseline: In the One Tam area of focus, a total of 7,817 acres of shrublands are currently mapped, including 4,113 acres of coastal scrub and 3,539 acres of chaparral (including 351 acres of maritime chaparral and 749 acres of serpentine chaparral) (GGNPC et al., 2021). Researchers have documented significant rates of forest succession leading to shrublands losses in Marin County over the past 70 years (Startin, 2022; Hsu et al., 2012; Chase et al., 2005), with Douglas-fir being the dominant colonizer.

Condition Goal: At least 7,580 net acres (97%) of shrublands are extant within 10 years.

Condition Thresholds:

- **Good:** Net shrublands loss of <23 acres per year (<0.3%/year).
- **Caution:** Net shrublands loss of >23 to 60 acres per year (>0.3%/year.).

- **Significant Concern:** Net shrublands loss of >60 acres per year (>0.75%/year).

Current Condition:

2016: N/A

We have changed this metric from "Acres without canopy-piercing Douglas-fir" to "Total acres," and are resetting the baseline to the current acreage. Since this is a new metric, there is no parallel condition assessment for 2016.

2022: Caution

Significant shrublands-to-forest succession has been documented on Bolinas Ridge over the past 70 years (Startin, 2022). Although shrublands expanded into grasslands during this time, there was a net loss of 51% of shrublands-to-forest succession. The 2014 Marin Water vegetation map (Aerial Information Systems, 2015) showed that 12% of shrublands habitat contained taller Douglas-fir, indicating that forestation of shrublands has continued apace.

Trend:

2016: N/A

A lack of consistent time-series data across the One Tam area of focus precludes a robust retroactive trend assessment for 2016. However, it is clear from quantitative analyses and qualitative observations that forested areas have inexorably expanded into shrublands relatively recently, as described below.

2022: Declining

Although we cannot make a comparison to 2016 to measure change over time using this new metric, many lines of evidence reveal that shrublands are giving way to forests in the One Tam area of focus. It is less clear what the overall rate of forest succession is, or if it is higher in some places than others. Table 7.2 lists three relevant studies conducted at different spatial and temporal scales that found different rates of shrublands loss to forest succession.

TABLE 7.2. ESTIMATED RATES OF SHRUBLANDS LOSS IN MARIN COUNTY, EXTRAPOLATED FROM THREE STUDIES.

Study Area	Years	Percent Shrublands Replaced by Forest
Palomarin Field Station, Marin County*	1981–2000	1.25%
Bolinas Ridge, Marin County**	1952–2018	0.77%
Sonoma, Marin Counties***	1985–2010	0.32%

**Chase et al., 2005; **Startin, 2022; ***Hsu et al., 2012*

Confidence:

2016: N/A

As a new metric in this updated report, there is no equivalent 2016 confidence level.

2022: Moderate

Quantitative and qualitative evidence indicate an ongoing trend of shrublands-to-forest succession, but time-series data that would determine the rate of change and degree of concern for the One Tam area of focus as a whole are lacking.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

- Marin Water vegetation maps (2009, 2014; GGNPC et al., 2021).
- Marin County Parks vegetation map, created with a methodology similar to that used by Marin Water (2008; Aerial Information Systems, 2008).
- National Park Service vegetation map (1994, used for National Park Service and California State Parks; Schirokauer et al., 2003).
- One Tam early detection and invasive plant mapping (Calflora, 2022).
- Marin Countywide Fine Scale Vegetation Map, 2018 (GGNPC et al., 2021).

ACREAGE CALCULATIONS

TABLE 7.3 METHODS AND DATA USED TO CALCULATE ACREAGES OF SHRUBLANDS VEGETATION COMMUNITIES

Indicator Plant Community	Types Included	Metrics	How Derived
Shrublands	• *Adenostoma fasciculatum* Alliance • *Arctostaphylos* (*bakeri, montana*) Alliance • *Arctostaphylos* (*canescens, manzanita, stanfordiana*) Alliance • *Arctostaphylos* (*nummularia, sensitiva*)–	Core areas	Aggregated all mapped shrublands vegetation polygons with shared boundaries, and selected polygons with areas >30 acres.
		Acres without priority invasive species	Dissolved all partner agency invasive plant polygons into a single layer. Summed acreage of all shrublands areas not overlaying the invasive plant layer.

Indicator Plant Community	Types Included	Metrics	How Derived
	Chrysolepis chrysophylla Alliance • *Arctostaphylos glandulosa* Alliance • *Artemisia californica–Salvia leucophylla* Alliance • *Baccharis pilularis* Alliance • *Ceanothus cuneatus* Alliance • *Ceanothus thyrsiflorus* Alliance • *Corylus cornuta/Polystichum munitum* Association • *Eriophyllum staechadifolium–Erigeron glaucus–Eriogonum latifolium* Alliance • *Frangula californica* ssp. *californica–Baccharis pilularis/Scrophularia californica* Association • *Gaultheria shallon–Rubus* (*ursinus*) Alliance • *Lotus scoparius–Lupinus albifrons–Eriodictyon* spp. Alliance • *Quercus durata* Alliance • *Quercus wislizeni–Quercus chrysolepis* (shrub) Alliance • Shrub Fragment • *Toxicodendron diversilobum–Baccharis pilularis* Association	Total acres	Summed the area of all mapped shrublands polygons.

(See Chapter 2, Indicator Analysis Methodology, for additional information about the overall methodology used for vegetation community analyses.)

INFORMATION GAPS

Plant Pathogen Early Detection, Inventory, and Surveillance: The presence and distribution of plant pathogens on Mt. Tam is incompletely known. Early detection and rapid response to incipient pathogens can prevent their unchecked spread. Inventory, mapping, and impact assessments for potentially harmful *Phytophthora* species such as *P. cactorum, P. cambivora, P. cinnamomi, and P. tentaculata* in susceptible shrub communities and restoration sites would provide valuable information for assessing the health of these areas.

Shrublands Plant Community Change Drivers: The demographics of most species in the shrublands communities on Mt. Tam are not well understood. A widespread coffeeberry dieback was observed by National Park Service staff during a historic drought in 2015. Such punctuated disturbances caused by drought, disease, or fire may result in rapid shifts in community composition that persist due to climate change. Current monitoring efforts, which are focused on specific vegetation types, do not capture compositional change in all communities at the landscape scale.

Time-Series Data: Shrublands, particularly coastal scrub, are among the more dynamic vegetation types in the One Tam area of focus. Vegetation maps should be updated in five-year intervals to detect expansions and contraction among grasslands, oak woodlands, and shrub vegetation types. Detection of Douglas-fir incursions is likely to require a longer time frame. Douglas-fir encroachment may also be balanced by the expansion of shrublands into grasslands.

Non-native, Invasive Species Impacts: Invasive species surveillance focuses on road and trail corridors and does not systematically cover shrublands' off-trail areas.

Percent tree cover: The 2018 Fine Scale Vegetation Map (GGNPC et al., 2021) did not measure percent tree cover by stand in shrublands. This is an important metric that can be used to monitor rates of forest succession, and so we recommend including it in future vegetation maps.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Encroachment Management: All One Tam partner agencies implemented succession management projects through Douglas-fir removal in shrublands. Significant projects included work in coastal scrub at Kent Canyon and Diaz Ridge, and in chaparral on San Geronimo Ridge and White Hill.

Invasive Species Management: There has been ongoing collaboration and investment in invasive plant control and early detection and rapid response programs among all One Tam partner agencies.

Disease Management: In response to the emerging threat of *Phytophora* introductions via nursery stock, the National Park Service and Parks Conservancy developed and implemented stringent sanitation protocols in their native plant nurseries. They also temporarily halted the production and outplanting of native host plant species while updating their facilities. All One Tam partner agencies adopted new construction best management practices to prevent the introduction or spread of these pathogens.

Past Work

Following are some of the stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Management:

- Coyote brush (*Baccharis pilularis*) reduction efforts were carried out where coastal scrub had expanded into grasslands (California State Parks).
- Ongoing brush reduction was scheduled in designated fuel-load-reduction zones, often in conjunction with grassland and open-canopy oak woodland preservation goals (Marin Water, Marin County Parks).

Monitoring:

- Aerial photo monitoring and interpretation of vegetation communities is repeated every five years (Marin Water).
- The One Tam Early Detection Rapid Response program covers all roads and trails, and selected drainages in the area of focus every three years (all agencies). Weed distribution maps are updated once every five years (Marin Water).

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists during the development of this report. These actions are not currently funded through agency programs and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Existing Program Support:

- **Succession Management:** In the continued absence of fire, sustain and expand the removal of encroaching Douglas-fir in shrublands.
- **Invasive Plant Management:** Sustain invasive plant control efforts in shrublands across the One Tam area of focus.

- **Invasive Plant Detection and Mapping:** Test efficacy of unmanned aerial vehicles (drones) for detecting and mapping invasive plants in remote locations.
- **Education:** Conduct community outreach and advocacy for fire preparedness and ecologically sound fuel management, including potential benefits of controlled burning.

Research:

- **Forest Succession Modeling:** To inform management priorities, analyze historical aerial imagery to determine patterns and rates of forest encroachment into different vegetation types across the One Tam area of focus.
- **Fire Regime:** To maintain chaparral systems and reduce catastrophic fire hazards, undertake exploratory modeling and risk analyses that investigate the potential for controlled burns across the One Tam area of focus.

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CHAPTER 8. MARITIME CHAPARRAL COMMUNITY ENDEMICS

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

2016	2022
Condition: Significant Concern	**Condition:** Significant Concern
Trend: Declining	**Trend:** Declining
Confidence: High	**Confidence:** Moderate

FIGURE 8.1 CONDITION, TREND, AND CONFIDENCE FOR MARITIME CHAPARRAL COMMUNITY ENDEMICS, ONE TAM AREA OF FOCUS

An incomplete metric in the 2016 report (Metric 5, acres and spatial distribution of *Phytophthora*-impacted habitat) has been recategorized as an important data gap and removed as a metric for this update. *Phytophthora ramorum* and *P. cinnamomi* are both known to affect chaparral plant species. Staff have observed mortality events consistent with *Pytophthora* infection, but the extent and impacts to maritime chaparral in the One Tam area of focus have not been quantified, and a comprehensive pathogen study is needed. Because this metric was not used to calculate the overall condition, trend, or confidence in the 2016 version, removing it has not affected our ability to make a fair comparison between years.

No significant changes in the metrics used for this indicator have been detected since 2016. National Park Service staff conducted surveys to monitor rare chaparral endemics in 2017 and 2020. These surveys did not encompass all known populations, so there is lower confidence in condition and trends than there was in 2016.

METRICS SUMMARY

Metrics in Table 8.1 were used to assess the health of maritime chaparral community endemics. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 8.1. Each metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 8.1 ALL MARITIME CHAPARRAL COMMUNITY ENDEMICS METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1: Number of individual Mason's ceanothus		
	2016	**2022**
Condition	Significant Concern	Significant Concern
Trend	Declining	Declining
Confidence	High	Moderate
Metric 2: Number of individual Point Reyes ceanothus		
	2016	**2022**
Condition	Significant Concern	Significant Concern
Trend	Declining	Declining
Confidence	High	Unknown
Metric 3: Number of individual Marin manzanita		
	2016	**2022**
Condition	Significant Concern	Significant Concern
Trend	Declining	Declining
Confidence	High	Moderate
Metric 4: Extent of rare species		
	2016	**2022**
Condition	Good	Good
Trend	No Change	No Change
Confidence	High	Moderate

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

Special status plant species and sensitive plant communities are often found clustered in areas with unusual geology, soils, aspects, elevations, microclimates, or a combination of these attributes. Mt. Tam has a number of microclimates, the result of its unique geography and location near the coast. Maritime chaparral, a community associated with several special status plant species, occurs on western ridgelines of the mountain that are subject to the marine layer.

Manzanitas characteristically dominate maritime chaparral, which is found on coastal slopes subject to summer fog or on ocean-facing uplands that receive heavy winter rainfall. More than half of the 95 species and subspecies of manzanita in California are locally endemic, occurring in lowlands adjacent to the coast and within the summer marine fog zone (Vasey & Parker, 2014). This abundance of locally endemic shrub species along the California coast results in a pattern of exceptional *beta* diversity, or high levels of species turnover in community composition across space (Vasey et al., 2014). As a result, maritime chaparral communities are recognized as one of the state's most diverse woody communities (Sawyer et al., 2009).

Maritime chaparral plant species of special interest in the One Tam area of focus include:

- The rare Marin manzanita (*Arctostaphylos virgata*). California Rare Plant Rank 1B.2: Plants rare, threatened, or endangered in California and elsewhere, moderately threatened in California (CNPS, 2022)

- Two rare wild lilacs:
    - Mason's ceanothus (*Ceanothus masonii*). California Rare Plant Rank 1B.2: Plants rare, threatened, or endangered in California and elsewhere, moderately threatened in California (CNPS, 2022)

    - Point Reyes ceanothus (*C. gloriosus* var. *exaltatus*). California Rare Plant Rank 4.3: Watch List: Plants of limited distribution, not very threatened in California (CNPS, 2022)

- Coinleaf manzanita (*Arctostaphylos sensitiva*). This species is prominent in maritime chaparral and is regionally endemic in the Santa Cruz Mountains and on Mt. Tam. Thus, it is a good indicator of maritime chaparral, complementing other locally endemic manzanita and ceanothus species in this community.

Maritime chaparral species like these can be used as indicators of biological integrity or diversity, natural disturbance regime, and habitat quality.

CURRENT CONDITION AND TREND

Maritime chaparral, a fog- and fire-dependent plant community of concern in California, is found in patches along California's central coast, from Santa Barbara to Sonoma County. The community on Bolinas Ridge is the best-known patch within the One Tam area of focus. Marin Water and National Park Service rare plant monitoring data from 2009 to 2016 detected approximately 100 individual Mason's ceanothus on Bolinas Ridge. The southerly slopes of Mt. Tam also support some stands of maritime chaparral that are smaller and less continuous than those on Bolinas Ridge.

Maritime chaparral communities on Mt. Tam are experiencing heavy Douglas-fir (*Pseudotsuga menziesii*) encroachment as a result of fire suppression, and fire-dependent shrubs are not recruiting. Based on National Park Service and Marin Water staff observations of an abundance of senescent and dead chaparral shrubs under encroaching Douglas-fir stands, the extent of maritime chaparral communities appears to be declining. However, even with fire suppression, few areas supporting chaparral escape fire for very long, and senescent stands often recover after fire-return intervals of more than a century, thanks to the persistence of long-lived soil seedbanks (Keeley, 2007).

The rare species chosen for the metrics that follow are restricted to maritime chaparral and are dependent on the fire and fog that allow these communities to persist. Consequently, their status and trends reflect those of the broader maritime chaparral community.

DESIRED CONDITION AND TREND

The desired condition is to maintain viable populations of maritime chaparral community endemics over a minimum of 90 acres of endemic habitat.

STRESSORS

Climate Vulnerability: Potential changes to fog patterns as a result of climate change could threaten maritime chaparral species dependent on summer fog for moisture. However, many questions remain regarding predicted fog dynamics in relation to climate change. While fog frequency decreased in coastal California by approximately 30% during the second half of the 20th century (Johnstone & Dawson, 2010), the number of foggy days is highly variable from year to year and no discernable trends have been identified over the past 20 years (Werner et al., 2022). Under a "warm/dry" future, one statewide model predicts low climate exposure for 80% of the current extent of maritime chaparral, while a "warm/wet" future would result in high climate exposure for the same extent (Thorne et al., 2017). Regardless of changes in total annual precipitation, climate scenarios tend to agree that seasonal weather is likely to become more erratic, with longer dry spells between rain events. This would result in greater drought stress, which is particularly problematic for "non-sprouting" species such as the rare species considered in this chapter, which are relatively shallow rooting (Paddock et al., 2013).

Fire Regime Change: Mt. Tam's vegetation mosaic is dynamic, and succession occurs under natural conditions largely mediated by the fire cycle. The removal of fire as a key ecosystem process is facilitating conifer encroachment in grasslands, chaparral, and oak woodlands. Chaparral, which is adapted to fire-return intervals of 30 to 150 years, requires periodic fire to regenerate (Kauffmann et al., 2015). Furthermore, shade-intolerant maritime chaparral species are vulnerable to over-topping by conifers in the absence of fire, which is heavily suppressed in the One Tam area of focus.

Disease: Manzanita species in the One Tam area of focus have been affected by the fungal pathogen *Phytophthora ramorum,* which causes Sudden Oak Death (SOD). *Phytophthora cinnamomi*, which is particularly deadly to some manzanitas, is also known to be on Mt. Tam. In general, pathogen-related dieback of large stands of madrone and manzanita would be expected to cause effects very similar to those of SOD, including changes in species composition in affected vegetation (primarily types of chaparral), changes in ecosystem functions, loss of food sources for wildlife, changes in fire frequency or intensity, decreased water quality due to increased erosion from exposed soil surfaces, and increased opportunities for weed invasion in open sites (Leonard Charles Associates, 2009).

Direct Human Impacts: Road and trail work can introduce plant pathogens via improperly or inadequately cleaned equipment. Rare chaparral species such as Marin manzanita do not sprout if they are cut during trail clearing or by mowing along the sides of fire roads.

CONDITION AND TREND ASSESSMENT

METRICS

METRIC 1: NUMBER OF INDIVIDUAL MASON'S CEANOTHUS

Baseline: National Park Service and Marin Water staff observed approximately 100 individual Mason's ceanothus in 2016 on Bolinas Ridge.
Condition Goal: Increase to and maintain 200 individual Mason's ceanothus on Bolinas Ridge, with both mature and juvenile plants present.

Condition Thresholds:

- **Good:** More than 160 individual Mason's ceanothus.
- **Caution:** 120-160 individual Mason's ceanothus.
- **Significant Concern:** Fewer than 120 individual Mason's ceanothus.

Current Condition:

2016: Significant Concern

The presence of only about 100 individuals warranted a status of significant concern.

2022: Significant Concern

The National Park Service monitored selected Bolinas Ridge populations in 2017 using abundance classes (e.g., 1–10, 11–100, etc.) to count patches of individuals. The results confirm a minimum of 58 individuals, with a median estimate of 240 and a maximum of 421. These results warrant a continued status of significant concern. Although there is a large confidence interval for the monitoring results, it is unlikely that the number of individuals has changed significantly since 2016.

Trend:

2016: Declining

Patterson (1990) noted "a few hundred" Mason's ceanothus plants, and their numbers have been in decline since. Setting trend thresholds is difficult for this fire-dependent species. However, a change of >10% in the number of individuals and size class would constitute a change in trend.

2022: Declining

In the absence of fire or management interventions, we anticipate that the slow decline in numbers will continue, although the rate of loss is uncertain.

Confidence:

2016: High

Monitoring efforts between 2009 and 2016 were reasonably comprehensive.

2022: Moderate

Monitoring efforts between 2016 and 2022 did not survey all known populations and utilized abundance classes, resulting in a large confidence interval of 58 to 421 individuals.

METRIC 2: NUMBER OF NNDIVIDUAL POINT REYES CEANOTHUS

Baseline: National Park Service rare plant data recorded approximately 15 individual Point Reyes ceanothus in 2013. Marin Water staff have noted fewer, and no recruitment.
Condition Goal: Increase to and maintain 30 individual Point Reyes ceanothus on Bolinas Ridge, with both mature and juvenile plants present.

Condition Thresholds:

- **Good:** More than 24 individual Point Reyes ceanothus.
- **Caution:** 16-24 individual Point Reyes ceanothus.
- **Significant Concern:** Fewer than 16 individual Point Reyes ceanothus.

Current Condition:

2016: Significant Concern

The presence of fewer than half the desired number of plants warranted a status of significant concern.

2022: Significant Concern

Point Reyes ceanothus has not been monitored since 2016, but it is unlikely that the condition has changed significantly in the past six years.

Trend:

2016: Declining

Setting trend thresholds is difficult with this fire-dependent species, but a change of >10% in the number of individuals would constitute a change in trend.

2022: Declining

In the absence of fire or management, we anticipate that the slow decline in numbers will continue, although the rate of loss is uncertain.

Confidence:

2016: High

Monitoring efforts between 2009 and 2016 were reasonably comprehensive.

2022: Unknown

National Park Service and Marin Water staff have not monitored known populations since 2016.

METRIC 3: NUMBER OF INDIVIDUAL MARIN MANZANITA

Baseline: Between 2010 and 2016, 40 individual Marin manzanitas were recorded by the National Park Service in Golden Gate National Recreation Area lands on Bolinas Ridge. Marin Water staff have recorded fewer than 30 consistently over the past decade, with no recruitment noted.

Condition Goals:

- Increase to and maintain 200 individual Marin manzanita on Bolinas Ridge, with both mature and juvenile plants present.
- Determine the potential to increase the number of individual Marin manzanita on the south slope of Mt. Tam and better assess the species' presence and potential for recruitment.

Condition Thresholds:

- **Good:** More than 160 individual Marin manzanita.
- **Caution:** 120-160 individual Marin manzanita.
- **Significant Concern:** Fewer than 120 individual Marin manzanita, and/or no recruitment.

Current Condition:

2016: Significant Concern

The presence of less than half of the desired number of plants warranted a status of significant concern.

2022: Significant Concern

The National Park Service monitored selected Bolinas Ridge populations in 2020, using abundance classes to count patches of individuals. The results confirm a minimum of 75 individuals, with a median estimate of 224 and a maximum of 372. It is encouraging that the National Park Service detected more individuals than previously known; however, these results still warrant a status of significant concern. Although there is a large confidence interval for the monitoring results, it is unlikely that the number of individuals has changed significantly since 2016. Because terrain and access make surveying difficult, the increase in numbers could easily be due to the detection of more extant plants (i.e., individuals previously missed) rather than a true increase in the population.

Trend:

2016: Declining

This species appears to be in decline due to Douglas-fir encroachment in the absence of fire (Kauffmann et al., 2015). Furthermore, SOD has caused the demise of some of the plants on Bolinas Ridge.

2022: Declining

In the absence of fire or management interventions, we anticipate that the slow decline in numbers will continue, although the rate of loss is uncertain.

Confidence:

2016: High

Monitoring efforts between 2009 and 2016 were reasonably comprehensive.

2022: Moderate

Monitoring efforts between 2016 and 2022 did not survey all known populations and utilized abundance classes, resulting in a large confidence interval of 75 to 372 individuals.

METRIC 4: EXTENT OF RARE SPECIES

Baseline: The extent of rare species in maritime chaparral on Bolinas Ridge was 90 acres in 2016.

Condition Goal: Maintain 90 acres of maritime chaparral community endemic habitat on Bolinas Ridge. Assess the possibility of recovering a second population of Marin manzanita on the south slope to increase the presence of maritime chaparral and create a second viable population within the One Tam area of focus.

Condition Thresholds:

- **Good:** 90 acres of maritime chaparral.
- **Caution:** Between 80 and 90 acres of maritime chaparral.
- **Significant Concern:** Fewer than 80 acres of maritime chaparral.

Current Condition:

2016: Good

The dispersion of Mason's ceanothus, Point Reyes ceanothus, and Marin manzanita was calculated using the minimum convex polygon methodology described by O'Neill & Williams (2006).

2022: Good

The current dispersion of Mason's ceanothus, Point Reyes ceanothus, and Marin manzanita is unknown because post-2016 monitoring did not cover all known populations. However—since geographic ranges and population boundaries are typically slower to change than population numbers, especially for long-lived perennials—we assume their condition has not changed by >10% over the past six years.

Trend:

2016: No Change

Dispersion of rare maritime chaparral endemics prior to 2016 was not known. However, based on repeated mapping of maritime chaparral habitat, it was inferred that no change had occurred during the previous 10 years (Aerial Information Systems, 2015). A change of five acres over a five-year time period would constitute a change in trend.

2022: No Change

The current dispersion of Mason's ceanothus, Point Reyes ceanothus, and Marin manzanita is unknown, and so cannot be compared to the 2016 dispersion. However, it is unlikely to have changed significantly in six years. The current estimate of the total extent of maritime chaparral habitat is 351 acres, represented by the *Arctostaphylos* (*nummularia, sensitiva*)–*Chrysolepis chrysophylla* Alliance in the 2018 Marin Countywide Fine Scale Vegetation Map (GGNPC et al., 2021). Differences in mapping methodology and time series prohibit a direct comparison with earlier vegetation maps.

Confidence:

2016: High

This assessment was based on reasonably comprehensive monitoring between 2009 and 2016.

2022: Moderate

While the data on current dispersion of rare chaparral endemics is only partial, the footprint is unlikely to have changed by >10% over the past six years.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

Note that we currently only have information from Bolinas Ridge proper, which is based on the following.

- National Park Service Rare_Plant_Population.gdb. Golden Gate National Recreation Area, GIS data (updated 2022).
- Marin Water rare plant maps and surveys (1990, 2009, 2012, and 2015).
- California Natural Diversity Database data for the One Tam area of focus (downloaded January 2016) (California Department of Fish and Wildlife, 2009).

See Chapter 2, Indicator Analysis Methodology, for additional information about the overall methodology used for vegetation community analyses.

INFORMATION GAPS

Genetics: Analysis of Mason's ceanothus is needed to determine if it is a viable species or a series of semi-stable or introgressing hybrids between *C. gloriosus* var. *exaltatus* and *C. cuneatus* var. *ramulosus*.

Seeds: Research on germination requirements and seed life for rare species is needed to determine if maritime chaparral that has been taken over by forest can return to chaparral after a fire or mechanical removal of overshading trees and forest litter or duff.

Plant Pathogens: Acreage and spatial distribution of *Phytophthora*-impacted habitat were identified as important metrics in 2016, but condition and trends were unknown. Some Marin manzanita have been infected with *P. ramorum* (California Oak Mortality Task Force, 2015), with roughly 10% to 25% mortality between 2015 and 2016 (Marin Water staff observation, 2016). Staff have also observed significant mortality in golden chinquapin and huckleberry. The cause of these mortality events has not been verified, but the presentation is consistent with *Phytophthora* infection. A comprehensive field study is needed to determine the specific pathogens that are affecting maritime chaparral as well as their impacts and spatial extent, especially for special status plants.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Other than the previously noted surveys, no new management or monitoring has occurred since 2016.

Past Work

Following are some of the stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Management: Forest understory manipulation has been used to reduce SOD thickets, which may reduce spore load and the Marin manzanita infection rate (Marin Water).

Monitoring: Rare plant surveys are conducted within Golden Gate National Recreation Area lands on Bolinas Ridge at one- to three-year intervals (as resources allow). These surveys focus on confirming and mapping the presence of previously recorded individual rare plants and searching for new occurrences in suitable habitat (National Park Service).

Conservation: In 2015, Mason's ceanothus and Marin manzanita were seedbanked as part of the Center for Plant Conservation California Plant Rescue program (Marin Water).

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists during the development of this report. These actions, which are not currently funded through agency programs, will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Existing Program Support:

- **Fuel Load Reduction, Roads- and Trails-Related Management:** Assess the feasibility of realigning trails within rare plant habitat to reduce both the introduction and spread of plant diseases and other potential impacts.

- **Succession Management:** Remove encroaching Douglas-fir saplings and trees.

- **Manage Fire-Dependent Communities:**

    - Establish an adaptive management program to include installation of burn box plots; if controlled burns within plots appear to result in successful recruitment, consider future controlled burns at isolated stands (frequency to be determined).

    - Absent prescribed fires, determine the efficacy of outplanting manipulated/fire-treated seed in test plots.

Inventory and Monitoring:

- ***Phytophthora* Monitoring Protocols:** If dieback of maritime chaparral is observed during routine monitoring, a protocol is needed to identify and assess the presence of *Phytophthora* species.

Potential Research:

- **Larger-Scale Succession and Fire Management:** Research is needed on how these management practices might be undertaken in maritime chaparral habitat at Bolinas Ridge to improve both overall community and rare species health.

Population Enhancement:

- Assess the feasibility of recovering a second population of *Arctostaphylos virgata* on the southern slope of Bolinas Ridge to increase the presence of maritime chaparral and create a second viable population.

- Assess similar enhancement actions in the vicinity of other populations of *A. virgata*: near the Sierra Trail, above Alice Eastwood Road, and at Old Stage Road off Alpine Trail on California State Parks lands (among other sites that may be identified in the future).

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CHAPTER 9. GRASSLANDS

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

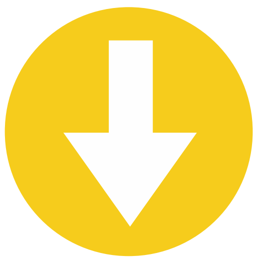
2016	2022
	
Condition: Caution	**Condition:** Caution
Trend: Declining	**Trend:** Unknown
Confidence: Low	**Confidence:** Low

FIGURE 9.1 CONDITION, TREND, AND CONFIDENCE FOR GRASSLANDS, ONE TAM AREA OF FOCUS

New information on grassland extent and composition was available to support this chapter update. This chapter establishes a new baseline from which a trend may be inferred in the future. Other key updates:

- A change in geographic boundaries for the One Tam area of focus increased grassland extent.
- The 2018 Marin Countywide Fine Scale Vegetation Map was published in 2021; its foundational imagery, which was collected in 2018, documented significantly fewer acres of grassland than had been documented on earlier maps.

METRICS SUMMARY

The metrics in Table 9.1 were used to assess grassland health. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 9.1. Each metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 9.1 ALL GRASSLAND METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1: Total acres		
	2016	**2022**
Condition	Caution	Caution
Trend	Unknown	Unknown
Confidence	Low	Low
Metric 2: Patch size		
	2016	**2022**
Condition	Good	Caution
Trend	No Change	Unknown
Confidence	Moderate	Moderate
Metric 3: Community composition and native species richness		
	2016	**2022**
Condition	Unknown	Unknown
Trend	Declining	Unknown
Confidence	Low	Low
Metric 3: Percent cover native grasses		
	2016	**2022**
Condition	Significant Concern	Significant Concern
Trend	Declining	Unknown
Confidence	Low	Low

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

California's native grasslands, among the nation's most endangered ecosystems, have decreased dramatically over the last 100 years. Today, they occupy less than 1% of their historical extent (Noss & Peters, 1995). This matters because perennial grasslands provide ample carbon storage in extensive below-ground root systems (Potthoff et al., 2005), and some species of native grasses can live for hundreds of years (Marty et al., 2005). Grasslands are the old-growth at our feet and a rich part of Marin County's natural heritage and contemporary ecology.

Nearly 90% of rare species listed in the California Native Plant Society's inventory of rare and endangered species in California (Skinner & Pavlik, 1994) occur in grasslands (D'Antonio et al., 2002). This is in addition to 30% of the threatened and endangered wildlife species (more than 40% of terrestrial animals) (CDFW, 2016). American badgers (*Taxidea taxus*) (Lay, 2008) and grassland-nesting birds (Rao et al., 2008) rely on large patches of grassland to reproduce and forage. Large, connected patches are necessary in order to maintain gene flow among grassland species and to minimize edge effects. Many grassland-dependent bird and mammal species are declining elsewhere in the Bay Area (BAOSC, 2011).

Grassland ecosystems are dominated by both perennial and annual herbaceous plants, with few to no trees or shrubs. Dominant native grassland species in the One Tam area of focus include purple needlegrass (*Stipa pulchra*), blue wild rye (*Elymus glaucus*), clovers (*Trifolium* spp.), California oatgrass (*Danthonia californica*), and red and blue fescue (*Festuca rubra* and *F. idahoensis*), among others. Dominant non-native species include wild oats (*Avena barbata*), perennial rye grass (*Festuca perennis*), Harding grass (*Phalaris aquatica*), and tall fescue (*Festuca arundinacea*) (Evens et al., 2006).

CURRENT CONDITION AND TREND

About 7% (2,737 acres) of the open space in the One Tam area of focus are grasslands (see Chapter 3 and Figure 3.2), which include native-species-dominated perennial grasslands, non-native annual grasslands, non-native perennial grasslands, serpentine grasslands, and seasonally wet meadows. Non-native plants are ubiquitous, primary components of most grasslands across Mt. Tam and the state. The *Manual of California Vegetation* defines a "native" grassland as one with as little as 10% relative cover of native species (CNPS, 2016). The 2018 Fine Scale Vegetation Map employs a threshold of 10% shrub cover for the California Annual and Perennial Mapping Unit, which is the finest scale available for grasslands in the vegetation map.

DESIRED CONDITION AND TREND

The desired condition for grasslands is the persistence of large, intact, native-rich blocks of this vegetation type, which supports grassland-dependent plant and wildlife species sensitive to edge effects and fragmentation. Good examples can be found on Pine Mountain, in scattered patches along Highway 1, and adjacent to Bootjack Creek below Mountain Theatre.

STRESSORS

Invasive Species Impacts: At nearly all grassland sites, non-native species make up the majority of plant cover—a situation unheard of and likely intolerable in any other vegetation type found on Mt. Tam. Invasive plant species result in the loss of native-species diversity, changes in nutrient cycling and hydrology, and shifts in invertebrate abundances (Evens et al., 2006; Steers & Spalding, 2013; Ford & Hayes, 2007).

Climate Vulnerability: The potential effects of climate change, including frequent drought conditions and increased climatic water deficit, may detrimentally affect Mt. Tam's grasslands. A statewide climate exposure model shows a wide range of variability in "Warm/Wet" and "Warm/Dry" futures for grasslands, which occur across elevations and slopes around the One Tam area of focus (GGNPC et al., 2021; Thorne et al., 2017). However, species' adaptive capacity to fire and seed recruitment will likely determine the health of this community in the future (Thorne et al., 2016). Within the One Tam area of focus, nearly all grasses—both in terms of number of species and area covered—are "cool-season," or C3, grasses. The few (native and non-native) species of "warm-season," or C4, grasses are wetland species, and their increased ability to take advantage of higher temperatures and CO2 levels may be tempered by concomitantly lower water availability (Zhu et al., 2016).

Fire Regime Change: Longer fire-return intervals allow northern coastal California grasslands to rapidly convert into scrublands, woodlands, and/or forest (Ford & Hayes, 2007). On Mt. Tam, coyote brush (*Baccharis pilularis*) and Douglas-fir (*Pseudotsuga menziesii*) are particularly successful at fragmenting and reducing grassland stands. This process is arrested on south-facing slopes and where soils are thin, seasonally saturated, or nutrient poor (Schoenherr, 1992).

Pollution/Contaminants: Air pollution contains reactive nitrogen compounds such as NOx, ammonia, and nitric acid that deposit on surfaces and act as nitrogen fertilizer. Impacts of nitrogen (N) deposition are well documented across California (Fenn et al., 2010; Weiss, 2006), and include increased annual grass and weed growth in grasslands. Grasslands on Mt. Tam are exposed to N deposition from <2 lbs-N ac-1 year-1 to ~10 lbs-N ac-1 year-1, which exceed the critical load needed to promote invasive annual grass growth beyond background rates (Fenn et al., 2010). Increased annual grass biomass leads to accumulation of thatch and loss of native biodiversity (Molinari & D'Antonio, 2014).

Direct Human Impacts: Grassland trails have few confining barriers, allowing recreationists to easily create non-system trails to viewpoints, shade, or other trails. Non-system trails contribute to erosion, localized soil compaction, and invasive plant spread.

Habitat Disturbance/Conversion/Loss: California's grasslands evolved with episodic disturbances, both anthropogenic and natural (fire and grazing ungulates such as tule elk [*Cervus canadensis nannodes*] and black-tailed deer [*Odocoileus hemionus columbianus*]). The loss of these disturbance sources has resulted in the loss of native-species productivity; diversity; and, ultimately, grasslands themselves as they convert to woody-dominated communities.

CONDITION AND TREND ASSESSMENT

METRICS

METRIC 1: TOTAL ACRES

Baseline: A review of historical aerial photographs indicates that grasslands in the One Tam area of focus have steadily decreased since the middle of the 20th century. A systematic comparison of geospatially rectified imagery from 1943 to 2009 for Marin Water lands detected a decrease of 850 acres (40%) independent of losses caused by the construction of Bon Tempe Reservoir and the raising of Peter's Dam. Recent analysis of an area on Bolinas Ridge found a 62% reduction of grasslands from 1952 to 2018 (Startin, 2022).

This loss is primarily attributed to succession into scrub, woodland, and forest vegetation types in the absence of fire or other disturbances, and secondarily, to encroachment from woody invasive species such as French broom (*Genista monspessulana*). While grassland loss in the area of focus has not been thoroughly analyzed, it is likely that its current extent is significantly less than in the recent past.

Condition Goal: Reverse woody encroachment into remnant grassland patches.

Condition Thresholds:

These thresholds are updated to reflect changes in scale for the One Tam area of focus and new information from the 2018 Fine Scale Vegetation Map (GGNPC et al., 2021).

- **Good:** Grassland extent is 2% (55 acres) >2018 levels (2,737 acres).
- **Caution:** Grassland extent remains =2018 levels or decreases by 10% (270 acres) over five years.
- **Significant Concern:** Grassland extent decreases by >10% (270 acres) over five years.

Current Condition:

2016: Caution

The extent of grasslands in the One Tam area of focus in 2016 was approximately 3,515 acres (but see below about changes in mapping for 2022). All One Tam agencies have active weed management programs, and two agencies strategically control Douglas-fir and/or coyote brush from grassland margins. However, it was unclear whether these efforts were keeping pace with the rate of woody-species encroachment.

2022: Caution

The mapped extent of grasslands used for the 2016 analysis is not directly comparable to the 2018 Fine Scale Vegetation Map for two reasons. First, the vegetation map used in 2016 to quantify grasslands on National Park Service and California State Parks lands was from 1994, obviating analysis over the time period identified in this update. Second, the 2018 map uses mapping rules that differ from those used in the 2016 analysis Notably, in the more recent map, the shrub cover threshold was reduced to 10%, causing some stands identified as grasslands in 2016 to now appear as Shrub Fragment, Oak Woodland, and other vegetation types.

An overall decline in mapped grasslands was detected at a rate of 30% between the data sources used for the 2016 grasslands chapter and the 2018 Fine Scale Vegetation Map. Some of this change occurred after of the 1994 mapping, some is attributable to new mapping rules, and some may be attributable to grassland succession to woody types.

This chapter establishes a new baseline for future comparisons. If vegetation mapping rules continue to evolve, comparisons may be made through separate analyses using aerial imagery (Startin, 2022).

Trend:

2016: Unknown

While a significant decline in grassland acres since the mid-1940s had been documented, the 2016 trend was unclear. Although Marin Water was the only jurisdiction with time-series map data, the grassland update was limited to classification changes and did not incorporate polygon boundary revisions. Therefore, small changes in the spatial extent of individual grassland patches were not captured. Anecdotal reports from field staff, local experts, and recreationists suggested that some patches represented as grasslands in the 1994 National Park Service and California State Parks maps, or even the later Marin Water and Marin County Parks maps, had decreased in size or completely transitioned into scrub or forested habitat.

2022: Unknown

While the significant decline in grassland acreage since the mid-1940s noted in the 2016 report stands, the current trend is unclear. Underlying stressors associated with non-native plant invasion and fire suppression are still at work, and anecdotal reports from field staff, local experts, and recreationists continue to indicate grassland losses. Additionally, some One Tam agencies engage in succession management to slow or reverse the encroachment of woody species.

Confidence:

2016: Low

Although grasslands had been mapped on all jurisdictions, much of the available information was outdated (1994 for National Park Service and California State Parks, 2004 for Marin Water, and 2008 for Marin County Parks).

2022: Low

As previously discussed, available data sources between 2016 and today are not comparable, which prevents a full assessment of this metric.

METRIC 2: PATCH SIZE

Baseline: Within the One Tam area of focus, 11 of 558 distinct patches of grassland habitat are >30 acres (Figure 9.2). Combined, they represent 42% of the mountain's grassland habitat. These 1,142 acres constitute important core areas for native grassland plants, birds, and other wildlife sensitive to edge effects, habitat fragmentation, and invasion (BAOSC, 2011).

Condition Goal:

Increase core areas of grasslands >30 acres in size to 50% of total grassland acres (1,370 acres).

Condition Thresholds:

- **Good:** 1,370 total acres of grassland exists within patches that are ≥30 acres.
- **Caution:** Between 1,200 and 1,370 acres of grassland exist within patches that are ≥30 acres.
- **Significant Concern:** Fewer than 1,200 acres of grasslands exist within patches that are ≥30 acres.

Current Condition:

2016: Good

Nineteen blocks of grassland vegetation >30 acres were mapped in the One Tam area of focus, for a total of 2,050 acres.

2022: Caution

Eleven blocks of grassland vegetation >30 acres have been mapped in the One Tam area of focus, for a total of 1,220 acres (Figure 9.2).

Trend:

2016: No Change

Although Marin Water was the only jurisdiction with time-series vegetation map data, the grassland update was limited to classification changes and did not incorporate polygon boundary revisions. Therefore, small changes in the spatial extent of individual grassland patches were not captured. Cumulatively, these changes were unlikely to have exceeded the condition threshold.

2022: Unknown

Data sources used in 2016 indicated that there were 19 patches of grasslands >30 acres with a total acreage of 2,050 acres. The reduction in core areas to 11 patches (1,370 acres) represents changes that occurred prior to the 2016 analysis on National Park Service and California State Parks land as well as changes in the mapping rules. The existing dataset does not clarify whether core areas were also lost between 2016 and 2022. A small-scale analysis of changes in grassland extent in the region (Startin, 2022) assess longer time periods. Therefore, the trend is unknown using the available datasets.

Confidence:

2016: Moderate

As discussed elsewhere, some maps used to identify core areas in these jurisdictions were outdated. Active fuelbreak expansion and trail realignment programs implemented by Marin Water and Marin County Parks had the potential to fragment grassland patches at a scale not discernible in landscape-level mapping.

2022: Moderate

Less than 50% of total grassland area falls within core areas >30 acres. Smaller grassland patches are more vulnerable to edge effects and encroachment by woody species in the absence of a natural disturbance regime.

METRIC 3: COMMUNITY COMPOSITION AND NATIVE SPECIES RICHNESS

Baseline: Grassland quality is not easily captured by landscape-scale aerial survey techniques. The high level of site-to-site and year-to-year variability in the relative abundance of many species creates a further complication. Thus, on-the-ground measurements of community composition are necessary.

Common metrics used to assess grassland community composition and quality include percent-cover estimates, relative abundance, presence/absence determinations, biomass measurements, and structural measurements. While ground sampling of grassland communities did occur as part of each One Tam partner agency's initial vegetation mapping and classification effort, these data were limited in scope and utility. Full floristics were collected in only a small subset of sampled plots. In 2013, the National Park Service completed a study of grasslands in the Marin Headlands as part of a protocol development for a regional, long-term, plot-based monitoring network, and in spring 2016, the Sonoma-Marin Grasslands Working Group also undertook mapping and classification (Kraft et al., 2014). From 2017 to 2018, the Parks Conservancy and the Redwood Creek Watershed Collaborative conducted assessments of grasslands dominated by native species; however, these data only covered approximately 2% of total grassland acres across the area of focus.

Baseline species richness throughout the range of grassland habitats in the One Tam area of focus cannot be derived from the existing datasets, in part because of the bias toward healthy grasslands with lower relative invasive plant cover. Therefore, thresholds for this metric have not been established. The determination of a condition goal is contingent on the establishment of a comprehensive plot system designed to monitor changes in species richness and other composition metrics over time. Species-richness targets, either overall or stratified by grassland type, can be set in the future if datasets representative of Mt. Tam grasslands are developed. Even though we cannot report on this metric, we are retaining it in this report in anticipation of being able to do so in the future.

Condition Goal: Not yet set.

Condition Thresholds: Not yet set.

Current Condition:

2016: Unknown

2022: Unknown

A plot network has not been established throughout the One Tam area of focus, and limited data make it impractical to establish a condition for this metric.

Trend:

2016: Declining

2022: Unknown

Anecdotal reports from field staff, researchers, local experts, and recreationists, as well as a review of historical museum specimens, suggest that species richness is declining on Mt. Tam in general, and in grasslands in particular. However, it is unknown whether that trend continued between 2016 and 2022.

Confidence:

2016: Low

2022: Low

While several plot studies have been conducted in the last five years, they examined only a fraction of the One Tam area of focus, and often have a bias toward native-dominated grasslands.

METRIC 4: PERCENT COVER NATIVE GRASSES

Baseline: The *Manual of California Vegetation* sets a threshold of 10% relative cover of native species for a grassland patch to be classified as an alliance or association with a native-grass component. The National Park Service (Golden Gate National Recreation Area/Point Reyes National Seashore) map's "Field Key to the Plant Communities" sets the percentage at >15% relative cover of native perennial grasses (Keeler-Wolf et al., 2003). The Marin Water map uses a 10% relative cover of a dominant genus/species to key to some alliances or associations, but this does not hold for all native grassland types (Evens et al., 2006). The coastal prairie mapping project classified <5% of its total grassland area as native, but sets a higher bar, with a >30% relative cover of native grasses as the qualifier. Thus, as can be seen, there is currently no broadly accepted percentage of cover—relative or absolute—of native grasses that defines a grassland as "native." For this metric, we have chosen a criterion of 15% relative cover of native perennial grasses.

Of the plots sampled in the 2012 National Park Service Marin Headlands study and 2016 Marin Water grassland assessment, nearly 70% had 15% (or more) relative cover of native grasses (Figure 9.2). In both studies, plot locations were targeted in grasslands believed to contain a high native-species component.

While there are insufficient data to allow for generalization across the One Tam area of focus, this limited sample size suggests that some grassland patches still support a significant native grass component. However, given that the studies were specifically focused on patches pre-identified as meeting the native-cover criterion and classification series, and based upon recent visits and ocular assessments by field staff in non-sampled stands that make up the majority of grassland acreage, we believe it is unlikely that the majority of grassland patches in the One Tam area could be classified as a native grassland.

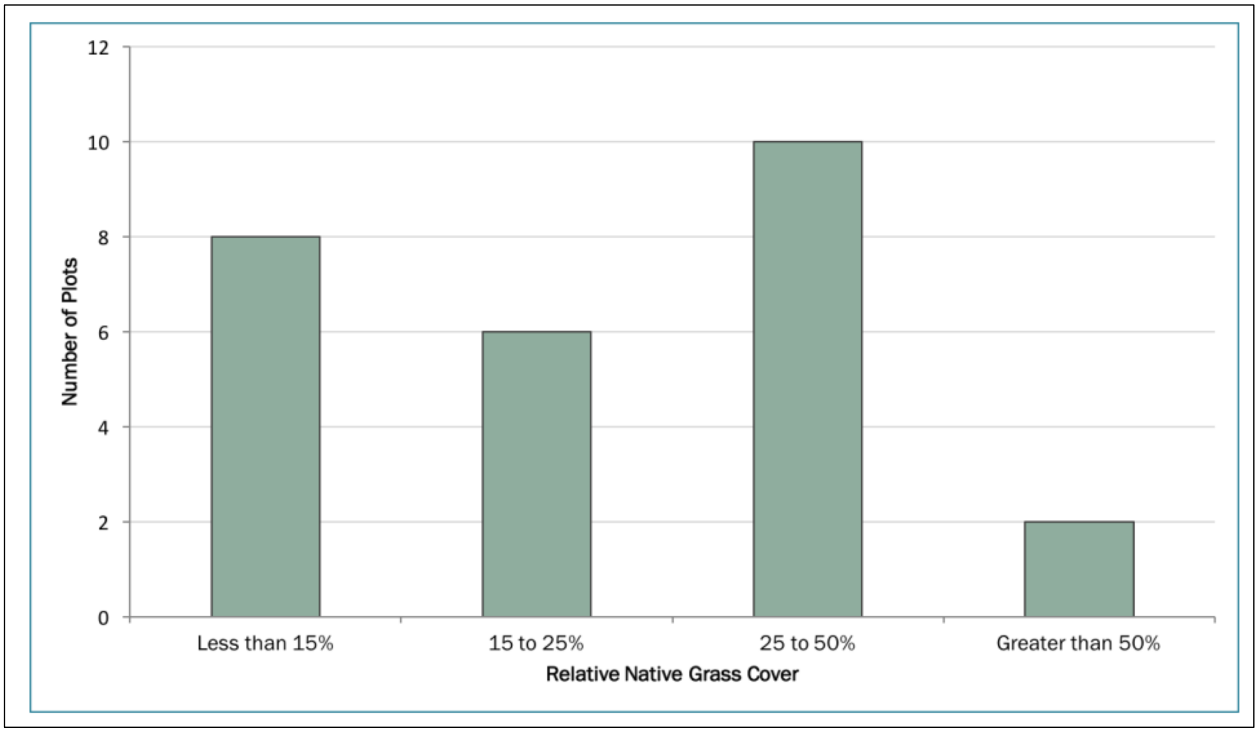


FIGURE 9.2 RELATIVE COVER OF NATIVE GRASSES IN SAMPLED PLOTS, NATIONAL PARK SERVICE AND MARIN WATER (STEERS & SPAULDING, 2013; MARIN WATER, 2016, UNPUBLISHED DATA)

Condition Goal:

Maintain 50% of existing grasslands with ≥15% relative cover of native grasses.

Condition Thresholds:

- **Good:** More than 80% of grasslands (2,190 acres) with ≥15% relative cover of native grasses.
- **Caution:** 60%–80% of grassland (1,640–2,190 acres) with ≥15% relative cover of native grasses.
- **Significant Concern:** Less than 50% of grassland (1,370 acres) with ≥15% relative cover of native grasses.

Current Condition:

2016: Significant Concern

The rationale for a condition of significant concern in 2016 was very similar to the way we arrived at this same conclusion for 2022 (following).

2022: Significant Concern

Twenty-nine percent of the 2013 and 2016 sampled grassland plots within the One Tam area of focus contained <15% relative cover of native grasses, despite being purposefully situated in locations where the overall quality was believed to be high. Thirty-three percent of targeted native-grassland plots on adjacent National Park Service lands outside of the One Tam area of focus had a similarly low level of native grasses.

These data are insufficient for extrapolation throughout the entire One Tam area of focus. In the datasets used in 2016, the totality of National Park Service and California State Parks acreage of California Annual Grassland with Native Component Mapping Unit within the area of focus was 23.7 acres; 891 acres were California Annual Grassland Mapping Unit, and 139 acres were Introduced Coastal Perennial Grassland Alliance. Data from Marin County Parks were not analyzed but represent <10% of total grassland acres. The 2018 Fine Scale Vegetation Map does not differentiate between annual and perennial grasslands.

Based on mapped acres of grassland types and extrapolating from the quality of the "best" acres sampled, we estimate that significantly fewer than 1,370 acres include the minimum cover of native grasses to qualify as "native" grassland.

Trend:

2016: Declining

Time-series data were not available. However, observations by field staff, local researchers active on Mt. Tam, and area experts indicated that invasive grasses had expanded dramatically in the previous five years. This had not been demonstrated to be to the detriment of native grass cover at that time.

2022: Unknown

No time series data are available to assess the trend for this metric.

Confidence:

2016: Low

The small sample size, targeted nature of plot placement, and location of all of the National Park Service plots outside the One Tam area of focus led us to assign a confidence of low.

2022: Low

Our confidence in this assessment remains low for the same reasons.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

In developing this update, we used several vegetation maps.

- Marin Water vegetation maps (2004, 2009, 2014; AIS, 2015)
- Marin County Parks vegetation map (2008; AIS, 2008)
- National Park Service vegetation map and study (2013)
- Redwood Creek grassland assessments (2017)
- One Tam grassland assessments (2018)
- Marin Countywide Fine Scale Vegetation Map (2018; GGNPC et al., 2021)

INFORMATION GAPS

Long-Term Monitoring: We lack time-series data for grassland acres, patch size, and composition on Mt. Tam. Where data exists, most are insufficiently cross-comparable (e.g., different vegetation maps) or are biased toward management goals (e.g., grassland assessments). Because these datasets serve larger purposes, their approaches are not likely to change to include the kinds of time-series data we need. One Tam partners are currently evaluating a plot design that would allow long-term monitoring of high-priority grasslands known to have a high ratio of native-to-invasive cover. While data from such a plot design would likely not allow staff to answer Metrics 3 and 4, they could provide helpful information for managing key grassland areas.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Succession Management: One Tam partners have addressed woody-species encroachment in several locations by removing shrub species (e.g., coyote brush and poison oak [*Toxicodendron pubescens*]), and tree species (e.g., Douglas-fir). Key locations include the core areas on southern Bolinas Ridge and Sky Oaks meadow. These efforts, which often align the management of healthy grasslands with fuels-reduction goals, allow individual projects to achieve multiple objectives. Grassland assessments in 2017 and 2018 evaluated those predetermined to be in good condition to inform woody-species encroachment work.

Invasive Species Management: Ongoing barbed goatgrass (*Aegilops triuncialis*) management in serpentine and non-serpentine grasslands is successfully reducing the spread of this species. Comprehensive starthistle management has been a priority on Mt. Tam, with particular emphasis on grasslands from Rock Spring north along West Ridgecrest Boulevard. Purple star thistle (*Centaurea calcitrapa*) populations have dropped by >95% since 2016, and labor required to manage yellow starthistle (*C. solstitialis)* has declined over the same time period. Managing these and other invasive plant species requires continued long-term effort.

Past Work

Following are some of the previous stewardship and management activities that were undertaken over the years to monitor, protect, and restore this health indicator.

- Volunteers remove invasive plants and encroaching woody species.
- The One Tam Early Detection Rapid Response program surveys and manages new invasive plants as they appear.
- California State Parks, Marin Water, and Marin County Parks manage woody-species encroachment through regular restoration activities and as part of larger fuels-reduction strategies where appropriate.

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as a part of the development of this report. These are actions not currently funded through agency programs and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Mapping and Assessments:

- Analyze post-2005 aerial imagery to determine the rate of grassland extent and patch-size change over time.
- Conduct comprehensive grassland assessments stratified to be representative of Mt. Tam's grassland types.
- Map grasslands to Alliance or Association.

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ADDITIONAL REFERENCE MATERIAL OF INTEREST

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CHAPTER 10. SERPENTINE BARREN ENDEMICS

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016*

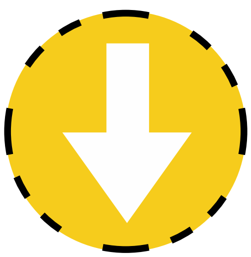
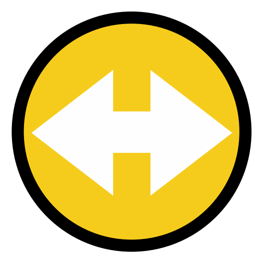
2016*	2022
	
Condition: Caution	**Condition:** Caution
Trend: Declining	**Trend:** No Change
Confidence: Moderate	**Confidence:** High

FIGURE 10.1 CONDITION, TREND, AND CONFIDENCE FOR SERPENTINE BARREN ENDEMICS, ONE TAM AREA OF FOCUS

**Because we had limited data in 2016, we also needed to rely on our best professional judgment and field experience to determine condition and trend for each metric. Also, the comparison of the overall condition and trend between 2016 and 2022 in Figure 10.1—a combined average of these metrics—looks at aligned but not exactly equivalent metrics, and represents a comparison of the condition and trend of this indicator to the best of our ability to understand them at the time the analyses were done. 2016 and 2022 should be viewed separately rather than compared as a measure of change over time.*

New data on barren occupancy and species abundance from the One Tam Serpentine Endemic Occupancy Project (initiated in 2016) are now available and have been used to inform this update. The project includes an inventory of 99 barrens across the area of focus. (A handful of inaccessible barrens have not been surveyed.) Nine of the surveyed barrens have been revisited each year (called "revisit barrens" in this chapter), and we now have between three and seven years of data for these sites. This allows us to set baselines, condition goals, and condition and trend thresholds for each metric, something that was not possible in 2016. The changes in each metric are described in more detail in the Condition and Trend Assessment section of this chapter.

Other highlights:

- Species groupings for each metric were reconsidered using a new inventory of serpentine barrens across the area of focus. Changes were made based on the frequency of the species across the landscape and considerations each species habitat preferences. This approach also eliminated redundancy by placing the two species with Recovery Plans into one metric rather than two.
- This chapter limits the study to annual endemic species, whereas the chapter written in 2016 considered some perennial species. Those species are largely adjacent to barrens in shrub or wetland areas, which is not the focus of this indicator.

METRICS SUMMARY

Metrics in Table 10.1 were used to assess serpentine barren endemic species health. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 10.1. Each metric is described in the Condition and Trend Assessment section later in this chapter. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

*TABLE 10.1 ALL SERPENTINE BARREN ENDEMIC METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE**

Metric 1: Percent of patches occupied by “common” rare plant species		
	2016	**2022**
Condition	Good	Caution
Trend	No Change	No Change
Confidence	Moderate	High
Metric 2: Percent of patches occupied by “rare” rare plant species		
	2016	**2022**
Condition	Caution	Caution
Trend	Declining	No Change
Confidence	Moderate	Moderate

Metric 3: Recovery goals met for Marin dwarf flax and Tamalpais lessingia		
	2016	**2022**
Condition	Caution	Caution
Trend	Declining	Declining
Confidence	Moderate	High

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

Serpentinite, California's state rock, creates serpentine soils, which are characterized by low amounts of calcium; high amounts of magnesium; relatively high concentrations of nickel, chromium, and other heavy metals; and low levels of nitrogen (USFS, 2016). Only certain plant species can survive in these soils. Serpentine is a rare soil type statewide, further limiting the distribution of plants specifically adapted to its harsh characteristics.

Serpentine barrens are characterized by open, rocky soil and support mostly scattered annuals such as jewelflowers, rosinweed (*Calycadenia multiglandulosa*), navarretias, and a few perennial plants such as lomatiums and buckwheats. Many rare, locally rare, and Mt. Tam endemic plants are also found in serpentine barrens.

CURRENT CONDITION AND TREND

There are 99 patches of various rare taxa on 30 acres of serpentine barrens in the area of focus, constituting less than 1% of its open space. Serpentine barrens are not distinctly mapped by the 2018 Marin Countywide Fine Scale Vegetation Map (GGNPC et al., 2021). Therefore, this analysis does not include a measure of serpentine barren habitat beyond the area of focus.

DESIRED CONDITION AND TREND

Four serpentine endemic annual species persist, with strong populations across their current range.

- Mt. Tamalpais bristly jewelflower (*Streptanthus glandulosus* ssp. *pulchellus*) is present, with abundance reflecting 2016–2022 goals in six of nine revisit barrens.
- Tiburon buckwheat (*Eriogonum luteolum* var. *caninum*) is present, with abundance reflecting 2016–2022 goals in eight revisit barrens.

- Marin navarretia (*Navarretia rosulate*) is present, with abundance reflecting 2016–2022 goals in five revisit barrens.

- Tamalpais jewelflower (*Streptanthus batrachopus*) is present, with abundance reflecting 2016–2022 goals in three revisit barrens.

In addition, two species, Marin dwarf flax (*Hesperolinon congestum*) and Tamalpais lessingia (*Lessingia micradenia*), meet recovery goals set by the U.S. Fish and Wildlife Service (1998).

STRESSORS

Historical Impacts: Development on serpentine barren habitats inside the area of focus, including the Mill Valley Air Force Station at West Peak.

Invasive Species Impacts: The unusual soils of these habitats make them largely resistant to invasion, but barbed goatgrass (*Aegilops triuncialis*), purple false brome (*Brachypodium distachyon*), and cheatgrass (*Bromus tectorum*) occur in or adjacent to approximately half of the inventoried barrens.

Climate Vulnerability: The relative rarity of serpentine soils limits where serpentine-adapted species could potentially migrate in response to shifting temperature and precipitation patterns predicted by different climate change scenarios (Ackerly et al., 2012).

Fire Regime Change: Lack of fire may allow native trees, shrubs, or grasses to overtake open areas.

Pollution/Contaminants: Air pollution contains reactive nitrogen compounds like NOx, ammonia, and nitric acid that deposit on surfaces and act as nitrogen fertilizer. Impacts of N-deposition are well documented across California (Fenn et al., 2010; Weiss, 2006), and include increased annual grass and weed growth in serpentine soils Mt. Tam spans a N-deposition gradient from quite clean coastal air on the west slopes (<2 lbs-N ac-1 year-1) to local hotspots (~10 lbs-N ac-1 year-1) on the eastern flanks close to urban areas (Fenn et al., 2010). Serpentine barrens may be particularly sensitive. Effects on serpentine grasslands are observed at ~6 lbs-N ac-1 year-1 (Fenn et al., 2010). Increased annual grass growth in serpentine barrens reduces open ground and crowds out the diminutive annual forbs restricted to open areas.

Direct Human Impacts: The open landscapes of serpentine barrens make them attractive to recreationists and therefore vulnerable to trampling.

METRICS

METRIC 1: PERCENT OF PATCHES OCCUPIED BY “COMMON” RARE PLANT SPECIES

Baseline: Mt. Tamalpais bristly jewelflower (*Streptanthus glandulosus* ssp. *pulchellus*) and Tiburon buckwheat (*Eriogonum luteolum* var. *caninum*) may be considered the more “common” rare plants. Many species in this category were not historically mapped and are not included in the California Natural Diversity Database (CNDDB), so in 2016, it was not possible to set a baseline. In the time since, the One Tam Serpentine Endemic Occupancy Project found Mt. Tamalpais bristly jewelflower at 36 barrens, including six that are annually monitored. This species is also seen on road cuts (Pam’s Blue Ridge); less frequently, it intergrades into serpentine grasslands, notably in the canyons of Pine Mountain. Tiburon buckwheat occurs at 93 barrens, including eight revisit barrens. This species intergrades into grasslands and runs along roadsides in serpentine soils. These data now allow us to set a baseline against which change can be measured over time.

Condition Goal: Maintain occupancy and abundance of Mt. Tamalpais bristly jewelflower and Tiburon buckwheat at 2016–2022 survey levels, which provide a sample of the total population.

Condition Thresholds:

- **Good:** Mt. Tamalpais bristly jewelflower is present in six revisit barrens and Tiburon buckwheat is present in eight. Abundance on the revisit barrens is maintained above the following thresholds over five years (Table 10.2).

TABLE 10.2 NUMBER OF INDIVIDUAL TIBURON BUCKWHEAT AND MT. TAMALPAIS BRISTLY JEWELFLOWER PLANTS AT REVISIT BARRENS REQUIRED TO MAINTAIN GOOD CONDITION

	Number of Individual Plants of Each Species	
	Tiburon Buckwheat	Mt. Tamalpais Bristly Jewelflower
Barren 1	3,000	450
Barren 2	5,000	N/A
Barren 3	5,500	N/A
Barren 4	7,000	350
Barren 5	500	4,000
Barren 6	5,000	2,700
Barren 7	8,000	2,500
Barren 8	N/A	7,000
Barren 9	400	N/A

- **Caution:** Mt. Tamalpais bristly jewelflower is present in six revisit barrens and Tiburon buckwheat is present in eight. A five-year abundance decrease of 1% to 10% in two or more revisit barrens for either species changes the condition to caution.
- **Significant Concern:** Absence of either species in revisit barrens, or five-year average decreases greater than 10% in two or more revisit barrens for either species, changes the condition to significant concern.

Current Condition:

2016: Good

2022: Caution

Because condition thresholds were not set in 2016, the condition of good was selected at that time, based on contemporary Marin Water inventories that showed extant populations of these species. However, data acquired between 2016 and 2022 now allow us to establish condition thresholds. Based on these thresholds, Mt. Tamalpais bristly jewelflower only falls below good condition in two barrens with five years of data, and Tiburon buckwheat in three. Tiburon buckwheat falls to the significant concern threshold in one barren. Occupancy thresholds have been met for both species. Combined, this results in an overall condition of caution for this metric.

Trend:

2016: No Change

2022: No Change

Annual plant populations fluctuate significantly with annual rainfall amounts and timing. Population abundance varies year-to-year, but the current dataset indicates no significant trend. Occupancy remained stable over the time period of the current dataset.

Confidence:

2016: Moderate

2022: High

The One Tam Serpentine Endemic Occupancy Project dataset contains three to seven years of data in nine barrens across the serpentine band of Mount Tam.

METRIC 2: PERCENT OF PATCHES OCCUPIED BY "RARE" RARE PLANT SPECIES

Baseline: Marin navarretia (*Navarretia rosulata*) and Tamalpais jewelflower (*Streptanthus batrachopus*) may be considered the "rarer" rare plants. These species were not historically mapped and are not included the CNDDB. As for Metric 1, lack of data in 2016 precluded setting a baseline for this metric at that time. Since then, the One Tam Serpentine Endemic Occupancy Project has found Marin navarretia at 40 barrens, including five revisit barrens. Despite occurring on 40 barrens, Marin navarretia can only occupy a small subset of any barren because it prefers areas of soil accretion, which retain some moisture longer than the gravelly soils typical of serpentine barrens as a whole. Tamalpais jewelflower was found at 12 barrens, including three revisit barrens. These species occur north of the mountain's peaks.

Condition Goal: Maintain occupancy and abundance of Tamalpais jewelflower and Tiburon buckwheat at 2016–2022 survey levels on revisit barrens.

Condition Thresholds:

- **Good:** Marin navarretia is present in five revisit barrens and Tamalpais jewelflower is present in three (Table 10.3). Abundance over five years on revisit barrens is maintained above the following thresholds.

TABLE 10.3 NUMBER OF INDIVIDUAL MARIN NAVARRETIA AND TAMALPAIS JEWELFLOWER PLANTS AT REVISIT BARRENS REQUIRED TO MAINTAIN GOOD CONDITION

	Number of Individual Plants of Each Species	
	Marin Navarretia	**Tamalpais Jewelflower**
Barren 1	500	N/A
Barren 2	3,500	1,400
Barren 3	N/A	N/A
Barren 4	5,800	350
Barren 5	N/A	N/A
Barren 6	N/A	N/A
Barren 7	7,600	1,100
Barren 8	N/A	N/A
Barren 9	1,900	N/A

- **Caution:** Marin navarretia is present in five revisit barrens and Tamalpais jewelflower is present in three. Five-year average decreases of 1% to 10% in two or more revisit barrens for either species changes condition to caution.

- **Significant Concern:** Absence of either species in revisit barrens, or five-year average decreases greater than 10% in two or more revisit barrens for either species, changes condition to significant concern.

Current Condition:

2016: Caution**

Marin Water inventories at the time showed most populations were at lower levels than what was historically present.

2022: Caution

Data acquired between 2016 and 2022 allow us to establish condition thresholds; however, the dataset does not yet have five years of monitoring data for these species in all occupied barrens. Marin navarretia appears very stable in two barrens with five years of data, but declined to caution in another barren; a 15% decrease was detected in a barren with three years of data. Tamalpais jewelflower declined to caution in two of three occupied barrens.

Trend:

2016: Declining**

Populations appeared to be declining due to encroachment, although exact thresholds for what would constitute meaningful change had not been determined.

2022: No Change

Annual plant populations fluctuate significantly with annual rainfall amounts and timing. Population abundance varies year to year, but the current dataset indicates no significant trend. Occupancy remained stable over the time period of the current dataset.

Confidence:

2016: Moderate**

It was the opinion of the authors at the time that three consecutive years of drought may have made survey results used to assess this metric in 2016 artificially low.

2022: Moderate

The One Tam Serpentine Endemic Occupancy Project dataset has three to seven years of data in nine barrens across the serpentine band of Mt. Tam. However, more years of data on Marin navarretia and Tamalpais jewelflower are needed.

**The species assemblage used for this metric in 2016 was different than the assemblage used in 2022.

METRIC 3: RECOVERY GOALS MET FOR MARIN DWARF FLAX AND TAMALPAIS LESSINGIA

Baseline: In the *Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area* (USFWS, 1998), occurrences are "defined by the CNDDB as a location separated from other locations of the species by at least one-fourth mile; an occurrence may contain one or more populations."

Agency staff survey and manage at the population level. Two populations of Marin dwarf flax are found within the area of focus. The population on Carson Ridge averages 100 plants, which falls below recovery plan goals. The second population, four patches south of Carson Ridge, surpasses 2,000 individuals in some years.

According to data from the CNDDB (CDFW, 2009), four populations of Tamalpais lessingia are found within the area of focus. However, one has not been seen since initial mapping in 1960. Two populations are found along Oat Hill, one of which surpasses 2,000 individuals. The Azalea Hill population comprises seven patches, including Rocky Ridge serpentine areas, which exceeds 2,000 individuals. In some years, total numbers of lessingia in the area of focus exceed 50,000 plants. More than 10,000 individuals were observed in surveys of the Carson Ridge region in 2016.

Condition Goals:

As stated in the *Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area* (USFWS, 1998) recovery for Marin dwarf flax and Tamalpais lessingia is defined as the existence of the following:

- Seven Marin dwarf flax populations from Carson Ridge north, mostly outside area of focus.
- Two Marin dwarf flax populations south of Carson Ridge to San Francisco.
- Six Tamalpais lessingia populations in its entire historic range.
- The seeds of both species are in two seedbanks.

Note that populations are defined as 2,000+ plants and populations must be stable or increasing for 20 years.

Condition Thresholds:

- **Good:** Two Marin dwarf flax populations in the area of focus; six Tamalpais lessingia populations in its entire historic range (USFWS, 1998); seeds of both species are in two seedbanks and each population is at least 2,000 individuals.

- **Caution:** Two Marin dwarf flax populations in the area of focus; six Tamalpais lessingia populations in the area of focus; seeds of both species are in a seedbank and each population is at least 1,000 individuals.
- **Significant Concern:** The number of populations of Marin dwarf flax and Tamalpais lessingia falls below one and three, respectively, in the area of focus, or half the populations have fewer than 1,000 individuals.

Current Condition:

2016: Caution

In 2016, populations of Marin dwarf flax and Tamalpais lessingia were in decline. The former had two shrinking populations and the latter had only two populations that met the size threshold.

2022: Caution

Marin dwarf flax has two small populations in the area of focus, with one having fewer than 200 plants observed during the survey period. Tamalpais lessingia is extant on 42 of 99 barrens, for a total of three populations; one revisited barren contains Tamalpais lessingia where it has remained stable over the time period of the current dataset.

Trend:

2016: Declining

The rationale for a declining trend in 2016 is the same as for the condition of caution—populations of both Marin dwarf flax and Tamalpais lessingia were in decline.

2022: Declining

With two shrinking populations, Marin dwarf flax is in decline. Tamalpais lessingia shows a more stable trajectory.

Confidence:

2016: Moderate

Based on the field staff's best professional judgment, these populations were extant, but Marin dwarf flax numbers were low.

2022: High

Marin dwarf flax occurs on one surveyed barren and in adjacent grassland or roadside habitat. Concerted efforts to review this species were made in 2021.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

SERPENTINE ENDEMIC OCCUPANCY PROJECT

This robust monitoring program started in 2016 and includes five of the six species covered in this chapter in 99 serpentine barrens across the area of focus. Nine of those barrens are revisited annually to deliver trend data associated with all species in this chapter (with the exception of the Marin dwarf flax). The dataset includes species presence, abundance, and phenology. Three annual grasses known to invade serpentine barrens and grasslands are also monitored. For more information about Marin dwarf flax, One Tam surveyed known locations for the same variables. All data include tabular and geospatial features.

OTHER DATASETS USED

- Marin Water rare plant surveys (2009–2019).
- CNDDB data for background on certain species (2016).
- Serpentine barrens visible on aerial imagery.

INFORMATION GAPS

Patch-related Data: We do not know if barren patch size influences rare species composition or occupancy resilience, or if patches should be subsampled or rotationally sampled to determine health of the whole system. The current data collection protocol of revisiting a subset of barrens assesses a sample of barrens across the area of focus.

Potential Population Enhancement Areas: We need to identify areas suitable for augmentation.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Inventories: The One Tam Serpentine Endemic Occupancy Project described elsewhere began in 2016.

Invasive Species Management: Barbed goatgrass is controlled annually in serpentine habitats at Azalea Hill and Pine Mountain. Cheatgrass has is also controlled annually at West Peak and adjacent impacted barrens.

Past Work

Below are some of the stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Management:

- Adaptive management trials on Marin Water lands were conducted to assess efficacy for controlling purple false brome.

FUTURE ACTIONABLE ITEMS

This section includes a need identified by agency and local scientists during the development of this report. The action is not currently funded through agency programs and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Resource Management and Monitoring: Expand monitoring to include repeated surveys of Marin dwarf flax. Expand monitoring of Tamalpais lessingia by incorporating more revisit barrens. Revisit barrens with purple false brome to determine if control is warranted.

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CHAPTER 11. VEGETATION, SOIL, AND HYDROLOGY INDICATOR NEEDS

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What remains unknown about Mt. Tam's vegetation communities and their associated soil and hydrological resources is evidenced by the information gaps identified in each chapter and by the initial proposed indicators not yet included due to a lack of data (see Appendix 1). This chapter summarizes some of the more pressing information gaps, the current state of our knowledge about them, and what it might take to gather enough information to include them in the next iteration of this assessment.

VEGETATION MANAGEMENT AND MONITORING

One Tam partner agencies manage their own vegetation programs as well as benefit from larger-scale efforts supported by the partnership. These include the mountain-wide early detection and rapid response program for invasive weeds and the 2018 Marin Countywide Fine Scale Vegetation Map (GGNPC, 2021). Each chapter in this report describes the information sources used to evaluate the respective indicator in detail. Also included are management, monitoring, restoration, and other efforts to support that indicator, as well as ways to fill key data gaps. The following section, therefore, focuses on information gaps that apply to multiple health indicators.

INVENTORY, MONITORING, AND ASSESSMENTS

- **Complete an Historical Conditions Analysis for Priority Taxa:** Many of the condition statements made about the mountain's health indicators are based on comparisons to historical ranges or population statuses. While for some species, especially rare ones, historical information is available electronically and has been incorporated, not all museum collection information has been gathered or can be readily accessed. Historical field notes and notebooks are rarely searchable online, and old reports are often on shelves, not servers. Partnering with natural history museums to make collections data computer-searchable and tracking down historical notes and reports will allow us to compare the past to the present and paint a more complete picture as we look to the future.

- **Institute Systematic Plant Community Monitoring:** All One Tam agencies should apply the National Park Service's San Francisco Bay Area Network Inventory & Monitoring (SFAN I&M) approach to tracking long-term changes in a suite of vegetation communities. This approach uses a network of strategically placed plots to monitor fine-scale floristic change over time in specific communities. Currently included are coastal prairies at Point Reyes National Seashore, redwood forests at Muir Woods National Monument, mixed chaparral at Pinnacles National Park, and coastal scrub at Golden Gate National Recreation Area. Within these communities, the goal is to answer questions such as:
    - Is the number of species present in a community changing over time?
    - Which plant species are moving into a community, and which are no longer present?
    - How is the ratio of native to non-native plants changing within the community?
    - Is vegetation changing at a community level (e.g., grassland to shrubland)?

Because it is specific to lands managed by the National Park Service, the geographic scope of the SFAN I&M program is limited. Establishing similar plots elsewhere within the One Tam area of focus and training other agencies' staff in similar protocols will allow us to pool and compare data across jurisdictions. Including additional vegetation types will improve our understanding of how the region's biodiversity is responding to various stressors and further inform how to better protect the health of the mountain's exceptional plant diversity.

- **Develop a Mt. Tam Climate Adaptation Strategy to Further Inform Vegetation Management:** The San Francisco Bay Area's climate is changing in ways that will likely impact spatial patterns or distributions of native plant communities. Several recent studies and predictive modeling efforts (Thorne et. al., 2016; Ackerly et. al., 2012) provide insights into the climate vulnerability of existing vegetation communities and the possible future distribution of dominant plant species under various climate futures. Exploring the connections between these models and their projections for Mt. Tam's vegetation is a vital step in crafting adaptive strategies that will sustain vibrant, diverse ecosystems into the future. For example, blue oak (*Quercus douglasii*) is a species that is currently rare inside the area of focus. However, predictive models suggest that in a more-arid future, this species has the potential to expand its range. One Tam partners may want to consider adding this and other currently uncommon or absent species or genotypes into restoration planting palettes as part of a climate-adaptive strategy that looks to a functionally drier future.

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MOUNTAIN-WIDE FLORISTIC DIVERSITY

WHY IS THIS AN IMPORTANT INDICATOR?

Although this report includes many plant communities as ecological health indicators, a holistic snapshot of the mountain's vegetation remains elusive in such a biodiverse region. A mountain-wide measure of floristic diversity derived from iNaturalist observations would allow us to track change over time and inoculate ourselves against Shifting Baseline Syndrome (Pauly, 1995). This phenomenon occurs when, based on limited experience and memory, our collective concept of "normal" shifts so gradually that changes go unnoticed. For example, a frequent visitor may enjoy diverse and abundant wildflowers and perceive this as the norm. However, if the wildflower community declines due to climate change or habitat loss, the next generation of visitors may not even realize that wildflowers used to be more varied and plentiful. Using crowdsourced community science data from iNaturalist could establish a mountain-wide floristic diversity indicator in a meaningful and repeatable way that also promotes public participation and stewardship.

MONITORING AND DATA COLLECTION NEEDS

In 2023, we conducted a proof-of-concept exercise with Andrea Williams at the California Native Plant Society to determine if iNaturalist data could tell us about mountain-wide floristic diversity. These data explorations made clear that coverage and search effort were sufficient to characterize species richness across the One Tam footprint. We tested different methodological approaches to address biases inherent in crowdsourced data and ecological diversity metrics. Two measures of uniqueness and an attempt to aggregate taxa phylogenetically yielded strongly different results in diversity measure approaches. However, these preliminary analyses underscored the importance of the mountain's wet meadow complexes. Using iNaturalist data to assess mountain-wide floristic diversity has tremendous potential that needs additional investment to be fully realized.

ENSURING DATA QUALITY AND REFINING ANALYTICAL METHODS

Best practices in crowdsourced data analysis must resolve issues around spatial and temporal coverage, geographic and taxonomic accuracy, and the limitations of presence-only data (Rapacciuolo et al., 2021). The dataset of 34,959 plant observations in iNaturalist from 2008 to 2022 adequately covers the One Tam footprint in space and time. Data explorations also showed that most records have reasonable accuracy. Some data biases can be mitigated through aggregation at different spatial scales. Preliminary work also highlighted the importance of experts and on-the-ground knowledge. For example, the dataset for the One Tam footprint and subsequent data exploration benefited from a decade-long background of botanical bioblitzes and deep knowledge by botanists involved in the collection and curation of iNaturalist plant observations (Williams et al., 2017). This active curation allows us to better tease out what may be artifacts of sampling bias, misidentification, or other vagaries of undirected non-professional data collection. Questions remain about the merits of focusing attention on the mountain's biodiversity hotspots and how to address biases toward identifiable, showy plants and the abundance of observations made along roads and trails.

INVESTIGATING RECORDS WITH OBSCURED GEOCOORDINATES

iNaturalist geocoordinates typically reflect the true location of the organism observed. However, true geocoordinates are automatically obscured when a sensitive taxon is involved or when a user elects not to share them. In either case, public geocoordinates are replaced with a random point in a 0.2 x 0.2-degree cell (i.e., about the same size as San Jose, California), and other context that would give away the location is modified. Our data exploration did not use obscured records, thus excluding about 4% of the total available dataset. While land managers have access to similar information on population presence, incorporating such information alters the metric from one that relies solely on crowdsourced data. It is possible to retrieve true coordinates from obscured records through a time-intensive process. Nevertheless, our preliminary analysis suggests that even without these records, there is value in a mountain-wide diversity metric derived from crowdsourced data.

BUILDING COMMUNITY SCIENTIST CAPACITY

Within the One Tam area of focus, iNaturalist has become the platform of choice for plant observation by non-professionals. For comparison, over the past decade, Calflora's approximately 300 users made just over 8,500 plant observations within the One Tam area of focus; iNaturalist has more than 1,500 users and 22,000 observations, and its numbers are increasing every year. With robust training, community scientists of all ages and backgrounds can produce high-quality data using the existing iNaturalist Data Quality Assessment framework. iNaturalist is also a social network with community guidelines and moderation. This can facilitate dialogue among project participants and One Tam staff, helping participants form a community. Finally, project participants can use iNaturalist beyond the scope of this project to satisfy their own curiosity and connect to nature and each other.

Ultimately, by offering more training for community scientists, we can improve the experience of observers and the quality of their data. Like all tools and technologies, iNaturalist has a learning curve that can be addressed with additional training (e.g., webinars, workshops) focusing on skills such as how to take photos that can be used for identification as well as data upload workflows and annotation. Ongoing efforts to build and share naturalist skills among community scientists should continue to be a priority.

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SEEPS, SPRINGS, AND WET MEADOWS

WHY IS THIS AN IMPORTANT INDICATOR?

Seeps, springs, and wet meadows are characterized by fresh groundwater discharge that rises to form distinctive wetland features. These are, in turn, often associated with unique aquatic ecosystems (Howard et al., 2010). However, there are some important differences among these habitats.

Springs and seeps are considered perennial if they flow continuously, or intermittent if they are naturally interrupted or sporadic. Their flows may also vary over time. For example, short-term flow changes can happen as a result of the “syphon effect,” in which groundwater channels fill and create periodic surges.

Wet meadows, a type of marsh that often resembles low-lying grasslands, are commonly found in poorly drained areas, such as land between shallow marshes and upland areas. Even though wet meadows lack standing water most of the year, a high water table allows the soil to remain saturated.

All of these habitats can be used as indicators of biological integrity and diversity, habitat quality, natural processes and disturbance regimes, and climate change vulnerability. A wet meadow acts as a natural filter, collecting and storing runoff and removing excess nutrients. Its nutrient-rich environment provides vital food and habitat for a wide range of wildlife. In addition to the aquatic, riparian, or terrestrial habitats springs and seeps may support, the areas around them that also receive moisture can foster unique microhabitats. These may be created by specific characteristics, including temperature, water depth, dissolved ion or oxygen composition, disturbance, or a suite of physical variables creating unique environments that can support high levels of endemic species (Baldwin et al., 2012). These associated plant communities may include rare plants such as Harlequin lotus (*Hosackia gracilis)*, Mt. Tamalpais thistle (*Cirsium hydrophilum* var. *vaseyi)*, marsh zigadenus (*Toxicoscordion fontanum)*, Gairdner’s yampah (*Perideridia gairdneri* ssp. *Gairdneri)*, and pink star-tulip (*Calochortus uniflorus)*.

Conversely, surrounding ecosystems are also likely to influence the physical conditions, plant colonization, wildlife and human uses, and other characteristics of seeps, springs, and wet meadows. In general, steep ecological gradients of environmental stability, chemistry, moisture availability, productivity, and other factors most strongly affect levels of biodiversity and endemism in these habitats (Malanson, 1993).

Springs may also function as refugia across ecological and evolutionary time scales (Springer et al., 2008). Short-term hydrologic changes to these ecosystems may be caused by individual storms or droughts, while longer-term ones may be caused by interannual climate variation or larger-scale climate and hydrologic changes. Spring discharge variability may affect the distribution of associated microhabitats (Springer et al., 2008), as much of the vegetation is limited by the presence of standing water.

MONITORING AND DATA COLLECTION NEEDS

MOUNTAIN-WIDE SEEPS AND SPRINGS MONITORING

Our current knowledge of the locations, discharge rates, and size of these habitats has been based on very limited monitoring and a few inventories, primarily on National Park Service lands. However, One Tam partners did a springs inventory in 2016, which established a baseline dataset and a map of spring locations in Mt. Tamalpais State Park and the Marin Water watershed. The study recorded disturbance sources, site conditions, flow duration and distance, substrate characteristics, vegetation cover, and dominant species (Kurzweil et al., 2021).

While this study provided important baseline data, we have not yet been able to translate it into a mountain-wide survey protocol and associated monitoring program that would help us understand flow and species composition nor how these landscape features are responding to climate change and other stressors.

Monitoring could include:

- Location and estimated extent.
- Native plant species richness and relative cover.
- Non-native and invasive plant species presence and relative cover.
- Rare, threatened, and endangered species presence and relative cover (data collection to include attributes consistent with agency partner rare plant monitoring protocols).
- Perennial or ephemeral classification.
- Discharge rate(s), potentially measured at multiple timeframes.
- Macroinvertebrate species presence/absence.
- Water chemistry/quality parameters.

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DOUGLAS-FIR FORESTS

WHY IS THIS AN IMPORTANT INDICATOR?

Douglas-fir, the dominant conifer species in the Pacific Northwest, is relatively tolerant of a wide range of climates and soils (Atzet & McCrimmon, 1990; Hermann & Lavender, 1990), though is restricted to areas with sufficient rainfall. If allowed, these trees can live to 500 years or more. Douglas-fir, and the forests it dominates, are important habitats for species such as the Northern Spotted Owl (*Strix occidentalis caurina*) (Cary et al., 1990; Glenn et al., 2004). Seeds of this tree are critical dietary components for many mammals, including mice, voles, shrews, chipmunks, and squirrels (Gashwiler, 1970; Arno, 2007), as well as many bird species, such as the Dark-eyed Junco (*Junco hyemalis*) and White-crowned Sparrow (*Zonotrichia leucophrys*) (Black, 1969; Arno, 2007).

Native Americans used fire as a management tool for thousands of years to open up forests, effectively removing or excluding Douglas-fir from many areas. Until the mid-20th century, this species was also heavily logged in Marin County. Although Douglas-fir is still widespread, the combination of fire and logging likely reduced its extent and density across Marin County and the One Tam area of focus. While it is assumed that the historical fire regime in these habitats was defined by frequent fires, available data indicate that they occurred, on average, approximately every 100 years in coastal Douglas-fir forests (Van de Water & Safford, 2011). Many areas of Mt. Tam have not burned for more than 100 years.

Forests classified as Douglas-fir (*Pseudotsuga menziesii-Notholithocarpus densiflorus-Arbutus menziesii* Alliance) encompass 9,484 acres of the One Tam area of focus, including lands not managed by One Tam partner agencies. These forests are found primarily in the moist microclimates north of Kent Lake, along portions of Bolinas Ridge's western slope, and around the mountain's northern, western, and southern slopes. Although Douglas-fir is the dominant tree species in these forests, other subdominant canopy and subcanopy tree species, such as California bay (*Umbellularia californica*), madrone (*Arbutus menziesii*), tanoak (*Notholithocarpus densiflorus*), and coast live oak (*Quercus agrifolia*), also are usually present.

There are few, if any, old-growth stands in the area of focus, leading managers to believe that this species has been steadily expanding its range and dominance since the cessation of logging and burning. This recolonization (or spread) is considered an invasion into other vegetation types, and management actions are often directed at removing this species.

MONITORING AND DATA COLLECTION NEEDS

Future monitoring could include:

- Impacts of stressors on this species and the forests it dominates.
- Stand demographic structure.

- Wildlife use and biodiversity.
- Differences in stand composition and health, in both burned and unburned areas.

VEGETATION TYPES INCLUDED

- Alliances and associations with Douglas-fir listed as the dominant canopy species.

SUPPORTING DATA AND ANALYSES

Given its widespread distribution, the Douglas-fir forest was analyzed extensively as part of the Marin Regional Forest Health Strategy (GGNPC, 2023). This included canopy mortality mapping to capture pathogen and other stressor effects. Figure 11.1 summarizes the total acres of Douglas-fir forest by percent canopy mortality classification.

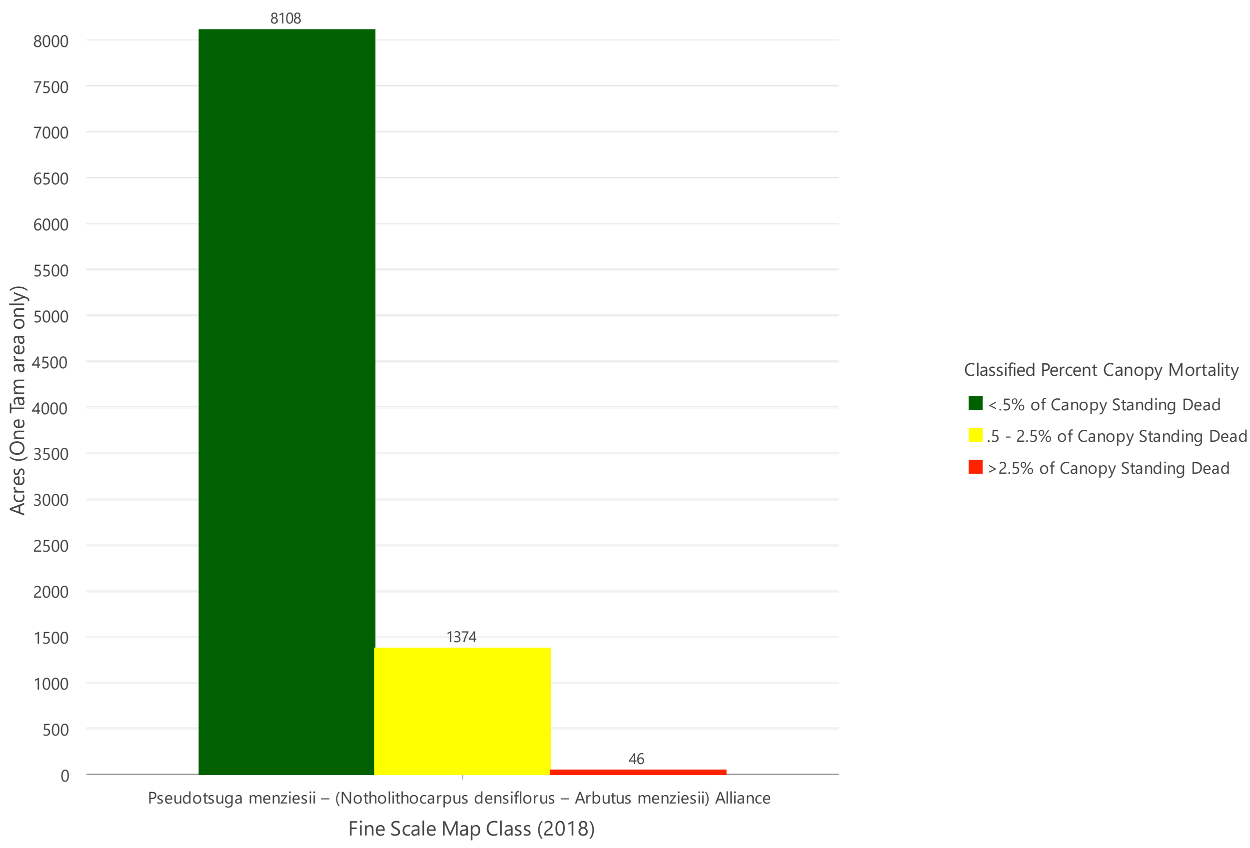

FIGURE 11.1 TOTAL ACRES OF DOUGLAS-FIR FOREST BY PERCENT CANOPY MORTALITY CLASSIFICATION, 2018

Analysis of woody plant encroachment in Marin County comparing historical aerial imagery from 1952 to 2018 found that 485 acres of grassland were replaced by woodland within the 4,745-acre study area, and that Douglas-fir accounted for 81% of that conversion (Startin, 2022). Within the One Tam area of focus, 35% of Douglas-fir forests (3,329 acres) is classified as structurally small, with a mean lidar-derived stand height of less than 60 feet (Figure 11.2). As described in greater detail in the Marin Regional Forest Health Strategy, these areas closely align with relatively recent areas of Douglas-fir forest expansion (e.g., since 1950).

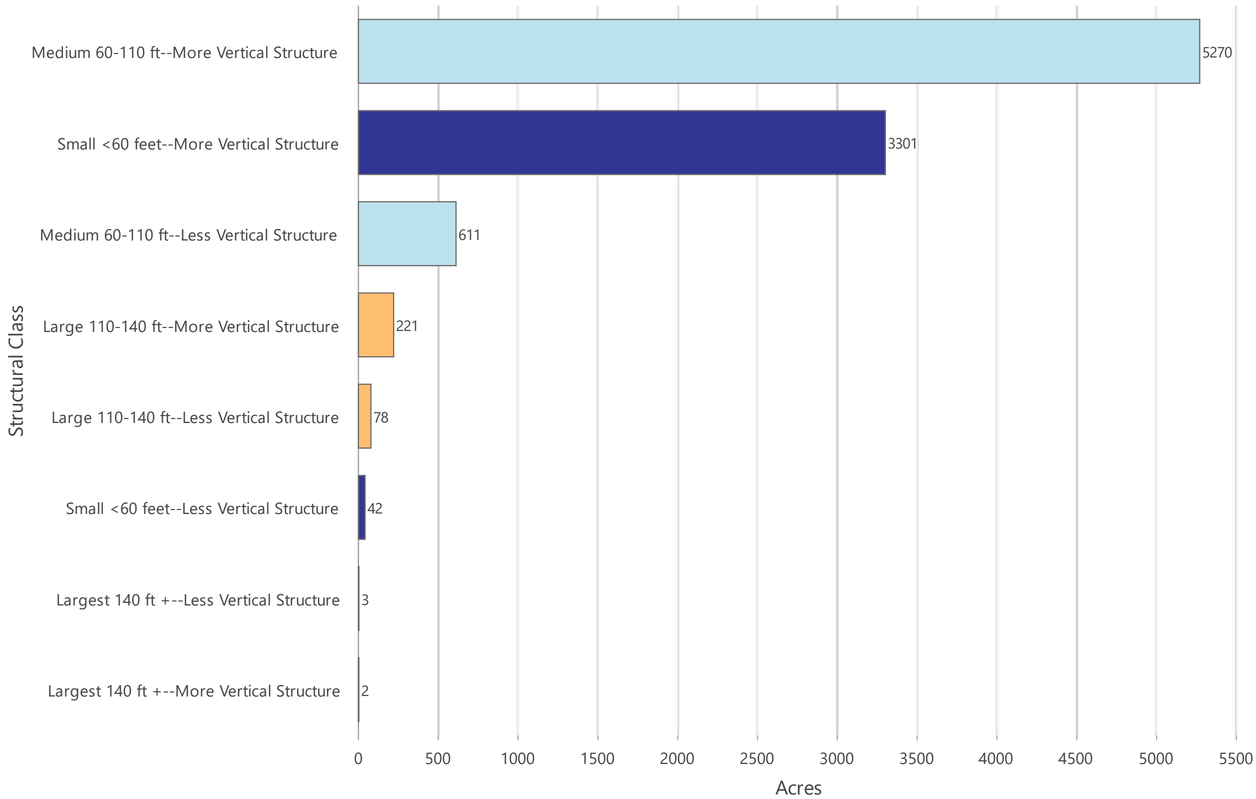

FIGURE 11.2 LIDAR-DERIVED DOUGLAS-FIR STRUCTURAL CLASSIFICATION, 2019 (GGNPC, 2023)

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HARDWOOD FORESTS AND WOODLANDS

WHY IS THIS AN IMPORTANT INDICATOR?

Hardwood forests and woodlands are vegetation types in which the canopy layer is dominated by one or more tree species other than those included in the open-canopy oak woodlands indicator chapter (Chapter 6). These include coast live oak (*Quercus agrifolia*), valley oak (*Q. lobata*), Oregon oak (*Q. garryana*), and California black oak (*Q. kelloggii*) as well as those that are exclusively riparian, such as red alder *(Alnus rubra*).

Thus, these hardwood forests and woodlands include areas dominated by California bay (*Umbellularia californica*), madrone (*Arbutus menziesii*), tanoak (*Notholithocarpus densiflorus*), canyon live oak (*Quercus chrysolepis*), chinquapin (*Chrysolepis chrysophylla*), buckeye (*Aesculus californica*), and bigleaf maple (*Acer macrophyllum*). Hardwood forests and woodlands are found throughout the One Tam area of focus but are most abundant where Douglas-fir (*Pseudotsuga menziesii*) and coast redwood (*Sequoia sempervirens*) (moist microclimates) and chaparral (dry microclimates) are not present.

The extent, integrity, and health of hardwood forests and woodlands are important indicators of the overall health of Mt. Tam. Within the One Tam area of focus, hardwood forests and woodlands account for 13,879 acres (42% of all native forests), including lands not managed by One Tam partner agencies. California bay woodland accounts for 63% (8,760 acres) of all hardwood forest within the area of focus. Bay tree leaves are a principal browse for deer (Biswell & Gilman, 1961; Sampson & Jespersen, 1963; Stein, 1974), and its fruits are an important food for the dusky-footed woodrat (*Neotoma fuscipes*), California deermouse

(*Peromyscus californicus*), Steller's Jay (*Cyanocitta stelleri*), and western gray squirrel (*Sciurus griseus*) (Stienecker & Browning, 1970; Stienecker, 1977).

California bay is also the largest contributor to the spread of Sudden Oak Death (SOD) caused by the pathogen *Phytophthora ramorum* (Davidson et al., 2005), which has been killing coast live oak, tanoak, California black oak, and other native species since it was first detected in 1995. As a result, previously oak-dominated forests and woodlands are slowly converting to stands dominated by other hardwoods, including California bay and madrone. However, California bay is susceptible to *Phytophthora cinnamomi* and may also be killed by the fungus *Raffaelea lauricola,* spread by the non-native redbay ambrosia beetle (*Xyleborus glabratus*) (Mayfield et al., 2013), which is killing trees in the Lauraceae family in the southeastern United States (Kendra et al., 2013).

Madrone, the third most abundant hardwood forest type after California bay (8,760 acres) and coast live oak (2,886 acres), covers an additional 21% (1,065 acres) of hardwood forest in the One Tam area of focus. Anecdotal evidence suggests that this species is experiencing local to widespread twig and tree mortality caused by drought stress and fungus (*Botryosphaeria dothidea*) (Bennett & Shaw, 2008). Although the extent and severity of this problem is unknown, it is likely relatively small. Madrone is also susceptible to two *Phytophthora* species (*P. cactorum* and *P. cinnamomi*). Both of these root diseases have been confirmed in Marin County. Their impact on madrone and other native species in the One Tam area of focus is unknown, but probably small.

Forests dominated by tanoak have been severely impacted by SOD, with many stands experiencing 50% to 100% stem dieback (McPherson et al., 2010; Swiecki & Bernhardt, 2013). In many cases, these stands are caught in a cycle of stem death followed by regeneration and subsequent stem death.

There are also smaller extents dominated by other hardwood species, including canyon live oak, buckeye, chinquapin, and bigleaf maple. While other kinds of hardwood forests are not known to support the high wildlife biodiversity as those dominated by oaks, they contribute to overall floristic and faunal biodiversity and are regarded as important habitat for a variety of wildlife. Each of these tree species is also susceptible to one or more species of *Phytophthora*.

MONITORING AND DATA COLLECTION NEEDS

THE EFFECTS OF STRESSORS

Hardwood species and the forests and woodlands they define are being impacted by many stressors, including pathogens; climate change; altered fire regimes; and non-native, invasive species. It would be important to monitor the changes and impacts as they react and respond to these stressors. Data needs include:

- Impacts of stressors on the trees and their associated ecosystems.

- Vegetation and associated changes driven by the stressors.
- Stand demographic structure and trends.
- Wildlife use and biodiversity.
- Differences in stand composition and health in both burned and unburned areas.

SUPPORTING DATA AND ANALYSES

The 2018 Fine Scale Vegetation Map (GGNPC et al., 2021) provided an opportunity to update the baseline inventory of hardwood forests and woodlands across the One Tam area of focus. Figure 11.3 details acreages for each of the hardwood forest types mapped within the One Tam area of focus. This new data confirms that California bay and madrone remain the most widely distributed hardwood forest types here (Figure 11.4). The 2018 map also depicts a significant number of acres of canyon live oak and shows limited distribution of bigleaf maple, tanoak, and buckeye. The 2023 Marin Regional Forest Health Strategy (GGNPC, 2023) includes analyses of forest condition and stressor impacts for hardwood forest and woodland types not characterized as open canopy oak woodlands that could also support future analyses. Examples of the kinds of information these two assessments can provide are summarized here.

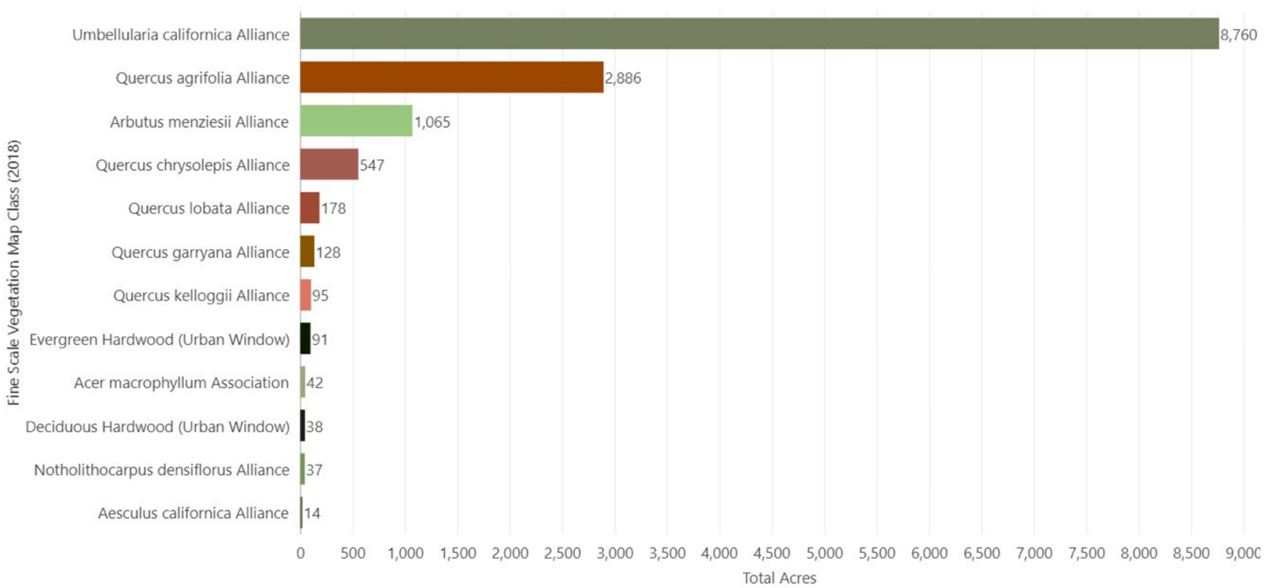

FIGURE 11.3 ACRES OF ALL HARDWOOD FOREST AND WOODLAND ALLIANCES/ASSOCIATIONS, ONE TAM AREA OF FOCUS (GGNPC ET AL., 2021)

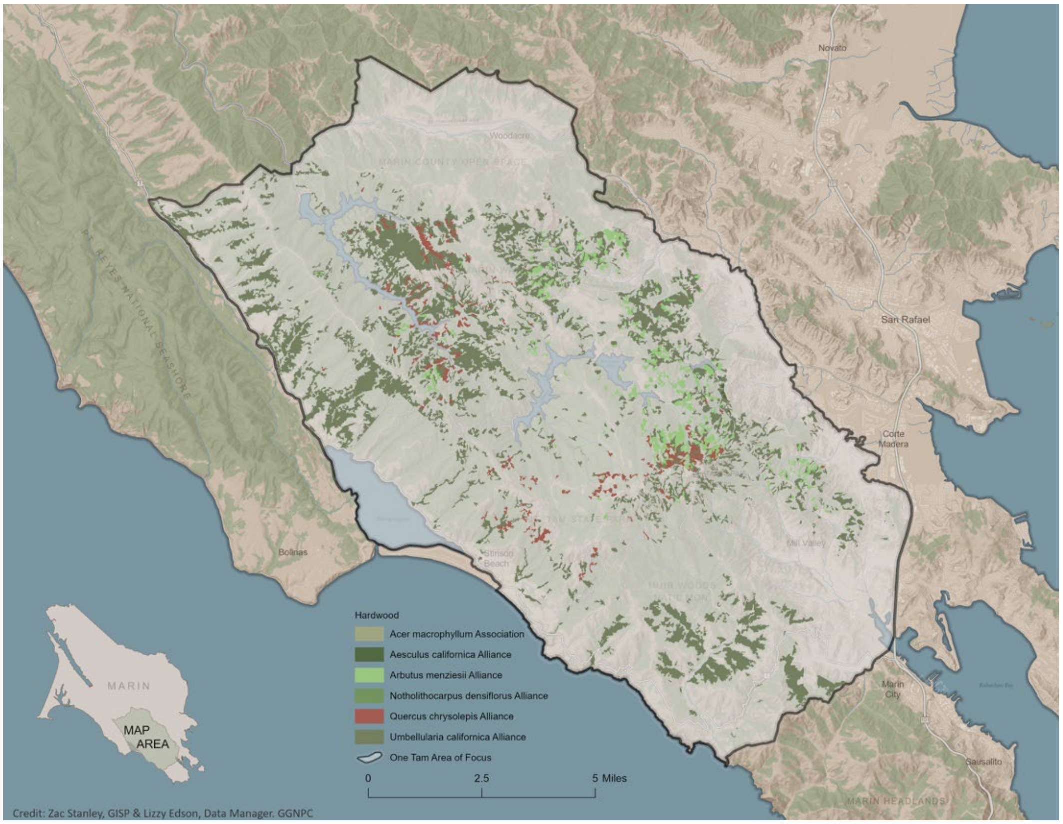

FIGURE 11.4 DISTRIBUTION OF HARDWOOD FOREST AND WOODLAND STANDS, ONE TAM AREA OF FOCUS (GGNPC ET AL., 2021)

Analyses performed as part of the Forest Health Strategy provide some insight into the condition of these forest types and impacts from stressors such as pathogens. To study and quantify impacts that can cause canopy mortality, photo-interpreters assigned a percent integer of visible canopy die-back for all forested stands in the 2018 Fine Scale Vegetation Map. Figure 11.5 details the extent of canopy mortality for each of the six hardwood forest types mapped within the One Tam area of focus. Notably, very few tanoak-dominated stands were mapped in 2018, and no stands with less than 0.5% to 2.5% canopy mortality, which is consistent with previous findings indicating severe SOD impacts. Table 11.1 details the percentage of canopy mortality by class and corresponding acres, and Figure 11.6 maps the distribution of hardwood forest by canopy mortality class.

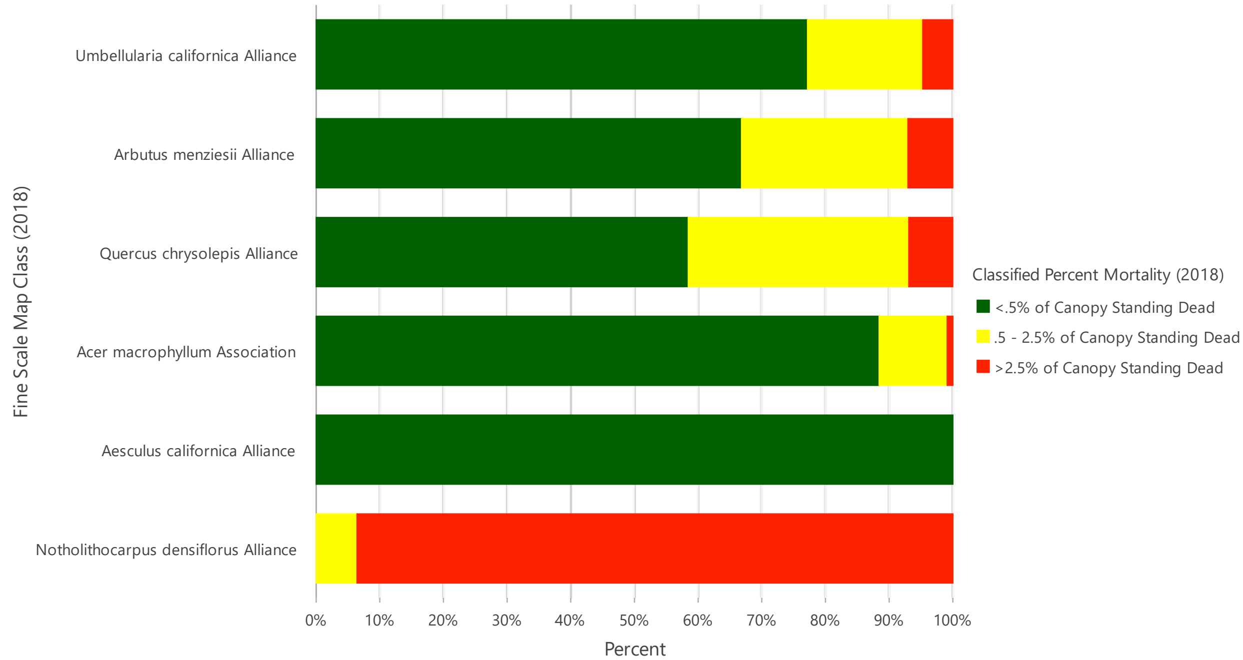

FIGURE 11.5 HARDWOOD FOREST AND WOODLAND ALLIANCES/ASSOCIATIONS WITH CLASSIFIED PERCENT CANOPY MORTALITY, 2018 (GGNPC, 2023)

TABLE 11.1 TOTAL ACRES AND PERCENT OF TOTAL FOR EACH CANOPY MORTALITY CLASS BY HARDWOOD FOREST AND WOODLAND TYPE (GGNPC, 2023)

	Standing Dead Classification (Acres/Percent of Total)					
Hardwood Forest/Woodland Map Class	**<0.5% Canopy Mortality (None or trace)**		**0.5% to 2.5% Canopy Mortality**		**<2.5% Canopy Mortality**	
California Bay (*Umbellularia californica*)	6,793 acres	77%	1,594 acres	18%	415 acres	5%
Madrone (*Arbutus menziesii*)	716 acres	67%	280 acres	26%	75 acres	7%
Canyon Live Oak (*Quercus chrysolepis*)	319 acres	58%	189 acres	35%	38 acres	7%
Bigleaf Maple (*Acer macrophyllum*)	42 acres	88%	5 acres	11%	<1 acres	1%
Tanoak (*Notholithocarpus densiflorus*)	0 acres	0%	2 acres	6%	34 acres	94%
Buckeye (*Aesculus californica*)	14 acres	100%	0 acres	0%	0 acres	0%

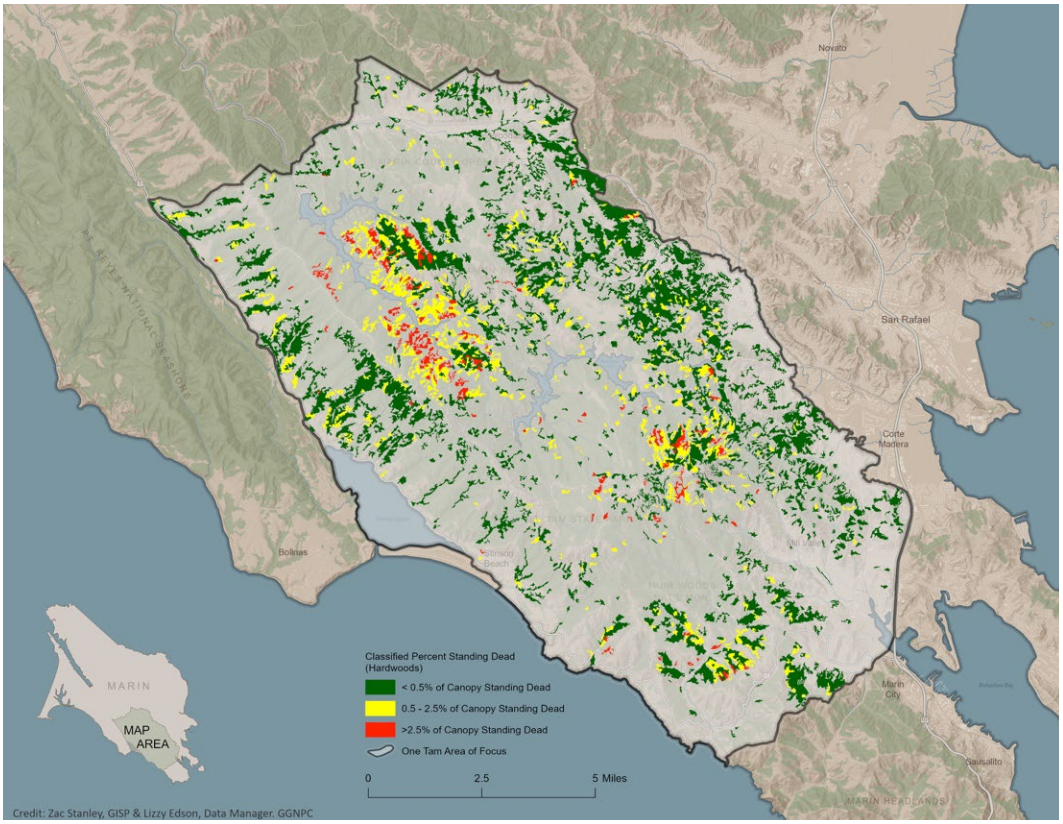

FIGURE 11.6 DISTRIBUTION OF HARDWOOD FOREST AND WOODLAND STANDS BY CLASSIFIED CANOPY MORTALITY, 2018 (GGNPC, 2023)

The Forest Health Strategy also considered adverse impacts of fire exclusion on hardwood forests, from either fire suppression or the removal of Coast Miwok people and disruption of traditional tribal forest-tending practices. One impact is the conversion of open-canopy oak woodland forests to Douglas-fir, which happens when fire exclusion facilitates Douglas-fir seedling growth that eventually pierces the canopy, crowds out other species, and causes a loss of oak vigor and abundance (Cocking et al., 2014). Using relative conifer versus hardwood density metrics in the 2018 Fine Scale Vegetation Map, the Forest Health Strategy mapped open-canopy oak woodland stands actively converting to conifer (presumably, but not exclusively, Douglas-fir) in which more than 10% conifer cover was detected. Hardwood stands with less than 10% conifer cover but within one-quarter mile of Douglas-fir stands were mapped as threatened with conversion. It is less well understood if the same Douglas-fir conversion dynamics are at work in other hardwood forests. However, the availability of relative conifer values for these non-open-canopy hardwood forest types provides baseline data for future analyses that can further explore the relationship between fire exclusion and conifer encroachment (Figure 11.7).

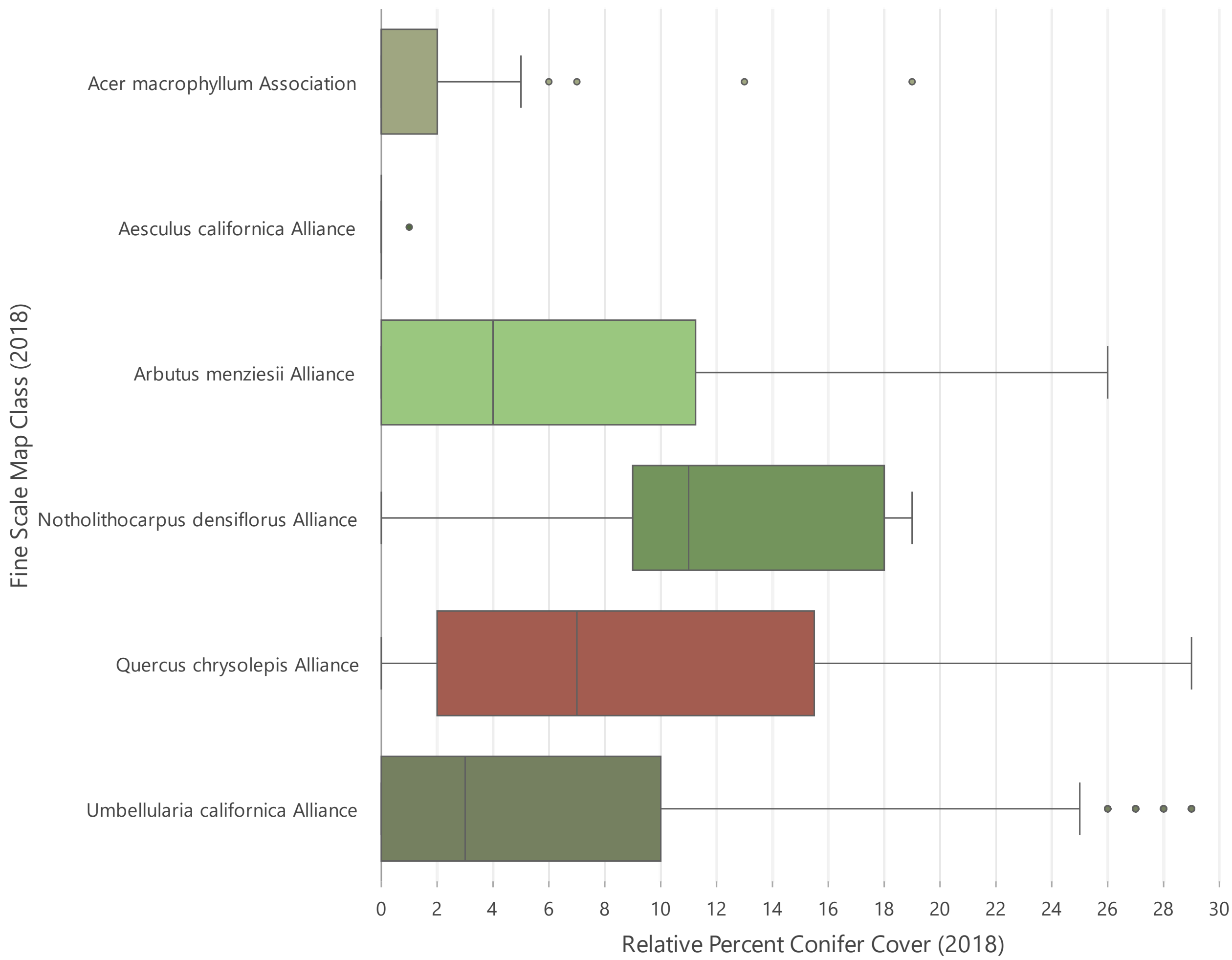

FIGURE 11.7 DISTRIBUTION OF RELATIVE PERCENT CONIFER COVER FOR HARDWOOD FORESTS AND WOODLANDS, ONE TAM AREA OF FOCUS

In addition to tracking the percentage of relative conifer cover for hardwood forests, the percentage of relative hardwood cover can be a useful metric for assessing stand dynamics and stressor impacts over time. Relative percent hardwood cover values established in 2014 were attributed to both Marin Water and Marin County Parks vegetation maps, which provided baselines for detecting changes in 2018 as part of the Forest Health Strategy.

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RIPARIAN WOODLANDS AND FORESTS

WHY IS THIS AN IMPORTANT INDICATOR?

Riparian areas comprise less than 1% of the land in the western United States (NRCS, 1996); however, native riparian plant communities are some of the most productive wildlife habitats in North America. Critically important to the life cycle of endangered salmonid species (FISRWG, 1998), the aquatic macro-invertebrates that these fish eat depend upon healthy riparian forests. Furthermore, the linear nature of riparian ecosystems provides distinct corridors that are important migration routes and connectors between wildlife habitats. They are also responsible for regulating critical ecosystem functions such as nutrient cycling, energy transfer, and water purification in adjacent aquatic environments—all of which are necessary to support plant and wildlife diversity (Lennox et al., 2011).

Specifically, riparian vegetation:

- Helps stabilize stream banks.
- Acts as a buffer to sediment, nutrient, and pathogen inputs from adjacent lands.
- Optimizes light and temperature conditions to maintain low water temperatures and regulate dissolved oxygen levels for aquatic plants, fish, and other wildlife.
- Contributes substantial quantities of large woody debris, which provides essential in-stream habitat for insects and fish.
- Deposits substantial amounts of leaf litter, insects, and nutrients that are crucial components of aquatic food webs.

Riparian woodland and forest habitat is limited to approximately 361 acres within the One Tam area of focus, including lands not managed by One Tam partner agencies. These areas include species such as Pacific willow (*Salix lasiandra*), arroyo willow (*S. lasiolepis*), western dogwood (*Cornus sericea* ssp. *occidentalis*), blue elderberry (*Sambucus nigra* ssp. *caerulea*), California wax myrtle (*Morella californica*), California blackberry (*Rubus ursinus*), coast twinberry (*Lonicera involucrata* var. *ledebourii*), and flowering currant (*Ribes sanguineum* var. *glutinosum*). Mt. Tam's riparian forests and woodlands are being impacted by many stressors, including groundwater depletion; climate change; and non-native, invasive species. It would be important to monitor changes and impacts to these ecosystems as they react and respond to these stressors.

MONITORING AND DATA COLLECTION NEEDS

Our current knowledge of both the integrity and connectivity of Mt. Tam's riparian habitats is limited to past monitoring focused on specific restoration projects or weed-detection surveys. Developing a mountain-wide assessment and associated monitoring program will improve our understanding of the health of these communities and how they are changing in response to climate change and other stressors.

Monitoring could include:

- Number of acres of late-successional native riparian habitat (characterized by complex/layered structure that includes large floodplain trees in the overstory, understory trees and shrubs, and vines and ground cover such as *Juncus* spp., *Carex* spp., and *Leymus* spp.
- Number of trees larger than 24 inches in diameter at breast height.
- Acres of woodland and forest habitat (ephemeral, intermittent, and perennial).
- Riparian cover characteristics required for adequate sediment buffering and stream channel shading.
- Presence and extent of priority non-native, invasive plant species.
- Corridor length, connectivity, and width.
- Fluvial geomorphic processes necessary to sustain long-term riparian succession and habitat formation.

The 2018 Marin Countywide Fine Scale Vegetation Map (GGNPC et al., 2021) provides some insight into the composition and distribution of riparian woodlands and forests, but more analysis is needed to fully establish baseline conditions. The map identifies 396 acres of obligate riparian forest and woodland tree species within the One Tam area of focus (Figure 11.8), including lands not managed by One Tam partner agencies. However, looking only at obligate species underrepresents the distribution of vegetation communities that are also *functionally* riparian in other areas. For example, areas that have species that grow in both riparian and non-riparian settings (e.g., California blackberry, coast redwood [*Sequoia sempervirens*], California bay [*Umbellularia californica*], and coast live oak [*Quercus agrifolia*]). Therefore, for a more thorough analysis, spatially delineating riparian corridors is required. Functional riparian mapping, which is possible with remote methods that use a combination of channel, top of bank, and floodplain mapping, could offer greater insight into the distribution and condition of riparian forests and woodlands (see Hydrologic Functions section).

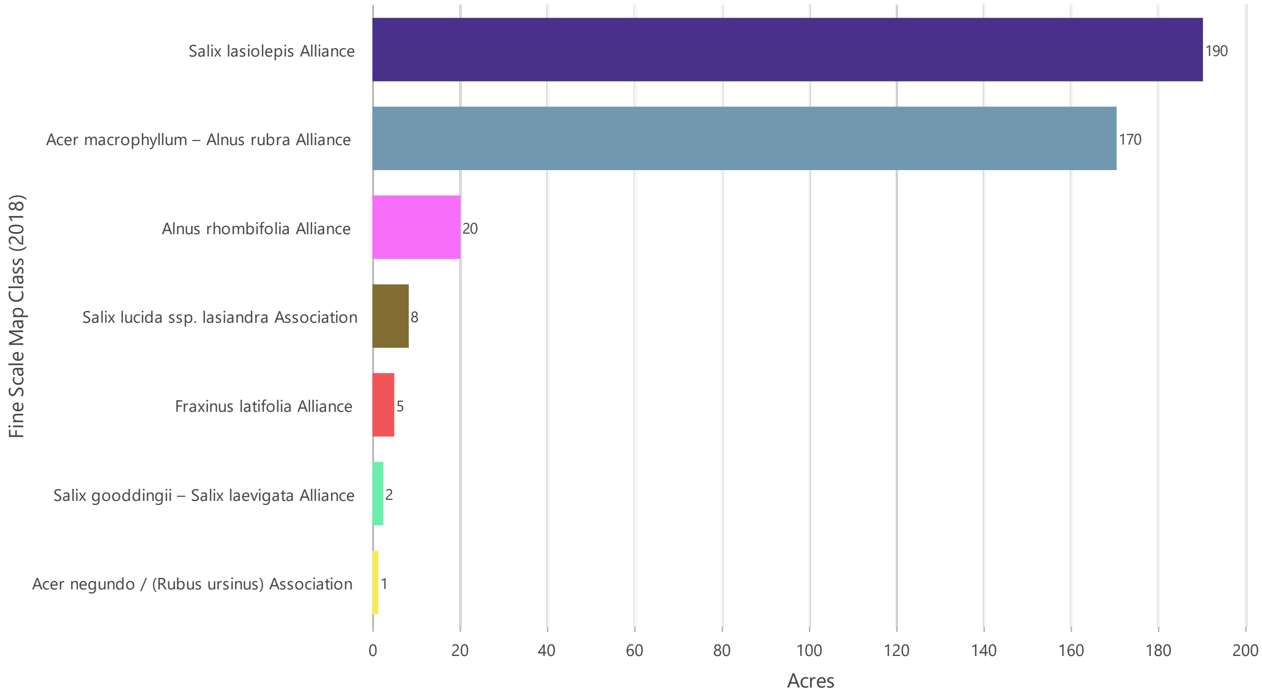

FIGURE 11.8 ACRES OF RIPARIAN FOREST AND SHRUBLAND ALLIANCES/ASSOCIATIONS, ONE TAM AREA OF FOCUS (GGNPC ET AL., 2021)

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LICHENS

WHY IS THIS AN IMPORTANT INDICATOR?

Mt. Tam hosts a remarkable diversity of lichens for the same reasons it supports so many different types of plants: its diverse array of habitats and microclimates. There are 350 lichen species reported in the One Tam area of focus, including one rare species, Methuselah's beard (*Usnea longissimia*), and the California state lichen, lace lichen (*Ramalina menziesii*). Ecologically, lichens are important because they provide a number of ecosystem services, including nesting material, food, habitat, soil development and stabilization, carbon fixation, and nutrient cycling. While there have been limited surveys in areas such as Roy's Redwoods Open Space Preserve (TLC, 2018) and on Marin Water lands (Carlberg & Benson, 2015), most areas on the mountain have yet to be explored.

Climate change has been identified as a key factor threatening Mt. Tam's biological diversity. Lichens, which are known for their sensitivity to air pollution and climate, are one of the first groups of organisms to respond to shifts in environmental conditions (Gries, 1996; Hawksworth & Rose, 1976). Therefore, a change in the lichen community can indicate impacts to the larger ecosystem's function and integrity.

In the last decade, research has also shown that lichens respond predictably along climate gradients and correlate to temperature and moisture changes (Geiser & Neitlich, 2007). Additionally, lichens are very responsive to nitrogen pollution. By monitoring status and trends in the lichen community, land managers can infer the extent and severity of pollution and climate impacts on other organisms and identify management actions to potentially reduce or ameliorate these impacts.

MONITORING AND DATA COLLECTION NEEDS

Implement a Systematic Lichen-Monitoring Plot Establishment and Inventory: A lichen-monitoring program should follow nationally standardized protocols and use regionally specific air quality and climate gradient models developed by the U.S. Forest Service (USFS, 2011). Four to five plots could be tied into current and future vegetation community monitoring plots and resampled once every five years (S. Benson, personal communication, 2016).

This research would help:

- Document a baseline for lichen community composition to detect sensitive indicator species before they disappear due to environmental stressors.
- Install a sustainable, cost-effective strategy for monitoring spatial pattern and temporal trends in air quality, climate, and biodiversity at multiple scales within both the One Tam area of focus and the broader region (as defined by the regional gradient model).

- Contribute to the One Tam lichen inventory using the species lists generated from lichen monitoring-plot data.

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SOILS

WHY IS THIS AN IMPORTANT INDICATOR?

Soil is increasingly recognized as a critical component of ecosystem health. The State of California's Healthy Soils Initiative defines healthy soils to be those "that enhance their continuing capacity to function as a biological system, increase soil organic matter, improve soil structure and water- and nutrient-holding capacity, and result in net long-term greenhouse gas benefits." In addition to ecosystem health, soil's remarkable biodiversity is increasingly recognized as providing benefits to human health because it can suppress disease-causing soil organisms and provide clean air, water, and food (Bardgett & van der Putten, 2014; Wall et al., 2015).

Nevertheless, little information exists on soil biodiversity and function in general, nor on Mt. Tam specifically, other than some limited sampling focused on *Phytopthora* species around Lake Lagunitas and Pilot Knob (Phytosphere Research, 2021). Yet, given its array of vegetation communities, soil types, diverse topography, and microclimates, the mountain may host an impressive amount of soil biodiversity.

The benefit of soils as an indicator is that they are known to be affected by a wide variety of human-induced changes, including climate change, and they influence so many other aspects of ecosystem and human health.

MONITORING AND DATA COLLECTION NEEDS

Develop and Implement Baseline Soil Sampling: Developing a survey protocol and collecting baseline data will help provide a more complete picture of biological diversity on Mt. Tam and establish a benchmark against which future resampling efforts can be used to assess the mountain's health.

Because no information on the biodiversity of soils currently exists, it will be necessary to consult experts in the field to:

- Align on the best metrics for inventorying and monitoring soil biodiversity.
- Determine if additional elements of soil health should be included (e.g., soil organic carbon).
- Conduct an inventory of soil biodiversity and other elements, if judged important.
- Align on monitoring goals and establish a protocol that most efficiently meets those goals.

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HYDROLOGIC FUNCTIONS

WHY IS THIS AN IMPORTANT INDICATOR?

Hydrologic functions are governed by complex interactions between global climate dynamics, regional- and landscape-scale physical drivers (e.g., precipitation, streamflow, fog, and groundwater recharge), and watershed- and site-scale conditions (e.g., watershed geology, vegetation communities, and fluvial geomorphology). These functions, central to the mountain's health, include indicators such as streamflow quantity and quality for fish and other aquatic organisms, soil moisture to support plant establishment and growth, sediment delivery from watersheds into streams, and much more. They are highly vulnerable to a range of human impacts, including global climate change, dams and other infrastructure, fire protection activities, and vegetation management.

Despite (or because of) their fundamental importance to ecosystem health and vulnerability to anthropogenic change, hydrologic functions can be challenging to monitor, analyze, interpret, and integrate into decision making. In a discussion of stream metrics for San Geronimo Creek, Booth and Singer (2009) provided an excellent overview of the difficulties facing those who attempt to develop hydrologic metrics within a management framework:

> "Although 'stream monitoring' is an ever-more common activity of jurisdictions, many such efforts either lack a coherent conceptual framework or appropriately chosen methods, and as such, do not provide adequate information to reach their intended goals. . .. The problem is generally not with executing specific monitoring protocols—many guidance documents exist that specify proper techniques for data collection. Instead, the major shortcoming is in choosing an approach that will provide sufficient data to answer particular management questions and that is feasible for the institutional context and available resources."

The challenges that Booth and Singer describe are magnified by the fact that the mountain's four public land managers each has distinct missions, management goals, institutional and administrative structures, and financial and staffing resources. However, identifying hydrologic functions as an important indicator for measuring the health of Mt. Tam offers an opportunity to define and apply a coherent, integrated, and fiscally feasible mountain-wide monitoring approach.

Existing monitoring is dominated by metrics with a regulatory nexus, such as streamflow, water quality, and bed composition in Lagunitas and Redwood Creeks (relevant to salmonids), the depths and distribution of pool habitat along Carson Creek (relevant to foothill yellow-legged frogs [*Rana boylii*]), and others. In these cases, monitoring, analysis, and reporting methods are typically dictated by resource agencies such as the California Department of Fish and Wildlife, the San Francisco Bay Regional Water Quality Control Board, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service. The questions that these data seek to address are typically narrow in scope and often of limited utility to broader management planning. Watersheds with a limited regulatory nexus, such as Corte Madera Creek, Arroyo Corte Madera del Presidio, Coyote Creek, and many others, are typically only monitored on an opportunistic basis, often by local advocacy groups and related organizations.

MONITORING AND DATA COLLECTION NEEDS

The absence of a landscape-scale, management-driven approach to monitoring hydrologic function makes it difficult for land managers to understand and address Mt. Tam's watershed health. Critically, the patchwork nature of the data describing existing conditions will make it even harder for land managers to assess the future impacts of climate change, including likely shifts in fundamental hydrologic drivers such as precipitation and temperature. While a complete description of hydrologic metrics, methods, and analyses is outside the scope of this document, future monitoring should at the very least address the following elements across the mountain:

- **Stream peak and low flows:** The spatial extent and temporal intensity, magnitude, and duration of peak flows and low flows drive the evolution of stream habitats and dependent plant, fish, and wildlife communities. Changes in these metrics can signal significant landscape changes.

- **Watershed runoff vs. infiltration:** Watersheds that favor infiltration instead of runoff are more likely to establish functional connections between groundwater and surface water, and support surface flows in streams and seeps, even during periods of extended drought.

- **Road density and conditions**: The density and condition of roads (particularly unpaved fire roads) within watersheds are major influences on sediment delivery to streams and can also act as vectors for the spread of invasive vegetation species (see Chapter 1, Ecological Stressors).

- **Floodplain connectivity:** Streams with higher degrees of floodplain connectivity provide better structural habitat and food web support for aquatic organisms, particularly salmonids, and can be indicative of watershed-scale hydrologic, hydraulic, and sediment transport processes.

The process of developing a mountain-wide monitoring approach should be guided by a new interdisciplinary technical advisory team that includes experts in watershed hydrology, water quality, fluvial geomorphology, vegetation communities, and fisheries, as well as representatives from land managers and relevant resource/regulatory agencies.

SUPPORTING DATA AND ANALYSES

While much more work is needed to comprehensively assess hydrologic function within the One Tam area of focus, several datasets developed as part of the 2018 Marin Countywide Fine Scale Vegetation Map and landscape database (GGNPC et al., 2021) project provide high-level insights into watershed health. Road density and conditions—and, more broadly, the location and extent of built features—are captured by countywide impervious-surfaces mapping based on 2018 aerial imagery. Figure 11.9 summarizes the surface area for each of the five built-feature classes within One Tam partner-managed lands inside the area of focus; the location of these features is depicted in Figure 11.10.

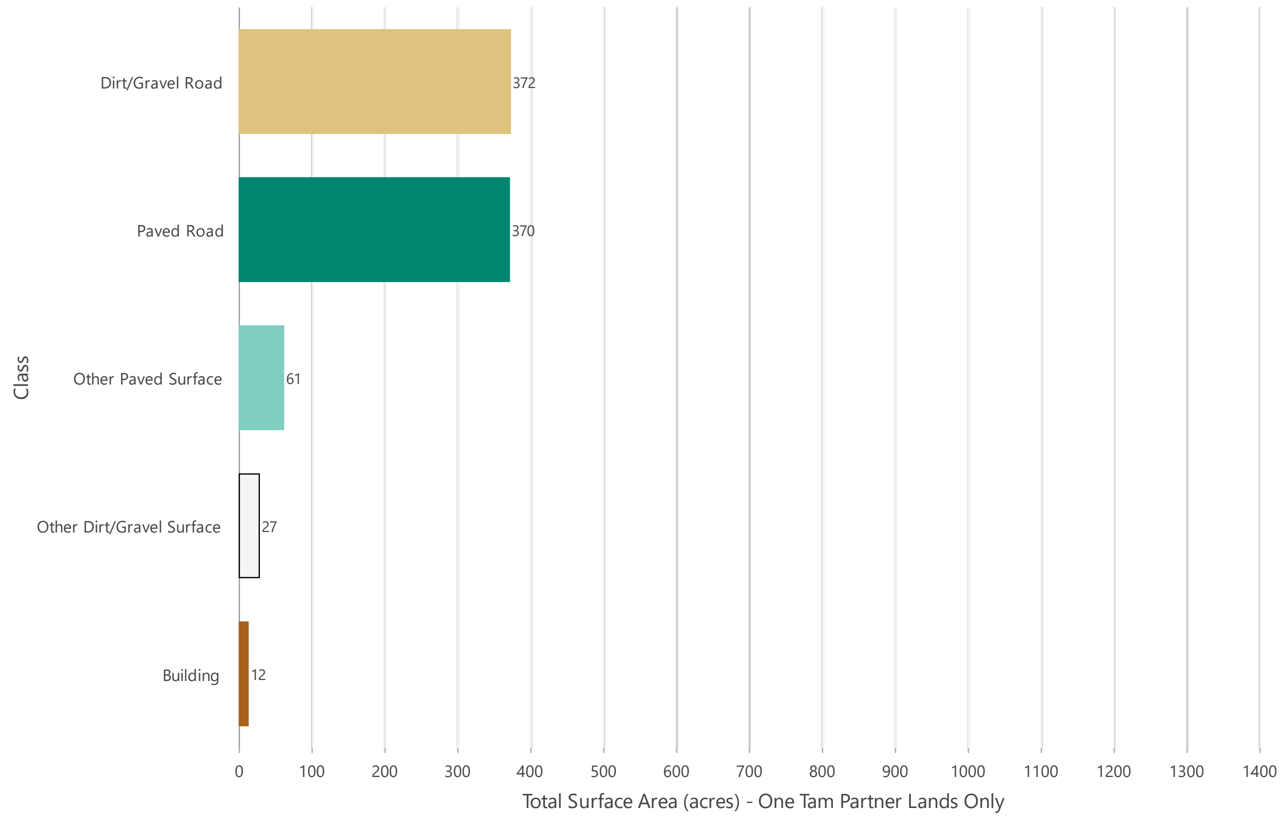

FIGURE 11.9 SURFACE AREA BY BUILT-FEATURE CLASS, MARIN COUNTYWIDE IMPERVIOUS SURFACE MAPPING, 2018 (GGNPC ET AL., 2021)

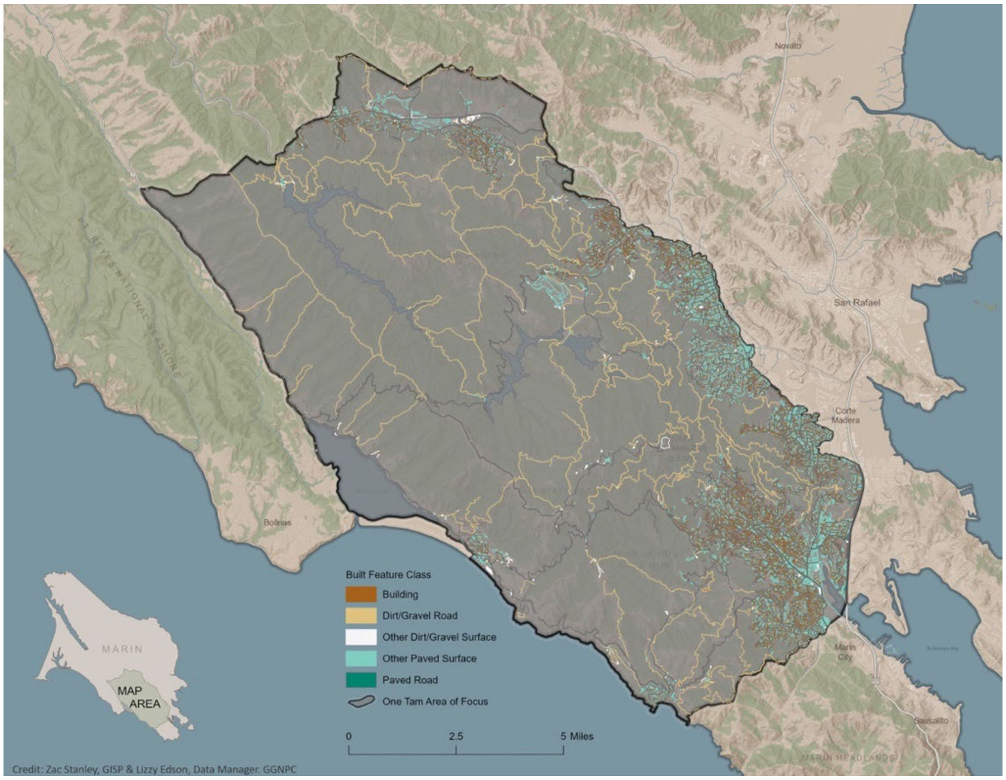

FIGURE 11.10 DISTRIBUTION OF BUILT FEATURES, ONE TAM AREA OF FOCUS, 2018 (GGNPC ET AL., 2021)

Hydrography derived from 2019 lidar was developed in collaboration with the California Department of Water Resources, USGS National Geospatial Program's National Hydrography Dataset (NHD), and Watershed Boundary Dataset (WBD) analysts (NV5 Geospatial 2021). The resulting datasets include improved mapping of watersheds at the HUC-12 and HUC-14 levels (Figure 11.11), as well as high-resolution GIS data for stream centerlines (thalwegs) with information on approximate flow accumulation (upstream catchment area) (Figure 11.12) and periodicity (Figure 11.13). This information could be expanded by future GIS analysis to develop mapping of riparian areas, including delineation of top-of-bank and floodplains.

FIGURE 11.11 SUBWATERSHED (HUC-14) BOUNDARIES, ONE TAM AREA OF FOCUS (UPDATED, LIDAR-DERIVED), 2019 (USGSb, 2022)

FIGURE 11.12 STREAM CENTERLINE DATA, ONE TAM AREA OF FOCUS (USGSa, 2022)

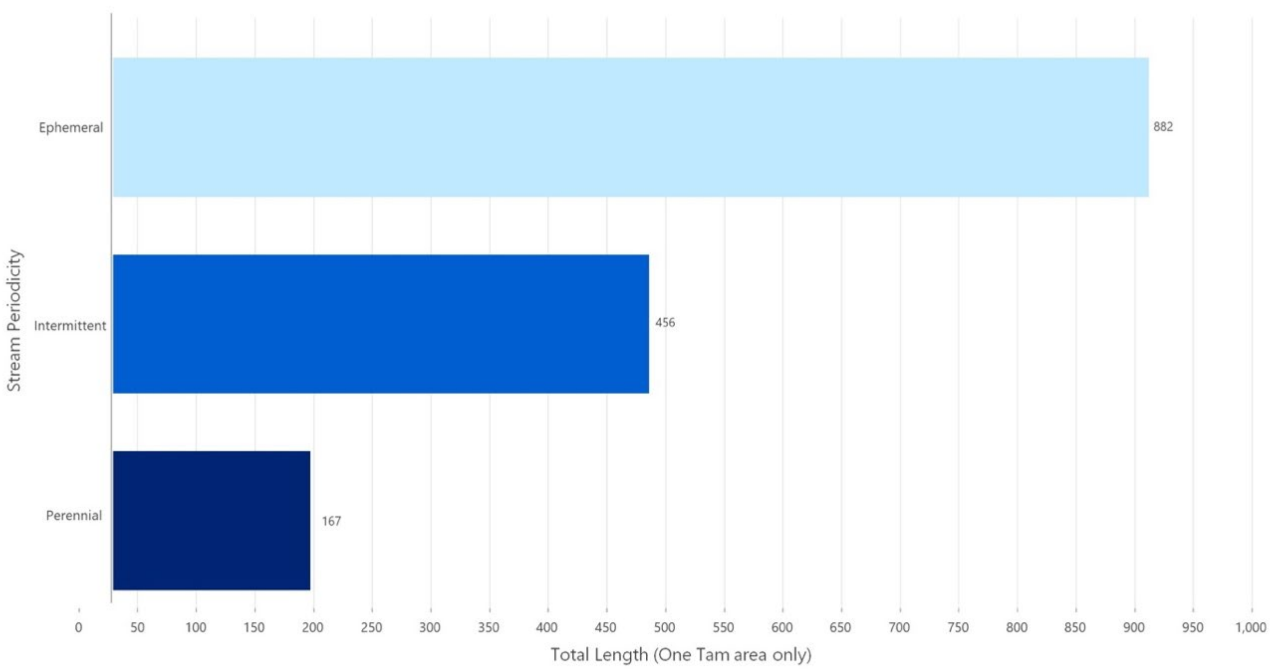

FIGURE 11.13 TOTAL LENGTH OF STREAMS BY PERIODICITY, ONE TAM AREA OF FOCUS (UPDATED, LIDAR-DERIVED), 2019 (USGSA, 2022)

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CHAPTER 12. WILDLIFE HEALTH INDICATORS SUMMARY

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OVERVIEW

Mt. Tam is home to myriad native wildlife, including at least 36 mammals, 184 birds, and 25 amphibians and reptiles (Figure 12.1; Appendices 5–9). While impressive, these are only the species that are known to the mountain's land agencies; actual numbers are likely higher.

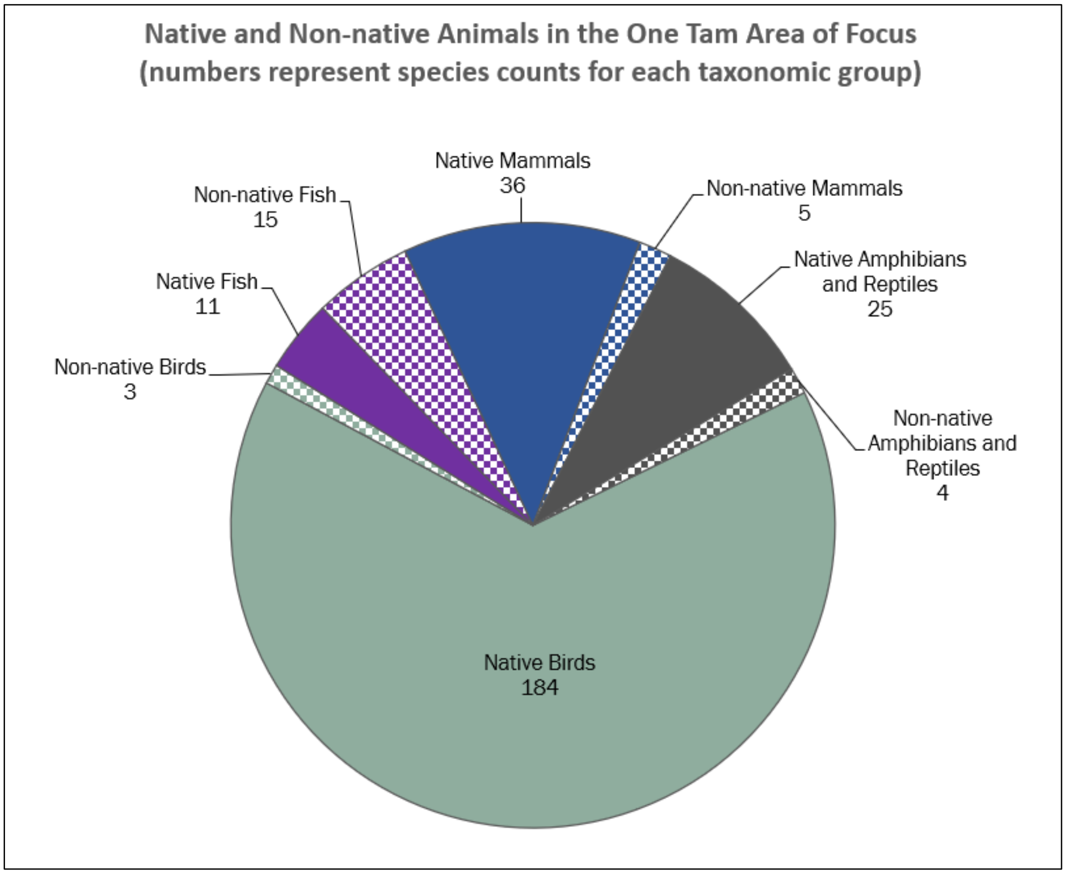


FIGURE 12.1 NUMBERS OF NATIVE AND NON-NATIVE ANIMAL SPECIES, ONE TAM AREA OF FOCUS

The wildlife indicators chosen for this report were, in part, selected based on the amount of information available. Data on the mountain's wildlife vary widely, depending on whether they have ever been inventoried or are regularly monitored. Some species, such as the threatened Northern Spotted Owl (*Strix occidentalis caurina*), have been tracked for years, whereas bat monitoring only began after the 2016 version of this report. Other groups, like invertebrates, had never been systematically inventoried or monitored on Mt. Tam prior to 2016. Bee inventory work was initiated in 2017, and this update now includes a chapter on these critical contributors to the mountain's ecological health.

Wildlife indicators were also chosen based on the likelihood that their condition and/or trend might reveal something about other aspects of ecosystem health. Certain species such as badgers reveal things about the extent and quality of Mt. Tam's grasslands. We may also be starting to see a pattern of western spotted skunks avoiding areas along the urban edge. In addition, broader changes in wildlife abundance, distribution, and community composition can be tied to stressors such as altered natural-disturbance regimes (e.g., grazing, fire), climate change, and non-native species. Taken together, they can indicate important aspects about the health of the mountain.

This chapter summarizes the wildlife included in this report and provides an overview of their condition and trend. Subsequent chapters provide greater detail on each species.

NEW INDICATORS

This updated Peak Health report includes three new indicators: **bats** (Chapter 22)**,** the **California giant salamander** (Chapter 15)**,** and **bees** (Chapter 13). Land managers and the Parks Conservancy began coordinating resources to monitor and understand all three better after the 2016 report identified them as key data gaps.

The chapter summaries that follow include a circle, an arrow, and a line icon that summarize overall condition, trend, and confidence, respectively (Figure 12.2). These results were derived by averaging the scores of metrics used to evaluate the health of each. (See Chapter 1 for definitions of terminology used throughout this chapter, how metrics are used to evaluate the health of each indicator, and other project methodology details.)

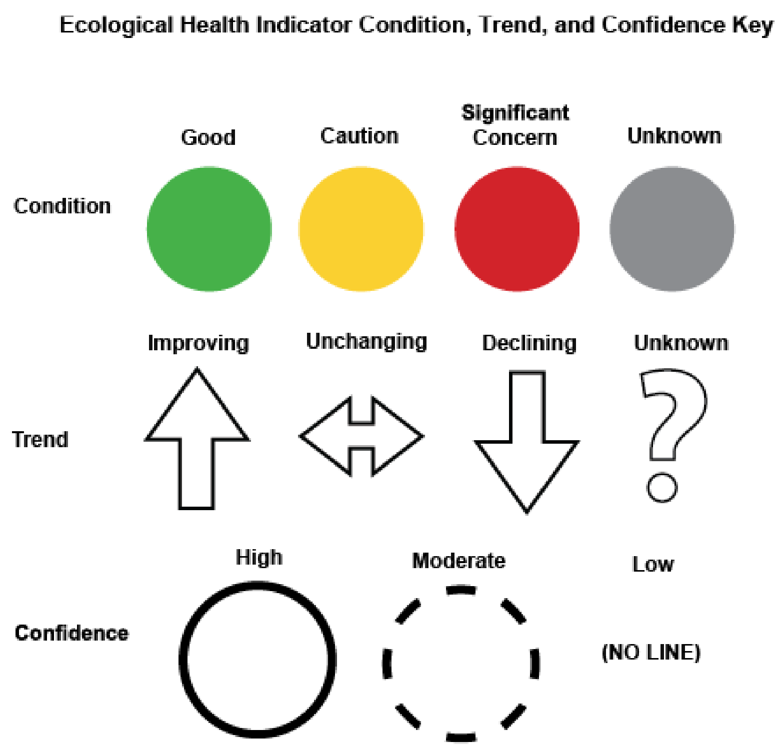


FIGURE 12.2 SYMBOLOGY USED SHOW OVERALL CONDITION, TREND, AND CONFIDENCE OF EACH INDICATOR

BEES (CHAPTER 13)

Condition: Unknown
Trend: Unknown
Confidence: Low

One Tam partners initiated **bee** studies in several Marin County locations in 2017, and preliminary data from these surveys were used to develop metrics for this 2022 update. While it is too soon to be able to assess the condition or trend of these metrics, some early signs are promising: 29% of known species and 84% of known genera were detected, and median species richness at all sites was 36. Given study limitations, this represents a remarkable recapture rate. In addition, 28% of known specialist species and 10 new specialist species were detected, including several that are rare and uncommon. This indicates that healthy populations of specialist host plants and suitable nesting habitat exist in the study area.

CALIFORNIA GIANT SALAMANDER (CHAPTER 15)

Condition: Unknown
Trend: Unknown
Confidence: Low

Another addition to this updated report, the **California giant salamander** (*Dicamptodon ensatus*) is found in Mt. Tam's streams and forests. This charismatic species' aquatic-terrestrial life cycle, low vagility, longevity, large body size, and varied diet make it an excellent indicator of the health of those particular ecosystems. The One Tam area of focus constitutes a large portion of the species' suitable forested habitat in Marin County. It is listed as Near Threatened by the IUCN and as a Species of Special Concern by the California Department of Fish and Wildlife, making it even more important to understand how they are faring. While metrics for this indicator need to be further developed, new technology (e.g., eDNA) and advances in crowdsourced data (e.g., iNaturalist) offer promising directions for the future.

BATS (CHAPTER 22)

Condition: Good
Trend: No Change
Confidence: Moderate

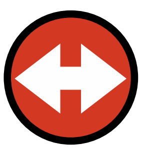
Although they represent one-fifth of the planet's mammal diversity, 80% of the world's **bat** species are either not well understood or are in need of conservation (Frick et al., 2019). Mt. Tam supports a diverse bat community with 13 known species; however, until recently, studies were limited (GANDA, 2003; Heady & Frick, 2004). The Marin County-wide bat monitoring program, initiated in 2017, has provided the preliminary data used to incorporate them in this 2022 update. Early results indicate that their condition is good, with a steady trend based on metrics of species richness and species presence and distribution. Thanks to this new monitoring program, we now know that Mt Tam is home to all bat species expected to be in our region and hosts some important maternity colonies. Long-term monitoring of these bat populations may provide important insights into the ways in which biological communities are changing over time. Bats are good indicators of ecological health because, in addition to being top predators of nocturnal insects, they are sensitive to a wide range of environmental factors, including climate change, habitat loss and fragmentation, pesticides and insect availability, disease, drought, wildfires, and human disturbance (especially at breeding colonies). They use a variety of roosting habitats (trees in various stages of decay; fallen wood and snags; rock outcrops; caves; and mines, bridges, and other human-made structures) and often return to the same roosts annually. Three local bat species have been designated as state Species of Special Concern. While bats in other areas of the western U.S. have been affected by solar and wind energy development and diseases such as white-nose syndrome, the biggest threat to Marin County's bats are habitat loss and roost disturbance.

UPDATED INDICATORS

The condition, trend, and confidence assessments of all the wildlife indicators from the 2016 report described below have been updated in this version, with the exception of the American badger, which has been folded into the larger Mammals chapter.

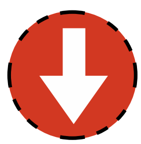
ANADROMOUS FISH (CHAPTER 14)

Coho Salmon, Lagunitas Creek



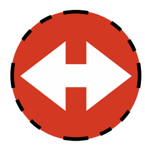
Condition: Significant Concern
Trend: No Change
Confidence: High

Coho Salmon, Redwood Creek



Condition: Significant Concern
Trend: Declining
Confidence: Moderate

Steelhead Trout



Condition: Significant Concern
Trend: No Change
Confidence: Moderate

Because they spend part of their lives in freshwater streams and part in the ocean, **anadromous fish** are good indicators of riparian habitat and hydrological conditions as well as of ocean health; they are also an important food source for many other species. Endangered coho salmon (*Oncorhynchuskisutch*) and threatened steelhead trout (*O. mykiss*) live in Redwood and Lagunitas Creeks in the One Tam area of focus. Very few indicators of ecosystem health are monitored as intensively as anadromous salmonids. In the Lagunitas and Redwood Creek Watersheds, biologists count adults during their winter migrations from the ocean, estimate the abundance of juveniles during the summer, and capture smolts on their ocean-bound outmigrations. Data collected since 2016 paint a complicated picture, with some signs of improvement but an overall continuing state of significant concern. The number of coho salmon juveniles and smolts in Lagunitas Creek increased between the baseline and the most recent nine-year period, improving these two metrics from significant concern to caution. Adult coho in Lagunitas Creek also increased, although this metric remains firmly in the significant concern category. In Redwood Creek, coho salmon have not increased, and despite active efforts to jumpstart their numbers using hatchery rearing techniques, the numbers of adults for two of three-year classes have decreased since 2016. No significant change has been observed in steelhead abundance.

CALIFORNIA RED-LEGGED FROG (CHAPTER 16)

Condition: Good
Trend: Improving
Confidence: Moderate

Amphibians are sensitive to changes in hydrology and precipitation as well as to pollutants and toxins, making them excellent indicators of freshwater ecosystem health. The threatened **California red-legged frog** (*Rana draytonii*) was once common from Mendocino County to Baja California, but its numbers have plummeted as a consequence of human harvesting, habitat loss, and invasive species. Within the One Tam area of focus, it is known to live in ponds and wetlands at Muir Beach and in the Olema Creek Watershed. The improving trend in California red-legged frog health in 2022 is a result of past habitat restoration and reintroductions in the Redwood Creek Watershed, the ongoing benefits of which have improved that population's resiliency even in the face of recent drought. It is also thanks to the 2017 discovery of a consistent California red-legged frog presence and moderate egg-mass production in historical breeding sites in the eastern part of the Bolinas Lagoon Watershed. This new location has been added to the thresholds and baselines for each 2016 metric as applicable.

FOOTHILL YELLOW-LEGGED FROG (CHAPTER 17)

Condition: Caution
Trend: Improving
Confidence: High

The **foothill yellow-legged frog** (*R. boylii*) has declined over half of its historical range, including a severe drop in numbers in the San Francisco Bay Area. Small populations in the One Tam area of focus are at risk of extirpation, but are less vulnerable than they were when the original 2016 report was written. For this update, the condition of this indicator species has been assessed as caution, which is an improvement from the significant concern determination in 2016. Factors most responsible for that improvement are the discovery of a new population in Cascade Canyon Preserve, two subadults observed in Devil's Gulch Watershed, more egg masses found in Big Carson Creek (possibly as a result of management actions to improve habitat there), a high rate of successful egg-hatching, and no observed human-caused egg-mass destruction in recent years.

NORTHWESTERN POND TURTLE (CHAPTER 18)

Condition: Caution
Trend: Improving
Confidence: High

The **northwestern pond turtle** (*Actinemys marmorata*) is a good indicator of freshwater aquatic conditions and is also considered vulnerable to climate change and invasive aquatic predators. Its population has declined dramatically throughout the state in recent decades, spurring the California Department of Fish and Wildlife to list it as a Species of Special Concern. Marin Water has been monitoring northwestern pond turtles since 2004, allowing us to have high confidence in the condition and trend assessment for this species. The number of metrics was reduced from three to two in 2022; the third metric (age structure) had not been consistently monitored and there were no plans to gather that data in the foreseeable future. Adjusting the 2016 overall condition and trend assessment to reflect only the two remaining metrics reveals that the species' condition has remained the same, but its trend is improving. This is thanks largely to reintroductions in the Redwood Creek Watershed. This new population, and the stability of the population in Marin Water's reservoirs, bodes well for the long-term persistence of the northwestern pond turtle in the lakes and streams on and around Mt. Tam.

BIRDS (CHAPTER 19)

Condition: Caution
Trend: No Change
Confidence: High

Birds, another charismatic and inspiring group, are also excellent indicators of the condition of a wide range of habitats. Agencies within the One Tam area of focus have a relatively long history of bird monitoring, which has enabled estimates of population trends for multiple species in a number of different vegetation communities. In addition to looking at the condition and trend of birds as a whole, several specific bird communities were included in this assessment: oak woodland, conifer and mixed hardwood forests, grassland, scrub and chaparral, riparian areas, and climate-vulnerable species. The overall condition for birds dropped from good in 2016 to caution in 2022 because declines were observed in a number of individual species within these communities; however, the trend remained at no change. Oak woodland birds showed a positive trend, moving from no change to improving, but the condition of scrub/chapparal and riparian birds declined from good to caution. With added monitoring of grassland-bird plots, those species' condition went from unknown to caution.

NORTHERN SPOTTED OWL (CHAPTER 20)

Condition: Good
Trend: No Change
Confidence: High

The threatened **Northern Spotted Owl** (*Strix occidentalis caurina*) is an important upper-level predator, making it a good indicator of forest health. The species' success in the One Tam area of focus depends on forest ecosystems that support sufficient populations of its favorite prey, the dusky-footed woodrat (*Neotoma fuscipes*). Marin County is home to the southernmost populations of this species, and One Tam land management agencies have a wealth of data for most of Marin County. Data on long-term trends in Northern Spotted Owl territory occupancy, reproductive success, and nesting habitat preferences help managers track population trends; avoid nesting-season disturbances; and evaluate the impacts of potential threats, including competition from the Barred Owl (*S. varia*), Sudden Oak Death, and climate change. Spotted Owl condition, trend, and confidence were the same in 2022 as 2016. The condition remained good, with no change in trend. Pair occupancy remained high and though fecundity varied, it was higher in the most recent five-year period (2017–2021) than the 1999–2021 study average. Barred Owl numbers remained low.

OSPREY (CHAPTER 21)

Condition: Significant Concern
Trend: Declining
Confidence: Moderate

Visitors to Mt. Tam's lakes and reservoirs are often treated to the sight of nesting **Osprey** (*Pandion haliaetus*). Because the species is sensitive to toxins and feeds almost exclusively on fish, its breeding success is a good indicator of water quality and fish abundance. The Osprey colony at Kent Lake has been continuously monitored since 1981, making it one of the longest-running Osprey nesting studies in the Pacific region. The most notable change since the 2016 report is the decrease in its condition from good to significant concern, due primarily to a decrease in reproductive effort as measured by Metric 1. That metric went from good to significant concern as a result of a precipitous decline in the number of occupied and active nests between 2017 and 2022. We are not certain what caused this decline, but believe there are a number of reasons (including competition with Bald Eagles [*Haliaeetus leucocephalus*]) rather than a single cause. There was also a less-dramatic decrease in habitat condition from good to caution as measured by Metric 3, which looks at the number of available nest trees.

MAMMALS (CHAPTER 23)

Condition: Good
Trend: No Change
Confidence: Moderate

Mammals are good indicators of ecological conditions because they are responsive to habitat change (Andren, 1994) and landscape connectivity, and play important roles in the food web as both predators and prey. Mammals' high energetic demands require habitats that support suitable prey bases.

Data from remote cameras installed in 2014 and from additional cameras installed in 2017 as a part of Marin Wildlife Watch (Marin Wildlife Picture Index Project in the 2016 report) have allowed us to consider a suite of native and non-native mammals and thus provide a more complete picture of how terrestrial ecosystems on Mt. Tam are doing. At the time of the 2016 report, the cameras had only been in place for two years and much of the data that had been collected had not yet been processed. For the 2022 update, we were able to use three years of data (2014–2017) from our North Array, and three seasons (summer, fall, and winter, 2017) in our South Array. More data and wider camera coverage around Mt. Tam increased our understanding of the mammal community as well as our confidence in our assessment of their condition and trend. We were also able to add two new native species to this update: the long-tailed weasel (*Mustela frenata)* and the American black bear (*Ursus americanus)*.

Overall, mammals are in good condition, with a steady trend. The four metrics used in this assessment included native species richness, which remained in good condition with an improving trend. In 2022, we were able to calculate a metric for species occupancy estimates and the Wildlife Picture Index (a way of using wildlife camera data to measure biodiversity trends). Species-specific abundance and stability were rated as good, and the Wildlife Picture Index was rated as caution. Our rare species metric moved from a condition of significant concern to good. Invasive species remained in good condition with no change in trend in 2022. Note that because we had only limited Marin Wildlife Watch camera data for badgers, we decided to drop that chapter from this 2022 update, instead including them as a rare species in this overall mammal chapter.

NORTH AMERICAN RIVER OTTER (CHAPTER 24)

Condition: Good
Trend: Improving
Confidence: Moderate

The charismatic **North American river otter** is an excellent ambassador for watershed conservation and wetland restoration. Historically extirpated from the San Francisco Bay Area, its return after a decades-long absence is remarkable. This apex predator plays an important role in ecosystem health, and its use of both terrestrial and aquatic habitats make it a good indicator for multiple habitat types. For this 2022 update, key findings are that the river otter is continuing its decade-long increase in Marin County and the broader San Francisco Bay Area, and that it now occupies most suitable water bodies within the One Tam area of focus. The 2016 and 2022 assessments remained the same, with its condition as good, and an improving trend.

EXTIRPATED SPECIES

A look at Mt. Tam's ecological health would not be complete without considering species that are no longer here. Since the time of European settlement, changing land use, development, hunting, wildlife persecution, collecting, and the introduction of non-native species have resulted in the loss of some of Mt. Tam's native wildlife.

A bright spot in the story of species loss is the recent return of the **American black bear** to the mountain. Anecdotal information suggests that this species benefited from rapid removal of grizzly bears after the start of the Gold Rush. However, Marin County's last black bear was taken from Redwood Creek Canyon in 1880 (Auwaeter & Sears, 2006). After sporadic black-bear observations over the last couple of decades, there were numerous sightings on Mt. Tam in 2021 and 2022, including of multiple animals. Increasing numbers of black bears to the north of Marin County could indicate a possible recolonization of Mt. Tam from those areas.

A confirmed **California ground squirrel** (*Otospermophilus beecheyi*) sighting by a Marin Water staff member has led us to remove this species from our extirpated list. However, it is still not known whether this species is actually established on the mountain or if so, to what extent. It was likely historically present on Mt. Tam, as there are museum specimens from adjacent Tennessee Valley. Evens (2008) describes ground squirrels as few and localized at nearby Point Reyes. However, Grinnell and Dixon (1918) reported that this species was rare in the majority of southern Marin County. We know that ground squirrels are present elsewhere nearby in Marin County, and there is a possibility of restoring them to appropriate areas on Mt. Tam.

Although this section looks at extirpation, widespread regional landscape changes have also dramatically affected wildlife abundance. For example, the loss of San Francisco Bay- and outer-coast wetlands, in conjunction with hunting pressures, has likely dramatically reduced the abundance of waterbirds and of many other species that depend on these habitats.

One Tam land management agencies have fairly good historical and current information on birds and medium- to large-size mammals (those greater than one kg), but smaller mammals are less well documented. Using one of the three categories that follow, Table12.1 provides the historical and current status for these better-understood groups; more detail is provided in the text that follows the table.

Historical Status:

- **Present:** Species with verified, documented historical occurrences.
- **Likely Present:** Species that were known to be present in nearby areas and/or similar habitats but for which we do not have definitive evidence that they were present here.
- **Unknown:** Species that may have been present but not enough verifiable evidence exists to say if they were likely to have been on Mt. Tam or in adjacent areas.

Current Status:

- **Extirpated:** We believe the species was once present but know that it is no longer on Mt. Tam.
- **Not Present:** We suspect (but are not sure) that the species was historically present but know that it is no longer here.
- **Unknown:** There is insufficient evidence to determine if the species is definitely no longer here.

TABLE 12.1 LIKELY EXTIRPATED WILDLIFE SPECIES, MT. TAM

Common Name	Scientific Name	Historical Status	Current Status
Mammals			
Fisher	*Martes pennanti*	Unknown	Not Present
Gray Wolf	*Canis lupus*	Unknown	Not Present
Grizzly Bear	*Ursus arctos* ssp.	Likely Present	Extirpated
Mountain Beaver	*Aplodontia rufa*	Likely Present	Unknown
North American Beaver	*Castor canadensis*	Unknown	Not Present
North American Porcupine	*Erethizon dorsatum*	Likely Present	Extirpated
Pronghorn Antelope	*Antilocapra americana*	Unknown	Not Present
Ringtail Cat	*Bassariscus astutus*	Likely Present	Unknown
Salt Marsh Harvest Mouse	*Reithrodontomys raviventris*	Likely Present	Unknown
Tule Elk	*Cervus canadensis nannodes*	Likely Present	Extirpated
Birds			
California Condor	*Gymnogyps californianus*	Likely Present	Extirpated
Greater Roadrunner	*Geococcyx californianus*	Likely Present	Extirpated

Restoring some of these species would be extremely challenging due to their need for large, connected habitats; existing development, roads, and other infrastructure; incompatible adjacent land uses; and, in some cases, potential public-safety issues. Having already lost many mammalian species from the mountain, it is important to provide opportunities for surviving species to persist, and to ensure that key ecological roles and functions are not lost. In addition, it is important to document the presence and location of rarer species as well as those that have not been confirmed on the mountain.

BIRDS

The only record for the **California Condor** (*Gymnogyps californianus*) near Mt. Tam cites "at least a dozen birds from the mountains near Fairfax in July of 1847." Koford (1953) and Shuford (1993) attribute this sighting to the ornithologist-painter Andrew Jackson Grayson. An egg record from "prior to 1869" (Grinnell & Miller, 1944) was corrected by Koford as being from the San Rafael Mountains in Santa Barbara County, not San Rafael in Marin County (Koford, 1953). Koford noted that with condors ranging from Napa County to Humboldt County in the mid-1800s, it is likely that they were in Marin County up to that time. Mt. Tam's rugged landscape and its proximity to the Pacific coastline would have made it an appropriate region for the species. Condor populations are increasing regionally thanks to reintroduction programs in Pinnacles National Park and Big Sur in central California as well as more recent efforts at Redwood National and State Park.

The **Greater Roadrunner** (*Geococcyx californianus*) was once a year-round resident of Marin County (Stephens & Pringle, 1933), but was likely extirpated by at least 1960 (Shuford, 1993). Because the species prefers arid, spacious shrubland, often adjacent to open oak savannah, in northern California, the Roadrunner would have benefitted from regular fires to keep these habitats intact (Shuford, 1993). Shuford notes that of the last three reported Marin County sightings, two came from Golden Gate Audubon Society field trips (published in *The Gull*): one at Homestead, Locust Station, Mill Valley on April 22, 1939, and another at San Rafael Hill on February 24, 1941. An additional sighting was reported on Mt. Tam "sometime in the 1950s" (Shuford, 1993). Shuford also cites Bryant (1916) in the observation that "Roadrunners were widely persecuted at one time because, based on limited evidence, they were thought to prey heavily on the eggs and young of quail." The Roadrunner may be a species that is able to expand its range with climate change, possibly back into Marin County.

MAMMALS

The loss of top-level predators such as bears and gray wolves affects prey species numbers (Carroll et al., 2001), which can have cascading ecosystem effects (Miller et al., 2001).

The **grizzly bear** (*Ursus arctos*) was fairly common in the San Francisco Bay Area at the time of the Gold Rush (1848–1955) but by 1902, was gone from northern California, and had been extirpated statewide by 1924 (Carroll et al., 2001).

Historical records on the distribution and abundance of the **gray wolf** (*Canis lupus*) in California are less definitive (Carroll et al., 2001; CDFG, 2011). While there is no substantive evidence to document its presence in California's lowlands, including Marin County (Evens, 2008), the area clearly had suitable habitat and prey species to support the species. Wolves were likely to have occurred at low numbers in California's Coast Ranges until the early 1800s, and were probably more numerous along the northern coast, which had greater elk abundance (Carroll et al., 2001; CDFG, 2011). They were rapidly extirpated from coastal northern California during the Gold Rush (Carroll et al., 2001). Wolves have been slowly recolonizing northern California; currently, there are three known wolf packs in the state.

The **fisher** (*Martes pennanti*) has never been documented on Mt. Tam, though its historical range maps extend from the north of Tomales Bay along its east side (Tucker et al., 2012).

The **tule elk** (*Cervus canadensis nannodes*), once abundant in coastal grasslands, was quickly extirpated through hunting and competition with cattle during the 1850s (Evens, 2008). This species was reintroduced to Point Reyes National Seashore in 1978, but is not currently found on Mt. Tam.

The **pronghorn antelope** (*Antilocapra americana*) was also noted in historical reports from early European exploration and settlement of Marin County. However, it is uncertain whether these observations were accurate. Grazing by elk and (possibly) pronghorn antelope likely helped maintain coastal grasslands in this region.

The **North American beaver** (*Castor canadensis*) is a keystone species because it modifies streams and creates wetlands (OAECWI, 2013). Although beavers were recently documented as once living in central California coastal watersheds, there is no substantive evidence documenting their presence specifically on Mt. Tam (OAECWI, 2013). Beavers are not currently found in Marin County.

The **North American porcupine** (*Erethizon dorsatum*) was not historically documented on Mt. Tam, although there is a species record from just outside Point Reyes National Seashore. While wildlife habitat relationship modeling indicates that most of Marin County is suitable porcupine habitat (CDFG, 2012), they are not currently known to live here.

The **ringtail cat** (*Bassariscus astutus*), **mountain beaver** (*Aplodontia rufa*), and **salt marsh harvest mouse** (*Reithrodontomys raviventris*) have not been confirmed in the One Tam area of focus, and their status is currently unknown. Although all these species have been documented in adjacent areas, they are rare. Point Reyes National Seashore will be undertaking a mountain beaver inventory that may provide additional useful information about this species.

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CHAPTER 13. BEES

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

2016	2022
This indicator was not included in the original 2016 report	
Condition: N/A	**Condition:** Unknown
Trend: N/A	**Trend:** Unknown
Confidence: N/A	**Confidence:** Low

FIGURE 13.1 CONDITION, TREND, AND CONFIDENCE FOR BEES, ONE TAM AREA OF FOCUS

Lack of data prevented the inclusion of bee species as a health indicator in the original 2016 version of this report. However, the identification of this important data gap led One Tam partner agencies to begin bee studies in several locations in Marin County in 2017. Preliminary data from these surveys were used to develop metrics for this 2022 update. While it is too soon to be able to assess the condition or trend of these metrics, early signs are promising: 29% of known species and 84% of known genera were detected, and the median species richness at all sites was 36 (a remarkable recapture rate, given study limitations). In addition, 28% of known specialist species and 10 new specialist species were detected, including several that are rare or uncommon. These findings indicate that there are healthy populations of specialist host plants and suitable nesting habitat in the study area.

METRICS SUMMARY

Metrics in Table 13.1 were used to assess bee health. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 13.1. Each metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 13.1 ALL BEE METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1: Native bee species richness		
	2016	**2022**
Condition	N/A	Unknown
Trend	N/A	Unknown
Confidence	N/A	Low
Metric 2: Specialist bee species richness		
	2016	**2022**
Condition	N/A	Unknown
Trend	N/A	Unknown
Confidence	N/A	Low
Metric 3: Native bee species abundance		
	2016	**2022**
Condition	N/A	Unknown
Trend	N/A	Unknown
Confidence	N/A	Low

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

The 2016 Peak Health report identified significant data gaps for all of Mt. Tam's terrestrial invertebrate taxa, insects in particular (see Chapter 25, Wildlife Indicator Needs Statements). With the exception of limited butterfly-related work, Mt. Tam's insects—a broad range of species—have not been systematically studied. Insects make up the largest component of the Earth's *known* biological diversity, comprising more than half of all named species; many more are still unnamed and undescribed (Grimaldi & Engel, 2005). Among their many important functions are herbivory, predation, parasitism, pollination, and decomposition—ecosystem services that are critical to sustaining healthy plant diversity and soil composition. Insects are also a food source for many other species and a vital part of the food web.

Bees are included in this report because they provide pollination—a key ecosystem service—for wild, agricultural, and horticultural plants. This species-rich group has lengthy evolutionary relationships with flowering plants, about 75% of which they pollinate. Pollinator declines may, therefore, increase extinction risk for native plant species (LeBuhn et al., 2012). California has more than 1,600 species of wild bees, approximately 40% of the nation's known bee diversity. Native wild bees provide most of the pollination services within the California Floristic Province. Consequently, thriving bee populations are crucial to the continued health of people and ecosystems on Mt. Tam and beyond.

CURRENT CONDITION AND TREND

Although the work included in this chapter focused on Mt. Tam's bees, Marin County as a whole may provide a more informative geographic context given bees can forage distances over two kilometers (Greenleaf et al, 2007) and most species' ranges and distribution are poorly understood (Orr et al, 2021). Beyond parks and open spaces, protected land in Marin is agricultural, so the health of bees is a salient concern throughout the region.

In collaboration with the One Tam partners, Dr. Gretchen LeBuhn and her lab at San Francisco State University completed studies of pollinators in lands managed by Marin County Parks, California State Parks, and Marin Water in 2017–2018. The goals were to provide baseline data for long-term monitoring and to set a standard against which other natural habitats in the region could be compared. Historical records and the baseline surveys identified about 276 species from 38 genera in Marin County (Figure 13.3). Approximately 40% of those species were found in systematically sampled sites on Mt. Tam. Combined historical and recent species records represent 17.5% of the known species in California on only 0.15% of its land. Because the native bee community assemblage changes naturally from year to year, the value of this work builds over time as long-term monitoring of species richness and abundance enables us to differentiate normal variations from those driven by disturbances.

Baseline survey results (LeBuhn, 2022) indicate that the current condition of bees within the One Tam area of focus is good, based on the following:

- Two years of aerial netting and pan trapping at 28 transects (Figure 13.2) detected 33% of the known species and added 39 new species records for Marin County (Figure 13.3).
- The same effort detected 28% of known specialist species and added 10 new specialist species records.
- Species richness at most sampling locations was high; the median number of species detected at all sites was 36.

- Annual abundance patterns were consistent with those in other bee-diverse regions; a few species are abundant and widespread, and many are uncommon and localized (Meiners et al., 2019; Carril et al., 2018).
- Of the species detected, 30% are considered either rare or uncommon in collections (Fowler, 2020; Koch et al., 2012; LeBuhn, 2022). Several of these species were widespread and/or abundant in our inventory.

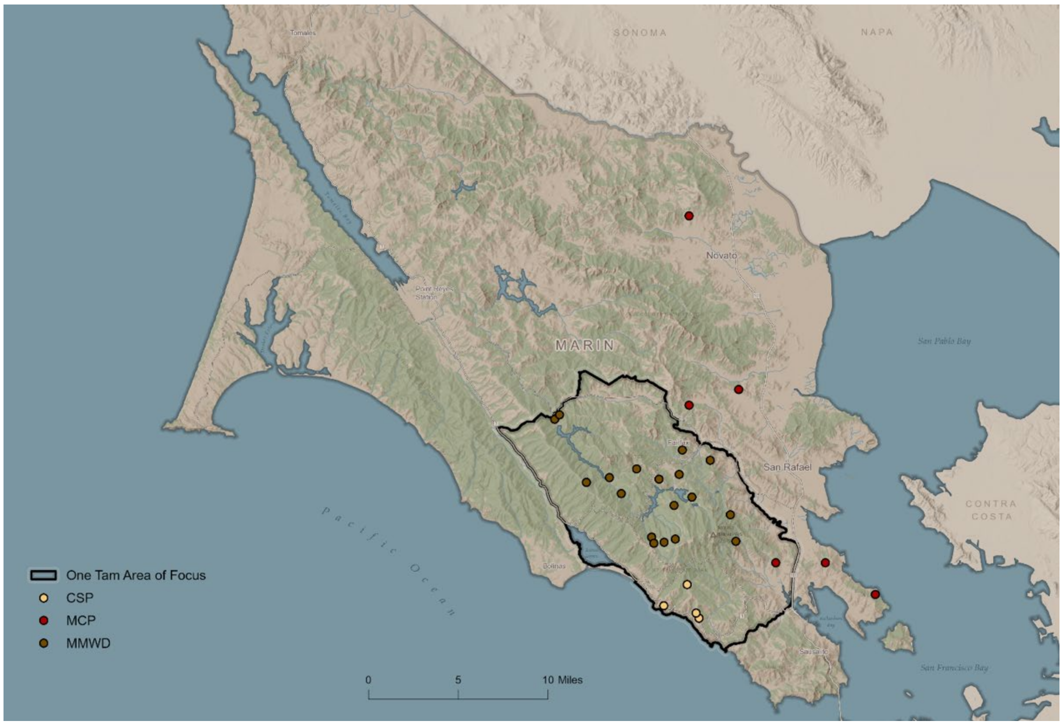

FIGURE 13.2 BEE SAMPLING SITES, 2017–2018

DESIRED CONDITION AND TREND

The desired condition for Mt. Tam's bee community is to maintain high levels of native biodiversity and the habitats that support that diversity. More specifically:

- A full suite of native bee species is present over the long-term.
- Native species diversity is high and stable or increasing; species are well represented across guilds; bees are distributed across the landscape in appropriate habitats.
- Rare and uncommon bee species are present in suitable habitat types; where appropriate, actions are taken to maintain or increase the abundance and distribution of rare bee species (e.g., grassland and sand dune restoration).
- Native bee abundance is stable over time; bees do not experience dramatic declines from stressors such as competition with non-native bees and emerging diseases.

- Habitat that supports native bees is protected and provides structure and forage necessary to maintain their richness/abundance over time.

STRESSORS

Bee species are highly diverse, and their responses to environmental disturbances are equally distinct. Recent studies indicate that they respond differently to stressors depending on their life histories. Because we do not yet have enough information on Marin County's bee fauna to evaluate how local populations will respond to each stressor, information included in this section broadly addresses potential impacts.

Climate Vulnerability: Native bee responses to climate change are context-dependent. Some species and groups are responding negatively to climatic shifts, while others exhibit neutral or positive responses. This variability is associated with differences in morphology, sociality, foraging behavior, range, and nesting habits. Recent studies indicate that larger-bodied, above-ground nesting, and generalist bees are decreasing in abundance and species richness, while smaller, ground-nesting, and specialist bees are stable or increasing (Pardee et al., 2022; Kammerer et al., 2021; Graham et al., 2021; Fründ et al., 2013; Minckley et al., 2013).

Disruption to bee and floral phenology is also concerning. Typically, bees' phenology synchronizes with their floral hosts, but as the climate changes, flowers may bloom before bees emerge and begin foraging, or they may bloom later in the year after their usual bee visitors have completed their flight season. This disruption could restrict available pollen and nectar resources and the diet breadth of native bees, particularly for species that only fly in summer and fall (Memmott et al., 2007). For certain species or groups, these changes could reduce abundance and cause range shifts (Pyke et al., 2016), resulting in novel communities with uncertain consequences for ecosystems.

Disease: While parasites and pathogens are present in native wild bee communities, managed bee populations pose a threat through the introduction of new pathogens and changes to transmission dynamics (Belsky & Joshi, 2019). Significant increases in infection rates have been observed in wild bees sharing habitat with commercial pollinators. For instance, the intestinal protozoans *Crithidia bombi* and *Nosema bombi* are widespread in managed honey- and bumble bee colonies. These protozoa are transmitted from managed to wild bees when they forage on the same flowers. This transmission pathway is sufficiently effective to cause significant spread among individuals and colonies (Colla et al., 2006). The introduction of these pathogens to wild bumble bees is considered one of the factors contributing to widespread declines in North America (Cameron et al., 2011). This may be less of a problem in Marin County, where bee-pollinated crops and commercial pollinators are less prevalent. However, Mt. Tam also borders urban areas that may have managed backyard honey bee colonies that can transmit pathogens to wild populations.

Pollution/Contaminants: Robust evidence shows that pesticides such as neonicotinoids decrease foraging success, colony growth, and queen production in social species such as bumble bees (Hopwood et al., 2016). There is growing evidence that solitary species are equally sensitive to these chemicals, although this has been less studied (Stuligross & Williams, 2020). Though bees are not usually the primary targets of pesticide use, they may be unintentionally sprayed, or exposed through indirect pathways such as wind drift or contaminated nest sites or materials (Kopit & Pitts-Singer, 2018). Exposure to plants treated with systemic pesticides is of great concern. Plant tissues (e.g., leaves, pollen, and nectar) absorb systemic pesticides, which makes the plants toxic to bees that are foraging or collecting nesting material. Further, these insecticides can persist in perennial plants for many years, affecting multiple generations of bees. Agricultural pesticides may be less prevalent in Marin County, but chemicals used in home and commercial landscaping can also have significant impact on wild bee populations. For example, in 2013, 50,000 bumble bees died after exposure to linden trees that had been sprayed with a systemic insecticide to control aphids (Xerces Society, 2022).

Habitat Disturbance/Conversion/Loss: Declines in the quality and quantity of floral resources and nesting habitat due to habitat fragmentation and loss are among the greatest threats to native bee communities (Potts et al., 2010). Adult and immature bees require both pollen and nectar, and sufficient sources near suitable nesting habitat are key factors in determining individual bee health and reproductive success (Belsky & Joshi, 2019). Smaller habitat patches may increase resource competition, which could impact individual apian fitness and lead to species richness or abundance losses. Fragmented patches may also have fewer forage-plant species, which would narrow the bees' diets and negatively affect their overall nutrition.

Competition: Introduced bee species, including the European honey bee (*Apis mellifera*), compete with native species for pollen and nectar resources. Recent studies estimate, over a three-month period, one healthy honey bee colony can gather the same amount of pollen as it would take to produce 100,000 offspring of an average solitary bee (Cane & Tepedino, 2016). This competition may impact native bee fitness and reproductive success, resulting in less-diverse bee communities (Henry & Rodet, 2018; Weaver et al., 2022).

In addition to direct competition for resources, introduced species' territorial behaviors can affect native species' foraging habits, leading to changes in local bee communities. For example, males of the introduced European wool carder bee (*Anthidium manicatum*) are notorious for their aggressive resource-guarding behaviors. They patrol floral resources and attack any bee that is not a female of the same species. As a result, native bumble bees avoid foraging in areas where *A. manicatum* is present. Given the potential for *A. manicatum* to rapidly expand its range, there is concern that certain habitats may become unusable by some native species (Strange et al., 2011; Graham et al., 2019.

Other Stressors: Native bees are resilient and have unique strategies to deal with individual stressors. For example, certain species may cope with drought and associated declines in floral resources by entering a diapause until conditions are more favorable. However, bee communities often face multiple threats simultaneously, which can intensify effects on populations. Interactions among different stressors and the way they affect bee populations are still being investigated, but evidence indicates that the synergistic effect of multiple stressors is one of the greatest threats faced by bees worldwide (Potts et al., 2010; Schweiger et al., 2010; Belsky & Joshi, 2019).

CONDITION AND TREND ASSESSMENT

METRICS AND GOALS

METRIC 1: NATIVE BEE SPECIES RICHNESS

Baseline: This metric measures the number of species detected using a combination of pan trapping and aerial netting in Marin County. The 2017–2018 baseline survey documented 119 species from 32 genera. Eighty of these species are known and 39 are new records (Figure 13.3). Historical collections have recorded 237 species here.

Condition Goal: Native bee species richness remains stable over time, although components of the community assemblage may vary from year to year.

Condition Thresholds:

- **Good:** Using various methods (i.e., pan trapping, aerial surveys), ≥75% of all known species and ≥85% of all genera are detected in the previous five years. Median species richness is >30 at all sites.
- **Caution:** Using various methods (i.e., pan trapping, aerial surveys), 50–74% of all known species and 50–84% of all genera are detected in the previous five years. Median species richness is 15–30 at all sites.
- **Significant Concern:** Using various methods (i.e., pan trapping, aerial surveys), ≤49% of all known species and ≤49% of all genera are detected in the previous five years. Median species richness is <15 at all sites.

Current Condition:

2016: N/A

2022: Unknown

The 119 species recorded in the 2017–2018 survey represent 7.5% of California's bee fauna on only 0.15% of its land. Of these 119 species, 39 were new Marin County records. While 157 of the historically known species were not detected, these 39 new records bring the total number of bee species known to be present in Marin County to 276 (Figure 13.3).

We do not have the five years of data needed to assess the condition for this metric; however, preliminary inventory results are encouraging. The 2017–2018 survey detected 29% of known species and 84% of known genera (Figure 13.3), and median species richness at all sites was 36 (Figure 13.4). Given the inherent interannual variability in bee faunas and survey design, this recapture rate is remarkable. The sampling period was relatively short (two years) with only 28 transects, and the survey did not include visits to historical sites to search for rare species (LeBuhn, 2022).

Most sites had high species richness. Fewer than 15 species were detected at only one site, three had 15 to 30 species, and 18 sites had more than 30 species. This consistency in richness indicates that diverse bee fauna are present in a variety of habitats in Marin County, despite differences in land management practices and proximity to urban areas (LeBuhn, 2022).

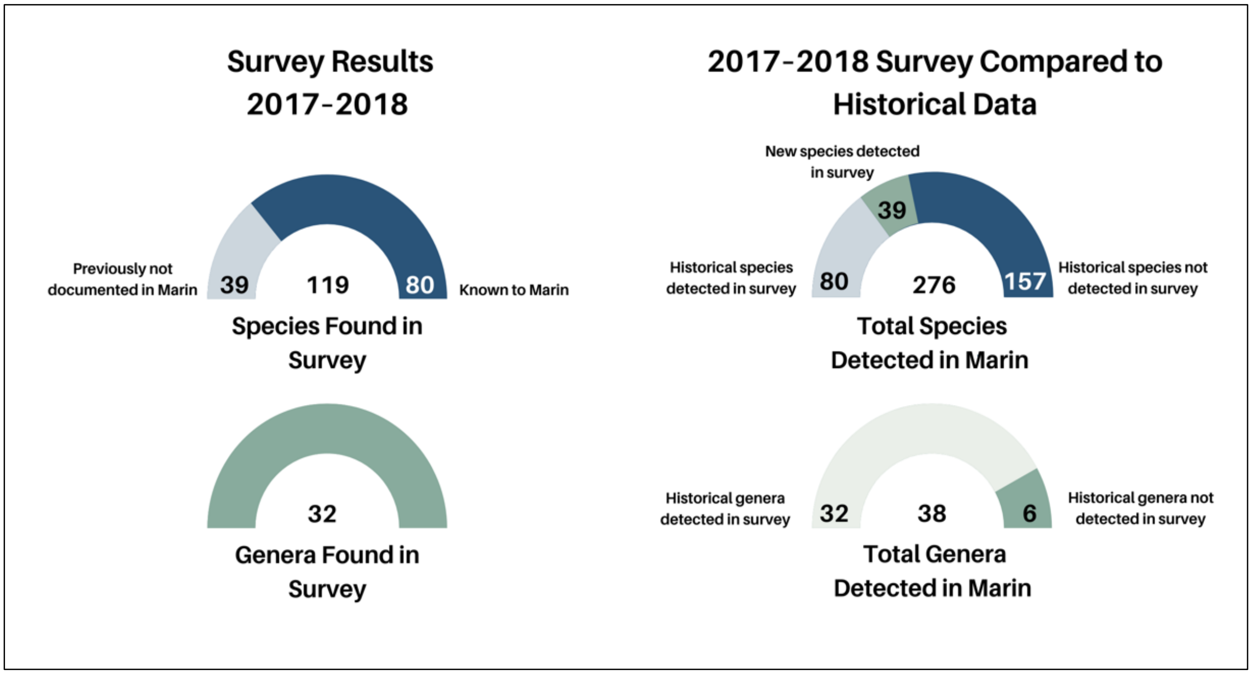

FIGURE 13.3 2017–2018 SURVEY RESULTS COMPARED TO HISTORICAL RECORD

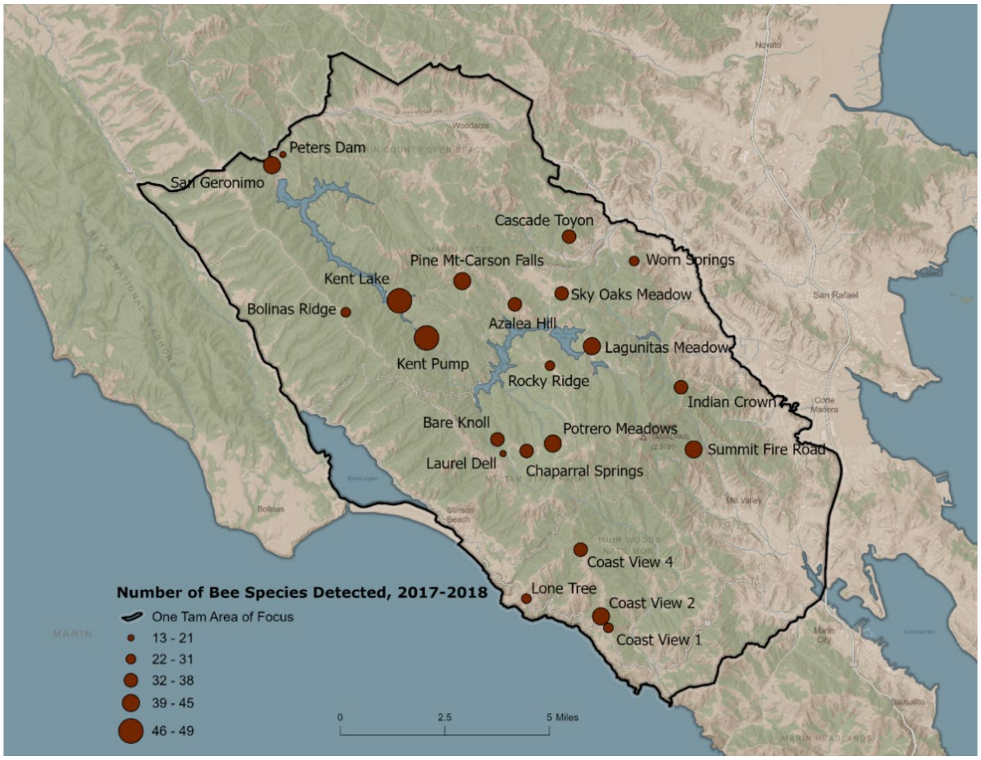

FIGURE 13.4 BEE SPECIES RICHNESS BY SAMPLING LOCATION, 2017–2018

Trend:

2016: N/A

2022: Unknown

The trend is unknown because only a baseline inventory of the bee species has been completed and at least five years of monitoring are needed to detect trend.

Confidence:

2016: N/A

2022: Low

Confidence in this assessment is low for several reasons: Bee life history is complex and there are knowledge gaps; interannual detection rates are variable and data is "noisy"; methods are not standardized; and there are collection biases and taxonomic issues.

Bees' complex life histories include high spatiotemporal turnover, short flight seasons, distinct habitat preferences, and unique behaviors, all of which make it challenging to comprehensively sample a community and set condition thresholds. Compiling a full species list takes years of intensive and systematic monitoring using multiple sampling techniques. Even with decades of monitoring, new species records can occur each year and detection rates for a given species can fluctuate significantly year to year. It is also possible to collect some species in only one year of a long-term monitoring project, or to detect a species only once every 10 years (Meiners et al., 2019; Carril et al., 2018).

Because detection rates can vary so greatly year to year, it can be difficult to detect an actual decline in species richness due to stressors over the noise of natural fluctuations (Williams et al., 2001). To confidently assess how Marin County's bees are faring and determine thresholds for concern and management actions, we need to understand the local bee communities' intrinsic variability. Prior to the 2017–2018 survey, there was no standardized monitoring of bee populations in Marin County, so we have little insight into natural variations that would inform contextually reasonable thresholds. Current thresholds are based on results of other inventory and monitoring projects on other public lands in the Western U.S. with diverse bee communities (see Mieners et al., 2019; Carril et al., 2018), but these may not accurately reflect the variability of Marin's bee fauna. With more years of data, the condition thresholds may change and alter our assessment.

The assessment based on current thresholds is limited by inconsistent sampling efforts between historical and current collections, and the fact that only two years of standardized monitoring have been completed. Without standardized monitoring efforts in Marin County, sampling effort for historical collections may be inconsistent and have taxonomic, geographic, temporal, or other biases that skew species representation. This could result in rare species or species of interest being over-represented in collections while common species are missing or underrepresented. The historical species list is also limited to records from public databases and may not account for unpublished studies and private collections. Records from those collections could increase the total species count for Marin County and change the detection rate of known species, influencing our condition assessment.

Additionally, historical data often have taxonomic issues that may skew this assessment. For example, the historical species list includes several species unknown to California (e.g., *Andrena fragilis, A. nigrae, Bombus ternarius, Eucera frater lata*) or even the U.S. (e.g., *Bombus campestris*). It is possible that these specimens were misidentified or mislabeled, or their metadata was entered incorrectly. It is also possible those species were once present in Marin County but have since disappeared. Because we do not have access to the physical specimens, we cannot be certain which is the case, so six historical species records were not included in this assessment. (They are, however, included in the species list for Marin County for reference.) This omission may result in an inaccurate historical species redetection rate. If these records can be verified, our confidence in this assessment would increase.

With only two years of data and inconsistent sampling efforts, we cannot confidently assess how the current species richness compares to historical conditions. As monitoring continues, the detection rate of historical species may decline, changing the assessment. We will have greater confidence once we have at least five years of data, though the results could be difficult to interpret without considering more variables. For example, if we observe a decline in detection rates of known species, it will be difficult to determine if it is due to natural variations in life histories, sampling biases, or because species have actually disappeared from our region.

These problems are pervasive in bee monitoring worldwide (Packer & Darla-West, 2021; Potts et al., 2010). Unfortunately, inconsistency in bee monitoring over time and the natural fluctuations in bee communities will always, to some degree, limit interpretation of results and our confidence in our assessment.

METRIC 2: SPECIALIST BEE SPECIES RICHNESS

Specialist bees use pollen from a narrow suite of floral resources. This specialization occurs on a spectrum from oligolectic bees that forage on plants within the same family to monolectic bees that forage on a single plant genus or species. Specialists may be more vulnerable to environmental disturbances that affect their preferred floral resources (Bommarco et al., 2010; Cane & Tepedino, 2006), but exhibit more resilience in other circumstances (Minckley et al., 2013). In both instances, specialist-species richness trends can signal environmental changes that may warrant management action. Approximately 44% of California's 1,600+ bee species are specialists; in Marin County, 60 specialist species are known from historical collections.

Baseline: The 2017–2018 baseline survey detected 27 specialist species (23% of total species detected). Of these specialists, 17 were previously recorded in historical collections and 10 were new records for Marin County (Table 13.2).

Condition Goal: Specialist bees' species richness remains stable over time.

Condition Thresholds:

- **Good:** Using various methods (i.e., pan trapping, aerial surveys), ≥75% of specialist species are detected in the previous five years.
- **Caution:** Using various methods (i.e., pan trapping, aerial surveys), 26-74% of specialist species are detected in the previous five years.
- **Significant Concern:** Using various methods (i.e., pan trapping, aerial surveys), ≤25% of specialist species are detected in the previous five years.

Current Condition:

2016: N/A

2022: Unknown

As with Metric 1, there is insufficient data to assess the condition for this metric, but preliminary results are encouraging (28% of the known specialist species and 10 new species were detected in the 2017–2018 survey). This recapture rate is noteworthy, considering the natural history of bees (e.g., year-to-year variability, elusive habits of specialists) and study design (e.g., a relatively short two-year sampling period, no targeted surveys of specialist habitats). Additionally, several rare and uncommon specialist species (Fowler, 2020; LeBuhn, 2022) were widespread and abundant in the 2017–2018 collections (see Metric 3). This indicates that there are healthy populations of specialist host plants and suitable nesting habitat in the study area.

TABLE 13.2 SPECIALIST BEE SPECIES RECORDED IN MARIN COUNTY AND THEIR FLORAL HOSTS

Oligolectic (Forage on Plants Within the Same Family)	
Floral Hosts	**Bee Species**
Asteraceae	***Andrena chlorosoma****
	Colletes fulgidus fulgidus*
	Colletes fulgidus lonti plumosus
	Diadasia enavata
	Heriades cressoni
	Megachile fidelis
	Megachile parallela*
	Megachile subnigra
	Megachile wheeleri
	Melissodes agilis
	Melissodes lupina*
	Melissodes moorei
	Melissodes rivalis
	Osmia californica*
	Osmia coloradensis*
	Osmia montana quadriceps
Boraginaceae	*Calliopsis fracta*
Brassicaceae	*Andrena piperi*
Cactaceae	***Diadasia rinconis***
Capparaceae	*Anthophora cockerelli*
	Perdita vittata
Ericaceae	*Osmia ribifloris biedermannii*
Fabaceae	***Anthidium utahense****
	Ashmeadiella prosopidis
	Ashmeadiella timberlakei
	Osmia integra
	Osmia nigrifrons
	Osmia obliqua
	Osmia regulina
Malvaceae	***Diadasia diminuta***
	Diadasia nigrifrons

***Bold** = detected 2017–2018, * = new record for Marin County*

Monolectic (Forage on Plants Within the Same Genus or Species)	
Floral Hosts	**Bee Species**
Arctostaphylos	*Andrena principalis*
	Andrena vandykei
Camissonia	*Andrena oenotherae hemileuca*
	Andrena chalybaea*
Cirsium	***Osmia texana****
Clarkia	***Diadasia angusticeps***
	Megachile pascoensis
	Melissodes clarkiae
Cordylanthus	***Anthidium placitum****
Cornus	*Andrena fragilis*
Cucurbita	*Peponapis pruinosa*
Eschscholzia	***Micralictoides ruficaudus****
Larrea	*Colletes clypeonitens*
	Colletes covilleae
Lasthenia	*Andrena orthocarpi*
	Andrena subchalybea
	Andrena submoesta
Limnanthes	*Andrena pulverea*
	Andrena torulosa
	Panurginus occidentalis
Lomatium	*Andrena microchlora*
Nemophila	***Andrena crudeni***
Penstemon	***Ashmeadiella australis****
	Atoposmia anthodyta
	Osmia brevis
Phacelia	*Dufourea trochantera*
Ranunculus	***Andrena caerulea****
	Andrena cuneilabris*
	Andrena suavis
	Panurginus melanocephalus
	Panurginus nigrihirtus*
Ribes	*Andrena caliginosa*
Salix	*Andrena frigida*
	Andrena nigrae
	Andrena salicifloris
Toxicoscordion	*Andrena astragali*

Trend:

2016: N/A

2022: Unknown

The trend is unknown because only a baseline inventory of the bee species has been completed and at least five years of monitoring are needed to detect trend.

Confidence:

2016: N/A

2022: Low

Like Metric 1, confidence in this assessment is low because the complexity of bee life histories makes it difficult to comprehensively sample a community and set condition thresholds (see Metric 1: Confidence for more detailed explanations). Confidence in the assessment using the current thresholds is limited by potential taxonomic issues with historical records and biases in sampling methods used for the baseline inventory.

The historical records' potential taxonomic issues complicate our understanding of specialist species richness. As mentioned, certain species in the historical records are not known to California (e.g., *Andrena fragilis* and *A. nigrae* are more typically found in eastern North America) or forage on plants not found in Marin County (e.g., *Colletes clypeonitens* and *C. covilleae* are monolectic on creosote, *Larrea* spp. [Fowler, 2020]). These records are limited to one specimen of each species collected in the 1920s or 1930s and were likely included due to an error in the metadata; confirmatory physical specimens do not exist. Therefore, these records were excluded from the assessment. If these records can be verified, our confidence in this assessment would increase.

Pan trapping and aerial netting are standard methods used to sample bees worldwide, but they have known biases that influence our confidence in our assessment of specialist-species richness. Pan traps collect large numbers of species from certain groups but rarely from others (Portman et al., 2020). Specialist bees are often underrepresented in pan traps because these traps lack certain cues present in specialist floral hosts, such as a particular color or trap height (Packer & Darla-West, 2021). Supplementing pan traps with aerial netting can mitigate some of the taxonomic bias, but results are dependent on the proficiency and style of individual netters and habitats sampled. The 2017–2018 inventory undersampled coastal chaparral and other habitats that specialists may use.

The limitations of current sampling methods may result in a lower detection rate of known specialist species. Future confidence levels will depend on which methods are used and the sampling effort dedicated to specialist floral hosts and habitats.

METRIC 3: NATIVE BEE SPECIES ABUNDANCE

Baseline: The 2017–2018 baseline survey collected 27,149 specimens, mostly from a few abundant and widespread species and many uncommon and localized species. Two families—Halictidae, the sweat bees (72%), and Apidae, the largest bee family, which includes honey bees, carpenter bees, and bumble bees (22%)—accounted for 94% of the collection. Four species—*Halictus tripartitus* (37%), *Lasioglossum* sp. (29%), *Ceratina acantha* (8%), and *Melissodes lupina* (4%)—comprised 75% of all specimens.

Condition Goal: Native bee species abundance remains stable or increasing over a long timescale even as bee abundance varies year to year.

Condition Thresholds: Not yet set.

Significant interannual variation in bee populations makes determining the actual abundance of a given species and setting thresholds for concern incredibly difficult. With only two years of sampling and no standardized baseline for comparison prior to 2017–2018, we have insufficient data to establish thresholds for this metric.

Current Condition:

> **2016:** N/A
>
> **2022:** Unknown

As with Metrics 1 and 2, we have insufficient data to assign a condition rating, but preliminary results are encouraging; abundance patterns in the 2017–2018 inventory are consistent with other bee-diverse public lands (i.e., Pinnacles National Park, Grand Staircase-Escalante National Park) (Meiners et al., 2019; Carril et al., 2018). Multiyear monitoring efforts show that communities in bee-diverse regions are often characterized by a few widespread, abundant species and many uncommon, localized species. Additionally, several rare and uncommon species (Fowler, 2020; LeBuhn, 2022; Koch et al., 2012) were widespread and/or abundant in our collections, which may indicate that Marin County and Mt. Tamalpais have unique habitats capable of supporting healthy populations of rarer species.

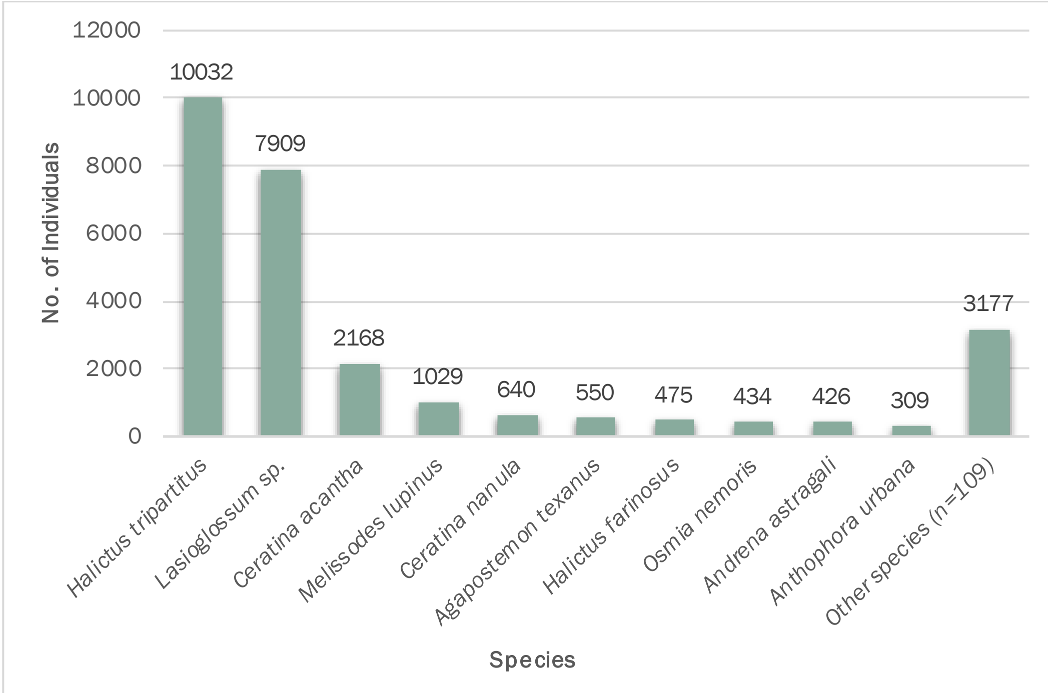

FIGURE 13.5 MOST ABUNDANT BEE SPECIES, 2017–2018 SURVEY

TABLE 13.3 WIDESPREAD AND/OR ABUNDANT UNCOMMON-RARE BEE SPECIES DETECTED, 2017–2018 SURVEY

Species	Rarity	Number of Individuals Collected	Number of Sites Detected
Andrena astragali	Uncommon*	426	20
Bombus californicus	Uncommon**	129	18
Bombus caliginosus	Uncommon**	71	12
Colletes fulgidus	Uncommon*	52	5
Diadasia bituberculata	Uncommon-Rare*	148	18
Melissodes clarkiae	Rare*, ***	34	8
Melissodes lupinus	Uncommon-Rare*	1,029	21
Micralictoides ruficaudus	Rare*	54	5
Panurginus nigrihirtus	Rare*	44	11

Bold *= new record for Marin, *Fowler, 2020; **Koch et al., 2012; *** T. Griswold, personal communication, 2022*

Trend:

2016: N/A

2022: Unknown

The trend is unknown because only a baseline inventory of bee species has been completed and at least five years of monitoring are needed to detect a trend.

Confidence:

2016: N/A

2022: Low

As with Metrics 1 and 2, confidence in this assessment is low because the complexity of bee life histories makes it difficult to comprehensively sample a community and set condition thresholds.

Bee abundance fluctuates greatly from year to year in response to changes in climate and habitat, especially precipitation, seasonal temperatures, and floral resource abundance (Kammerer et al., 2021; Graham et al., 2021). Floral resources exhibit strong seasonality, typically with greater observed abundance in spring than in summer and fall (Kuhlman et al., 2021). Further complicating matters is the diversity of life histories within bee communities. Species that are social or have multiple generations per year will typically be more abundant than solitary species with only one generation per year. With only two years of sampling and no standardized baseline for comparison prior to 2017–2018, we are not confident in our assessment of the current status of local bee abundance.

Even with additional years of monitoring, it may be difficult to interpret results, as abundance calculated by pan trapping and aerial netting results may not accurately reflect the actual abundance of bees in an area. Observed bee community composition is heavily influenced by sampling methods (Portman et al., 2020; Thompson et al., 2021). As previously discussed, known biases in pan trap and aerial netting methods influence our confidence in this assessment. In particular, pan traps tend to catch individuals in the family Halictidae (sweat bees); *Halictus tripartitus* and *Lasioglossum* spp. comprise the majority of pan-trap-collected specimens in the U.S. (LeBuhn 2022, Portman et al., 2020). While the supplementation of passive pan trapping with targeted aerial netting mitigates some bias, netting is time- and labor-intensive, resulting in uneven sampling efforts and skewed abundance numbers.

Interpretations of pan-trap results must also consider the context in which the traps were deployed. Evidence suggests that pan traps deployed near abundant floral resources often collect fewer specimens because bees prefer visiting flowers over the traps, which would result in smaller landscape-level population estimates. Conversely, traps may also collect disproportionately large numbers of a particular species if placed close to nesting sites, which may lead to overestimations of their relative abundance within a bee community.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

- One Tam Pollinators Survey, 2017–2018 (LeBuhn, 2022)
- Historical and Current Bee Species in Marin County (Appendix 5)

INFORMATION GAPS

Interannual variability in local bee communities: Understanding the natural year-to-year fluctuations in local bee species richness and abundance is necessary to detect real declines in populations and make informed management decisions.

Sentinel species: Given the complexity of monitoring hundreds of species with diverse life histories, it may be more useful to identify and focus on a few species that function as community indicators. Bumble bees are often considered strong candidates because they are experiencing widespread declines and can be sampled without lethal methods.

Nesting: As most bees forage close to their nesting sites, understanding which habitats are important for nesting will help prioritize areas for monitoring and management.

Floral associations: Availability of floral resources is a key factor influencing bee communities. Identifying and monitoring key plant/pollinator relationships will provide critical information to understand local bee health and make informed management decisions.

Impacts of different land management practices: The effects of, for example, grazing, controlled burns, forest clearing, and invasive species removal on bee communities are largely unknown in Marin County's public lands. Early evidence suggests that native bee species richness is lower at forest treatment sites and that additional investigation and monitoring may be warranted. Understanding how specific land-management practices positively and negatively impact bee populations will help inform management decisions and planning.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Following are some of the stewardship and management activities that have been undertaken since 2016 to monitor, protect, and restore this health indicator.

Inventories:

- Pan trap and aerial netting surveys have been done on Marin Water, Marin County Parks, and California State Parks lands (2017–2018).
- Species records in Marin County were reviewed to compile a historical species list (2017–2018)

- Pan trap and aerial netting surveys were done on National Park Service lands: Golden Gate National Recreation Area and Point Reyes National Seashore (2021–2022).

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as a part of the development of this report. These are actions not currently funded through agency programs, and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Revise or Develop New Metrics: The complex variability inherent to bee communities (see Confidence Sections in Metrics) brings into question how useful trends in species richness and abundance are as metrics for population health. New metrics that look at certain species, functional groups, or habitats may be more informative in terms of determining management actions.

Develop a Monitoring Program: A long-term monitoring program is needed to track and evaluate the health of Mt. Tam's bees. However, there is no consensus among bee researchers on the best way to approach this diverse group. Some advocate broad monitoring of bee populations to better understand their inherent variability, to track trends over time, and to understand how they respond to stress (LeBuhn et al., 2012; Graham et al., 2021; Meiners et al., 2019; Packer & Darla-West, 2021). Others call for more focused, action-oriented approaches that target specific management questions, prioritize species or habitats most vulnerable to climate change and other stressors, and minimize lethal take (Portman et al., 2020; Tepedino et al., 2014; Montero-Castaño et al., 2022). Determining which approach and methods are best suited for our goals should be prioritized and carried out in coordination with broader efforts to monitor bee populations (see Woodard et al., 2020).

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ADDITIONAL REFERENCE MATERIAL OF INTEREST

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CHAPTER 14. ANADROMOUS FISH

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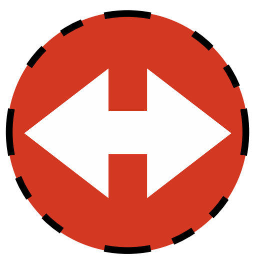
UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

COHO SALMON (*ONCORHYNCHUS KISUTCH*), LAGUNITAS CREEK

2016

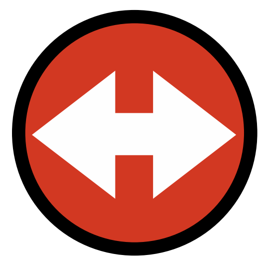


Condition: Significant Concern

Trend: No Change

Confidence: Moderate

2022



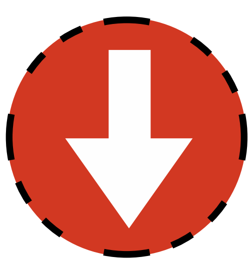
Condition: Significant Concern

Trend: No Change

Confidence: High

COHO SALMON, REDWOOD CREEK

2016

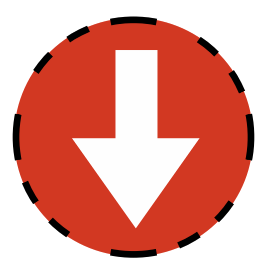


Condition: Significant Concern

Trend: Declining

Confidence: Moderate

2022



Condition: Significant Concern

Trend: Declining

Confidence: Moderate

STEELHEAD TROUT (O. MYKISS)

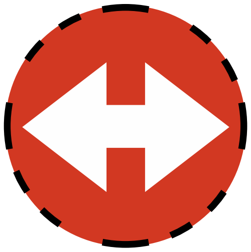
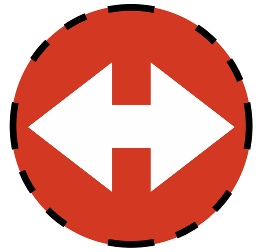
2016	2022
	
Condition: Significant Concern	**Condition:** Significant Concern
Trend: No Change	**Trend:** No Change
Confidence: Moderate	**Confidence:** Moderate

FIGURE 14.1 CONDITION, TREND, AND CONFIDENCE FOR ANADROMOUS FISH, ONE TAM AREA OF FOCUS

Very few indicators of ecosystem health in the One Tam area of focus are monitored as intensively as anadromous salmonids. In the Lagunitas and Redwood Creek Watersheds, biologists count adults during their winter migrations from the ocean, estimate the abundance of juveniles during the summer, and capture smolts on their ocean-bound migrations. Data collected since 2016 paint a complicated picture; while there are some signs of improvement, overall, there is still cause for significant concern.

Highlights for this indicator include:

- The number of coho salmon juveniles and smolts in Lagunitas Creek, including the major tributaries of San Geronimo Creek, Olema Creek, and Devil's Gulch, *increased* between the baseline and the most recent nine-year period, improving these two metrics from significant concern to caution.
- Adult coho in Lagunitas Creek increased, although this metric remains firmly in the significant concern category.
- In Redwood Creek, coho salmon have not increased and, despite active efforts to jumpstart their numbers using hatchery-rearing techniques, the number of adults for two of the three-year classes has decreased since 2016.
- No significant change has been observed in steelhead abundance.
- We removed the wood-loading metric (Metric 4) for Redwood Creek coho salmon from this update because it does not fully describe good habitat conditions for fish in

Redwood Creek. However, removing this metric from the calculation of the overall condition or trend score for 2016 did not change that result.

METRICS SUMMARY

Metrics in Table 14.1 were used to assess anadromous fish health. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 14.1. Each metric is described in the Condition and Trend Assessment section later in this chapter. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 14.1 ALL ANADROMOUS FISH METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Coho Salmon, Lagunitas Creek		
Metric 1: Coho salmon adult escapement (adult spawners and redds)		
	2016	**2022**
Condition	Significant Concern	Significant Concern
Trend	No Change	No Change
Confidence	High	High
Metric 2: Outmigrant coho salmon smolts		
	2016	**2022**
Condition	Significant Concern	Caution
Trend	Improving	Improving
Confidence	High	High
Metric 3: Juvenile coho salmon		
	2016	**2022**
Condition	Significant Concern	Caution
Trend	No Change	Improving
Confidence	Moderate	Moderate

Metric 4: Wood loading		
	2016	**2022**
Condition	Significant Concern	Significant Concern
Trend	No Change	No Change
Confidence	Moderate	High
Coho Salmon, Redwood Creek		
Metric 1: Coho salmon adult escapement (adult spawners and redds)		
	2016	**2022**
Condition	Significant Concern	Significant Concern
Trend	Declining	Declining
Confidence	High	Moderate
Metric 2: Outmigrant coho salmon smolts		
	2016	**2022**
Condition	Significant Concern	Significant Concern
Trend	Declining	Declining
Confidence	Moderate	Moderate
Metric 3: Juvenile coho salmon		
	2016	**2022**
Condition	Significant Concern	Significant Concern
Trend	Declining	Declining
Confidence	High	Moderate
Metric 4: Wood loading		
	2016	**2022**
Condition	Caution	N/A. This metric was not used in this update.
Trend	Improving	
Confidence	High	
Steelhead Trout		
Metric 1: Steelhead adult escapement (adult spawners and redds)		
	2016	**2022**
Condition	Significant Concern	Significant Concern

Trend	No Change	No Change
Confidence	Moderate	Moderate
Metric 2: Stream occupancy		
	2016	**2022**
Condition	Significant Concern	Significant Concern
Trend	No Change	No Change
Confidence	Moderate	Moderate
Metric 3: Outmigrant steelhead smolts		
	2016	**2022**
Condition	Significant Concern	Significant Concern
Trend	No Change	No Change
Confidence	Moderate	Moderate

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

Endangered coho salmon and threatened steelhead trout live in Redwood and Lagunitas Creeks in the One Tam area of focus. Lagunitas Creek is home to the world's southernmost completely wild population of coho salmon (remnant populations as far south as Santa Cruz are being augmented with hatchery fish). Conservation of these salmonids is the principal focus of the Lagunitas Creek Stewardship Plan (Marin Water, 2011) and the collaborative stakeholder group known as the Lagunitas Creek Technical Advisory Committee. Mt. Tam's land management agencies and their partners have been monitoring coho salmon and steelhead populations for decades, counting adult spawners; estimating summer juveniles; and, since 2006, monitoring smolts heading to the ocean. Steelhead have proven to be more difficult to monitor than coho, primarily because they tend to migrate to and from the ocean in late winter when stream flows can be high. As a result, there remains a fair amount of uncertainty about the condition and trend of our local steelhead populations.

Spending part of their lives in freshwater streams and part in the ocean, anadromous fish are good indicators of riparian habitat and watershed hydrology as well as of ocean health (Quinn, 2005). They are also an important food source for many species and a source of marine-derived nutrients for aquatic and riparian communities (Quinn, 2005). Salmonids, iconic and charismatic species, are compelling for public engagement and environmental education.

CURRENT CONDITION AND TREND

Coho Salmon, Lagunitas Creek: Listed as a federally threatened species in 1996 and as endangered in 2005, the Lagunitas Creek coho population reached a low point in 2008, when fewer than 60 adult fish returned from the ocean. Coho numbers have rebounded in recent years, but remain far below the 2,600 adults considered necessary to keep the population safe from extinction.

Coho Salmon, Redwood Creek: Currently, coho salmon are in steep decline and at risk of being lost from the Redwood Creek Watershed. As in Lagunitas Creek, these coho salmon experienced a major decline in 2007–2008, when only four adult fish were observed. However, unlike their northern neighbors, Redwood Creek coho have not rebounded. In an effort to save the population, the California Department of Fish and Wildlife (CDFW) collected juvenile coho, reared them to adulthood at Warm Springs Hatchery, then returned those adults to the creek from 2016 to 2019. Despite these efforts, low numbers of adults persist for two of the three cohorts. Additional restocking is planned for 2024–2026 to help increase the likelihood that the Redwood Creek population will persist.

Steelhead Trout: Far more resilient than coho, and with more flexible habitat needs and lifecycles, steelhead trout appear to be relatively widespread in the One Tam area of focus's streams. They have suffered, however, from the same anthropogenic impacts that have plagued coho, namely dam construction, stream-channel alteration, and development. Steelhead trout along the central California coast were listed by the federal government as a threatened species in 2005.

DESIRED CONDITION AND TREND

Coho Salmon (Lagunitas and Redwood Creeks): Pacific salmon have evolved many mechanisms to persist in highly variable freshwater and marine environments, including high fecundity and the ability to recolonize nearby streams if those populations are extirpated. Unfortunately, adjacent coho populations are too small to repopulate Lagunitas Creek in the event of a local catastrophe, so this population needs to be large enough to persist indefinitely on its own. The creek's aquatic habitats will need to support the diverse life histories of coho salmon (sometimes called "the portfolio effect"), which can provide resilience in a highly variable environment (Schindler et al., 2010). The following desired condition for the Lagunitas Creek and Redwood Creek coho populations are therefore described in terms of numerical targets for each coho life stage and the critical habitat conditions that support those life stages.

Steelhead Trout: Living in both estuarine and stream habitats that vary in depth, velocity, temperature, and shelter, steelhead are less dependent on stream habitat conditions for their survival. To persist indefinitely, steelhead should occupy more streams in the Mt. Tam area of focus and should migrate to the ocean in numbers sufficient to allow a viable number of adult steelhead to return each year and spawn.

Historical Impacts: Dam construction and loss of hydrologic connectivity (between estuarine and stream habitats and between creeks and floodplains) have reduced anadromous fish survival rates during their freshwater life stages. Historical logging, ranching, and road construction increased the amount of fine sediment that entered local streams and smothered fish eggs and gravel nest sites (known as "redds"). Removal of large woody debris and the reduction and/or modification of riparian and stream areas have also reduced the amount of habitat available to these species (Moyle et al., 2008).

Invasive Species Impacts: The New Zealand mud snail (*Potamopyrgus antipodarum*) was discovered in Lagunitas Creek in 2017 and in Redwood Creek in 2019; since then, it has spread through much of the watershed. These mollusks have the potential to impact salmonids' diet by reducing benthic macroinvertebrate prey species while being indigestible themselves (Vinson & Baker, 2008). The spread of invasive Japanese knotweed (*Fallopia japonica*), periwinkle (*Vinca* spp.), and ivy species could suppress native riparian vegetation and insect production as well as alter streambank dynamics (Urgenson, 2006).

Climate Vulnerability: The coho salmon in the One Tam area of focus is a cold-water fish at the southern edge of its global distribution. This makes the species highly vulnerable to increases in water temperatures and reductions in summer base flows resulting from climate change. Of the 19.3 km stream length identified as priority for coho salmon habitat for this report, more than half (10.6 km) is in the Lagunitas Creek area (BAOSC, 2019).

Forecasted warmer water temperatures and more variable stream flows affect multiple life phases for anadromous fish, including spawning, egg survival, and smolt production (Torregrosa et al., 2020). By midcentury (2035–2064), under the high-emissions scenario, extreme precipitation events—in Marin County, two days of successive rainfall >1.68 inches—is projected to occur on average of three times per year (Pierce et al., 2018). Timing of these extreme events is critical to the life cycle of anadromous fish. In the absence of suitable refugia, increased frequency, intensity, and/or duration of winter flood events could disturb spawning gravels and wash salmonid embryos downstream. Later in the year, fall drought conditions could result in insufficient flows to support upstream migration for spawning.

Longer and more intense droughts characterized by higher temperatures and lower base flows will impact summer rearing habitats by creating warmer water temperatures and reducing the extent of connected pool habitats needed to support the growth and survival of juvenile coho prior to smolt outmigration. Stream temperatures that exceed 21.5˚C are lethal to coho salmon, and warmer water conditions below this threshold can reduce the growth rates of juveniles, which, in turn, reduces smolt survival and outmigration. Under a warmer and wetter climate, recent projections for the Lagunitas Creek drainage predict that about 25% of the stream length will exceed lethal temperatures; 83% will exceed this threshold under a warmer and drier climate by midcentury (2040–2069) under natural flow conditions (Torregrosa et al., 2020). Currently, stream temperature and flows in Lagunitas Creek are mitigated by cold water reservoir releases managed by Marin Water.

Fire Regime Change: The last major wildfire in the Lagunitas Creek Watershed took place in 1945, and in the Redwood Creek Watershed in 1966. A buildup of fuel coupled with longer and hotter fire seasons has increased the risk of catastrophic wildfire in these watersheds. High-intensity fires could reduce canopy cover as well as increase water temperature and sediment delivery into streams.

Disease: A half-dozen coho salmon smolts trapped in 2018 had fungal growth on their bodies. Although the fungal disease could not be identified, potential diseases consequent to a warming climate and resource management remain a concern.

Pollution/Contaminants: Coho salmon have been found to be acutely sensitive to a chemical commonly found in automobile tires (Tian et al., 2020). Recent testing has detected the chemical in a tributary to Lagunitas Creek, but at levels below toxicity. Salmonids have also been shown to be sensitive to pesticides (Marlatt et al., 2019) and endocrine disruptors (Kar et al., 2020).

Direct Human Impacts: Poaching of anadromous fish seems to be rare in the One Tam area of focus. Recreation adjacent to salmonid-bearing streams appears to have a more significant impact, causing loss of riparian vegetation, sedimentation, and bank failure.

Habitat Disturbance/Conversion/Loss: Loss of spawning and rearing habitat continues to be a challenge for anadromous fish in the One Tam area of focus (Stillwater Sciences, 2008). Although much of their stream habitat in this area is on protected open-space lands, water withdrawals and extreme hydrologic and climatic events may still take a toll. Additionally, coarse sediment is being retained in reservoirs, which results in finer, more mobile streambeds that are not replenished. This, in turn, leads to channel incision and a loss of floodplain connectivity downstream. Reservoirs may also retain large woody debris and affect the hydrological and geomorphic processes needed to support downstream salmonid habitat.

Predation/Competition: Predation by native piscivorous birds can put severe pressure on anadromous fish populations when in-stream shelter is lacking.

Other Stressors: Anthropogenic changes are not limited to freshwater environments. Marine overharvesting of salmonids and their prey (e.g., sardines) reduces salmonid survival. Changes to ocean food webs related to climate change are increasingly threatening these species (Moyle et al., 2008). The quality and quantity of estuarine habitats are also likely affecting Redwood Creek coho salmon, though recent restoration work at Muir Beach was intended to improve habitat conditions there.

CONDITION AND TREND ASSESSMENT

METRICS

COHO SALMON (LAGUNITAS CREEK)

METRIC 1: COHO SALMON ADULT ESCAPEMENT (ADULT SPAWNERS AND REDDS)

Baseline: Approximately 300 adult coho salmon returned to Lagunitas Creek each year between 2007–2008 and 2015–2016. Biologists track adult abundance by counting redds, and assume that each redd represents two adult fish. Three generations provide the minimum period for determining an upward population trend.

Condition Goal: The number of adult coho salmon spawners in Lagunitas Creek must be 1,300 to be considered for downlisting from federally endangered to federally threatened status, and 2,600 for delisting as defined by National Marine Fisheries Service (NMFS) recovery goals (NMFS, 2012). As per the NMFS 2012 recovery plan, these target numbers must be sustained for nine consecutive years to meet the standard. Lagunitas Creek is one of 28 populations that need to achieve specific goals before coho in the Central California Coast Ecologically Significant Unit could be downlisted or delisted.

Condition Thresholds:

- **Good:** Nine consecutive years (three generations of each of the three year classes) of ≥1,300 redds.
- **Caution:** Nine consecutive years of 650 redds, but <nine consecutive years of 1,300 redds.
- **Significant Concern:** Fewer than nine consecutive years of 650 redds.

Current Condition:

2016: Significant Concern

Between 2007–2008 and 2015–2016, the average number of redds was approximately 20% of the downlisting goal (Figure 14.2).

2022: Significant Concern

Between 2014–2015 and 2021–2022, the average number of redds was approximately 35% of the downlisting goal.

Trend:

2016: No Change

Two of three coho year classes showed increases over two generations, while the third year class (represented at the time by the 2013–2014 adult run) increased over one generation.

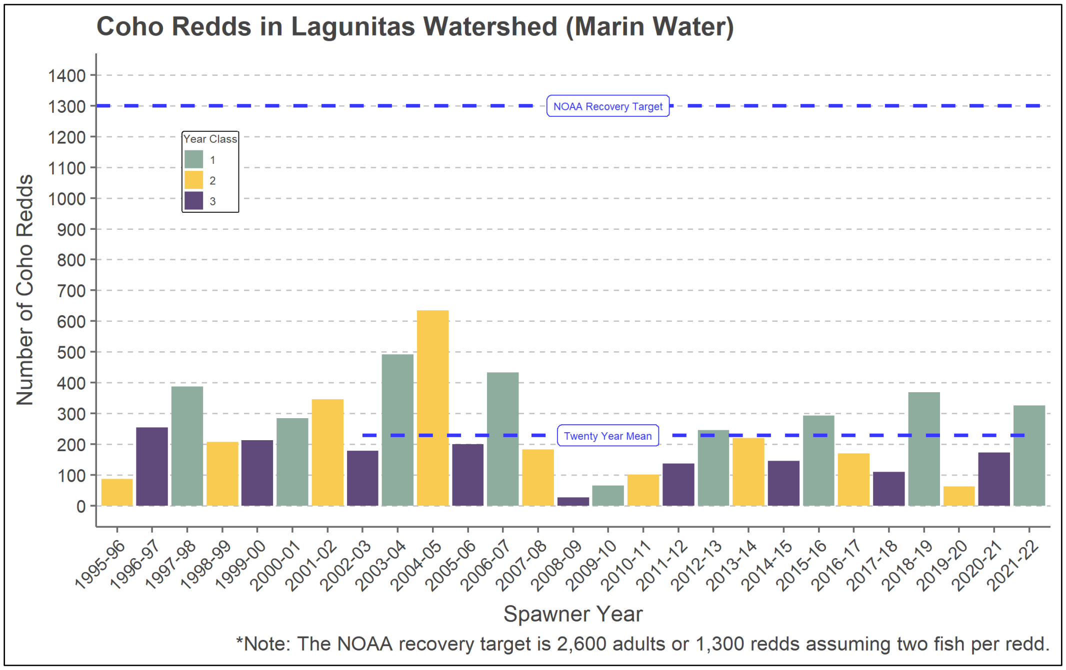


FIGURE 14.2 COHO REDDS, LAGUNITAS CREEK WATERSHED (MARIN WATER INTERNAL DATA)

2022: No Change

Of the three coho year classes, one increased, one decreased, and one was stable for the most recent three generations.

Confidence:

2016: High

On a weekly basis, when flows allowed, surveyors covered all creek reaches where anadromous fish were found.

2022: High

Surveyors continue to cover the same creek reaches at the same frequency.

METRIC 2: OUTMIGRANT COHO SALMON SMOLTS

Baseline: Between 2007 and 2015, coho smolt outmigration estimates averaged 9,000 fish.

Condition Goal: To reach the coho recovery goal of 2,600 adults (NMFS, 2012), and assuming a marine survival rate of 5% (close to average in recent years), 52,000 coho salmon smolts would need to migrate from Lagunitas Creek. Such abundance would need to persist for at least nine years (three generations). Smolt abundance is also a useful way to look at the overwintering survival rate of juvenile coho salmon and provide an indicator of watershed health.

Condition Thresholds:

- **Good:** A nine-year average of ≥26,000 smolts.
- **Caution:** A nine-year average of 13,000 to 26,000 smolts.
- **Significant Concern:** A nine-year average of <13,000 smolts.

Current Condition:

2016: Significant Concern

In 2016, the nine-year average for Lagunitas Creek was approximately 7,600 smolts (Figure 14.3).

2022: Caution

The nine-year average (2014–2022) has been approximately 15,000 coho smolts.

Trend:

2016: Improving

Two of the three-year classes increased over two generations. The third year class, while only increasing over one generation, reached a record level in 2014 (Figure 14.3).

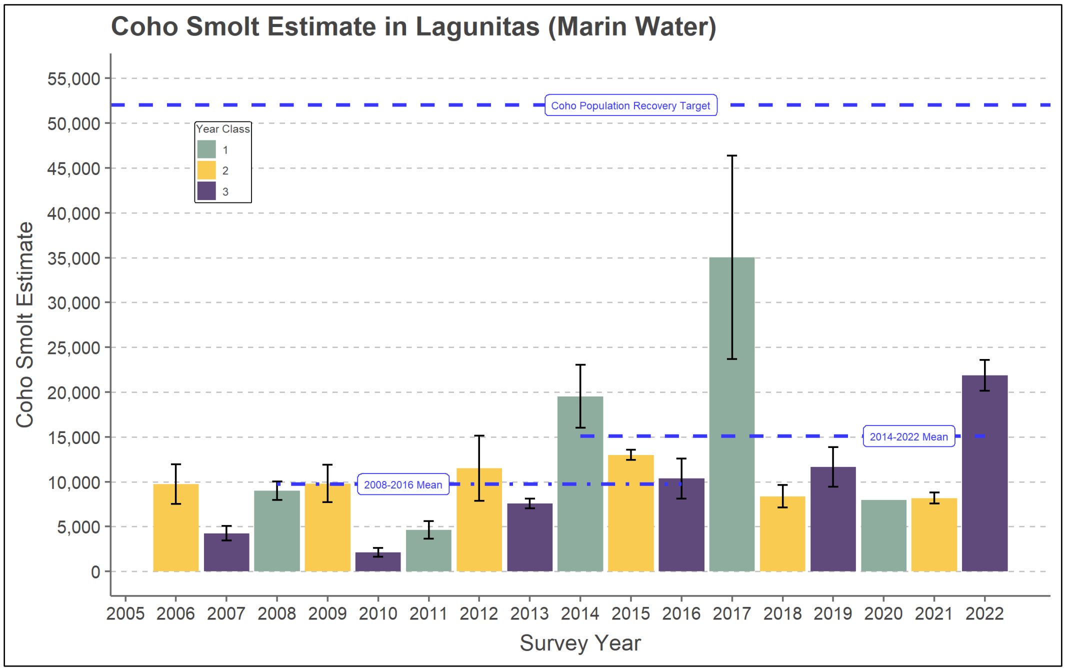


FIGURE 14.3 COHO SMOLTS, LAGUNITAS CREEK WATERSHED (MARIN WATER INTERNAL DATA)

2022: Improving

The number of coho smolts during the most recent nine-year period (2014–2022) was significantly higher than the nine-year average estimated in 2016.

Confidence:

2016: High

Smolt estimates are the most accurate of the coho life-stage estimates. Generally, the entire migration period was monitored and the efficiency of smolt traps could be accurately estimated.

2022: High

Smolt monitoring continues to follow established protocols that produce reliable estimates.

METRIC 3: JUVENILE COHO SALMON

Baseline: Over a nine-year period (2007–2015), an estimated 26,000 juvenile coho were present in the Lagunitas Creek Watershed (Ettlinger et al., 2016).

Condition Goal: An estimated 120,000 individual juvenile coho salmon in the Lagunitas Creek watershed, based on observed densities of as many as three coho per meter and accessible habitat of 40 km of stream (Ettlinger et al., 2016).

Condition Thresholds:

- **Good:** Nine-year average of >60,000 juvenile coho.
- **Caution:** Nine-year average of 30,000–60,000 juvenile coho.
- **Significant Concern:** Nine-year average of <30,000 juvenile coho.

Current Condition:

2016: Significant Concern

Juvenile coho salmon abundance during the baseline period exceeded 60,000 in two years, but also fell to <2,000. This high volatility demonstrated the risk of the population dropping below a depensation threshold (Figure 14.4).

2022: Caution

Juvenile coho salmon abundance for the most recent nine-year period (2013–2021) was ~31,000. The population also remained >10,000 during that period.

Trend:

2016: No Change

The juvenile coho population in Lagunitas Creek fluctuated widely between 2007 and 2015 (three generations), but did not show an overall trend.

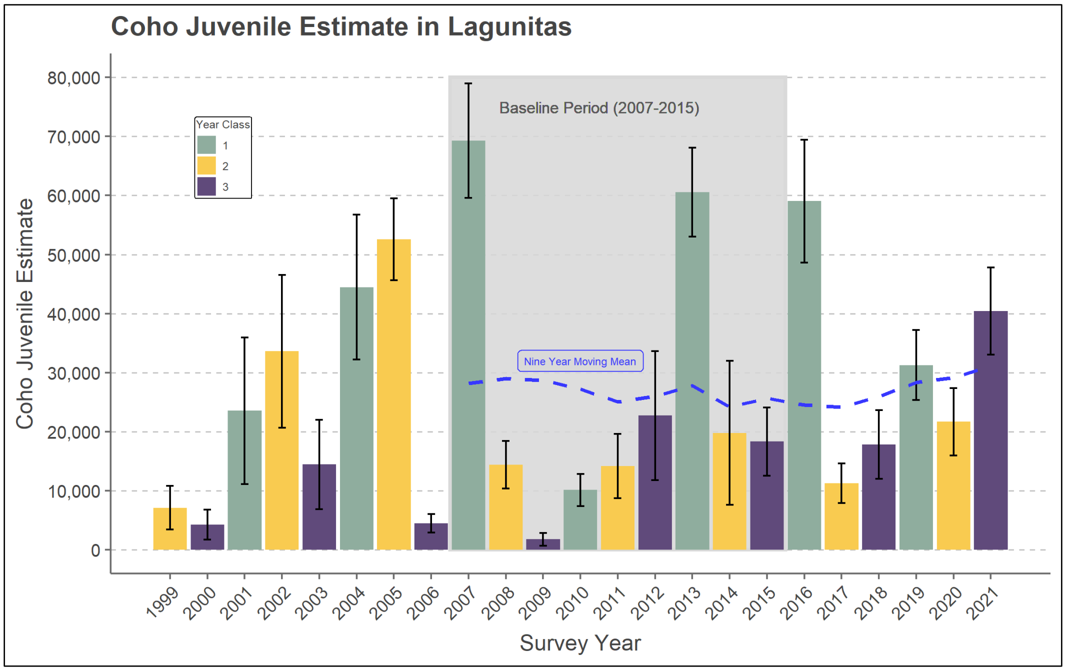


FIGURE 14.4 JUVENILE COHO, LAGUNITAS CREEK WATERSHED (MARIN WATER INTERNAL DATA)

2022: Improving

In 2021, the nine-year average exceeded 30,000 for the first time.

Confidence:

2016: Moderate

Marin Water and National Park Service biologists surveyed only a small fraction of the watershed, so the confidence intervals around these estimates were very large.

2022: Moderate

Survey methods have remained largely unchanged in recent years and still cover just a small fraction of the watershed. Therefore, our confidence is moderate that the nine-year average is above the 30,000 threshold.

METRIC 4: WOOD LOADING

Baseline: Prior to 2016, wood volume in the Lagunitas Creek Watershed had not been measured in detail, but counts of individual logs indicated that it was far below levels known to be beneficial for juvenile coho. In 2011, 520 logs were counted in pools in Lagunitas Creek and two tributaries (Ettlinger et al., 2013).

Condition Goal: Wood loading meets established criteria for the forest type: 300 cubic meters (cu m) m/hectare (ha) in redwood channels and 100 cu m/ha in hardwood channels (CRWQCB, 2014).

Condition Thresholds:

- **Good:** More than 300 cu m/ha in redwood channels; 100 cu m/ha in hardwood channels.
- **Caution:** Between 150 and 300 cu m/ha in redwood channels; 50–100 cu m/ha in hardwood channels.
- **Significant Concern:** Fewer than 150 cu m/ha in redwood channels; <50 cu m/ha in hardwood channels.

Current Condition:

2016: Significant Concern

Based on the 520 logs counted in 2011, an estimate of 23 ha of channel surveyed, and an extremely rough estimate of four cu m of wood per log, wood loading was approximately 90 cu m/ha. Wood loading appeared to be lower in redwood channels than in hardwood channels, so the redwood channel loading was less than 150 cu m/ha.

2022: Significant Concern

The most recent habitat typing survey for Lagunitas Creek (Ettlinger, 2017) found a highly variable distribution of wood between streams and stream reaches. Overall, wood loading in the redwood-dominated reaches of Lagunitas Creek was only 152 cu m/ha. In hardwood-dominated reaches, wood loading was approximately 74 cu m/ha.

Trend:

2016: No Change

Wood volume had not been measured prior to 2016, and log counts in Lagunitas Creek were not conducted consistently. No reliable trend could be seen in the data. (Table 14.2).

TABLE 14.2 LOG COUNTS IN SURVEYED STREAMS (ETTLINGER ET AL., 2013)

Stream	Reach	2003	2006	2011
Lagunitas Creek	Nicasio Cr.–Tocaloma	70	81	115
	Toc.–Devil's Gulch	54	113	107
	D.G.–Shafter Bridge	56	130	93
	Shafter–Peters Dam	15	42	28
San Geronimo Creek	Mouth–Larsen Cr.	~30	27	40
	Larsen Cr.–Dixon Weir	~90	91	80
Devil's Gulch		36	65	57
Total		**351**	**549**	**520**

2022: No Change

The wood-loading survey conducted in 2016 will be repeated in late 2022, but for now, the data do not exist to detect a trend in wood loading.

Confidence:

2016: Moderate

Although many assumptions went into the 2016 wood-loading estimate, it represented a reasonable assessment of conditions as they existed.

2022: High

Wood loading has been measured thoroughly in Lagunitas Creek and the resulting data provide an accurate snapshot of this critical component of coho salmon habitat.

COHO SALMON (REDWOOD CREEK)

METRIC 1: COHO ADULT ESCAPEMENT (ADULT SPAWNERS AND REDDS)

Baseline: From 2008 to 2016, average coho escapement was 32 adults (based on average counts of 16 redds). Biologists tracked adult abundance by counting redds and assuming that each redd represented two adult fish.

Condition Goal: The number of adult coho salmon spawners in Redwood Creek must be 136 for downlisting from federally endangered to federally threatened status, and 272 for delisting as defined by recovery goals (NMFS, 2012). The target numbers must be sustained for nine consecutive years to meet the standard as per the NMFS 2012 recovery plan. (Redwood Creek is one of 28 populations that need to achieve specific population goals before coho in the Central California Coast Ecologically Significant Unit can be downlisted or delisted.)

Condition Thresholds:

- **Good:** Nine consecutive years (three generations of each of the three year classes) of ≥136 adult coho.
- **Caution:** Nine consecutive years (three generations of each of the three year classes) of ≥65 but <136 adult coho.
- **Significant Concern:** Nine consecutive years (three generations of each of the three year classes) of >65 adult coho.

Current Condition:

2016: Significant Concern

The nine-year average was approximately 12% of the delisting goal (Figure 14.5).

2022: Significant Concern

No nine-year average was calculated because four of those years were augmented with hatchery-reared adults. However, average numbers for the last three year classes are much less than the target of 65 adult coho.

Trend:

2016: Declining

Over the previous nine years (three generations), two of the three year classes remained at dangerously low levels in Redwood Creek, while the third had recently declined.

2022: Declining

There has been no improvement in any of the three year classes.

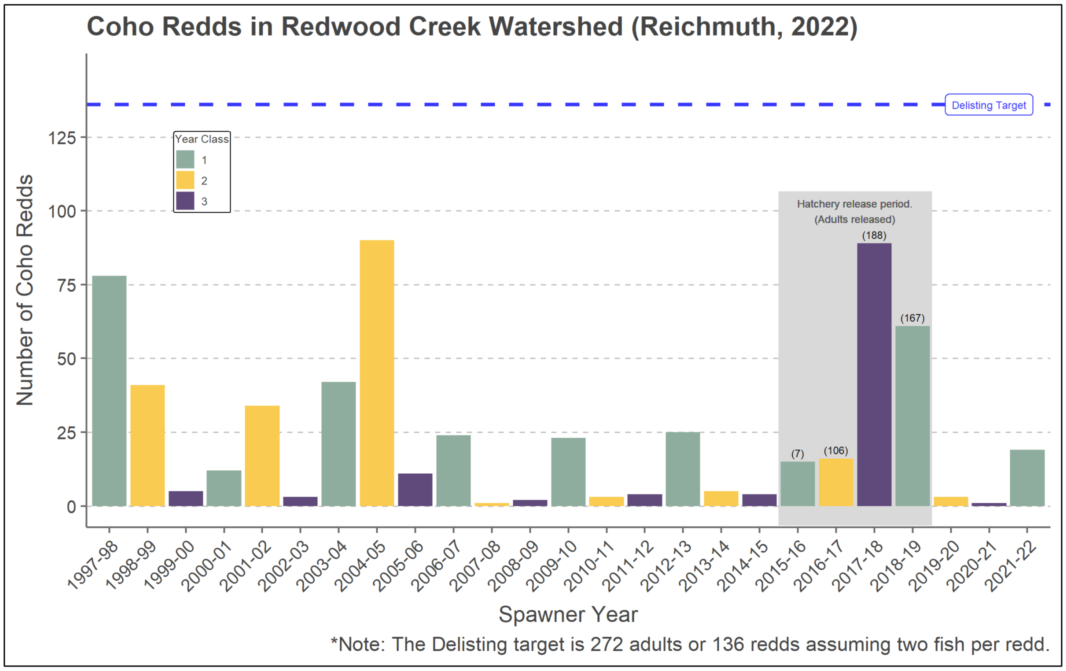


FIGURE 14.5 COHO REDDS, REDWOOD CREEK (NATIONAL PARK SERVICE INTERNAL DATA)

Confidence:

2016: High

When flows allowed, surveyors covered all anadromous reaches weekly.

2022: Moderate

Because hatchery-reared adults were released several years in a row, we are less certain about our trend assessment than we were in 2016, as hatchery fish make up some proportion of our count rather than these numbers representing a self-sustaining population.

METRIC 2: OUTMIGRANT COHO SALMON SMOLTS

Baseline: From 2008–2016, coho smolt production in Redwood Creek averaged approximately 1,310 fish.

Condition Goal: An average of 14,000 coho salmon smolts in Redwood Creek over nine years (three generations), with 2% marine survival based on 10 years of data (Carlisle et al., 2016), i.e., the number of coho salmon smolts needed to meet the adult recovery goal for delisting (NMFS, 2012). This metric is also a useful way to look at overwintering survival of juvenile coho salmon and provide an indicator of watershed health.

Condition Thresholds:

- **Good:** An average of 7,000 coho salmon smolts over nine years.

- **Caution:** An average of 3,500 but <7,000 coho salmon smolts over nine years.
- **Significant Concern:** A nine-year average of <3,500 coho salmon smolts over nine years.

Current Condition:

2016: Significant Concern

Average smolt numbers for Redwood Creek were approximately 9% of the delisting target (1120 individuals).

2022: Significant Concern

The average smolt number for Redwood Creek for the latest nine-year period (2014–2022) was approximately 8% of the delisting target (1,063 individuals). No data were available for 2020 because surveys were suspended as per COVID-19 restrictions.

Trend:

2016: Declining

Two of three Redwood Creek year classes had declined and the third did not show a significant trend (Figure 14.6).

2022: Declining

The last two years of trapping resulted in <100 estimated coho smolts. There was no sampling in 2020 due to COVID-19 restrictions, but given a relatively low summer abundance in 2019, it is unlikely there were large numbers of smolts.

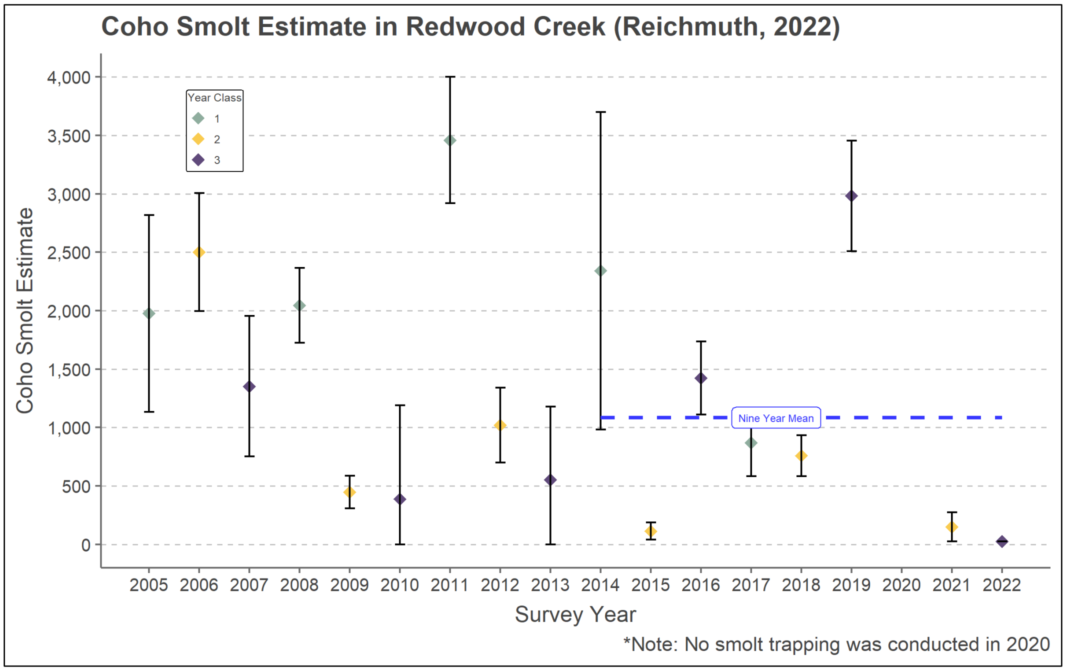


FIGURE 14.6 COHO SMOLT ESTIMATES, REDWOOD CREEK (NATIONAL PARK SERVICE INTERNAL DATA)

Confidence:

2016: Moderate

While smolt estimates are the most accurate of any of the coho life-stage estimates, coho smolts can more easily avoid the fyke trap in Redwood Creek than they can the rotary screw trap used in Lagunitas Creek. This resulted in a greater degree of uncertainty around the Redwood Creek smolt estimates (Carlisle et al., 2016).

2022: Moderate

Our confidence in this assessment remains moderate because we continue to use the same sampling methods.

METRIC 3: JUVENILE COHO SALMON COUNTS

Baseline: In the nine years prior to 2016, the average number of juvenile coho in Redwood Creek was estimated at 1,900 (Carlisle et al., 2016).

Condition Goal: An estimated 27,000 juvenile coho salmon fry in Redwood Creek, based on a maximum density of three coho/m and accessible habitat of 9 km of stream (Carlisle et al., 2016).

Condition Thresholds:

- **Good:** A nine-year average of ≥13,500 juvenile coho.

- **Caution:** A nine-year average of ≥7,000 but <13,500 juvenile coho.
- **Significant Concern:** A nine-year average of <7,000 juvenile coho.

Current Condition:

2016: Significant Concern

Two of three year classes had been hovering at near-extirpation levels since 2008 (Figure 14.7).

2022: Significant Concern

The nine-year average (2013–2021) for juvenile coho is 1,835.

Trend:

2016: Declining

The population of juvenile coho salmon in Redwood Creek had dropped drastically since 2006 (three generations) (Figure 14.7).

2022: Declining

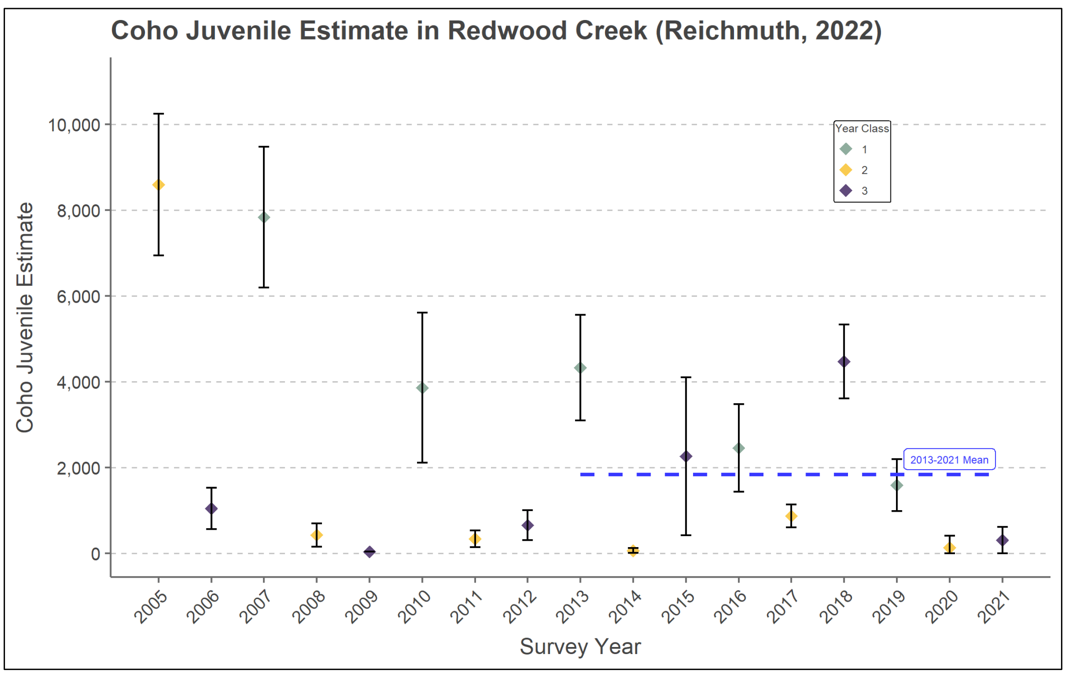


FIGURE 14.7 JUVENILE COHO POPULATION ESTIMATES, REDWOOD CREEK (NATIONAL PARK SERVICE INTERNAL DATA)

Confidence:

2016: Moderate

National Park Service biologists surveyed the majority of anadromous habitat available within the watershed.

2022: Moderate

Because hatchery-reared adults were released several years in a row, we are less certain about our trend assessment than we were in 2016. This is because progeny of those fish make up some proportion of the juveniles counted rather than these numbers representing a self-sustaining population.

STEELHEAD TROUT

METRIC 1: STEELHEAD ADULT ESCAPEMENT (SPAWNERS AND REDDS)

Baseline: Between 2009 and 2016 (representing two generations and four year classes) the number of adult steelhead returning to Lagunitas Creek averaged 300 fish (based on an average of 145 redds). In Redwood Creek, the number of steelhead averaged less than 20 fish (based on an average of seven redds) during that same period.

Condition Goal: The number of adult steelhead spawners must be between 38 and 78 in Redwood Creek and 2,600 in Lagunitas Creek for them to be removed from the endangered species list. Target numbers must be sustained for eight consecutive years (typically, two generations) to meet the standard as per the NMFS draft recovery plan (NMFS, 2015).

Condition Thresholds:

- **Good:** Eight consecutive years (two generations) of ≥325 redds (650 fish, a quarter of the delisting target) in Lagunitas Creek, and ≥29 redds (58 fish, the full delisting target) in Redwood Creek.
- **Caution:** Eight consecutive years (two generations) of ≥100 redds in Lagunitas Creek and ≥15 redds in Redwood Creek, but <eight consecutive years of ≥325 redds in Lagunitas Creek and ≥29 redds in Redwood Creek.
- **Significant Concern:** Less than eight consecutive years (two generations) of ≥100 redds in Lagunitas Creek, or <eight consecutive years of ≥15 redds in Redwood Creek

Current Condition:

2016: Significant Concern

The 2009–2016 average was approximately 11% of the delisting goal for Lagunitas Creek and 36% of the goal for Redwood Creek. However, local biologists (S. Carlisle, E. Ettlinger, D. Fong,

M. Reichmuth) believed that, given the steelhead's high fecundity, life-history flexibility, and general resiliency, the Lagunitas Creek target was too high. In their professional opinion, steelhead were likely to persist in Lagunitas Creek at population levels far below the current recovery threshold, and that the threshold should be eight years of at least 100 redds (200 fish) for the species to no longer qualify for the significant concern condition.

Steelhead runs in Lagunitas Creek exceeded that threshold five out of eight years, while in Redwood Creek, more than 15 steelhead redds were observed in only one year. This may have been the result of ending monitoring seasons before spawning was completed, but it may also have indicated very small populations. The condition of the Redwood Creek steelhead population was therefore conservatively considered to be at high risk of extirpation.

2022: Significant Concern

At least 100 steelhead redds have been observed in Lagunitas Creek for 11 straight years, with the notable exception of 2016–2017, when only 35 redds were seen. High stream flows that year precluded surveys for most of the winter, but abundant juvenile steelhead in 2017 retrospectively indicated a large run (Figure 14.8).

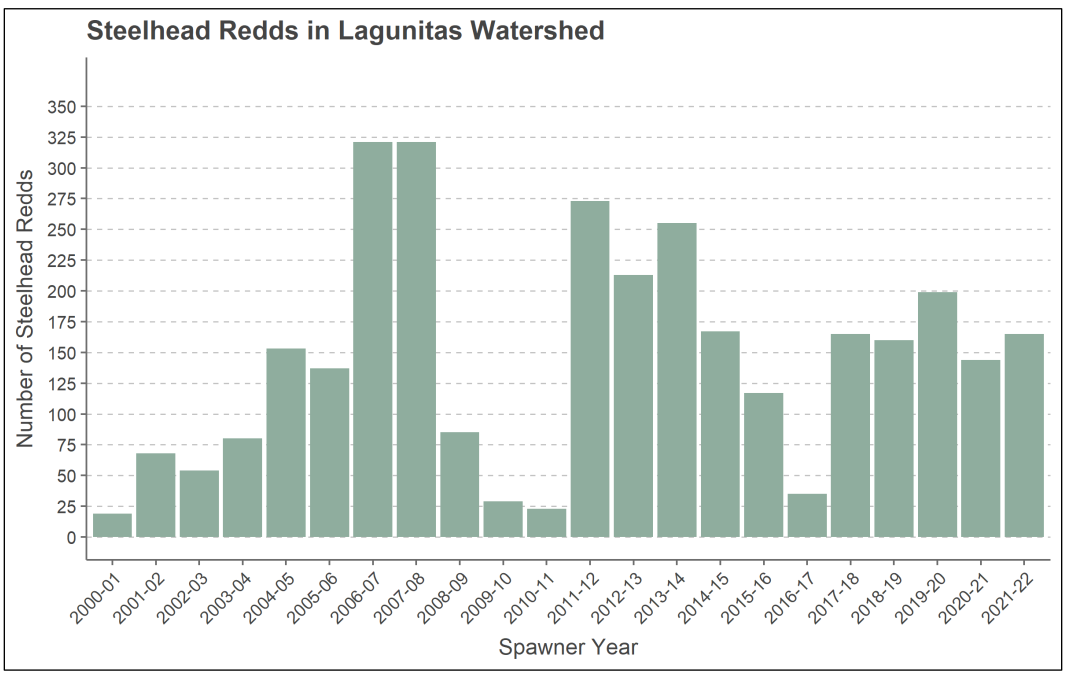


FIGURE 14.8 STEELHEAD REDD ESTIMATES, LAGUNITAS CREEK WATERSHED

Steelhead abundance in Lagunitas Creek, if considered independently, would warrant a condition of caution, while extremely low numbers of steelhead redds in Redwood Creek indicate a persistently small population. Fewer than 15 redds have been observed in five of the last eight years.

Trend:

2016: No Change

Steelhead redd counts in Lagunitas Creek and Redwood Creek showed no strong trend between 2008 and 2015.

2022: No Change

Steelhead redd counts remained stable in Lagunitas Creek between 2015 and 2022. In Redwood Creek, average steelhead redd counts, although still low, have increased since 2016, with an eight-year average of 20 redds compared to 2016, in which the eight-year average was 10 redds.

Confidence:

2016: Moderate

Steelhead spawner surveys did not continue through the latter months of the run, so large numbers of fish and redds may have been missed (Ettlinger et al., 2015a). Available data, however, were adequate to roughly assess run sizes and trends.

2022: Moderate

The difficulties of accurately quantifying adult steelhead persist, but consistent methods over many years support this population assessment. In future years, we anticipate that sonar camera footage near the mouth of Lagunitas Creek and additional spawner surveys will increase our confidence in adult steelhead trends over time.

METRIC 2: STREAM OCCUPANCY

Baseline: In 2016, anadromous steelhead occupied 80.5 km of stream in the One Tam area of focus (MarinMap GIS, “Anadromous fish” layer; internal Marin Water data). Note that streams above Marin Water reservoirs are considered permanently inaccessible and are not included in these stream distances.

Condition Goal: Increase extent of occupied stream habitat (currently, ~84 km).

Condition Thresholds:

- **Good:** At least 133.5 km of stream occupied by anadromous steelhead, representing 75% of the 177 km of stream in the One Tam area of focus (MarinMap GIS; internal Marin Water data).
- **Caution:** 88.5–133.5 km of stream occupied by anadromous steelhead, representing 50%–75% of the 177 km of stream in the One Tam area of focus.
- **Significant Concern:** Fewer than 88.5 km of stream occupied by anadromous steelhead, representing <50%of the 177 km of stream in the One Tam area of focus.

Current Condition:

2016: Significant Concern

Fewer than 88.5 km of stream were occupied by anadromous steelhead in 2016. In addition, a 2003 inventory had found numerous migration barriers in the Corte Madera Creek Watershed and Mill Valley Creeks (Ross Taylor & Associates, 2003).

2022: Significant Concern

Since 2016, no significant migration barriers have been removed within the One Tam area of focus; steelhead distribution continues to be impeded.

Trend:

2016: No Change

The extent to which the 117 km of streams identified in the One Tam area of focus were historically accessible to steelhead was unknown. Additionally, as of 2016, the extent of the One Tam area of focus occupied by steelhead trout—either anadromous or resident forms—had not been accurately determined, nor had the upstream limits of anadromy in many streams.

2022: No Change

Expansion of stream occupancy by steelhead would most likely require the removal of migration barriers. No full migration barriers have been removed in the One Tam area of focus in recent years.

Confidence:

2016: Moderate

Baseline surveys to establish the full extent of steelhead occupancy had not been completed.

2022: Moderate

The full extent of steelhead occupancy remains a data gap.

METRIC 3: OUTMIGRANT STEELHEAD SMOLTS

Baseline: An average of 2,400 steelhead smolts emigrated annually from Lagunitas Creek between 2008 and 2015.

Condition Goal: An average of 26,000 steelhead smolts emigrating from Lagunitas Creek over eight years (two generations), with 10% marine survival based on eight years of data. This number of steelhead smolts and marine survival rate would result in 2,600 adults and meet the draft adult recovery goal (NMFS, 2015). In Redwood Creek, an emigration of 780 steelhead smolts and 10% marine survival would result in 78 adult steelhead trout and meet the draft recovery goal.

Condition Thresholds:

- **Good:** An eight-year average of ≥13,000 steelhead smolts in Lagunitas Creek and ≥390 steelhead smolts in Redwood Creek.
- **Caution:** An eight-year average of ≥6,500 steelhead smolts in Lagunitas Creek and ≥200 steelhead smolts in Redwood Creek, but <13,000 steelhead smolts in Lagunitas Creek and <390 steelhead smolts in Redwood Creek.
- **Significant Concern:** An eight-year average of <6,500 steelhead smolts in Lagunitas Creek or <200 steelhead smolts in Redwood Creek.

Current Condition:

2016: Significant Concern

Between 2008–2015, the average steelhead smolt estimate for Lagunitas Creek was 2,400 (Figure 14.9). While the adult recovery target and related smolt target were likely too high, steelhead smolt numbers were also too low. Limited data were available for steelhead smolt abundance in Redwood Creek.

2022: Significant Concern

Between 2015 and 2022, steelhead smolt abundance in Lagunitas Creek averaged 2,600, which warrants an assessment of significant concern (Figure 14.9).

Trend:

2016: No Change

Steelhead smolt estimates between 2008 and 2015 showed no strong trend.

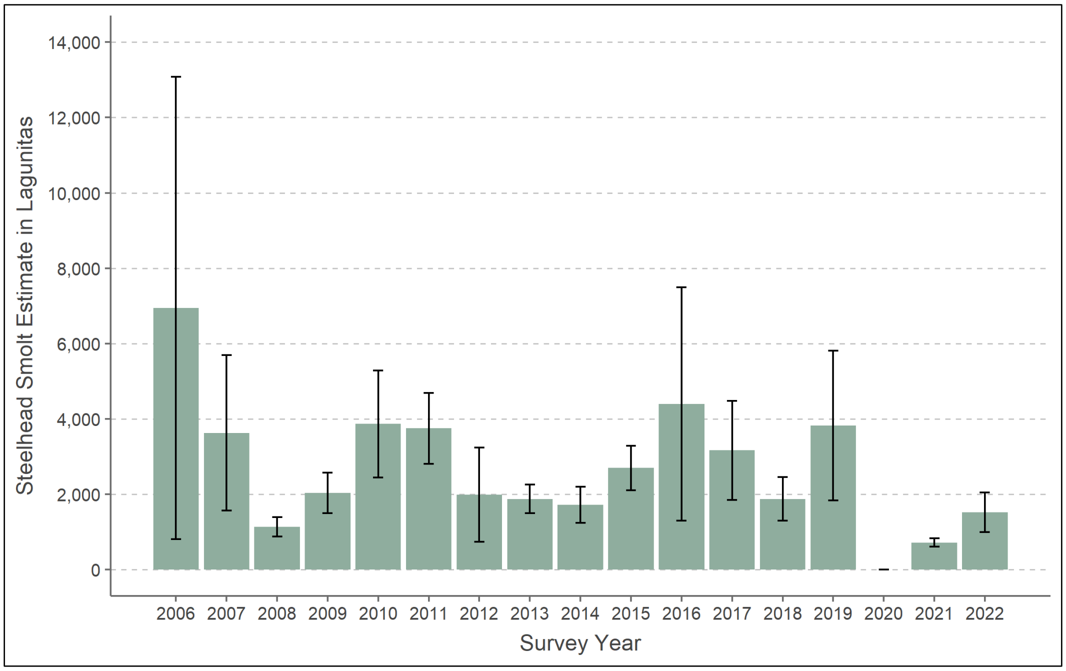


*FIGURE 14.9 STEELHEAD SMOLT ESTIMATES, LAGUNITAS CREEK WATERSHED**

**Abundance not estimated in 2020 due to the COVID-19 pandemic.*

2022: No Change

While the eight-year average for steelhead emigration has not changed significantly since 2016, steelhead smolt estimates in 2021 and 2022 were below average. Additional monitoring will determine if the last two years were unusual or the start of a declining trend.

Confidence:

2016: Moderate

The steelhead smolt monitoring period missed unknown but possibly significant numbers of early smolts (Ettlinger et al., 2015b).

2022: Moderate

Early migrants continue to be missed during smolt monitoring, but evidence suggests that the majority of steelhead smolts migrate during the monitoring period.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

- NMFS Federal Register documents (NMFS, 2012 & 2015)
- National Park Service inventory and annual monitoring (Carlisle et al., 2016)
- Marin Water annual monitoring reports (Ettlinger et al., 2023)

- Redwood Creek Watershed Assessment (Stillwater Sciences, 2011)

A summary of key monitoring programs follows. More information about each program can be found in the accompanying citations.

ANNUAL ADULT SALMONID MONITORING

Marin Water fisheries staff walk Lagunitas Creek and two of its tributaries weekly between November and mid-March. Salmonid redds are counted and classified to species. Live fish and carcasses are also counted. Run sizes for each species are conservatively estimated by assuming each redd represents two adult fish. These surveys have been conducted annually since 1995–1996 (Ettlinger et al., 2021). National Park Service staff monitor adult salmonids in Olema Creek and Redwood Creek using similar methods (Carlisle et al., 2016) but have expanded steelhead surveys annually through the spring steelhead spawning period to increase accuracy of the steelhead spawning estimate.

ANNUAL SUMMER JUVENILE SALMONID MONITORING

Marin Water fisheries staff conduct electrofishing and snorkel surveys at established index reaches in Lagunitas Creek. These surveys were first conducted in 1970 and then annually starting in 1993. The National Park Service monitors juvenile salmonids in Olema Creek and Redwood Creek employing a basinwide estimation procedure that uses snorkel surveys calibrated by electrofishing. In addition, index sections are electrofished (Carlisle et al., 2016).

ANNUAL SMOLT MONITORING

Since 2006, Marin Water has operated a rotary screw trap near Point Reyes Station to estimate coho salmon and steelhead smolts migrating from Lagunitas Creek to the ocean. The efficiency of the trap, which catches a portion of the migrating fish, is estimated by marking a small number of fish each day, releasing them upstream, and counting the number recaptured (Ettlinger et al., 2015b). Salmonids are also counted by National Park Service and Salmon Protection and Watershed Network (SPAWN) staff using fyke net traps on Olema, Redwood, and San Geronimo Creeks (Carlisle et al., 2016; SPAWN internal data).

SALMONID HABITAT MONITORING

Approximately every five years, Marin Water staff measure salmonid habitat in the Lagunitas Creek study area. Habitats are classified (pool, riffle, run, or glide); their dimensions are measured; and characteristics such as fish shelter, bank characteristics, and canopy are quantified (Ettlinger et al., 2013). The National Park Service measures and classifies stream habitats in Redwood Creek annually (Carlisle et al., 2016). In the winter, the National Park Service maps habitat suitable for winter occupancy by juvenile salmon along Redwood Creek in Muir Woods National Monument to assess performance of instream habitat restoration.

INFORMATION GAPS

Monitoring Data: Current monitoring targets coho salmon, but surveys could be expanded to build a more robust dataset for steelhead trout.

Fish Migration and Habitat: The timing and magnitude of salmonid movements between streams using Passive Integrated Transponder (PIT) tag technology would provide valuable information on habitat needs during multiple life stages. Expanding existing PIT tagging to steelhead trout would provide data on smolt emigration prior to the start of trapping.

Pool Habitat: Availability of pool habitats was identified as an important metric for coho salmon. However, we lack consensus on how to define these habitats, how different kinds of pools are classified, or the ideal frequency of pools along a stream. Developing site-specific criteria for pool frequencies using appropriate data (e.g., geomorphic, sediment-loading, pool-scour potential, roughness, large woody debris loading, etc.) would allow us to measure this important aspect of salmonid habitat health more comprehensively in the future.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Lagunitas Creek Coho Salmon Winter Habitat Enhancement: Between 2017 and 2019, eight large woody debris installations were implemented to improve coho salmon winter habitat. The goals of the project were to provide flow and predator refuge and increase the frequency and duration of floodplain inundation along Lagunitas Creek.

Passive Integrated Transponder (PIT) Tag Monitoring: In late 2020, two PIT tag antennas were installed in lower Lagunitas Creek to identify tagged coho salmon as they migrated between the creek and the ocean. In 2021, two more antennas were installed in lower Devil's Gulch and San Geronimo Creek.

Past Work

Following are some of the previous stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Restoration:

- Extensive habitat restoration has been done in Lagunitas Creek, including installing large woody debris installations and reducing fine-sediment inputs (Marin Water).
- Redwood Creek habitat restoration has included fish-passage barrier removal, habitat structure installation, native plant restoration, and restoration of natural processes and hydrology at the creek's mouth at Muir Beach (National Park Service).

- Realignment and reconnection of Green Gulch Creek to Redwood Creek (after many decades of separation) provided valuable off-channel habitat for coho salmon (National Park Service and San Francisco Zen Center).
- Culvert barriers for adult and juvenile steelhead were removed in Jewel Creek (National Park Service land, implemented by Marin Water).
- Banducci restoration included large woody debris installation and creek realignment in 2003, removing levies and fill from the floodplain in 2007, and groundwater recharge improvements in 2015 (National Park Service).
- High-priority sites for barrier removal were identified in Redwood Creek through the 2003 Marin County Fish Passage Assessment, leading to the installation of a new culvert connecting Kent Canyon and the mainstem of Redwood Creek and replacement of an undersized culvert under Muir Woods Road (National Park Service).

Management:

- The multiagency Coho Jumpstart program rears coho salmon and releases them back into Redwood Creek (initiated in 2015).
- Water releases have been made into Lagunitas Creek to maintain streamflow for salmonids (Marin Water).
- Sedimentation has been reduced as a result of the Dias Ridge restoration project (National Park Service); multiple projects along the Bootjack Trail (National Park Service and California State Parks); Alice Eastwood Road culvert removal (California State Parks); fire-road and trail sediment reduction projects in San Geronimo/Lagunitas Watershed (Marin County Parks); and several significant projects stemming from the implementation of Marin Water's 2005 Mt. Tamalpais Watershed Road and Trail Management Plan.

Monitoring:

- Long-term life-cycle (juvenile, smolt, adult spawner/redds) monitoring of salmonids is conducted in Lagunitas and Redwood Creeks (Marin Water and National Park Service).
- Annual adult and smolt monitoring are done in the San Geronimo Valley (SPAWN).

Outreach:

- AmeriCorps has led volunteer salmon enhancement projects and watershed education programs in schools (Marin Water).
- The Spawner Day Program takes place at Samuel P. Taylor State Park.
- There is an annual Welcome Back Salmon event at Muir Beach (National Park Service in partnership with the Federated Indians of Graton Rancheria).

- Thousands of volunteer hours have been invested in habitat restoration and stewardship and salmonid monitoring SPAWN, Golden Gate National Parks Conservancy, National Park Service, California State Parks, Marin Resource Conservation District, San Geronimo Valley Planning Group, and many others.

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as a part of the development of this report. These are actions not currently funded through agency programs and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Existing Program Support:

- **Juvenile Coho Habitat Improvements, Redwood Creek**: Continue to remove a portion of the rock riprap along the creek in Muir Woods and move fallen trees on the forest floor into the creek to allow the natural movement of water to form habitat features needed for juvenile salmon survival.
- **Hydrologic Restoration, Roy's Redwoods Preserve:** Conduct an assessment of wetland features and hydrologic function within the Roy's Redwoods region to determine the feasibility of reconnection to Larsen's Creek, a salmonid-bearing stream.
- **Visitor Use Infrastructure Improvements, San Anselmo Creek at Cascade Canyon Preserve:** Implement visitor-use improvements, including social trail management, bridge installation, and subsequent restoration to reduce sedimentation into the creek.
- **San Anselmo Creek, Downstream of Cascade Canyon Preserve:** Partner with private landowners to remove downstream salmon migration barriers.
- **Summer Instream Flows, Redwood Creek:** Leverage funds from the existing California Proposition 1 grant–funded project at the Muir Beach Community Service District to support implementation of recommendations from a feasibility study on improving groundwater recharge in the Redwood Creek Watershed.
- **Muir Beach Restoration:** Complete the final phase of this project to remove floodplain connection barriers, including replacement of the Pacific Way Bridge and subsequent floodplain and habitat restoration upstream and downstream of barrier removals.
- **Redwood Creek Trail Realignment:** Implement this project to reroute the current trail out of the floodplain, restore the floodplain, eliminate horse fjords, and replace many existing bridges and culverts to reduce sedimentation and visitor-use impacts.

Potential Research:

- **Potential Impacts of Targeted Non-Native Species:** Learn how weeds negatively affect the vegetation cover and structure necessary to maintain habitat conditions for fisheries (e.g., shade required to sustain optimal water temperatures and reduce evaporation).

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CHAPTER 15. CALIFORNIA GIANT SALAMANDER (*DICAMPTODON ENSATUS*)

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

2016	2022
This indicator was not included in the original 2016 report	
Condition: N/A	**Condition:** Unknown
Trend: N/A	**Trend:** Unknown
Confidence: N/A	**Confidence:** Low

FIGURE 15.1 CONDITION, TREND, AND CONFIDENCE FOR THE CALIFORNIA GIANT SALAMANDER, ONE TAM AREA OF FOCUS

Though various streams within the One Tam area of focus support populations of the California giant salamander, limited data precluded the inclusion of this species in the 2016 Measuring the Health of a Mountain report. At that time, we had only a larval inventory for Redwood Creek in Muir Woods and Mount Tamalpais State Park, limited stream surveys by the U.S. Geological Survey on federal lands in the region, and incidental observations made during fish surveys. Though metrics for this indicator remain to be developed, new tools present some potentially exciting future directions:

- Successful amphibian and reptile education and outreach efforts (i.e., Foothill Yellow-Legged Frog Docents, Turtle Observers), which could help increase our baseline understanding of this species' distribution.

- Advances in availability of contemporary crowdsourced data (e.g., iNaturalist) and historical data.

- Advances in *Dicamptodon ensatus* landscape genetics.

- Advances in eDNA methods that could be used to detect this species in the mountain's streams.

- Development of a North American *Batrachochytrium salamandrivorans* (*Bsal*) Task Force to address the threat of this emerging fungal pathogen.

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

The California giant salamander (*Dicamptodon ensatus*) is a charismatic and iconic species that lives in Mt. Tam's streams and forests. Known for its protruding eyes, marbled skin, and appetite for banana slugs, at between roughly 7 to 12 inches long, it is among the largest terrestrial salamanders on the planet (Smith, 1949; Stebbins & McGinnis, 2011) (Figure 15.2). The species is found only from Santa Cruz to Sonoma Counties, and is notably absent from the San Francisco Peninsula, East Bay, and Petaluma Gap (Good, 1989; Lavin et al., 2021). Additionally, recent evidence suggests that the Marin, Santa Cruz, and Sonoma County populations are genetically distinct from one another (Lavin et al., 2021).

Although it is not federally listed, the species is considered to be of concern by several organizations. It is listed as near-threatened by the International Union for Conservation of Nature (IUCN), while NatureServe ranks it as S2/S3 (imperiled/vulnerable). The California Department of Fish and Wildlife (CDFW) lists it as a Species of Special Concern. A large portion of its suitable forested habitat is found in Marin County in the One Tam area of focus, which underscores the need for further monitoring and protection (Fong & Howell, 2006; Kessel & Kessel, 1943b; Lavin et al., 2021).

FIGURE 15.2. CALIFORNIA GIANT SALAMANDER, TERRESTRIAL ADULT, MARIN COUNTY

Photo: Daniel George, National Park Service, via iNaturalist

Finally, Pacific giant salamanders (i.e., members of the genus *Dicamptodon*) can be indicators of the health of forests, headwater streams, and adjacent riparian areas (Fong & Howell, 2006; Welsh et al., 2019; Welsh & Ollivier, 1998). Salamanders originated and evolved in North America, and 9 of 10 salamander families favor temperate biomes (Wiens, 2007). Consequently, salamanders are key components of many North American forest and riparian ecosystems (Davic & Welsh, 2004; Welsh & Ollivier, 1998). They link food webs as both predator and prey, move energy and nutrients between streams and forests, contribute to soil formation and carbon storage, and delight people of all ages (Davic & Welsh, 2004; Fellers et al., 2010; NABTF, 2022). Pacific giant salamanders replace fish as the dominant predator of benthic invertebrates in headwater streams, where they also serve as prey for other vertebrates (Bury, 1972; Parker, 1994). In some systems, the number and biomass of Pacific giant salamanders can exceed that of other amphibians and salmonids. Salamanders spend part of their lives underground and their contributions to below-ground biomass (i.e., as they die and decay) and soil formation processes may be underestimated (i.e., bioturbation, nutrient cycling). The traits that make the California giant salamander a suitable ecological health indicator include an aquatic-terrestrial life cycle, low dispersal, longevity, large body size, and a varied diet. California giant salamander spend one to three summers as aquatic larvae in headwater streams, making the indicative of local watershed conditions (Kessel & Kessel, 1943a, 1943b). The species depends on streams with high habitat complexity, including undercut banks; coarse, woody debris; and rocks to build nest chambers (Nussbaum, 1969). While some individuals remain in the stream as neotenic adults, metamorphosed adults move into adjacent upland areas often crossing trails and roads.

CURRENT CONDITION AND TREND

No geographically comprehensive (i.e., range-wide, from Santa Cruz to Sonoma County), systematic sampling has been undertaken for *Dicamptodon ensatus* (Lannoo, 2005), which makes it difficult to ascertain its current condition. Within Marin County and the One Tam area of focus, assessments are outdated, lean heavily on anecdotal evidence or ad-hoc survey efforts, or have limited geographic scope (Fellers et al., 2010; Fong & Howell, 2006; Kessel & Kessel, 1943a, 1943b). Although larvae are readily spotted, terrestrial adults are difficult to study, even with traditional standardized methods (e.g., visual encounter surveys, cover boards, pit fall traps, etc.) (Fellers et al., 2010). While there is still much to learn about the California giant salamander's natural history and ecology, new methods such as community science and eDNA present opportunities to fill in some of the gaps (Halstead et al., 2018; Lavin et al., 2021; Pilliod et al., 2014). In this section, we will discuss Marin County and the One Tam area of focus concurrently in order to make the most of what we do know and to contextualize knowledge gaps and future directions.

Available evidence suggests that within Marin County, California giant salamanders have been and continue to be concentrated in the redwood forests within the One Tam area of focus. Metadata for 160 preserved adult and larval museum specimens collected in Marin County from 1896 to 2018 is available through the Global Biodiversity Information Facility (GBIF). Distribution in the Redwood Creek and Lagunitas Creek watersheds can be approximated through these 160 available museum specimens with reasonably accurate geocoordinates (Figure 15.3; GBIF.org, 2022). Museum collection of *Dicamptodon ensatus* specimens has declined since the 1970s, and data is sparse until the 2010s, when crowd-sourced citizen-science observations were popularized by iNaturalist (Figure 15.3; iNaturalist Community, 2020). This citizen-science platform allows observers to upload evidence (i.e., photos, audio) of opportunistic encounters and aggregates these records over time. However, the exact coordinates of these observations are obscured in iNaturalist, meaning that they are only shared with an inquiring user (i.e., a One Tam staffer) with permission from the observer (iNaturalist, 2022). At the time of this report, exact coordinates for 91 observations had been shared with staff via the One Tam Peak Health project. These data are subject to sampling bias and suggest that further, more systematic investigation is necessary.

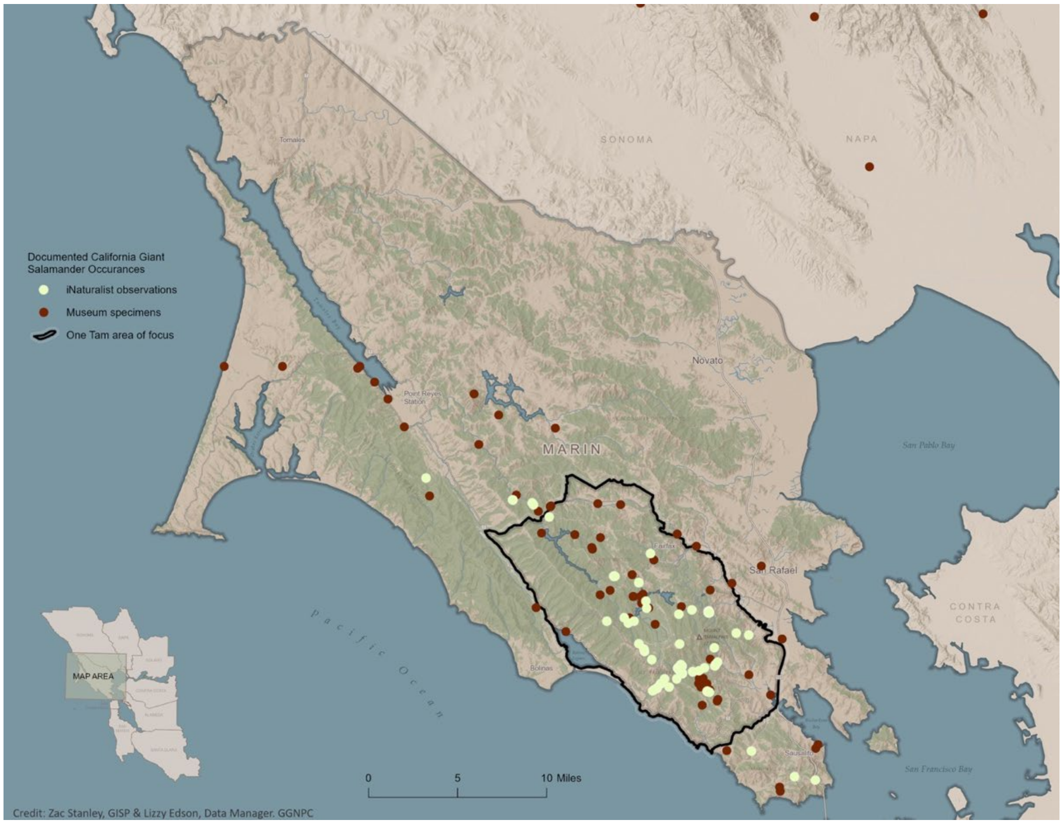

FIGURE 15.3 HISTORICAL AND CURRENT CALIFORNIA GIANT SALAMANDER DISTRIBUTION, ONE TAM AREA OF FOCUS

National Park Service staff surveyed and mapped the 1997–1998 distribution of the California giant salamander and the non-native, invasive signal crayfish (*Pacifastacus leniusculus*) (Fong & Howell, 2006). The signal crayfish is a concern because it competes with the California giant salamander to the point of excluding it from its habitats. The signal crayfish was found primarily in the main downstream segment of Redwood Creek; it was not found above certain physical thresholds (e.g., the confluence of Fern and Redwood Creeks and fish barriers). An equivalent resurvey has not occurred, but iNaturalist data from 2012–2022 show that signal crayfish distribution remains within the footprint established in 1997–1998. No comparisons of the historical and contemporary extent of signal crayfish in other parts of the One Tam area of focus are available.

DESIRED CONDITION AND TREND

Further review of crowdsourced data, museum specimens, and available expertise is needed to establish desired condition(s).

STRESSORS

Historical Impacts: Amphibian dispersal and habitat quality have been affected by human activities (e.g., deforestation and dam and road construction) that increase sediment runoff into streams. Stream siltation is known to decrease habitat quality for larval Pacific giant salamanders, with mixed outcomes over time (Welsh et al., 2019; Welsh & Ollivier, 1998). Additionally, roads and changes to hydrologic connectivity may present dispersal barriers for adult metamorphs and larvae. Stream-channel modification (e.g., riprap in the Muir Woods National Monument section of Redwood Creek) and the presence of culverts may also result in mixed outcomes for salamanders, degrading habitat in some instances but creating favorable habitat in others (Fellers et al., 2010; Fong & Howell, 2006; Foster & Olson, 2014).

Invasive Species Impacts: Signal crayfish are present throughout the One Tam area of focus and may competitively exclude the California giant salamander, although the exact mechanisms by which this happens need additional study (Fong & Howell, 2006). The American bullfrog (*Rana catesbeiana*), which was introduced to California for meat around 1900, is a known predator of many endemic amphibian, reptile, fish, and bird species and a vector for amphibian diseases, especially amphibian chytrid fungus (*Batrachochytridium dendrobatidis*) In fact, American bullfrogs and Batrachochytrium *dendrobatidis* are both on the IUCN list of 100 of the World's Worst Invasive Alien Species (GISD 2023).

Climate Vulnerability: Climate change poses multiple threats to amphibians, including shifts in suitable habitat and prey and to conditions that may favor pathogens and invasive competitors. This species' multiyear larval stage and its neotenic adults rely on groundwater-fed streams and freshwater springs. Therefore, the climate resiliency of these streams, springs, and redwood forests is crucial to its health. For example, the California giant salamander has been documented to be plumper after rainy winters, although the exact mechanisms that produce improved body condition are unknown (Fong & Howell, 2006; Kessel & Kessel, 1943a, 1943b).

Disease: Viruses, infectious fungi, and parasites can threaten amphibian populations, especially when combined with other stressors. California giant salamander adults with visible signs of infection (e.g., warty skin appearance and/or subcutaneous edema) from an unknown parasite or pathogen are occasionally documented throughout the species' range. Emerging pathogens are of particular concern because they can cause local extirpations. The salamander chytrid fungus, *Batrachochytridum salamandrovirans* (*Bsal*), a Southeast Asian pathogen, has not yet been detected in North America (Martel et al., 2013; Waddle et al., 2020). However, multiple publications have identified it as a significant threat and advise landscape-level surveillance and prevention (Gray et al., 2015; NABTF, 2022; Richgels et al., 2016; Waddle et al., 2020). Although the effect of *Bsal* infection on *Dicamptodon* remains undetermined, lab trials found that the fungus is lethal to other salamanders in the redwood forest community, including newts (*Taricha* spp.; NABTL, 2022).

Pollution/Contaminants: Amphibians are especially sensitive to water contamination through their larval stage. Adult amphibian skin, a sensitive surface for gas exchange and immune function, is also sensitive to contaminants. In riparian systems, salamanders can bioaccumulate toxins and heavy metals from prey (Davic & Welsh, 2004)

Direct Human Impacts: The metamorphosed terrestrial adult California giant salamander moves slowly and is vulnerable to trail and road collisions. Trail mortality and injuries have been documented on iNaturalist throughout the species' range. Unlike other amphibians found in this region (e.g., *Taricha* spp. newts near Lexington Reservoir in Los Gatos and Chileno Valley Road near Laguna Lake), it is not the victim of mass roadkill mortality (Moskal, 2022; Parsons & Valtierra, 2019). However, since little is known about the species' terrestrial form, the impact of trail and road collisions is not fully understood.

Habitat Disturbance/Conversion/Loss: California giant salamander larvae depend on headwater streams with coarse sediment and heavy, woody debris for adequate development. Excessive sediment in streams and the removal of this type of debris can negatively affect salamander success (Foster & Olson, 2014; Welsh et al., 2019; Welsh & Ollivier, 1998). And, because California giant salamander larvae also need well-aerated pools with cobbles and gravel in which to forage and hide, they are vulnerable to recreational and/or maintenance in-stream disturbances.

CONDITION AND TREND ASSESSMENT

METRICS AND GOALS

Further review of existing data, concurrent amphibian conservation activities, and staff capacity is needed to establish desired conditions, metrics, and goals (see Information Gaps).

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

HISTORICAL DATA

As noted previously, museum specimens of Marin County adult and larval California giant salamanders (1896–2018) can be found at the California Academy of Sciences and the UC Berkeley Museum of Vertebrate Zoology. Vouchering of *Dicamptodon ensatus* specimens has declined since the 1970s as natural history and taxonomy have fallen out of fashion and lost funding despite their importance to understanding biodiversity.

- Museum specimen metadata are available via Global Biodiversity Information Facility.
- Map is available via AmphibiaWeb.

NATIONAL PARK SERVICE, 1997–1998 SURVEY, REDWOOD CREEK WATERSHED

This 1997–1998 survey found larval California giant salamanders in small headwater tributaries of Redwood Creek and the species was noted as a potential as indicator of the health of this habitat. Signal crayfish were found in the primary downstream segment of Redwood Creek and in lower Fern Creek, but several physical barriers to their spread were also identified. Hypotheses about the effects of in-stream restoration through Muir Woods were discussed in the survey report. (For details, see Fong and Howell, 2006.)

NATIONAL PARK SERVICE, 2019 SURVEY, REDWOOD CREEK WATERSHED

California giant salamanders and signal crayfish were measured and counted during the 2019 restoration of the Redwood Creak streambed through Muir Woods.

CROWD-SOURCED INATURALIST DATA, MARIN COUNTY, 2013–PRESENT

The citizen-science platform iNaturalist allows observers to upload evidence (i.e., photos, audio) of opportunistic encounters and aggregates these records over time. *Dicamptodon ensatus* is an obscured taxon in iNaturalist, meaning that exact coordinates of each observation are only shared with permission from one user to another user (iNaturalist, 2022). As of the time of this report, exact coordinates for 91 observations have been shared with staff via the One Tam Peak Health project. These data are subject to sampling bias and suggest that further, more systematic investigation is necessary.

SALAMANDER CHYTRID FUNGUS, NORTH AMERICAN SURVEY, 2020

An intensive survey of North American amphibians showed that *Bsal* is not present in wild populations. The study examined 99 swabs from Marin County *Dicamptodon ensatus*. (For details see Waddle et al., 2020).

PHYLOGEOGRAPHY AND GENETIC STRUCTURE STUDY, 2021

The study established the existence of a distinct Marin County clade of California giant salamanders and discusses biogeographic hypotheses, historical demography, and contemporary threats to this species. This work provides molecular methods, including primers to sequence mitochondrial and nuclear DNA markers for *Dicamptodon ensatus*. Sequences from this study can be found on GenBank, along with some sequences from historical material. (For details, see Lavin et al., 2021).

INFORMATION GAPS

California Giant Salamander Occurrence and Distribution: Within Marin County and the One Tam area of focus, assessments are outdated, lean heavily on anecdotal evidence or ad-hoc survey efforts, have been limited in their geographic scope, or are incomplete. Crowd-sourced data from iNaturalist may help fill some of these gaps.

California Giant Salamander Body Condition: Salamanders were trapped, measured, and relocated during the 2019 restoration of Redwood Creek in Muir Woods. Detailed body condition data are available from museum specimens and reports from the 1940s in Corte Madera Creek, and 1997–1998 and 2019 in Redwood Creek (Fong & Howell, 2006; Kessel & Kessel, 1943a, 1943b). Previous studies suggest that salamander body condition is better after rainy winters, although no mechanistic explanation is yet known (Fong & Howell, 2006; Kessel & Kessel, 1943b). Future comparisons of these data may reveal trends about salamander body condition over the course of the past century.

Disease Monitoring: The *Bsal* chytrid fungus is an identified threat to salamanders in this region and, should an epidemic or pandemic emerge, taking a proactive stance toward wildlife disease can save precious time. Sampling occurred in 2016 but has not been carried out since then (Waddle et al., 2020). Minimally invasive sampling of the amphibian skin microbiome is methodologically possible, and the North American *Bsal* Task Force (NABTF) has a surveillance framework in place.

Invasive Species Co-occurrence and Distribution: The invasive signal crayfish and American bullfrog are two potential competitor species for native amphibians, including the California giant salamander. Updated, precise data on the distribution of these threats could help identify potential management efforts.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Past Work

Following are some of the stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Restoration:

- Riprap was removed from Redwood Creek to restore stream habitat in Muir Woods. (National Park Service, 2019).
- Signal crayfish and American bullfrogs were removed to help protect foothill yellow-legged frogs. American bullfrogs are a threat to all native amphibians, including the California giant salamander (Marin Water, ongoing).

Monitoring:

- California giant salamander surveys were carried out in Muir Woods (National Park Service, 1997–1998, 2019).

Outreach:

- Newsletter and social-media outreach efforts were made on behalf of the California giant salamander (Parks Conservancy, One Tam, 2020).
- The Peak Health project was created on iNaturalist (One Tam, 2021).

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as part of the development of this report. These actions are not currently funded through agency programs and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Community Outreach and Education: The California giant salamander, a charismatic and local iconic species, can be a powerful ambassador for the mountain's healthy forests and streams. Direct disturbance of and harm to salamanders can be addressed through thoughtful community outreach and education. Educating local visitors about community science can increase their capacity to contribute crowd-sourced data and thus address some information gaps. Given that One Tam partner agencies have a strong track record in amphibian conservation through community education (e.g., Western Pond Turtle Observers and Foothill Yellow-Legged Frog Docents), this approach has high potential value.

Proactive Engagement with the Salamander Chytrid Fungus Task Force: A North American framework for a proactive stance in the face of this emerging pathogen exists, and One Tam partner agencies would benefit from becoming familiar with its tools and practices.

Establish Metrics and an Inventory and Monitoring Program: Fong and Howell (2006) outlined a framework for a *Dicamptodon ensatus* monitoring program in the Redwood Creek watershed. One Tam partner agencies should consider revisiting and adjusting this framework to reflect metrics, staff and community capacity, and advances in crowd-sourced data and eDNA methods.

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- AmphibiaWeb *Dicamptodon ensatus*
- *Bsal* Basics: Better Together webinar, Partners in Amphibian and Reptile Conservation & North American *Bsal* Task Force
- California Herps *Dicamptodon ensatus*
- North American *Bsal* Task Force website

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CHAPTER 16. CALIFORNIA RED-LEGGED FROG (*RANA DRAYTONII*)

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

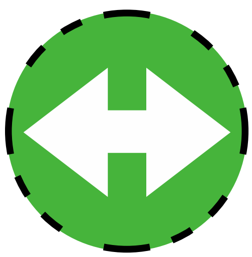
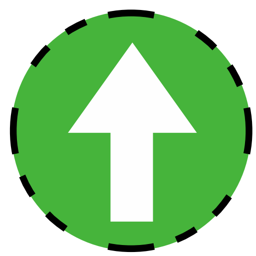
2016	2022
	
Condition: Good	**Condition:** Good
Trend: No Change	**Trend:** Improving
Confidence: Moderate	**Confidence:** Moderate

FIGURE 16.1 CONDITION, TREND, AND CONFIDENCE FOR THE CALIFORNIA RED-LEGGED FROG, ONE TAM AREA OF FOCUS

The improving trend in California red-legged frog health in 2022 is a result of past habitat restoration and reintroductions in the Redwood Creek Watershed, the ongoing benefits of which have improved that population's resiliency even in the face of recent drought. It is also thanks to the 2017 discovery of a consistent California red-legged frog presence and moderate egg mass production in historical breeding sites in the northern part of the Bolinas Lagoon. This new location has been added to the thresholds and baselines for each metric that was set in 2016 where it applies.

Other notable updates to our assessment of the condition and trend of the California red-legged frog in the One Tam area of focus since 2016:

- Metric 3 was removed from this update because no regular data has been collected on invasive, non-native predators since 2016 to be able to assess this metric, and there is not likely to be any in the near future. Removing Metric 3 from the 2016 analysis did not change its overall condition, trend, or confidence from what was originally reported, so the comparison remains the same (Figure 16.1).

- The thresholds for Metric 1 have been changed from 2016 to look at total occupancy in both wet and dry years.
- We now know that winter weather conditions influence breeding at Redwood Creek. The distribution of active breeding sites and egg-mass production at Redwood Creek reflects the amount of available breeding habitat and is linked to wet and dry winters. This helps explain annual variations and gives us helpful information for monitoring, habitat restoration, or other management actions needed to support this species.
- Egg mass production and breeding site occupancy have stabilized in the Redwood Creek Watershed.

METRICS SUMMARY

Metrics in Table 16.1 were used to assess California red-legged frog health. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 16.1. Each metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 16.1 ALL CALIFORNIA RED-LEGGED FROG METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1: Presence in suitable breeding habitats		
	2016	**2022**
Condition	**Redwood Creek:** Good **Olema Creek:** Unknown	**Redwood Creek:** Good **Olema Creek:** Unknown **Bolinas Lagoon:** Caution
Trend	**Redwood Creek:** No Change **Olema Creek:** Unknown	**Redwood Creek:** Improving **Olema Creek:** Unknown **Bolinas Lagoon:** Improving
Confidence	**Redwood Creek:** High **Olema Creek:** Low	**Redwood Creek:** High **Olema Creek:** Low **Bolinas Lagoon:** High
Metric 2: Number of egg masses observed during breeding surveys		
	2016	**2022**
Condition	**Redwood Creek:** Good **Olema Creek:** Unknown	**Redwood Creek:** Good **Olema Creek:** Unknown **Bolinas Lagoon:** Good
Trend	**Redwood Creek:** Improving **Olema Creek:** Unknown	**Redwood Creek:** Improving **Olema Creek:** Unknown

		Bolinas Lagoon: Improving
Confidence	**Redwood Creek:** High **Olema Creek:** Low	**Redwood Creek:** High **Olema Creek:** Low **Bolinas Lagoon:** Moderate
Metric 3: Number of sites occupied by non-native predators		
	2016	**2022**
Condition	Caution	N/A. This metric was not used in this update as no new data have been collected since 2016.
Trend	No Change	
Confidence	Low	

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

The California red-legged frog was federally listed as a threatened species in 1996, and Mt. Tam is part of a core area the U.S. Fish and Wildlife Service (USFWS) identified as critical to its recovery. Within the One Tam area of focus, the National Park Service and its partners have been working to help this species by improving trail systems to protect aquatic habitats, constructing ponds and wetlands for breeding, and restoring native vegetation at Muir Beach. The National Park Service and U.S. Geological Survey (USGS) conduct egg-mass surveys and non-breeding season surveys for larvae, juveniles, and adults (Fong et al., 2010). California red-legged frog egg masses are large (fist-sized) and attached to vegetation in relatively shallow waters close to shore (Alvarez et al., 2013). Hence, they are relatively easy to find and document, allowing for high confidence in our abundance estimates.

Amphibians in general are good indicators of freshwater conditions because they are relatively long-lived and breed and rear in wetland and other aquatic sites. Their sensitivity to hydrology and precipitation changes as well as susceptibility to pollutants and toxins make them excellent indicators of ecosystem health.

CURRENT CONDITION AND TREND

Now eliminated from 70% of their former range, the California red-legged frog is primarily found in coastal drainages from Marin County south to San Simeon. Within the One Tam area of focus, they are known to live and breed at Muir Beach, the Olema Creek Watershed, and now within the eastern Bolinas Lagoon Watershed as well. We do not have enough data to know the status of the Olema Creek watershed population. However, the population at Muir Beach has increased thanks to stream restoration, breeding-pond creation, and egg-mass reintroductions (Shoulders

& Fong, 2015). The breeding location on the northern side of the Bolinas Lagoon is in a wetland on National Park Service lands (Fong et al., 2022).

The 1 of the California red-legged frog are based on data from the Muir Beach and Bolinas sites; little information is available from the eastern and southern portions of the One Tam area of focus. We have recommended the use of eDNA to address the occupancy question within the One Tam area of focus footprint. Breeding sites within the area of focus may also be connected to those outside this footprint, but not much is known about potential metapopulation dynamics. Therefore, while we recognize that looking at this species across a larger landscape could provide a more complete picture of their status and trends, we do not currently have the data to do this.

DESIRED CONDITION AND TREND

As recommended by the USFWS recovery plan (USFWS, 2002), the goal is to achieve an unchanged or increasing long-term population trend for the California red-legged frog.

STRESSORS

Historical Impacts: See the Habitat Disturbance/Conversion/Loss section for important historical land-use impacts.

Invasive Species Impacts: Non-native American bullfrogs (*Lithobates catesbeianus*) and non-native, invasive fish prey on the California red-legged frog and compete with the species for resources. Bullfrogs are present at several sites within the Olema Creek Watershed but are not found in the Redwood Creek Watershed (Figure 16.2). Historical data indicate the presence of non-native crayfish and introduced fish at ponds in the Olema Creek Watershed and the presence of crayfish in the Redwood Creek watershed within the One Tam area of focus (Fong, 1996).

FIGURE 16.2 DETECTIONS OF THE AMERICAN BULLFROG, CALIFORNIA RED-LEGGED FROG, AND CALIFORNIA GIANT SALAMANDER, NATIONAL PARK SERVICE LANDS IN MARIN COUNTY, 1993–2014 (GGNRA, 2015)

Climate Vulnerability: Climate change models predict warmer temperatures, increasingly variable rainfall, and rising sea levels. How these climate model predictions will play out locally and how they are manifested in their effects on local breeding California red-legged frog populations are uncertain. That being said, such conditions are likely to decrease egg mass and tadpole survival and increase uncertainty in breeding from year to year (Allen & Kleeman, 2015). More frequent high tides that intrude farther inland could also raise salinity levels in low-lying breeding habitats (Allen & Kleeman, 2015). The northern Bolinas Lagoon site is particularly sensitive to this threat.

For the area of focus, we have approximately 20 years of California red-legged frog breeding data, along with ancillary data such as rainfall, temperature, and streamflow. Once these data are analyzed, relationships between annual weather patterns; streamflow patterns; and responses in the timing, spatial extent, and abundance of breeding activity can be established. At that time, we will be better able to provide more informed estimates on how changes in climate conditions could affect breeding activity and, ultimately, population trends. Continued monitoring will also reveal the extent of drought effects on breeding red-legged frogs. While this species is able to rebound from shorter-term habitat impacts, there is some concern that prolonged, multiyear droughts may cause more permanent habitat loss.

Fire Regime Change: The loss of the natural fire cycle within the area of focus has likely been one of the reasons that vegetation in some areas has shifted from coastal grassland and scrub habitats to a habitat dominated by forests. A more forested landscape can reduce streamflow by increasing the amount of water lost to transpiration (Neary et al., 2003). (Occasional fires adjacent to and in riparian areas may provide light gaps that are beneficial for aquatic food production.)

Disease: Chytrid fungus (*Batrachochytrium dendrobatidis*) is responsible for chytridiomycosis, a potentially lethal disease in amphibians that has caused worldwide amphibian population declines. The chytrid fungus is present on Mt. Tam, but so far, does not seem to be affecting the California red-legged frog.

Habitat Disturbance/Conversion/Loss: A 25-acre freshwater/brackish lagoon complex present at Muir Beach in the mid-1850s was lost to due to sedimentation from overgrazing and logging to the extent that the lagoon no longer showed on an 1892 map (PWA, 2003; Jones & Stokes, 2007). Some of this habitat has been replaced by recently created off-channel ponds and backwater areas at the site. In addition to ponds and wetlands, the California red-legged frog also uses creek channels as rearing habitat. However, a high frequency of dry creek conditions downstream from water diversions was noted in the 1980s, 1990s, and early 2000s (Hofstra & Anderson, 1989; Smith, 1994; Smith, 2003). Water diversions are present in the Redwood Creek Watershed, although the magnitude of their impact is likely reduced thanks to conservation measures by the Muir Beach Community Services District and cessation of pumping for agricultural use.

CONDITION AND TREND ASSESSMENT

METRICS

METRIC 1: PRESENCE IN SUITABLE BREEDING HABITATS

Baseline: This metric is defined as the number and percent occupancy of suitable breeding sites.

Currently within the area of focus, there are three potentially suitable breeding sites within the Olema Creek Watershed and three within the Bolinas Lagoon Watershed east of Highway 1 including two in the Martin Griffin Preserve at Audubon Canyon Ranch. The ACR sites in the Bolinas Lagoon Watershed have been discovered since the baseline was set in 2016. The species has been breeding at one site in the Bolinas Lagoon Watershed east of Highway 1 since 2017. Since 2016, infrequent surveys have documented California red-legged frog breeding at one of the potential breeding sites in the Olema Creek Watershed.

Eighteen potentially suitable breeding sites exist in the lower Redwood Creek Watershed near Muir Beach, up from the 13 that we knew about in 2016. In the 2021 breeding year, breeding occurred in four sites. The number of breeding sites has increased since 2001, likely as a result of habitat restoration and CRLF dispersal following their reintroduction in 2010–2011. No other reports of current breeding sites in the One Tam area of focus (CDFW, 2022) exist, although the level of survey effort in the eastern and southern portions is unclear.

Since 2016, a comparison of precipitation and California red-legged frog breeding within the Redwood Creek Watershed has shown that the number of active breeding sites has been influenced by the amount of rain. During the wettest year (breeding year 2017), the number of active breeding sites peaked at eight (Figure 16.3). In the driest year (breeding year 2021), we recorded the fewest (four). Wet years give the California red-legged frog opportunities to breed in seasonally flooded sites that are dry and are not used during drought years. The inclusion of both wet and dry years during our monitoring period and changes in how California red-legged frogs respond and use different breeding localities has caused us to modify our condition thresholds from what we had in 2016.

Condition Goal: The number and percent occupancy trend remain unchanged or increase for at least a 15-year period, which is approximately four to five generations of the California red-legged frog (USFWS recovery criterion #2; USFWS, 2002).

Condition Thresholds:

- **Good:** Breeding is observed in ≥50% of potentially suitable habitat areas in the Olema and Redwood Creek Watersheds in the area of focus within the most recent five years, and there is ≥33% within the Bolinas Lagoon Watershed site within that same timeframe.
- **Caution:** Breeding is observed in 33% to 49% of potentially suitable habitat areas in the Bolinas, Olema, and Redwood Creek Watersheds in the area of focus within the most recent five- year period.
- **Significant Concern:** Breeding is observed in ≤32% of potentially suitable habitat areas in the Bolinas Lagoon, Olema Creek, or Redwood Creek Watersheds in the area of focus.

Current Condition:

2016:

Redwood Creek: Good

Olema Creek: Unknown

Monitoring indicated that the California red-legged frog was stable in the Redwood Creek Watershed (internal National Park Service data) and was increasing in the Muir Beach area due to habitat restoration and egg-mass reintroductions. However, only sparse data existed for the Olema Creek Watershed within the area of focus.

2022:

Redwood Creek: Good

Olema Creek: Unknown

Bolinas Lagoon: Caution

Breeding has occurred in 9 of 18 potentially suitable areas in the Redwood Creek Watershed over the last five years gives a condition of good, but breeding in one of the three of the potential habitat areas near Bolinas Lagoon gives a condition of caution for that watershed (Figure 16.3). There are still no data to assess the condition of this species in the Olema Creek Watershed.

Trend:

2016:

Redwood Creek: No Change

Olema Creek: Unknown

The number and occupancy of breeding sites had been stable in the Redwood Creek Watershed over a 15-year period. The trend for the Olema Creek Watershed was unknown due to a lack of data.

2022:

Redwood Creek: Improving

Olema Creek: Unknown

Bolinas Lagoon: Improving

The number and occupancy of breeding sites has remained stable in the Redwood Creek Watershed over a 15-year period. The trend for the Bolinas Lagoon Watershed is improving thanks to the post-2016 discovery of a new breeding population. The trend for the Olema Creek Watershed is still unknown due to a lack of data.

Confidence:

2016:

Redwood Creek: High

Olema Creek: Low

Different levels of available data yielded different confidence levels for these two watersheds.

2022:

Redwood Creek: High

Olema Creek: Low

Bolinas Lagoon: High

Ongoing long-term monitoring in the Redwood Creek Watershed gives us a high level of confidence in our assessment. Our monitoring effort in Bolinas Lagoon Watershed likewise gives us a high level of confidence in our results. As there are still no data for Olema Creek, we maintain a confidence of low there.

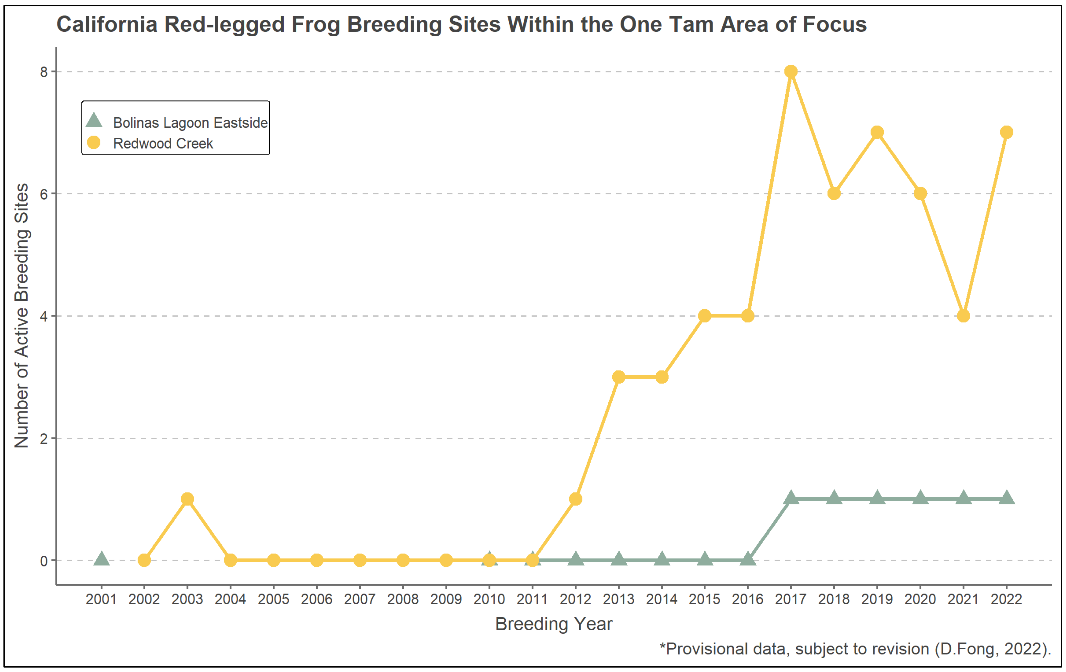


FIGURE 16.3 NUMBER OF ACTIVE CALIFORNIA RED-LEGGED FROG BREEDING SITES, ONE TAM AREA OF FOCUS

METRIC 2: NUMBER OF EGG MASSES OBSERVED DURING BREEDING SURVEYS

Baseline: This metric is summarized by watershed rather than on a per-site basis. For the Redwood Creek Watershed, the 15-year average is 22 egg masses per year and a positive trend over this period (Figure 16.4). For the Bolinas Lagoon Watershed, the six-year average is zero egg masses per year. No recent data are available for the Olema Creek Watershed.

Condition Goal: The annual abundance of egg masses is unchanged or increasing for at least a 15-year period, which is approximately four to five generations of the California red-legged frog (USFWS recovery criterion #2; USFWS, 2002).

Condition Thresholds:

- **Good:** All three watersheds in the area of focus have egg masses present and there is no significant negative trend in annual abundance of egg masses for 15 years or longer.
- **Caution:** One watershed has a significant negative trend in annual abundance of egg masses for 15 years or longer.
- **Significant Concern:** All three watersheds have significant negative trends in annual abundance of egg masses for 15 years or longer.

Current Condition:

2016:

Redwood Creek: Good

Olema Creek: Unknown

Egg-mass counts at breeding sites in the Redwood Creek Watershed showed increasing numbers (Figure 16.4). There were no data with which to assess this metric in the Olema Creek Watershed.

2022:

Redwood Creek: Good

Olema Creek: Unknown

Bolinas Lagoon: Good

Although there have been some declines in egg-mass counts in the Redwood Creek Watershed since 2016, the overall 15-year trend (2008–2022) remains positive and significant (non-parametric Mann-Kendall statistic =64, p-value (two-sided) =0.001). The egg-mass trend for the Bolinas Lagoon Watershed is likewise improving (non-parametric Mann-Kendall statistic =53, p-value (two-sided) <0.001). We still have no data to evaluate the trend for the Olema Creek Watershed.

Trend:

2016

Redwood Creek: Improving

Olema Creek: Unknown

The trend in 2016 was stable over a 15-year period despite an initial loss of small populations and subsequent reintroduction in breeding years 2010–2011 (Figure 16.4).

2022:

Redwood Creek: Improving

Olema Creek: Unknown

Bolinas Lagoon: Improving

As this metric is measuring a trend, the same logic applies here as for the condition assessment.

Confidence:

2016:

Redwood Creek: High

Olema Creek: Low

Different levels of available data yielded different confidence levels for these two watersheds.

2022:

Redwood Creek: High

Olema Creek: Low

Bolinas Lagoon: Moderate

As was the case in 2016, different levels of available data yielded different confidence levels for these three watersheds.

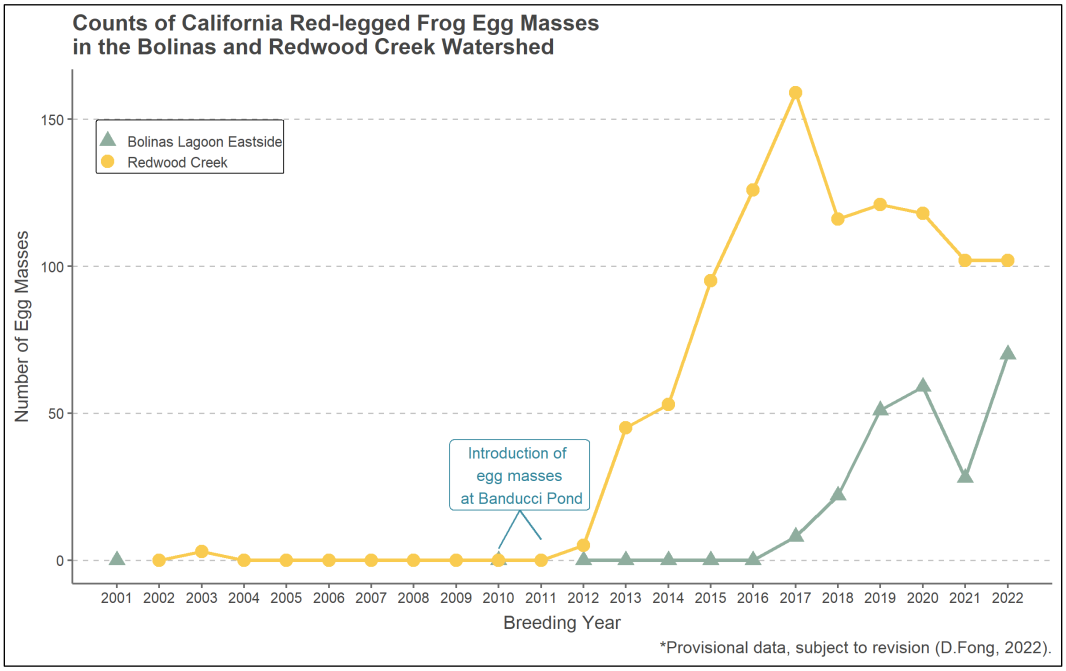


FIGURE 16.4 TOTAL COUNTS OF CALIFORNIA RED-LEGGED FROG EGG MASSES, BOLINAS AND REDWOOD CREEK WATERSHEDS, 2001–2022 (FONG ET AL., 2022)

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

NATIONAL PARK SERVICE LANDS

The National Park Service and USGS have collected sporadic data on breeding California red-legged frog populations in the Olema Valley Watershed. However, consistent annual surveys have been made in the Redwood Creek Watershed since 2002 and in the Bolinas Lagoon Watershed since 2010. Monitoring includes winter egg-mass surveys that provide long-term data to assess breeding frog abundance trends. Fong et al. (2010) includes a full description of this monitoring program and its methods.

OTHER LAND MANAGERS WITHIN THE ONE TAM AREA OF FOCUS

There are no reported observations of California red-legged frog breeding in the portion of the One Tam area of focus managed by Marin Water; these areas are generally too forested and too steep to support breeding habitats for this species. There are likewise no California red-legged frog populations on Marin County Park or California State Parks lands in the area of focus. In 2022, Audubon Canyon Ranch initiated breeding surveys at aquatic sites in Martin Griffin Preserve, the data from which may help expand our evaluation of this chapter's metrics in the future.

Number of Sites with Non-Native Predators (Formerly Metric 3: Number of sites occupied by non-native predators in the 2016 report): Historical data include the presence of two species of non-native crayfish (swamp crayfish, *Procambarus clarkia* and signal crayfish, *Pacifastacus leniusculus*), American bullfrogs, and non-native fish. Our most recent Redwood Creek fisheries data indicate that while there are no persistent non-native fish, non-native crayfish were present (McNeill et al., 2020). No recent data are available for Olema Creek Watershed sites within the area of focus. The 2016 version of this report included a third metric that looked at this important aspect of California red-legged frog health. However, we removed that metric in this update because there is no regular monitoring being conducted to provide the data needed to assess condition or trend. It is also unlikely that future monitoring will obtain adequate data to report on this metric.

Climate Change: It is not known how climate change may affect the California red-legged frog, though higher temperatures and/or precipitation-pattern changes may hasten seasonal breeding-pond drying and prevent tadpole metamorphosis. Sea-level rise may also increase salinity in lower-elevation floodplain habitats. Many habitat variables (e.g., timing and duration of ponding, water temperature) can now be easily and inexpensively monitored with dataloggers. As noted previously, a long-term dataset is available to determine the influence of climate-related factors such as droughts and floods on California red-legged frog populations. Combined, these data could allow us to add a new metric based on physical habitat condition (e.g., duration of breeding-site ponding) in the future.

Population Variables: Factors affecting abundance and distribution (e.g., survival, recruitment, population dynamics) are poorly understood.

Stream Data: Though data about the California red-legged frog in pond-breeding habitats are available, similar breeding data for streams are lacking throughout the area of focus.

Eastern and Southern One Tam Area of Focus Inventories: Although there are no current California red-legged frog observations within these areas, low-lying freshwater marshes (e.g., Arroyo Corte Madera del Presidio) and streams may not have been surveyed often enough to detect this species. There have been recent sightings in bay-fringing marshes in the nearby areas of Tiburon and San Rafael, further supporting the idea that better inventory data are needed for potentially suitable breeding habitats.

Olema Creek Monitoring: Consistent monitoring data from Olema Creek breeding sites are needed to better understand the species' condition and trends in the area of focus.

Habitat Connectivity: We do not know the metapopulation dynamics for this species within and beyond the area of focus. Genetic analyses for populations here and on adjacent lands could be used to evaluate the degree of genetic connectivity and measures of population robustness within and between watersheds (e.g., between Mt. Tam and the Marin Headlands). These data could be contrasted with populations that have lost habitat connectivity (e.g., Mori Point and

Sharp Park) and could provide important information for population management of isolated sites. Emerging technology such as eDNA surveys could be used to help reveal the species' presence/absence in unsurveyed areas as well as the presence of invasive predators, which would help prioritize places for future surveys and/or management actions. A recently completed county-wide vegetation map could also be used to help identify sites on which to focus monitoring (GGNPC et al., 2021).

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

- **Habitat Restoration:** Data show an increase in breeding site occupancy in the Redwood Creek Watershed since 2001, which is likely the result of recent habitat restoration and other management actions.
- **Monitoring:** The National Park Service has been able to maintain a consistent and persistent monitoring effort both within and outside the One Tam area of focus since 2002. These data have shown the value of active management such as reintroductions combined with habitat restoration in improving California red-legged populations.

Past Work

Following are some of the stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Restoration:

- Breeding pond and backwater habitats were created in 2007 and 2009 in the Redwood Creek watershed (National Park Service).
- Relocating egg masses and/or adult frogs has helped bolster the population in the Redwood Creek watershed (National Park Service).

Monitoring: Annual breeding frog surveys have been ongoing, as mentioned elsewhere (National Park Service).

Research:

- Habitat use and movement studies have been conducted in the Olema, Bolinas, and Redwood Creek Watersheds (USGS).
- Genetic studies were done to determine diversity of the Redwood Creek Watershed population (National Park Service and USGS).

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as a part of the development of this report. These are actions not currently funded through agency programs, and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Existing Program Support:

- **Habitat Protection:**
  - Identify habitat impairments throughout the One Tam area of focus and implement priority wetland and creek restoration actions.
  - Minimize the impacts of removing artificial breeding and rearing habitat (i.e., stock ponds) through strategic removal and/or modifications that help protect California red-legged frog populations.

- **Inventory and Monitoring:**
  - Continue broadly distributed breeding monitoring within and outside of the area of focus; include and support monitoring assistance by individual land managers.
  - Implement a more focused inventory effort on California State Parks lands, a systematic approach to monitoring this species in Olema Valley, and monitoring to detect bullfrogs, emerging diseases, and other population stressors throughout the area of focus.
  - Building off ongoing groundwater monitoring at Muir Beach, expand hydroperiod monitoring to include key wetland and other aquatic breeding sites.
  - Other potential monitoring sites in the One Tam area of focus include Audubon Canyon Ranch and several artificial stock ponds that have historically had frogs (but are hard to survey). The use of eDNA surveys would be a much less staff-intensive way to find out where this species is within the range of potential sites so that we can better focus future inventory and habitat restoration/protection efforts.

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CHAPTER 17. FOOTHILL YELLOW-LEGGED FROG (*RANA BOYLII*)

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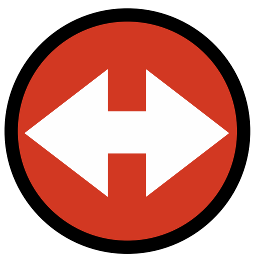
UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

2016



Condition: Significant Concern

Trend: No Change

Confidence: High

2022

Condition: Caution

Trend: Improving

Confidence: High

FIGURE 17.1 CONDITION, TREND, AND CONFIDENCE FOR THE FOOTHILL YELLOW-LEGGED FROG, ONE TAM AREA OF FOCUS

Small populations of the foothill yellow-legged frog in the One Tam area of focus are at risk of extirpation but are less vulnerable than they were when the original 2016 Peak Health Report was written. For this update, the condition of this indicator species has been assessed as caution, which is an improvement from the significant concern assessment in 2016. The factors most responsible for that improvement are:

- The discovery of a new population in Cascade Canyon Preserve near Fairfax.
- Two subadults observed in Devil's Gulch Watershed (Golden Gate National Recreation Area) in Spring 2020.

- More egg masses found in Big Carson Creek, possibly as a result of management actions to enhance breeding habitat, relocate egg masses away from a road crossing, and remove non-native predators.
- A high rate of successful egg hatching and no observed human-caused egg mass destruction in recent years.

Sightings of more frogs in more places signifies an improvement in the condition and trend of this indicator of ecosystem health, with a high degree of confidence.

METRICS SUMMARY

The metrics in Table 17.1 were used to assess foothill yellow-legged frog health. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 17.1. Each metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 17.1 ALL FOOTHILL YELLOW-LEGGED FROG METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1: Species presence in suitable streams or historically occupied streams (proportion of sites occupied)		
	2016	**2022**
Condition	Significant Concern	Caution
Trend	No Change	Improving
Confidence	Moderate	High
Metric 2: Number of egg masses observed during breeding surveys		
	2016	**2022**
Condition	Significant Concern	Caution
Trend	No Change	Improving
Confidence	High	High
Metric 3: Percent of egg masses observed to successfully hatch		
	2016	**2022**
Condition	Good	Good
Trend	No Change	No Change
Confidence	High	Moderate

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

The foothill yellow-legged frog's range includes streams from northern Oregon to Monterey County, California, including those at elevations up to 6,300 feet in the Sierra Nevada. This species has been extirpated from more than half of its historical range and has declined sharply in the San Francisco Bay Area (Center for Biological Diversity [CBD], 2021). In 2020, the foothill yellow-legged frog was listed as threatened or endangered under the California Endangered Species Act in five regions of California. Frogs in the North Coast Region, which includes the One Tam area of focus, remain listed as a Species of Special Concern.

Throughout its range, the foothill yellow-legged frog is listed as a federal species of concern and as a Forest Service sensitive species. In 2021, the US Fish and Wildlife Service (USFWS) issued a proposed rule listing two Distinct Population Segments (DPS) in California as endangered under the federal Endangered Species Act (Federal Register, 2021). USFWS found insufficient evidence to warrant a federal listing of the North Coast DPS, which includes the One Tam area of focus. Marin Water, which has invested in monitoring this species since 2004, has implemented restoration and other protection measures to benefit it within the One Tam area of focus.

The foothill yellow-legged frog is a good indicator of both perennial and ephemeral stream conditions because it relies on fast-flowing water for breeding and post-metamorphic habitat. Early life stages are sensitive to streamflow fluctuations and changes in water temperature and are vulnerable to both recreational use and invasive aquatic species. Its sensitivities to temperature and precipitation levels are considered to make this species vulnerable to climate change.

CURRENT CONDITION AND TREND

A review of historical records, museum specimens, and California Natural Diversity Database (CNDDB) records and focused field surveys (GANDA, 2003; Kleinfelder, 2022) indicate that both the foothill yellow-legged frog's range and numbers have declined significantly in Marin County and in the One Tam area of focus over the last 75 years. Museum specimens and CNDDB records reveal that foothill yellow-legged frogs lived at Rock Spring Meadow, Redwood Creek, and Cataract Creek well into the middle of the twentieth century.

Today, the largest foothill yellow-legged frog populations in the One Tam area of focus are in Little Carson and Big Carson Creeks, both tributaries of Kent Lake (Figure 17.2a). Breeding surveys conducted by Marin Water since 2004 indicate that both populations are growing (Kleinfelder, 2022). In 2017, a new population was discovered in Cascade Canyon Preserve (Figure 17.2b) and has been monitored by Marin County Parks staff in the years since. Just outside the One Tam area of focus, a pair of foothill yellow-legged frogs was observed in Devil's

Gulch (Samuel P. Taylor State Park) in 2020. They likely traveled over the ridge from the Nicasio Creek Watershed, and, it is hoped, are establishing a new population.

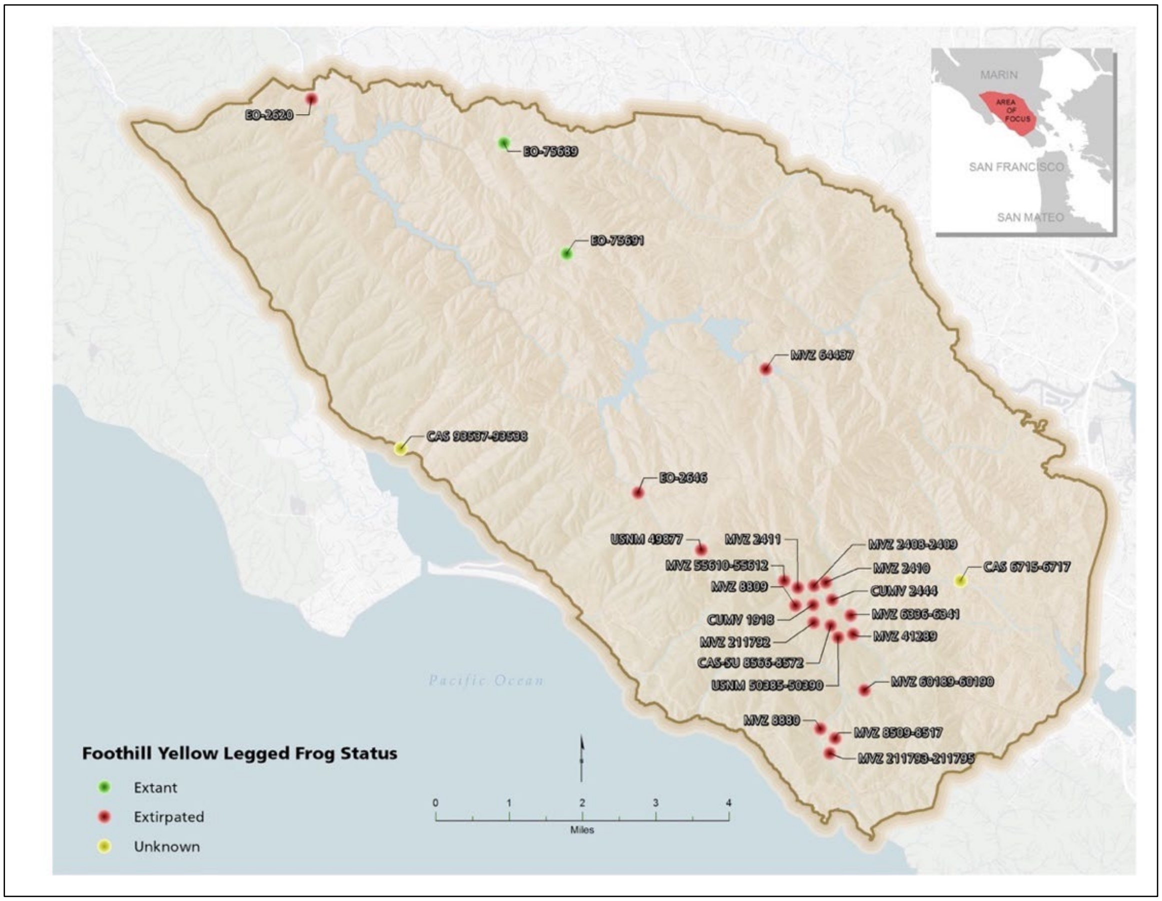


FIGURE 17.2A FOOTHILL YELLOW-LEGGED FROG OCCURRENCES (GANDA, 2010)

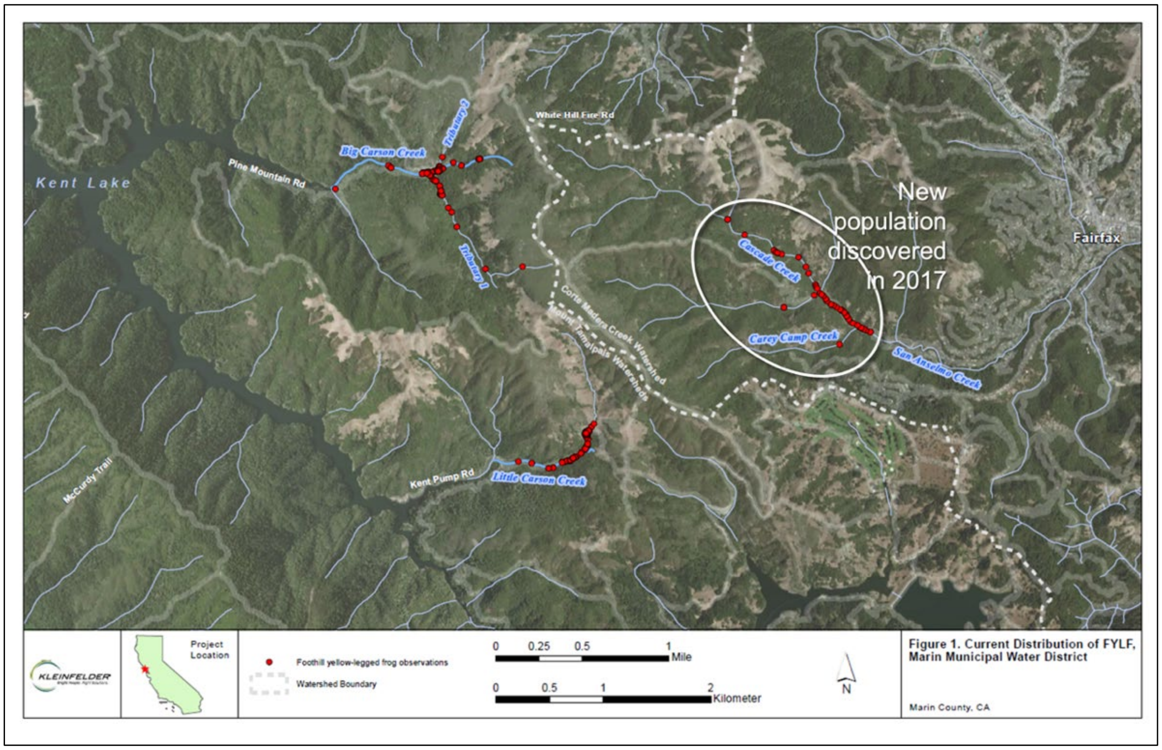


FIGURE 17.2B FOOTHILL YELLOW-LEGGED FROG OBSERVATIONS AS OF 2021 (KLEINFELDER, 2022)

DESIRED CONDITION AND TREND

- Continued presence of all life stages in currently occupied streams (Little Carson and Big Carson Creeks), with stable or increasing numbers of egg masses and individual adults detected each year.
- Re-establishment of breeding populations in historically occupied streams, including Cataract and Redwood Creeks.
- Improved breeding habitat quality, including sunny openings above breeding pools; reduction in human-caused impacts on creek bottoms/cobble in and adjacent to breeding pools; and continued non-native predator management.

STRESSORS

Climate Vulnerability: The foothill yellow-legged frog is vulnerable to extreme temperatures and flow fluctuations, both of which may occur under future climate change scenarios. The One Tam area of focus is projected to experience an average annual temperature increase of 3.4ºF by mid-century under the high emissions (RCP 8.5) scenario (Pierce et al., 2018).

Fire Regime Change: In forest ecosystems, fire often opens up riparian canopy. Fire suppression within the One Tam area of focus may have allowed these canopy gaps to close and deprived frogs of the sunny areas they prefer. Marin Water actively manages vegetation along the banks of creeks where this species is found to maintain or create sunny openings.

Disease: Chytrid fungus (*Batrachochytrium dendrobatidis*) is responsible for a potentially lethal disease called chytridiomycosis, which has caused amphibian population declines worldwide. Chytrid fungus is present on Mt. Tam, but so far, it does not seem to be affecting the foothill yellow-legged frog (GANDA, 2013b).

Habitat Disturbance/Conversion/Loss: During the breeding season (February through May), foothill yellow-legged frogs congregate to deposit egg masses among cobbles and gravel in sunny pools where the water is warm and well aerated. Eggs and tadpoles are highly vulnerable to in-stream disturbances that shift or compact these large and small rocks. Both high-flow events and in-stream human activities can cause egg mass and breeding habitat disturbance and loss.

Predation/Competition: The foothill yellow-legged frog is vulnerable to predation by invasive bullfrogs (*Rana catesbeiana*) and signal crayfish (*Pacifastacus leniusculus*), as well by as native newts (*Taricha* spp.). The presence of non-native predators in permanent water bodies, such as Marin Water reservoirs, may limit the foothill yellow-legged frog's ability to disperse into unoccupied habitat. Breeding pools are monitored for these species, and any bullfrogs and signal crayfish found are removed.

Other Stressors: Potential inbreeding. Small, isolated populations of the foothill yellow-legged frog may be vulnerable to inbreeding, which could negatively affect their health (California Fish and Game Commission, 2020). While frogs in Little Carson and Big Carson Creeks and Cascade Canyon can migrate through suitable upland habitat to interbreed, a lack of habitat connectivity likely prevents the introduction of new genetic material from populations elsewhere in Marin County (such as Nicasio Creek) (GANDA, 2013b).

CONDITION AND TREND ASSESSMENT

METRICS

METRIC 1: SPECIES PRESENCE IN SUITABLE STREAMS OR HISTORICALLY OCCUPIED STREAMS (PROPORTION OF SITES OCCUPIED)

Baseline: This metric is defined as the number and percent occupancy of suitable breeding sites.

Museum specimens and CNDDB records establish the presence of the foothill yellow-legged frog in Rock Spring Meadow, Redwood Creek, and Cataract Creek well into the middle of the last century. However, protocol-level surveys conducted by both the National Park Service and Marin Water have not detected the foothill yellow-legged frog in these locations during this century.

The species is presumed to have been extirpated everywhere within the One Tam area of focus, with the exception of Little Carson and Big Carson Creeks and their tributaries.

Condition Goal: Re-establish breeding populations within 100% of streams with suitable habitat.

Condition Thresholds:

- **Good:** Three consecutive years of egg mass or tadpole detection in two additional streams.
- **Caution:** Three consecutive years of egg mass or tadpole detection in one additional stream.
- **Significant Concern:** No egg masses or tadpoles detected outside of Little Carson and Big Carson Creeks.

Current Condition:

2016: Significant Concern

2022: Caution

Trend:

2016: No Change

2022: Improving

Confidence:

2016: Moderate

2022: High

Our evaluation of condition, trend and confidence has improved since 2016 thanks to the discovery of a new breeding population of the foothill yellow-legged frog in the Cascade Canyon Preserve outside of Fairfax in 2017. While this population is not within the One Tam area of focus, it likely has strong connections to the populations at Little Carson and Big Carson Creeks and strengthens the viability of those populations. Surveyors have observed egg masses in Cascade Creek every year since 2018 (Kleinfelder, 2022).

METRIC 2: NUMBER OF EGG MASSES OBSERVED DURING BREEDING SURVEYS

Baseline: As of the first iteration of this report in 2016, the total number of egg masses observed at Little Carson and Big Carson Creeks combined was relatively stable, with a 12-year overall average of 24 egg masses per year and a five-year running average at or above this level since 2011 (Figure 17.3). No egg masses or tadpoles were reported in Redwood or Cataract Creeks in recent years.

Since 2016, the number of egg masses observed in the One Tam area has been considerably higher than during the previous five-year period, largely due to increases in Big Carson Creek and the recent discovery of the Cascade Canyon population. An average of 45 egg masses have been counted in the 2017–2021 period, compared with 29 egg masses between 2012 and 2016.

Condition Goals:

- Maintain a five-year running average of no less than 24 egg masses observed in Little Carson Creek and Big Carson Creek and its tributaries, combined.
- Establish self-sustaining breeding populations of the foothill yellow-legged frog, as evidenced by observations of 10 or more egg masses per creek per year for a minimum of three years in a row, in habitat deemed suitable based on past occurrences and current and projected habitat conditions.

Condition Thresholds:

- **Good:** A five-year running average of 24 egg masses combined for Little Carson and Big Carson Creeks (including tributaries) as well as a five-year running average of 10 or more egg masses per creek in formerly inhabited streams.
- **Caution:** A five-year running average of 18 to 24 egg masses combined for Little Carson and Big Carson Creeks (including tributaries), as well as observed egg masses of <10 per year in formerly inhabited streams.
- **Significant Concern:** A five-year running average of <18 egg masses observed at Little Carson and Big Carson Creeks (including tributaries) as well as the continued absence of egg masses in formerly inhabited streams.

Current Condition:

2016: Significant Concern

2022: Caution

Over the last five years, an average of 39 foothill yellow-legged frog egg masses were documented in Little Carson and Big Carson Creeks—far more than the 24 egg masses required to qualify this metric as being in good condition. In addition, an average of 11 egg masses per year were documented in the Cascade Canyon Preserve over the last three years. The recent discovery of this population, however, may indicate that this level of breeding is a fairly new phenomenon. Caution continues to be warranted until self-sustaining breeding populations are firmly established in this or other streams.

Trend:

2016: No Change

2022: Improving

Egg mass numbers have increased since 2016 (Figure 17.3).

Confidence:

2016: High

2022: High

Since 2003, egg mass surveys of known breeding pools have been conducted by trained biologists using consistent techniques and levels of effort.

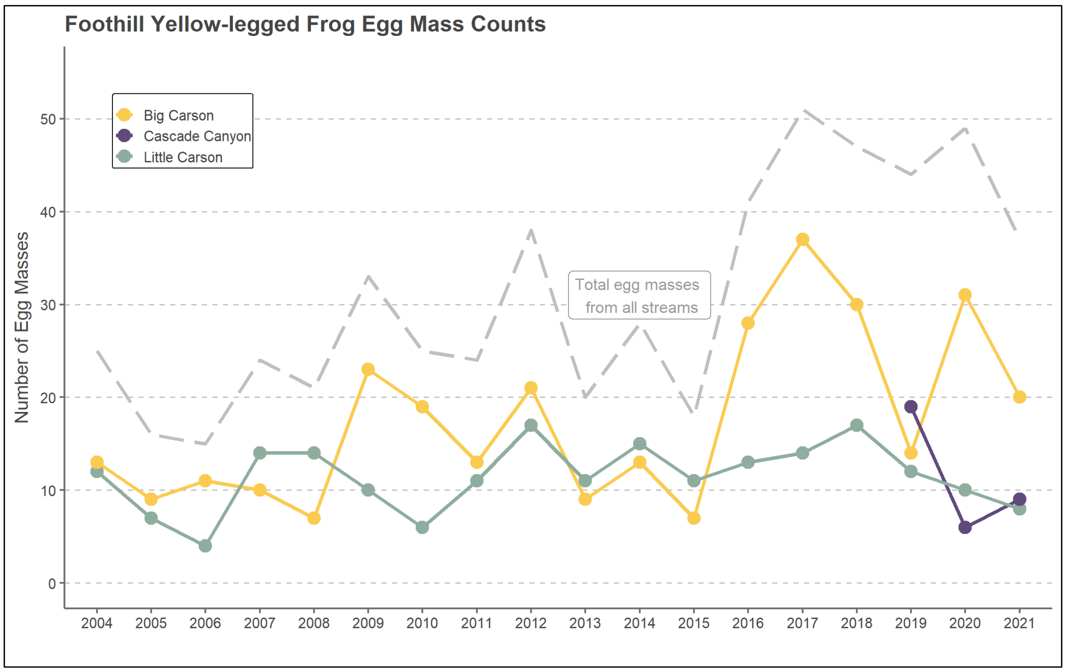


FIGURE 17.3 ANNUAL EGG MASS COUNTS, FOOTHILL YELLOW-LEGGED FROG POPULATIONS, LITTLE CARSON AND BIG CARSON CREEKS, 2004–2021 (KLEINFELDER, 2022)

METRIC 3: PERCENT OF EGG MASSES OBSERVED TO SUCCESSFULLY HATCH

Baseline: The 12-year average for egg mass maturation in Little Carson and Big Carson Creeks is estimated to be greater than 94% (GANDA, 2005, 2006, 2007, 2009, 2011, 2013a, 2013b, 2016). Egg mass maturation rates are indicative of in-stream conditions. Prior to the emergence of tadpoles, foothill yellow-legged frog egg masses are vulnerable to scouring caused by high-flow events, predation by both native and non-native species, and human-caused disturbances to the in-stream cobble and gravel substrate on which the egg masses are anchored.

Condition Goals:

- More than 94% of egg masses reach maturation each year.

- No egg masses lost due to in-stream disturbances caused by maintenance work or recreational activities.

Condition Thresholds:

- **Good:** Five-year running average maturation rate >90% and no egg masses lost due to human activity for two consecutive years.
- **Caution:** Five-year running average maturation rate between 80% and 90% and/or more than two egg masses crushed/lost due to human activity for two consecutive years.
- **Significant Concern:** Five-year running average maturation rate <80% and/or four or more crushed masses due to human activity for two consecutive years.

Current Condition:

2016: Good

2022: Good

The rate of successful egg mass maturation averaged 92% between 2017 and 2021, giving this metric a good condition. Human activity was not determined to be the cause of any egg mass loss during that period. However, because direct observation of egg mass destruction is not always possible, documented egg mass loss is therefore a minimum estimate.

Trend:

2016: No Change

2022: No Change

The trend for this metric is no change because the condition has remained the same. It would switch from no change to improving with three consecutive years of no crushing, and from no change to declining with two consecutive years of two or more crushed egg masses.

Confidence:

2016: High

2022: High

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

MARIN WATER COMPREHENSIVE SURVEY OF MT. TAMALPAIS WATERSHED, 2003

In 2003, Garcia and Associates (GANDA) conducted foothill yellow-legged frog surveys on behalf of Marin Water from April 7 to April 23 at a number of sites following the protocol outlined in Fellers & Freel (1985). They used binoculars to scan for frogs, and slowly walked in the water or on adjacent banks to search for eggs, larvae, and adults. All detections of sensitive, listed, and common herpetofauna observed during surveys were recorded. Weather conditions (air temperature and wind speed) and water temperature were also recorded. Because of their potential indirect or direct effects on foothill yellow-legged frog populations, fish presence was also recorded. (See GANDA [2003] for additional details about this monitoring project.)

MARIN WATER ANNUAL BREEDING SUCCESS MONITORING, 2004–PRESENT

Kleinfelder, Inc. (formerly GANDA) conducts foothill yellow-legged frog surveys on behalf of Marin Water (formerly Marin Municipal Water District) at Big Carson Creek and two of its unnamed tributaries near Pine Mountain Road, and at Little Carson Creek near Kent Lake following methods described in Seltenrich & Pool (2002). Beginning in 2019, Kleinfelder expanded these surveys to streams in the Cascade Canyon area, surveying tributaries from the downstream end to the upstream end during all survey rounds. For each egg mass observed, a standard list of parameters is measured and recorded, including location; attachment substrate; distance from shore; depth of egg mass and maximum depth at the egg mass; velocity at the egg mass; surface velocity; microhabitat; stream substrate; water temperature; egg mass shape; egg mass color; egg mass size; and Gosner developmental stage (Gosner, 1960).

Although surveys focus on locating egg masses, they document all life stages of frogs (i.e., egg mass, tadpole, juvenile, and adult) encountered. Data collected for captured frogs included location; sex; snout-urostyle length (millimeters); weight (grams); condition (gravid or spent); activity; habitat and microhabitat type; and dominant substrate. A photograph taken of the chin of each frog captured from 2008 to 2015 is used to identify individual frogs by matching their unique mottling patterns. They also record notes on frogs with injuries or deformities. Uncaptured frogs are also noted, and data collected to the extent possible. Surveyors attempt to remove any bullfrogs or signal crayfish encountered during these surveys. (See Kleinfelder [2022] for a complete description of this monitoring program and its findings.)

NATIONAL PARK SERVICE AND CALIFORNIA STATE PARKS DETECTION SURVEYS, MUIR WOODS, 2013

An amphibian survey conducted in 2013 that covered approximately 700 meters of creek near a planned project to replace the bridge on Bootjack Trail spanning Rattlesnake Creek did not find any foothill yellow-legged frogs. (See Kleeman [2013] for a full project summary.)

INFORMATION GAPS

Population Viability Analysis: Consistent surveys in Little Carson and Big Carson Creeks over the last 18 years provide time-series data on the foothill yellow-legged frog at life stages from egg mass through breeding adult. Sufficient data is available for the development of a simplistic population model and viability analysis, which would help land managers better refine recovery targets for reintroduction efforts in Redwood and Cataract Creeks.

Range: Individual frogs can be identified by the unique pattern of markings on each frog's chin, enabling researchers to maintain annual records on individual frogs' vigor, reproductive state, and location. Chin-pattern analyses combined with mark and recapture studies indicate that there is very little movement between frogs at Little Carson and Big Carson Creeks, suggesting that dispersal and gene flow between the two locations are limited (Marlow et al., 2016). However, the potential range for individual frogs is not known, which limits land managers' ability to identify steps to enhance gene flow and dispersal. Sampling for the presence of eDNA could offer a less staff-intensive way to detect this species in other drainages and watersheds.

Habitat Requirements: While habitat conditions needed for successful egg laying and tadpole maturation are reasonably well understood, less is known about the foothill yellow-legged frog's requirements at other life stages or for movement from one breeding site to another.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Egg Mass Relocation: Marin Water continues to translocate egg masses out of the Pine Mountain Road wet crossing to prevent crushing by authorized vehicle traffic and recreationists at Big Carson Creek (Kleinfelder, 2022).

Docents: Since 2017, a volunteer frog docent program has engaged more than 1,200 weekend hikers during the breeding season at Carson Falls. No disturbance of egg masses related to humans or their dogs have been observed during that period (GANDA, 2017, 2019).

Past Work

Below are some of the stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Management:

- A trail was rerouted, and informational signs were installed at Carson Falls in 2007 to reduce recreational impacts to breeding pools while increasing visitor safety and opportunities to observe frogs from a designated viewing area.

- Bullfrogs and signal crayfish found in Little Carson and Big Carson Creeks are removed during breeding season surveys.

- Canopy thinning at Big Carson Creek in 2013 and relocating egg masses out of the road crossing were likely responsible for the increase in the number of egg masses observed since 2016, and possibly the subsequent dispersal of frogs into Cascade Canyon.

Outreach: Since 2008, volunteer Marin Water docents have helped protect sensitive habitats at Little Carson Creek during the breeding season. A seasonal public education program at Carson Falls started in 2005 has also increased visitor awareness of the frogs and of the need to stay out of breeding pools between the months of February and June.

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as part of the development of this report. These actions are not currently funded through agency programs, and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Existing Program Support:

- **Reintroductions:**
  - Implement the priority actions identified within the completed feasibility study (GANDA, 2010) for reintroduction at Cataract Creek.
  - Reintroduce at Cataract Creek while source populations in Little Carson and Big Carson Creeks are considered stable and eggs can be translocated to reintroduction sites or captive breeding facilities.
- **Predator Management:** Continue efforts to manage numbers of non-native predators, and consider expanding efforts to manage bullfrogs and signal crayfish known to occur in potentially suitable habitat in Cataract Creek (GANDA, 2010).

Potential frog-breeding areas should be assessed to quantify canopy cover, stream substrate, slope, and other factors. Areas that could benefit from canopy opening should be identified.

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CHAPTER 18. NORTHWESTERN POND TURTLE (*ACTINEMYS MARMORATA*)

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

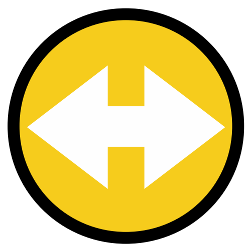
2016: ALL THREE METRICS

Condition: Good

Trend: No Change

Confidence: High

2016: ADJUSTED TO JUST METRICS 1 AND 2*



Condition: Caution

Trend: No Change

Confidence: High

2022: METRICS 1 AND 2

Condition: Caution

Trend: Improving

Confidence: High

FIGURE 18.1 CONDITION, TREND, AND CONFIDENCE FOR THE NORTHWESTERN POND TURTLE, ONE TAM AREA OF FOCUS

**Three metrics were used to evaluate northwestern pond turtle health in 2016 (left circle, above), but the number of metrics was reduced to two in 2022 due to a lack of continued monitoring of the third metric and no plans to gather that data in the foreseeable future. To make a fair comparison with 2022, the overall condition, trend, and confidence for 2016 were adjusted so that they only include Metrics 1 and 2 (center circle, above). This reveals that the condition between 2016 and 2022 (right circle, above) has remained the same when considering these two metrics, but the trend is improving. This is thanks largely to reintroductions in the Redwood Creek Watershed. This new population, and the stability of the population in Marin Water's reservoirs, bodes well for the long-term persistence of northwestern pond turtles in the lakes and streams around Mt. Tam.*

Other highlights since 2016 include:

- In collaboration with the San Francisco Zoo and Sonoma State University, the National Park Service reintroduced 42 northwestern pond turtles to Redwood Creek between 2017 and 2021.
- Volunteer "Turtle Observers" spent hundreds of hours counting native and non-native turtles in Marin Water's reservoirs. Since 2016, both native and non-native turtle populations have remained relatively stable.
- In 2020, a shell fungal disease that has been implicated in the decline of northwestern pond turtles in Washington State was discovered on red-eared sliders in Santa Cruz. Samples from turtles in Redwood Creek have been collected but have not yet been analyzed for this pathogen.
- The 2016 Peak Health Report established a goal of successful northwestern pond turtle reproduction and early life stage survival, based on age and size data. However, no such data have been collected, so no age structure goal has been included in this update.

METRICS SUMMARY

Metrics in Table 18.1 were used to assess northwestern pond turtle health. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 18.1. Each metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 18.1 ALL NORTHWESTERN POND TURTLE METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1: Habitat occupancy (lakes, ponds, streams, freshwater marshes) in current versus historically occupied water bodies		
	2016	**2022**
Condition	Caution	Caution
Trend	No Change	Improving
Confidence	High	High
Metric 2: Abundance		
	2016	**2022**
Condition	Good	Good
Trend	No Change	Improving
Confidence	High	High

Metric 3: Age structure		
	2016	**2022**
Condition	Good	N/A. This metric was not used in this update as no new data have been collected since 2016.
Trend	No Change	
Confidence	Moderate	

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

The western pond turtle is California's only native freshwater turtle. Based on a synthesis of molecular and morphological data (Bury et al., 2012), populations north of San Francisco Bay have been recognized as *Actinemys marmorata*, or the northwestern pond turtle. Pond turtles south of San Francisco Bay have been designated as the southwestern pond turtle (*A. pallida*) (van Dijk et al., 2014). Both are California Department of Fish and Wildlife Species of Special Concern and are being considered for listing under the Endangered Species Act. The major threats to these species are disease, contaminants, land conversion, predation by non-native species, and drought (Shaffer, 2019). Marin Water has been monitoring northwestern pond turtles since 2003 and has implemented restoration and other protection measures for this species in the One Tam area of focus. The National Park Service also has northwestern pond turtle inventory data from the One Tam area of focus from 1996 (Fong, 2002) and from 2014 to 2015.

Western pond turtles are good indicators of freshwater aquatic conditions and, to some extent, terrestrial grassland conditions. In their aquatic habitats, they are vulnerable to predation and competition with invasive species. On land, breeding adults, nests, and hatchlings are vulnerable to habitat degradation and predation by unnaturally abundant native predators such as raccoons, opossums, and striped skunks.

CURRENT CONDITION AND TREND

Western pond turtles once numbered in the millions in the Sacramento and San Joaquin Valleys, with smaller populations along the entire California coast, but by the early 20th century, widespread wetland destruction and commercial harvesting had decimated these populations. Ongoing habitat loss continues to shrink turtle populations to this day. This chapter focuses exclusively on the population within the One Tam area of focus because, although there are northwestern pond turtles on nearby National Park Service and Marin County Parks lands, there is little evidence of individuals moving between populations. A notable exception was a turtle that moved 18 miles from Ross to Point Reyes Station, which garnered significant media attention (Prado, 2011).

Except for data compiled by Barbara Stein and Mark Jennings covering National Park Service lands (Museum of Vertebrate Zoology, 1999), historical population records and museum specimen collections have not been systematically reviewed for the One Tam area of focus. Anecdotal accounts from long-time residents report turtles from a large backdune pond at Stinson Beach that has since been filled and converted to a parking lot. A small number of northwestern pond turtles were observed at Muir Beach by consultants and researchers in the early 1990s (PWA et al., 1994; Ely, 1993), but this population had disappeared within a decade (Fong, 2002). The National Park Service, in collaboration with the San Francisco Zoo and Sonoma State University, initiated a "head start" program and began reintroducing northwestern pond turtles to Redwood Creek in 2017. Marin Water has monitored turtles in its reservoirs since 2003, largely through a volunteer "Turtle Observer" program. Observers have documented consistently low numbers of northwestern pond turtles, among a much larger population of non-native turtles (Sherman, Howe, & Ettlinger, 2021).

DESIRED CONDITION AND TREND

Northwestern pond turtles should be found in all historically occupied habitats, and the population in the One Tam area of focus should be stable or increasing.

STRESSORS

Invasive Species Impacts: Red-eared sliders (*Trachemys scripta elegans*) and other non-native turtles in Mt. Tam's reservoirs may compete with northwestern pond turtles for basking habitat or food (GANDA, 2003). Non-native turtle species have also been implicated in the spread of an ulcerative shell disease (caused by the fungus *Emydomyces testavorans*) plaguing western pond turtles in other parts of California and the Pacific Northwest. Shell-disease sampling has been conducted on the Muir Beach population, but results are pending.

While less visible than red-eared sliders, non-native bullfrogs (*Lithobates catesbeianus*) and bass (*Micropterus* spp.) may constitute greater threats to northwestern pond turtles by preying on hatchlings. Sunfish (*Lepomis* spp.) also compete with turtles for insect prey.

Climate Vulnerability: Temperature increases and/or changes in precipitation patterns as a result of climate change could affect the streams and small ponds upon which this species depends. For example, extreme drought is shrinking both stream and lake habitat for turtles. Predicting how precipitation timing and intensity may change is fraught with uncertainty, however. Climate change models predict an increase of 3.4°F annual average temperature in the One Tam focus area by mid-century under a high emissions scenario, and 6°F by end of century (Pierce et al., 2018). Because this species is subject to temperature-dependent sex determination, higher temperatures during egg incubation can result in more female turtles. Such a sex-ratio change would have unknown effects on the population. (Although not a concern for this species in the One Tam area of focus, sea level rise and inundation also threaten western pond turtles in coastal areas.)

Direct Human Impacts: Releasing non-native turtles contributes to the growth of their already large population and potentially introduces disease. Turtles are vulnerable to automobile strikes as they disperse to new areas or migrate to nesting sites. Recreational fishing can incidentally capture pond turtles, with unknown mortality rates. Other recreational activities can disturb basking turtles or cause females to abandon their nest sites.

Habitat Disturbance/Conversion/Loss: Nesting habitat may be lost as invasive species (e.g., broom) or native trees (e.g., Douglas-fir) encroach on grasslands.

Predation/Competition: Certain native predators such as skunks, raccoons, ravens, and crows thrive near human development and can reach higher-than-normal numbers in places like Marin County and the One Tam area of focus.

CONDITION AND TREND ASSESSMENT

METRICS

METRIC 1: HABITAT OCCUPANCY (LAKES, PONDS, STREAMS, FRESHWATER MARSHES) IN CURRENT VERSUS HISTORICALLY OCCUPIED WATER BODIES

Baseline: A 2003 survey of Marin Water lands found northwestern pond turtles in Phoenix, Lagunitas, and Alpine Lakes and in Bon Tempe Creek (GANDA, 2003). One of three Olema Valley ponds has an extant record (NPS, 2015, unpublished data). There are anecdotal historical observations at Stinson Beach, and both historical observations and archeological remains at Redwood Creek at Muir Beach, but no current observations as of 2016 when this baseline was set (NPS, 2015, unpublished data). However, the head start program mentioned previously began reintroducing northwestern pond turtles to this site in 2017.

Condition Goal: Proportion of sites occupied by the northwestern pond turtle similar to or higher than historical conditions.

Condition Thresholds:

- **Good:** All historically occupied sites in the One Tam area of focus continue to be occupied.
- **Caution:** Pond turtles are no longer present at one previously occupied site, which is too remote (more than two miles from an occupied site) to be naturally recolonized.
- **Significant Concern:** Pond turtles are no longer present at multiple, distant, and/or previously occupied sites.

Current Condition:

2016: Caution

2022: Caution

Northwestern pond turtles continue to occupy the four Marin Water reservoirs they occupied in 2016. They now inhabit Redwood Creek as well, thanks to the head start program. However, the population is still small and faces numerous stressors. The current condition of caution reflects the relatively recent occupancy at Muir Beach and that these turtles have yet to demonstrate successful reproduction and recruitment.

Trend:

2016: No Change

2022: Improving

The expansion of the population into Redwood Creek is cause for cautious optimism and an improving trend rating. However, as previously noted, the Muir Beach population has not yet demonstrated natural recruitment. Hopefully by the next update to this report we will see breeding and be able to make this trend assessment with more certainty.

Confidence:

2016: High

2022: High

Turtles are charismatic and relatively easy to see when they are basking, making them good candidates for community science monitoring. Marin Water's volunteer Turtle Observers continue to document northwestern pond turtles in all previously occupied sites. The National Park Service continues to monitor the success of the Redwood Creek head start program.

METRIC 2: ABUNDANCE

Baseline: A 2003 Marin Water survey captured, marked, and released 30 northwestern pond turtles (GANDA, 2003).

Condition Goal: Population numbers increasing or stable against the baseline.

Condition Thresholds:

- **Good:** Three-year average of northwestern pond turtles observed at the sites surveyed in 2003 is ≥ 30.
- **Caution:** Three-year average of northwestern pond turtles observed at the sites surveyed in 2003 is between 20 and 29.
- **Significant Concern:** Three-year average of northwestern pond turtles observed at the sites surveyed in 2003 is <20.

Current Condition:

2016: Good

2022: Good

In 2021, volunteer Turtle Observers counted 30 northwestern pond turtles in Marin Water's reservoirs. While this was the same number as was counted in 2003, the three-year average was only 27 turtles, which could be a cause for some concern. As of summer 2021, the National Park Service monitors had counted 34 juveniles (of the 42 introduced since 2017) in the Redwood Creek Watershed, bringing the number in the One Tam area of focus to nearly double the 2016 baseline estimate.

Trend:

2016: No Change

2022: Improving

The 2022 improving trend reflects the increase in northwestern pond turtle numbers in the Redwood Creek Watershed.

Confidence:

2016: High

2022: High

Long-term monitoring has yielded consistent counts, regardless of effort level (Figure 18.2), giving us high confidence in this condition and trend assessment.

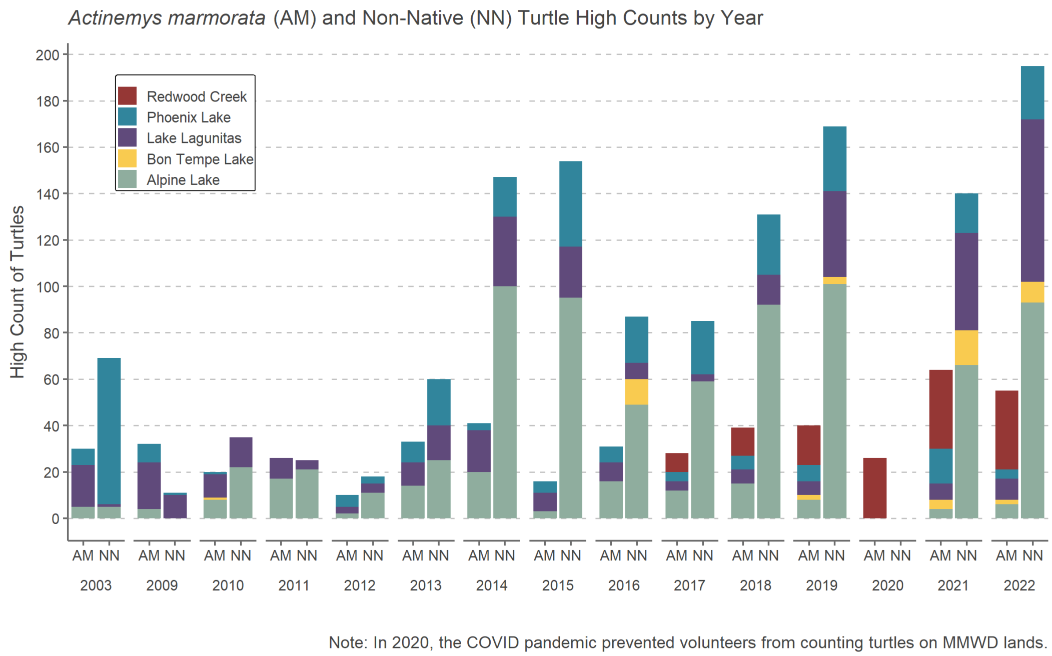


FIGURE 18.2 NORTHWESTERN POND TURTLE AND NON-NATIVE TURTLE COUNTS, ONE TAM AREA OF FOCUS

Note: The large increase in non-native (NN) turtles in 2014 was largely due to the use of new spotting scopes, which allowed volunteers to better identify turtle species. In previous years, many of those turtles would likely have been identified as "unknown species."

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

MARIN WATER SURVEY OF THE MT. TAMALPAIS WATERSHED IN 2003

Habitat characterizations in April and August 2003 at the Alpine Lake, Bon Tempe Creek, Bon Tempe Reservoir, Lake Lagunitas, and Phoenix Lake study sites included:

- Documentation of key characteristics of northwestern pond turtle habitat to create a map showing essential habitat areas for hatchlings, juveniles, and adults (e.g., aquatic habitat, basking areas, potential nesting areas).
- An assessment of known northwestern pond turtle population size and distribution within the region.
- A population study of northwestern pond turtles and non-native turtle species using collected mark-recapture data (repeated trapping and release of marked turtles).

(See GANDA [2003] for a full description of study methodology and results.)

MARIN WATER IRREGULAR MARK AND RELEASE EFFORTS BETWEEN 2004 AND 2016

Turtle trapping has been conducted irregularly in Marin Water reservoirs with the primary objective of removing non-native turtles. As part of that effort, northwestern pond turtles were captured, measured, marked, and released. These surveys provide some indication of population sizes, age estimates, and sex ratios in each reservoir (Ettlinger, 2016).

MARIN WATER VOLUNTEER TURTLE OBSERVER PROGRAM

Since 2009, trained volunteers have visited various locations around Lake Lagunitas, Bon Tempe Lake, Alpine Lake, and Phoenix Lake. They use binoculars and spotting scopes to observe both native and non-native turtles and record qualitative observations about each turtle's appearance and behavior. Marin Water staff review these observations and use the highest single-day count for each species as a conservative estimate for that year's population.

(See Sherman, Howe, & Ettlinger (2021) for a full description of volunteer monitoring methodology and results.)

TURTLE INVENTORIES CONDUCTED ON NATIONAL PARK SERVICE LANDS (1996, 2014–PRESENT)

Using visual encounter methods, herpetologist Ed Ely conducted the first systematic surveys in 1993 as part of a general Golden Gate National Recreation Area herpetological inventory. Turtle surveys conducted in 1996 used baited traps and visual encounter methods. Visual surveys were repeated in 2015–2016 in the Olema and Redwood Creek Watersheds within the One Tam area of focus (NPS, 2016, unpublished data). Monitoring of released head start turtles at Redwood Creek, which was initiated in 2017, consists of annual trapping and more-frequent telemetry surveys.

INFORMATION GAPS

Population Drivers: We do not know enough about factors affecting western pond turtle abundance, survival, and recruitment (e.g., egg and hatchling predation rates). The root cause of the decline and loss of northwestern pond turtles from the Muir Beach area is also not known. Additional research into the influence of local coastal climatic conditions on breeding ecology is also needed.

Demographics: Data are lacking on the relationships between size, age, and survival of self-sustaining western pond turtle populations in coastal California.

Surveys: Some presence/absence surveys of historical populations were not covered by the 2003 Marin Water surveys. There may be potential habitat in Cascade Canyon, but it has never been surveyed for northwestern pond turtles.

Disease: In 2020, ulcerative shell disease was discovered in wild red-eared sliders in Santa Cruz, California, prompting a search for *Emydomyces testavorans* in Bay Area turtle populations (J. Bushell, personal communication, March 30, 2021). Turtles from the Redwood Creek Watershed have been recently sampled, but turtles from other areas in the One Tam area of focus have not been tested for the disease. (As of this update, results were not yet available for Redwood Creek or other populations in the region.)

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Marin Water's Volunteer Turtle Observer Program: Since 2016, 70 Turtle Observers have spent a combined 423 hours identifying turtles. In 2021 alone, Turtle Observers spoke with more than 100 watershed visitors and explained the ecological damage done by releasing pet turtles into the wild.

Invasive Species Management: In 2019, an invasive New Zealand mud snail (*Potamopyrgus antipodarum*) was found in lower Redwood Creek at sites where northwestern pond turtles are present. It is unknown how the snail will affect the food web and what impacts, if any, it will have on the turtles. There are no known control mechanisms for the snail in a landscape setting.

Reintroductions (National Park Service): As previously noted, 42 juvenile pond turtles were released as part of a joint project with the San Francisco Zoo, Sonoma State University, and the National Park Service at lower Redwood Creek. The National Park Service is currently monitoring this population and working with the USGS Western Ecological Center to assess how the turtles move and use their habitat.

Past Work

Below are some of the stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Restoration: Stream and wetland restoration and enhancement activities have been conducted in the Muir Beach vicinity from 2006–present.

Management:

- Red-eared slider removal from Marin Water reservoirs has taken place in 2004, 2005, 2014, 2015, and 2016.
- Nest site protection measures and exclusion fencing have been used in the Phoenix Lake area (2009, 2010).

- Basking habitat enhancements (log installations) have been made in Phoenix Lake and Lake Lagunitas (multiple years, 2004–present).

Monitoring and Surveys:

- A habitat and population survey was conducted (2003).
- Irregular mark-and-release efforts have taken place over the years (2004–2016).
- Periodic turtle trapping is conducted to remove non-native turtles and provide some data on northwestern pond turtle population sizes, age estimates, and sex ratios in each reservoir.
- The volunteer Turtle Observer program collects age, date, time interval, weather, and a series of qualitative observations about each turtle's appearance and behavior.
- The National Park Service conducts a turtle inventory (1996, 2014–present).

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as a part of the development of this report. These actions not currently funded through agency programs, and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Resource Management and Monitoring: One of this project's technical reviewers noted that human disturbance would negatively affect turtle nesting behavior and success. This risk is present at Muir Beach, which experiences high visitation, especially during the summer, when female turtles leave the water to nest. However, time-intensive nest surveys and/or remote telemetry are needed to identify nest sites for protection.

Existing Program Support:

- **Northwestern Pond Turtle Nursery Areas:** Create a nursery area where non-native fish are excluded to prevent them from eating young turtles (Marin Water).
- **Reintroduction:** Continue reintroduction program for northwestern pond turtles at appropriate sites at Muir Beach (National Park Service).

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CHAPTER 19. BIRDS

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

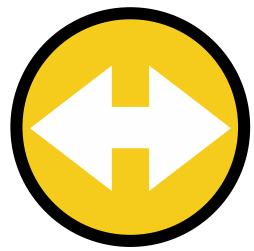
2016

Condition: Good

Trend: No Change

Confidence: High

2022



Condition: Caution

Trend: No Change

Confidence: High

FIGURE 19.1 CONDITION, TREND, AND CONFIDENCE FOR BIRDS, ONE TAM AREA OF FOCUS

The overall abundance of birds in the One Tam area of focus (and some surrounding areas) has remained relatively stable (no change) since 2016. However, we detected some changes in condition when looking at all birds, and for the condition and trend of some of the specific guilds examined (Table 19.1). This warrants concern and a change in condition to caution for this update. Our confidence in the results of this assessment remains high. In 2022, 79 species were assessed, including 26 that were not previously included. Of these, we were able to apply at least one of the parameters of our metric evaluation—condition, trend, and/or confidence—to 67 species. The remaining 12 species were classified as unknown across all parameters.

Key findings for this report update:

- The overall condition of birds went from good to caution (Figure 19.1) because the abundance condition goal was only partially (26%–75%) met. This is despite the fact that across all birds, the abundance trend rolled up to no change. We chose caution because quite a few species were either declining, showing mixed trends across datasets, or while we lacked enough data for trend analysis, we had enough information to warrant concern about their overall condition (Table 19.2). Even if we excluded those species for which we had limited data (the latter category), the overall condition of all birds in the area of focus would fall in the caution category. At its core, the shift from good to caution means that in 2022, we have greater concern about the trends for more species than we did in 2016.

- On a positive note, the Oak Woodland Bird guild trend went from no change to improving. This may be in part because the number of species included increased, with a few species assigned to this habitat in 2022 that were either not previously included or were included but for which we lacked adequate data to analyze a trend.

- Potentially concerning changes since 2016 include the condition of Scrub/Chaparral, Riparian, and Climate-Vulnerable Bird guilds, which went from good to caution, while our confidence for Scrub/Chaparral Birds went from high to moderate. Species included in the Scrub/Chaparral and Riparian Bird guilds changed slightly between 2016 and 2022, but the species included in Climate-Vulnerable Birds remained the same.

- Monitoring of Grassland Birds (a new effort undertaken after a data gap was identified in the 2016 Peak Health report) resulted in a change in their condition from unknown to caution, and the confidence in this assessment from unknown to low.

- Additional years of bird surveys included here have been conducted since 2016 as part of long-term monitoring efforts on lands managed predominantly by Marin Water (where a new analytical approach also allowed us to include more species) and in riparian habitat throughout western Marin County on lands managed predominantly by the National Park Service.

METRICS SUMMARY

One metric—bird population abundance—was applied to five habitat guilds, as well as to a group of species deemed vulnerable to climate change, and to all species combined (including those not represented in the five habitat guilds) (Table 19.1). Bird guild groupings by habitat were based on the vegetation communities with which these species are primarily or secondarily associated. Note, some species are included in the overall all species guild, or potentially in the climate-vulnerable guild, but not in any of the specific habitat guilds because they are associated with three or more habitats; and some species are included under two habitat types (see Assigning Species Guilds and Applying the Roll-up Method later in this chapter for more details); thus, the numbers listed by habitat guild (Table 19.1) do not add up to the total number of birds. As previously mentioned, we assessed 79 bird species; for 67, we had sufficient data or information to assess the population-abundance condition and/or trend; the remaining 12 were classified as unknown.

The condition, trend, and confidence for each of these groupings was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 19.1. The metric and scoring methodologies are described in the Condition and Trend Assessment section later in this chapter. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 19.1 ALL BIRD GUILDS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1 (of 1): Population abundance		
	2016	**2022**
ALL BIRDS (*n*=79)		
Condition	Good	Caution
Trend	No Change	No Change
Confidence	High	High
Oak Woodland Birds (*n*=16)		
Condition	Good	Good
Trend	No Change	Improving
Confidence	High	High
Coniferous Forest/Mixed Hardwood Forest Birds (*n*=26)		
Condition	Good	Good
Trend	Improving	No Change
Confidence	High	High
Grassland Birds (*n*=7)		
Condition	Unknown	Caution
Trend	Unknown	Unknown
Confidence	Unknown	Low
Scrub/Chaparral Birds (*n*=8)		
Condition	Good	Caution
Trend	No Change	No Change
Confidence	High	Moderate
Riparian Birds (*n*=24)		
Condition	Good	Caution
Trend	No Change	No Change
Confidence	High	High
Climate-Vulnerable Birds (*n*=30)		
Condition	Good	Caution
Trend	No Change	No Change
Confidence	High	High

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

Birds have long been a national conservation priority, and native species are protected by the Migratory Bird Treaty Act. However, many of the birds included in this chapter are both common and widespread in the One Tam area of focus and the surrounding region, and lack any special conservation status, making birds an ideal resource to study here. Exceptions include the federally and state threatened Northern Spotted Owl (Chapter 20) and several California Species of Special Concern, among them, Northern Harrier[4], Olive-sided Flycatcher, Purple Martin, Grasshopper Sparrow, and local subspecies of Savannah Sparrow and Common Yellowthroat (Shuford & Gardali, 2008).

The area of focus supports a rich diversity of birds (see Appendix 8). It also has a long history of bird monitoring by One Tam partner agencies and their collaborators, enabling population trend estimates for many species across multiple vegetation communities. For example, the National Park Service (Gardali et al., 2020) and Marin Water (Cormier et al., 2020) both have ongoing landbird monitoring programs co-developed and implemented by Point Blue Conservation Science (Point Blue). The resulting robust datasets helps provide the statistical power needed to identify population changes. By studying the entire bird community, these data can also reveal mechanisms behind observed changes (e.g., changes that may be specific to a particular habitat, foraging guild, or migratory status).

Birds, which are also highly visible, also engender a great deal of public interest, attracting many bird watchers to the Mt. Tam region and delighting visitors and local residents alike. Monitoring migratory bird populations provides a way to connect the mountain to ecosystems and people well outside of the Bay Area. Several bird-focused, community-science projects generate data and engage the public (e.g., eBird, iNaturalist, Audubon's Christmas Bird Count, and the current Marin County Breeding Bird Atlas effort). Bird watching can also have a significant positive impact on local to national economies (Carver, 2013).

Finally, birds are recognized indicators of ecological change (Carignan & Villard, 2002). They provide a wide variety of ecosystem services, including feeding on pests, pollinating flowers, dispersing seeds, scavenging carrion, cycling nutrients, and modifying the environment in ways that benefit other species (Whelan et al., 2015). Since birds are relatively easy to monitor, observations of changes in their populations can help identify early indications of shifts in other parts of the ecosystem (insects, plants, small mammals, etc.) that may be harder to monitor or in which to detect patterns.

[4] *For scientific names of species mentioned in this chapter, see Appendix 8.*

CURRENT CONDITION AND TREND

Our assessment of birds in the One Tam area of focus is predominantly based on extensive regional monitoring combined with the expertise of those with deep knowledge of the mountain and the county's birds. Similar to the non-jurisdictional nature of the One Tam partnership, we included locations outside of the area of focus in our analyses. This approach also suits these highly mobile animals, which can and do travel quite widely.

Most of the data that contributed to our species selection and guild analyses came from a collaborative, long-term landbird community monitoring project within the One Tam boundary conducted by Point Blue and Marin Water. Other data came from long-term riparian landbird monitoring conducted by Point Blue's Palomarin Field Station in collaboration with the National Park Service, Marin County Parks, and California State Parks. Survey areas for the latter effort are partially located within the One Tam area of focus, including along Redwood Creek in Golden Gate National Recreation Area and Mount Tamalpais State Park. Areas outside the area of focus in Point Reyes National Seashore, the Bolinas Lagoon Open Space Preserve, and other portions of Golden Gate National Recreation Area were also surveyed and included herein. Additional Point Blue data came from a 2018–2019 cross-jurisdictional effort to fill data gaps identified in the 2016 Peak Health report bird chapter, with a focus on grasslands (DiGaudio & Humple, 2019). Additional data were contributed by the Golden Gate Raptor Observatory (for the 2016 bird chapter) and by other data-collection efforts (see monitoring work detailed in Chapter 20, Northern Spotted Owl) However, while monitoring occurs throughout the region, including in much of the area of focus, trend data still do not exist for all habitats or areas.

The status of birds in the One Tam area of focus and nearby areas included in this analysis is predominantly stable, with the overall condition flagged as being of some cause for concern (caution) when looking at birds both as a whole and by some of the guilds. Our confidence in these results is high. The designation of caution for birds overall is because enough species either showed clear declines, or their trends differed between studies and regions but were declining in one of them (e.g., declining in National Park Service riparian habitat but increasing on Marin Water lands), or there were. While it is encouraging that some birds are doing well, the number of species with stable (no change) or improving trends was not sufficient to produce an average condition of good for birds overall.

Furthermore, the status of birds by guilds is similar to that of all birds, with some noteworthy departures. For Scrub/Chaparral, Riparian, and Climate-Vulnerable Birds, the conditions are indeed similar to all birds, with relatively stable (no change) trends for all three guilds but with the condition of caution due to enough individual species within the guilds showing clear declines or mixed patterns; for these, there is a mix of moderate to high confidence in the results. For Grassland Birds, a lack of data over time means that trends remain unknown (as in 2016), with a condition of caution and low confidence in these limited results, because we only have monitoring data for a snapshot of time rather than across a time series. For Conifer Forest/Mixed Hardwood Forest Birds, we see a good condition, a no change trend, and high confidence in our results. The most encouraging results are for Oak Woodland Birds, which have an improving trend, a good condition, and for which we have high confidence in the results.

DESIRED CONDITION AND TREND

The desired status of the abundance of birds in the One Tam area of focus (including some of the nearby environs as described previously) is for the combined condition for all birds to be good, the trend to be improving or no change, and confidence to be high. This would represent stable-to-increasing populations, no immediate cause for concern, and high confidence in our understanding of the patterns we are seeing. This status would also apply to the majority of the individual species assessed as well as for the different habitats and other guilds (e.g., Oak Woodland Birds, climate-vulnerable species) we included.

STRESSORS

Historical Impacts: While much of the One Tam area of focus is protected from development, there are parcels of private land where development historically occurred and, in some cases, continues today. In addition, extensive logging of Mt. Tam's forests undoubtedly had an impact on the bird community, with effects that continue to be felt. While the logged forests have somewhat regrown, the distribution and density of old-growth forests (e.g., redwoods; Chapter 4) have been altered, and we do not know if bird populations have returned to their pre-logging diversity and abundance. Recent continent-wide bird population analyses have shown steep declines in the last 50 years (Rosenberg et al., 2019; NABCI, 2022). While protecting land can buffer against some of these losses (Dettling et al., 2021), the forces behind these population declines are generally undeterred by human-created borders.

Invasive Species Impacts: Invasive plants may create novel habitats that—depending on their respective nesting and foraging needs—some bird species may adapt to while others may not. For example, non-native annual grasses that replace native perennial bunchgrasses, or non-native broom species that replace native shrubs, provide little structural value for nesting and are not commonly used by birds (authors, personal observations). These invasive plants can also alter fire regimes, which affects bird habitat.

Climate Vulnerability: Birds in western North America are affected by climate change in a number of ways (Seavy et al., 2018). The distribution (e.g., latitudinally or altitudinally) and composition of bird communities associated with a particular vegetation assemblage may change with climate change–driven habitat shifts or losses. Weather (e.g., drought, altered precipitation regimes, temperature extremes or shifts) may also affect bird survival (Dybala et al., 2013) and productivity, potentially leading to population-wide changes. There is evidence that climate-driven changes are already causing "phenological mismatches" (Olliff-Yang et al., 2020), in which what birds need at a particular time in its life cycle no longer aligns as optimally with a resource they depend upon. For example, a species may arrive or fledge their young before its preferred food source is most abundant. Migratory birds may also experience shifts in other important life stages, such as when they nest or molt their feathers (Seavy et al., 2018);

and shifts in arrival timing might cause a later phase (e.g., feeding young, molting) to no longer be as aligned. Migration timing for some songbird species at the nearby Palomarin Field Station in Point Reyes National Seashore has changed over recent decades (Nur et al., 2018). The relative paucity of such studies assessing climate change impacts on birds from California, and in the West more generally (Seavy et al., 2018), makes this an important area of future study. (See Chapter 26 for more on this topic in general.)

Fire Regime Change: Lack of recent fire on Mt. Tam has undoubtedly affected bird populations through vegetation changes, such as a transition of grassland or coastal scrub into forest (Startin, 2022). Since many bird species are tied to specific vegetation, changes in the plant community will result in changes in the bird community, with some species benefiting and others not.

Disease: In the past couple of decades, West Nile Virus has affected wild bird populations, especially corvids (e.g., crows and jays). For the past several years, the incidence of West Nile Virus has been very low, but the disease is not completely gone. A new strain of avian influenza (H5N1) that reached the U.S. in 2022 has been detected in Marin County's wild birds. The virus is highly transmissible, and while it is unclear at this time what effect it will have on local bird populations, it has already had a significant impact in other regions around the globe. Sudden Oak Death (or SOD, caused by the water mold *Phytophthora ramorum*), poses another threat. The loss of oak (*Quercus* spp.), tanoak (*Notholithocarpus densiflorus*), and other native trees to SOD reduces nesting sites as well as important food sources for some species. However, the disease also changes the forest structure in ways that likely benefit other avian species—for example, by creating openings and standing snags (Cormier et al., 2020).

Pollution/Contaminants: While this may not be a stressor to many of the avifauna in the One Tam area of focus, some species or parts of the population could be affected. For example, many populations have recovered from historical DDT use, although residues have been recently documented in birds in the San Francisco Bay Area (Ackerman et al., 2014; Ross et al., 2016). More generally, pesticides are known to have an impact on birds—especially grassland species—both on their breeding grounds in North America and wintering grounds to the south (Rosenberg et al., 2019); DDT is still used in some parts of South America. These and other contaminants may affect birds that forage both within and beyond the One Tam area of focus (e.g., oil spills entering the Bolinas Lagoon or nearby in the region; Hampton et al., 2003; rodenticide used in residential areas that has impacts to raptors, owls, and scavengers that ingest poisoned prey; see Chapter 20).

Direct Human Impacts: Vegetation management along trails, fire roads, public roads, and on private property and public lands can directly and indirectly affect nesting birds. However, the need to reduce fuel loads has increased in recent years as the area's fire regime changes, and commensurate impacts to birds are to be expected. Vegetation-management activities that cause direct disturbance can be timed as much as possible for the non-nesting season (fall and winter), and those during the nesting season mitigated with surveys by specialists to find and buffer active nests (see Allen & Cormier [2021] for landbirds; see Chapter 20 for Spotted Owls). Additionally, studies have shown that window collisions are a major cause of bird mortality, especially in the wildland-urban interface (Basilio et al., 2020). Collisions can be reduced by identifying problematic windows and applying one of a number of preventative solutions (for details, see American Bird Conservancy, Glass Collisions, Preventing Bird Window Strikes).

Habitat Disturbance/Conversion/Loss: Habitats in the One Tam region have changed over recent decades, including a loss of grassland/meadow to encroaching coastal scrub, or coastal scrub/prairie to Douglas-fir. Whether due to fire-regime change, modified human uses (e.g., altered grazing regimes), or other factors, these changes affect bird populations using these areas. For example, this has been well documented at the Palomarin Field Station in Point Reyes National Seashore, where significant conversion to Douglas-fir forest and to the associated bird community has occurred (Porzig et al., 2018). It is particularly important for grassland birds, which typically need relatively large patches to occupy the habitat (DiGaudio & Humple, 2019). Finally, migratory species are experiencing habit loss and degradation both locally (Iverson et al., 2023) and in their wintering or breeding grounds elsewhere (Humple et al., 2020).

Predation/Competition: Free-ranging domestic and feral cats have been shown to have a substantial negative impact on native birds and other animals (Loss et al., 2013). Cats are highly efficient predators that our native fauna have not evolved with, and birds within the area of focus adjacent to or in human communities would be expected to be most impacted by them. Cats can also have less direct impacts such as competing with native predatory bird species and potentially introducing novel diseases.

CONDITION AND TREND ASSESSMENT

METRIC

ASSIGNING SPECIES GUILDS AND APPLYING THE ROLL-UP PROCESS

We began by classifying each bird species by habitat guild, based on expert opinion and regional monitoring data. Species primarily associated with two habitat types (i.e., with primary and secondary associations) were considered in the metrics assessment for both guilds. Similar to 2016, if a species was classified as a generalist (defined as associated with three or more of the habitat guilds shown in Table 19.1), they were not included in the metrics for any guild. However, they were included in the assessment of birds overall and, if designated as such, in climate-vulnerable species.

In a few cases, we reclassified primary and secondary habitat associations for some, modifying their classifications from 2016. This was generally done because of a change in determination of secondary habitat association, which can be more difficult to classify. We also combined “conifer forest” and “mixed hardwood forest” into a combined habitat (“coniferous forest/mixed hardwood forest”) at the species level, since that is how they are presented at the guild level in both the 2016 and 2022 versions of this chapter; this moved some species out of the generalist category as those two associations were reduced to one. In addition, habitat associations were assigned to the 26 species not included in the 2016 assessment.

In addition to habitat guilds, in 2016, all species were classified according to their climate-change vulnerability. (For this update, we did not reclassify climate-vulnerable status for any species, nor classify the 26 new species not included in the 2016 assessment, as that was done through an extensive process that was not repeated during this update.)

After habitat and climate-vulnerable guild associations were determined, each species was assigned a condition (good, caution, significant caution, unknown) and a trend (improving, no change, declining, unknown) based on available data, as well as a level of confidence in our assessment of the condition and trend (high, moderate, low, and unknown).

To assess the combined condition, trend, and confidence for each grouping, species-specific assessments were then "rolled up" by habitat guilds, climate-vulnerable species, and for the bird community overall (all species). The explanation of each and how roll-ups were assigned their condition and trend are described in the section immediately following. (See the Database Approach section for more details.)

METRIC 1 (OF 1): BIRD POPULATION ABUNDANCE

Baseline: Unlike other chapters in this report, in which baselines reflect what was known in 2016, the baseline for this chapter is set at the year when the first bird survey included in this chapter was undertaken. Hence, for Marin Water lands, the baseline for birds was established in 1996 (Cormier et al., 2023). For the riparian landbird study in Golden Gate National Recreation Area, Bolinas Lagoon Open Space Preserve, Mount Tamalpais State Park, and adjacent Point Reyes National Seashore lands, it is 1997 (Dettling et al., 2021). For new grassland monitoring data, it is 2018–2019 (DiGaudio & Humple, 2019). In the future, baselines will need to be established for species not well-sampled by these efforts (e.g., raptors, waterbirds).

Condition Goal: Stable or increasing populations for both individual species and for habitat guilds, over the past quarter-century.

Note that this is different from the Condition Goal in the 2016 report, which was looking at population trends for the upcoming five years. We made this change because a longer timeframe allows us to use more of the available long-term data. We can then much more meaningfully use these data to look back and see what is happening rather than to project forward.

We acknowledge that environmental change, and in particular climate change, complicates the establishment of static long-term goals, especially across a complex suite of species. Having said that, based on available long-term datasets, we consider a condition goal of stable or increasing populations over the past quarter-century to be a reasonable timescale within which to work. Species and guilds will likely vary in how they respond to these changes, including by shifting ranges (Stralberg et al., 2009), and sufficient population size and fitness are likely to be important components of a species' ability to track environmental change (Williams et al., 2008). As such, while it is unrealistic to anticipate stable or increasing abundance for all species, maintaining habitat conditions with the goal of supporting stable or increasing bird populations is likely to benefit bird species whose distributions may shrink or shift away from the area of focus.

Condition Thresholds:

Based primarily on their population trends, individual species were assigned one of the conditions listed, and in some cases—when we had abundance but no trend data—on static abundance:

- **Good:** The individual species' trend has either been stable or has increased over the past 25 years and, where multiple trend assessments are available from separate analyses, is relatively consistent (i.e., not showing conflicting trends).
- **Caution:** The individual species' trend has shown conflicting patterns (with at least one, but not all, dataset in which it is declining), or there are relatively extensive data demonstrating the species' abundance/occurrence in the area of focus, but data to assess trends are limited or absent (e.g., grassland species, Purple Martin, Nuttall's White-crowned Sparrow).
- **Significant Concern:** The individual species' trend has decreased over the past 25 years and, where multiple trend assessments are available from separate analyses, is relatively consistent (i.e., not showing conflicting trends).
- **Unknown**: The individual species' trend is not available, either because it has not been assessed or because there are insufficient data to demonstrate the species' distribution in the area of focus, let alone to assess its trend. These species were omitted from the roll-ups.

Current Condition: Because this analysis covers so many species and groupings, we have deviated from the format used in other chapters and listed the current condition for both 2016 and 2022 in Table 19.1.

Trend Thresholds:

Population abundance trends for individual bird species were assigned one of the categories (described as follows) according to the results of recent analyses for riparian sites across jurisdictions and for Marin Water lands. These individual assessments were then aggregated. (Note that this is a deviation from the scoring approach described in the project methodology in Chapter 2.) These aggregations yielded a rolled-up trend assessment for all species combined, for habitat guilds, and for climate-vulnerable species as shown in the *State of Mt. Tam Bird Species Traits & Status Database* (see the Database Approach section).

If different databases for a species showed different but not necessarily conflicting trends, (e.g., stable vs improving, as opposed to declining vs improving), that species was assigned the trend that matched the trend of its primary habitat association, or its most prevalent habitat, across One Tam. Take, for example, a species with an increasing trend in riparian sites across jurisdictions but a no change trend in Marin Water sites (which has relatively little riparian): if the species is primarily associated with riparian habitat, then it was classified as improving because of the significance of that habitat for that species in the region; or if it was primarily associated with chaparral or another dominant habitat types surveyed on Marin Water lands, it was classified as no change.

The rolled-up trend assessment for all species and for each guild was determined after arranging the species in the following order: declining, no change, or improving (species where the trend was unknown were excluded). The roll-up was then assigned a median value. If the median fell halfway between two values, we used our best professional judgement, including based on how representative the habitat or dataset was for the species, or how abundant each species is. For example, in Scrub/Chaparral Birds, three species were declining, two were no change, and one was improving. The median, therefore, fell between declining and no change. However, because the no change and improving species are very common through the region, and the three declining species are far less common, we weighted the assessment by population size and distribution and assigned a rolled-up assessment of no change. As noted previously, this methodology deviates from that used for our condition assessment, as well as in other chapters in this report. However, it was necessary to accommodate the relatively small number of trends with which we had to work.

- **Improving:** The individual species' trend is increasing, and for roll-ups, improving is the median category, using the process described above (including for when the median falls in between categories).
- **No Change:** The individual species' trend is "stable" (no trend detected), and the result is considered reliable, with sufficient precision in the estimate to detect a trend. For roll-ups, no change is the median, using the process described above.
- **Declining:** The individual species trend is "decreasing," and for roll-ups, declining is the median category, using the process described above (including for when the median falls in between categories).
- **Unknown**: The Individual species' trend is not available, or it was assessed (Cormier et al., 2023) but lacked sufficient statistical power to determine a trend. These species were omitted from the roll-ups.

Current Trend: See Table 19.2.

Confidence Thresholds:

Population abundance trends for individual bird species were assigned one of the following confidence levels. We assumed that if a bird had been given a condition in this evaluation, the confidence level in that status would at least be low, (i.e., it could not be unknown, such as for grassland species and a few species that were assigned a condition but no trend). For categories for which the rolled-up trend status had to be determined with best professional judgment because the median fell between two categories, we reduced the confidence by one level to account for the uncertainty.

- **High:** The individual species' trend is known with high confidence per statistical analyses; for roll-ups, the average of the numerical values assigned to each species classified it as high.
- **Moderate:** The individual species' trend is known with moderate confidence typically because they showed mixed regional trends (e.g., improving in one database, declining in another; uncertain in one database, increasing in another) and for which it was possible to identify the dominant regional trend. For roll-ups, the average of the numerical values assigned to each species classified it as moderate.
- **Low:** The individual species' trend is known with low confidence, typically because we have knowledge of their abundance or distribution but no trend data (e.g., some grassland species). For roll-ups, the average of the numerical values assigned to each species classified it as low.
- **Unknown:** The individual species' confidence is not available (trend not assessed or could not be determined due to insufficient data, and condition is also unknown). These species were omitted from the roll-ups.

Current Confidence: See Table 19.2.

TABLE 19.2 SPECIES INCLUDED IN ROLL-UPS (FULL DATABASE ONLINE HERE; SEE DATABASE APPROACH SECTION FOR DETAILS)

Focal Bird Species	Hab1[a]	Hab2[a]	Climate Vulnerable	Condition	Confidence	Trend
Acorn Woodpecker	FM		Yes	Good	High	Improving
Allen's Hummingbird	Gen		Yes	Good	High	No Change
American Goldfinch	Gen		Not	Significant	High	Declining
American Kestrel	G	OW	Unknown	Caution	Low	Unknown
American Robin	FM		Not	Significant	High	Declining
Anna's Hummingbird	Gen		Not	Good	High	Improving
Ash-throated Flycatcher	OW	R	No	Significant	High	Declining
Bald Eagle	Ot	CHF	Yes	Good	Moderate	Improving
Band-tailed Pigeon	OW	CHF	No	Good	High	Improving
Belted Kingfisher	Ot	R	Yes	Unknown	Unknown	Unknown
Bewick's Wren	SC	R	Not	Caution	Moderate	Declining
Black Phoebe	R	Ot	Not	Unknown	Unknown	Unknown
Black-headed Grosbeak	R	OW	No	Significant	High	Declining
Black-throated Gray	OW	CHF	Yes	Good	High	Improving
Blue-gray Gnatcatcher	OW	SC	No	Good	High	Improving
Brown Creeper	CHF		Yes	Good	High	Improving
Brown-headed Cowbird	R		Not	Significant	High	Declining

Focal Bird Species	Hab1[a]	Hab2[a]	Climate Vulnerable	Condition	Confidence	Trend
Bushtit	Gen		Not	Significant	High	Declining
California Quail	Gen		Not	Significant	High	Declining
California Scrub-Jay	Gen		No	Caution	Moderate	Declining
California Thrasher	SC		No	Unknown	Unknown	Unknown
California Towhee	Gen		Not	Significant	High	Declining
Cassin's Vireo	CHF		Not	Unknown	Unknown	Unknown
Chestnut-backed	CHF	R	Not	Good	High	No Change
Chipping Sparrow	CHF		Not	Significant	High	Declining
Common Merganser	Ot	R	Yes	Unknown	Unknown	Unknown
Common Yellowthroat	R		Unknown	Significant	High	Declining
Dark-eyed Junco	CHF	OW	Yes	Good	High	No Change
Double-crested Cormorant	Ot		Yes	Unknown	Unknown	Unknown
Downy Woodpecker	CHF	R	Yes	Caution	Moderate	Declining
European Starling	FM		Not	Significant	High	Declining
Golden-crowned Kinglet	CHF		Yes	Significant	High	Declining
Grasshopper Sparrow	G		Yes	Caution	Low	Unknown
Hairy Woodpecker	CHF		Yes	Good	High	Improving
Hermit Thrush	CHF		Not	Good	High	Improving
Hermit Warbler	CHF		Yes	Good	High	Improving
House Finch	R		Not	Good	High	Improving
Hutton's Vireo	OW	R	Not	Good	High	Improving
Lark Sparrow	OW	G	No	Caution	Low	Unknown
Lazuli Bunting	Gen		No	Significant	High	Declining
Lesser Goldfinch	OW		Not	Good	High	Improving
Marsh Wren	R		Yes	Unknown	Unknown	Unknown
Mourning Dove	Gen		Not	Significant	High	Declining
Northern Flicker	FM		Not	Unknown	Unknown	Unknown
Northern Harrier	G		Yes	Caution	Moderate	Declining
Northern Spotted Owl	CHF		No	Good	High	No Change
Nuttall's White-crowned Sparrow	SC		Yes	Caution	Low	Unknown
Nuttall's Woodpecker	OW	R	No	Good	Moderate	Improving
Oak Titmouse	OW		No	Good	High	Improving
Olive-sided Flycatcher	CHF	Ot	Unknown	Caution	Moderate	No Change
Orange-crowned Warbler	FM		Not	Good	High	No Change
Osprey	Ot		Yes	Caution	High	Declining
Pacific Wren	CHF	R	Yes	Good	High	No Change
Pacific-slope Flycatcher	CHF	R	Not	Good	High	No Change
Pileated Woodpecker	CHF		Yes	Significant	High	Declining
Purple Finch	FM		Not	Good	High	No Change
Purple Martin	OW		Yes	Caution	Low	Unknown
Pygmy Nuthatch	CHF		Not	Good	High	Improving
Red Crossbill	CHF		Yes	Unknown	Unknown	Unknown
Red-breasted Nuthatch	CHF		Yes	Unknown	Unknown	Unknown

Focal Bird Species	Hab1[a]	Hab2[a]	Climate Vulnerable	Condition	Confidence	Trend
Red-winged Blackbird	R		Not	Significant	High	Declining
Rufous-crowned Sparrow	SC		No	Significant	High	Declining
Savannah Sparrow	G		No	Caution	Low	Unknown
Sharp-shinned Hawk	FM		Unlikely	Good	Moderate	Unknown
Song Sparrow	R	SC	Unknown	Significant	High	Declining
Spotted Towhee	SC	R	Not	Good	High	Improving
Steller's Jay	CHF		Yes	Significant	High	Declining
Swainson's Thrush	R	CHF	Yes	Good	High	Improving
Tree Swallow	R		Yes	Unknown	Unknown	Unknown
Warbling Vireo	R	CHF	Yes	Caution	Moderate	Declining
Western Bluebird	OW	G	No	Good	High	No Change
Western Meadowlark	G		No	Caution	Low	Unknown
Western Screech-Owl	OW		Yes	Unknown	Unknown	Unknown
Western Wood-Pewee	FM		Not	Significant	High	Declining
White-breasted Nuthatch	OW		No	Good	High	Improving
White-tailed Kite	G		Unknown	Caution	Low	Unknown
Wilson's Warbler	R	CHF	Yes	Good	High	Improving
Wrentit	SC	R	No	Good	High	No Change
Yellow-rumped Warbler	CHF		Unknown	Good	High	Improving

[a]Primary and Secondary Habitat Associations (Hab1+Hab2): CHF=Conifer Forest-Mixed Hardwood Forest, FM=Forest (Mixed); G=Grassland; Gen=Generalist, R=Riparian/Wetland, OW=Oak Woodland, Ot=Other, SC=Scrub/Chaparral.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

We were able to reevaluate many species due to the following: new bird survey data collected through continued long-term monitoring efforts by Point Blue and collaborating partner agencies in the area of focus and surrounding environs; and new monitoring data collected to fill data gaps identified in the 2016 report, especially in grassland habitat. Additionally, some analyses were refined, which allowed us to include new species.

There was no workshop held to re-evaluate the status for species lacking new data since 2016, therefore for a subset of species for which no new analyses were available, condition, trend, and confidence generally remained as reported in the 2016 chapter and also in the *State of Mt. Tam Bird Species Traits & Status Database*. However, in a few instances, changes were made when the professional judgment of the current report author(s) could be applied. These were typically minor and mostly resulted in dropping a species (i.e., so little was known that retaining it seemed without merit). In such instances, the roll-ups were not affected, as “unknowns” are not scored and thus, do not influence the averages.

Information for this update came from the following sources.

- Continuation of a long-term landbird-community monitoring collaboration between Point Blue and Marin Water, which involves extensive point counts throughout lands primarily managed by Marin Water within the area of focus. This now includes three additional years of data (2016, 2019, 2022 [Cormier et al., 2023]) since the 2016 report. Report authors (Cormier et al., 2023) also applied a new analytical approach that allowed inclusion of additional species, increase trend-detection sensitivity for a number of species, and improve the ability to differentiate relatively stable populations from those for which trends are unknown (e.g., possibly due to our limited capacity to detect them). Additionally, the 2016 bird chapter did not include all species analyzed in the most recent Marin Water report at the time (Cormier et al., 2014), whereas for this update, we included all 56 species analyzed in the latest Marin Water report (Cormier et al., 2023). This included 30 species that were listed in the original *State of Mt. Tam Bird Species Traits & Status Database* and 2016 Peak Health report, 11 that were previously analyzed for the Marin Water report (Cormier et al., 2014) but were not included in the database or 2016 Peak Health report, and 15 not previously analyzed.

- Continuation of another a long-term landbird-community monitoring collaboration, this between Point Blue and the National Park Service, Marin County Parks, and California State Parks. This effort involves point counts and constant-effort mist netting throughout riparian habitats in western Marin County conducted by researchers at Point Blue's Palomarin Field Station both within and outside of the area of focus (within Point Reyes National Seashore, Golden Gate National Recreation Area, Bolinas Lagoon Open Space Preserve, and Mount Tamalpais State Park). This now includes an additional eight years of data (2012–2019 [Dettling et al., 2021]) since the 2016 Peak Health report, which included results from the most recent project report at the time (Humple & Porzig, 2014), resulting in additional years or point count data for 10 species, and point count data for four species that were not in the original Peak Health report (note, these four were also added to the most recent Marin Water analysis, above). For species other than those 14, the results from the prior report (both point counting and mist netting; Humple & Porzig, 2014) remain part of the current roll-ups.

- Continuation of annual long-term Northern Spotted Owl monitoring throughout Marin County, a collaboration between National Park Service, Point Blue, Marin County Parks, Marin Water, and California State Parks. (See Chapter 20 for details.)

- Point Blue monitoring at additional sites in 2018–2019 (DiGaudio & Humple, 2019) in collaboration with the Parks Conservancy and One Tam partner agencies to fill data gaps related to land management and particular habitats (most notably grasslands) identified in the 2016 Peak Health report. While this contributed new data to the grassland condition assessment, without long-term data we cannot assess trends. See Figure 19.2 for an overview of new, continuously monitored, and revisited historic survey locations that are part of this study.

Following are the changes in how we analyzed our metric compared to the 2016 Peak Health report:

- Condition, trend, and confidence assessments were based on 79 species instead of 57.
- The definition of riparian habitat was expanded to include wetlands, creek-seep areas, and reservoir edges, which allowed us to add species such as Red-winged Blackbirds.
- For a few species, based on the chapter authors' expert opinion, we slightly modified habitat designations in the *State of Mt. Tam Bird Species Traits & Status Database*. Additionally, we made a slight alteration to the habitat classification groupings overall related to species associated with conifer forest and/or closed-canopy mixed forest. In 2016, those were considered two separate classifications in the database, and then were merged into a single habitat classification (conifer forest/mixed hardwood forest) for the chapter, in keeping with the habitat designations discussed throughout the Peak Health report. In 2022, we combined the grouping in the database as well, which resulted in species associating with both conifer forest and mixed hardwood forest being designated a single habitat classification instead of two. This meant that in 2022 those that also associated with one additional habitat were not considered generalists ("associating with three or more habitats") and were instead included in the roll-ups for both habitats.
- Trends for this chapter's dominant data sources (Marin Water landbirds; Cormier et al., 2023) followed a different approach than other data sources and the earlier dataset included in 2016 (Cormier et al., 2014). Trends were then converted to standard Peak Health designations in the *State of Mt. Tam Bird Species Traits & Status Database* as follows:
    - Those assigned to "stable" in the *State of Mt. Tam Bird Species Traits & Status Database* also included those that were possibly increasing, or showed a small statistically significant (but possibly not biologically significant) increase.
    - Those assigned to "uncertain" in the *State of Mt. Tam Bird Species Traits & Status Database* also included those that were possibly decreasing, or showed a small statistically significant (but possibly not biologically significant) decrease.
- We clarified how we classified the trend for roll-ups when the median fell between two categories.
- We did not evaluate categories other than habitat guilds for the 26 new species added in 2022. This means that the condition, trend, and confidence for birds in the climate-vulnerable guild utilized the same species makeup as in 2016.

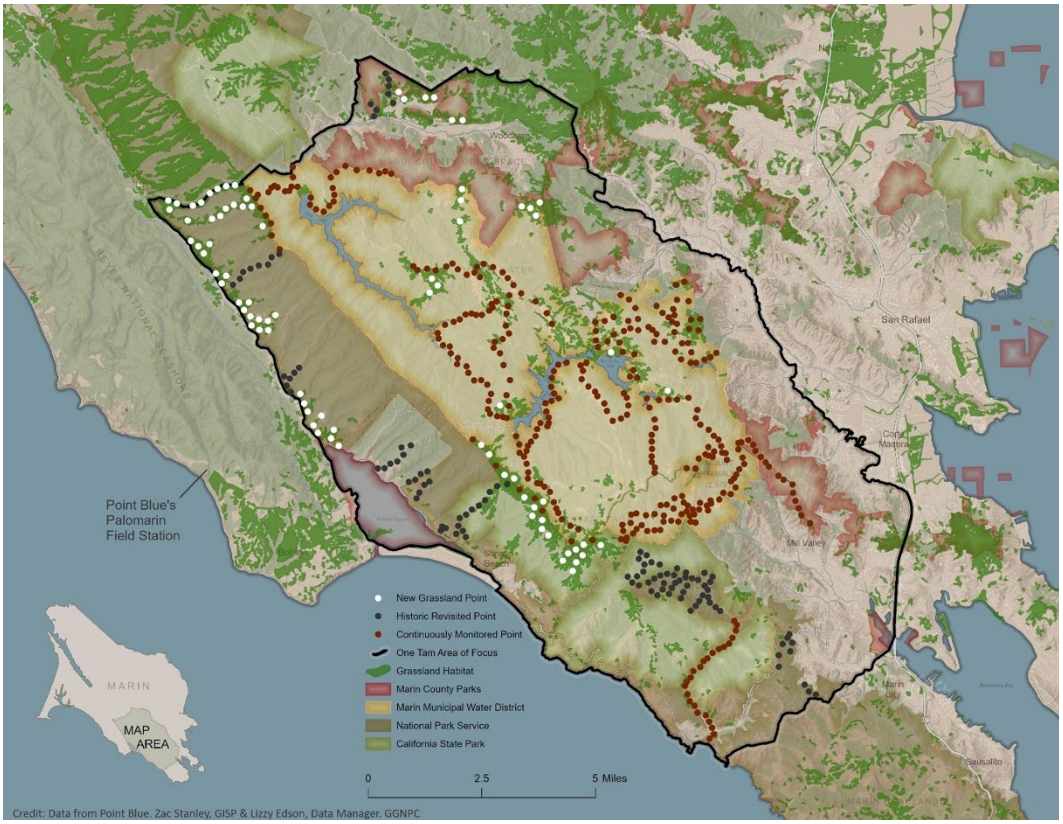


FIGURE 19.2. POINT BLUE POINT COUNT STATIONS SURVEYED IN 2018–2022, ONE TAM AREA OF FOCUS (DIGAUDIO & HUMPLE, 2019)

DATABASE APPROACH

We revised the *State of Mt. Tam Bird Species Traits & Status Database* developed in 2016 to facilitate a flexible approach to assessing the status of bird populations in the area of focus. For example, all species were evaluated based on the same criteria, including life-history characteristics, predicted climate change vulnerability, and known stressors. Status of birds could then be summarized by affiliation to vegetation communities, climate-change vulnerability, and across all species.

How We Identified Species to Include: The lead author of the initial bird chapter of the Peak Health report, Tom Gardali, developed the list of species included based on his local knowledge and expertise in California avian conservation planning (e.g., Shuford & Gardali, 2008). This draft was vetted and improved upon during a February 2016 workshop. Fifty-seven species were ultimately included in 2016; the full web-based database of species traits and status for the original chapter can be viewed here.

Seventy-nine species selected for the 2023 version of this chapter can be viewed in the current web-based database here (along with information on an additional four species that were included in the original chapter but excluded from this one). Much of the information from 2016 is also found in the 2023 *State of Mt. Tam Bird Species Traits & Status Database*. The simplified

version of the database shown in Table 19.2 provides an overview of the species; their habitat associations; their climate vulnerability (if assessed); and their conditions, trends, and confidence levels. (We retained the 2016 habitat associations and metrics in the 2023 web-based database for comparison.)
https://docs.google.com/spreadsheets/d/1LzdDeDBdiodyIxThUBKkZEMbuBfJ9FcjZS-dyct7eus/edit?usp=sharing

What We Included in the Database: In 2016, the Health of Mt. Tam's Natural Resources Advisory Committee discussed the variety of information that might be needed in the *State of Mt. Tam Bird Species Traits & Status Database*, and ultimately ended up with 27 fields (Table 19.3). These fields captured general life history information (e.g., habitat association); regulatory status; if it is considered iconic status; threat and risk factors (e.g., climate vulnerability, sensitivity to disturbance); condition, confidence, and trend; and finally, types of available data (e.g., abundance) and how many agencies have those data. For each field, a specific data description was drafted, and a menu of standard data options was created.

Populating the Database: Four biologists with local bird ecology and conservation expertise populated the database in 2016: Thomas Gardali and Renée Cormier (Point Blue), Allen Fish (Golden Gate Raptor Observatory), and Bill Merkle (National Park Service). In the 2023 version, nine new fields were created by the current chapter lead author to reflect the status as of 2023: habitat association (three new fields for 2023; additionally, authors retained the 2016 fields for comparison); two fields for recent analyses (Dettling et al., 2021; Cormier et al., 2023); and four fields for Condition, Confidence, Trends, and related Notes. In addition, records were added for the new species; the only fields populated for the added species are those listed in the preceding sentence, along with their current Regulatory Status (below). Historical fields and species were retained for comparison.

Life History Data: The primary sources used included Shuford (1993), Billerman et al. (2022), and expert opinion.

Regulatory Status: State and federally threatened and endangered status lists were consulted, as was the California Department of Fish and Wildlife's Bird Species of Special Concern (Shuford & Gardali, 2008). This list was created in 2016 and updated in 2023.

Iconic: We used the definition developed by Gardali et al. (2011) as guidance, but acknowledge that it is subjective and hence reflects the opinion of the scoring biologist. This category was created in 2016 and remained unchanged in 2023.

Threats and Risk Factors: Rather than selecting the full suite of threats and risk factors for every species, biologists attempted to identify the most imminent or likely threats to each. The primary sources used included Shuford (1993), Rodewald (2015), and expert opinion. For climate-change vulnerability, authors of the 2016 chapter used Gardali et al. (2012) and online probability-of-occurrence models (data.prbo.org/cadc/tools/ccweb2/index.php). Authors compared a species' current occurrence (in 2016) with that under two different future climate models and considered the species vulnerable when their probability under a climate change scenario was predicted to decline. This approach was created in 2016 and retained unmodified in 2023, so the climate vulnerability of new species added in 2022 was not assessed.

Condition, Confidence, and Trend: Information for most species came primarily from data collected on Marin Water lands (Cormier et al., 2023). The second most relied-upon database was from riparian areas on lands managed predominantly by the National Park Service within and near the area of focus (Dettling et al., 2021). We also consulted Humple & Porzig (2014) for additional riparian-associated species not included in the more recent analysis but from the same study (Dettling et al., 2021). These sources evaluated abundance trends for individual species. Additionally, a summary from a recent monitoring effort (DiGaudio & Humple, 2019) was consulted for a few additional species (especially grasslands associates). For wider-ranging species such as diurnal raptors, the 2016 report authors also consulted migration counts from the Marin Headlands (Golden Gate Raptor Observatory, unpublished data), and the Audubon Christmas Bird Count data for southern Marin County (netapp.audubon.org/CBCObservation/Historical/ResultsByCount.aspx). The different condition, trend, and confidence categories were assigned as previously described.

Data Availability: For three types of data, scoring biologists in 2016 listed the number of agencies that, based on their personal knowledge, have data available of work in the One Tam area of focus. In many cases, data exist for multiple agencies but their time series, which is needed for this assessment, is not noted. This category was created in 2016 and retained unmodified in 2023.

TABLE 19.3 DATA DICTIONARY OUTLINING FIELD HEADINGS, FIELD DESCRIPTIONS, AND VALID VALUES FOR THE STATE OF MT. TAM BIRD SPECIES TRAITS & STATUS DATABASE

Data Type	Description	Menu Options
Life History		
Primary Affiliation	The vegetation affiliation most strongly associated with the focal species.	Open-canopy oak woodland, Conifer Forest/Mixed Hardwood Forest, Grassland, Riparian/Wetland, Tidal marsh, Scrub/Chaparral, Serpentine barrens, Sargent cypress, Lakes
Secondary Affiliation	A vegetation affiliation also associated with the focal species.	
Three or More Vegetation Types	If the species associates with three or more vegetation types, is it regarded as a generalist.	Yes/No
Trophic Level/Diet	The main role the species plays within its ecosystem.	Carnivore, Insectivore, Omnivore, Piscivore, Granivore, Detritivore/decomposer, Herbivore, Primary producer

Data Type	Description	Menu Options
Reproduction-Specific or Habitat Requirement	Primary nesting guild. Only the most important to a species should be chosen.	Tree/snag cavity, Wetland/aquatic, Ground nester, Shrub nester, Canopy nester, Subterranean nest/den/burrow, Fire
Landscape Requirement	The home-range size the species requires to carry out all necessary life functions.	Small area required, Large area required, Beyond Mt. Tam
Regulatory Status		
Current Regulatory or Other Special Status	Conservation list(s) on which the species currently appears.	Federal threatened and endangered, State threatened and endangered, Global Natural Conservation (NatureServe) rank, California Department of Fish and Wildlife Species of Special Concern, Other, None
Iconic		
Iconic	Does the species fit one of the following categories? ▪ Charismatic to local cultural perspectives. ▪ Status is likely to draw broad attention/concern. ▪ Emblematic of a local habitat or region. ▪ Widely recognized by the public, and/or name refers to a locality within the area of focus.	Yes/No
Threats and Risk Factors		
Climate-Change Vulnerability	Is the local species population particularly vulnerable to likely changes in climate? (Vulnerability is a measure of a population's susceptibility to or amount of risk from negative impacts. We define "climate vulnerability" as the level of evidence that climate change will negatively impact a population. Consideration should be given to a species' intrinsic traits [e.g., physiological tolerances] that make them vulnerable, and extrinsic factors [e.g., increasing temperature or habitat loss] consequent to climate change. For example, a species highly sensitive to increasing temperature would be more vulnerable if the magnitude of climate change is larger within that species'	Yes/No/Unlikely/Unknown/ Not-Assessed

Data Type	Description	Menu Options
	geographic range than it would be if the magnitude of climate change for its range was smaller.)	
Highly Restricted Distribution	Level of endemism for species with restricted distribution	Mt. Tam only, Marin only, Regional only, Locally rare, Not restricted
Mechanical Disturbance	Is the local species population particularly sensitive to disturbance from mechanical processes, such as grass- or brush-cutting, fuel-break maintenance, etc.?	Yes/No
Invasive Species	Is the local species population particularly vulnerable to threats from invasive species?	Yes/No
Disease	Is the species particularly sensitive to threats from disease?	Yes/No
Fire Regime Change	Is the species particularly vulnerable to threats from significant change in fire regime (existing or future change, increase and/or decrease)?	Yes/No
Pollution (Air, Water, Noise)	Is the species particularly sensitive to threats from pollutants (e.g., noise, water pollution, air pollution)?	Yes/No
Compaction Or Trampling	Is the species particularly sensitive to threats from trampling/disturbance or ground compaction?	Yes/No
Human Presence	Is the local species population particularly sensitive to proximity to human presence?	Yes/No
Drought	Is the local species population particularly sensitive to drought-related threats?	Yes/No
Pesticides, Herbicides, Rodenticides	Is the local species population particularly sensitive to pesticides, herbicides, or rodenticides?	Yes/No
Habitat Loss and Fragmentation	Is the local species population particularly sensitive to the effects of reduced habitat or reduced habitat connectivity?	Yes/No
Trophic Level Disruptions	Is the local species population particularly sensitive to changes in its ecosystem trophic levels, beyond what is considered natural (e.g., in availability of preferred prey or increased predation by natural predators)?	Yes/No
Data Availability		
Presence/Absence	How many One Tam agencies have presence/absence data for this species?	

Data Type	Description	Menu Options
Abundance	How many One Tam agencies have abundance data for this species?	One agency, Two agencies, Three agencies, All agencies, Not available
Reproductive Success	How many One Tam agencies have reproductive success data for this species?	

INFORMATION GAPS

Vegetation Community: Because long-term data primarily come from the Marin Water landbird monitoring project, where grassland study sites were relatively few and with additional sites added only recently with long-term data not yet available, we were unable to estimate trends for grassland-associated birds. Additionally, these birds naturally occur in relatively low densities, reducing the power to detect trends. In 2018 and 2019, grassland bird surveys were initiated in the area of focus (DiGaudio & Humple, 2019) in response to the data gap identified in the 2016 Peak Health Report. While these surveys allowed us to estimate the condition of some grassland species in this chapter, they do not yet provide long-term data to assess a trend. DiGaudio and Humple (2019) recommend repeating some of the surveys, and within the area of focus, which has so far only been done on Marin Water lands. Additionally, grasslands in National Park Service lands adjacent to the area of focus contain larger grassland patches and potentially higher numbers of grassland birds, would be ideal for new inventory and monitoring efforts. This would also help us understand regional grassland bird community patterns. Similarly, coastal scrub birds were a previously identified data gap, which led to some historical monitoring being repeated in 2018–2019 in the area of focus; as yet, however, no long-term monitoring is being done in coastal scrub there (DiGaudio & Humple, 2019), although there is an emphasis on this habitat elsewhere in the region not far from the boundary of the area of focus (Porzig et al., 2018). (See Future Actionable Items for recommendations for additional monitoring work.)

Land Ownership/Management: As previously discussed, the bulk of long-term landbird community monitoring within the One Tam area of focus has been carried out on Marin Water lands (DiGaudio & Humple, 2019). Within the area of focus, additional but less extensive long-term monitoring takes place in Mount Tamalpais State Park, Marin County Park preserves, and Golden Gate National Recreation Area, and, at the time the 2016 Peak Health Report was being assembled, some single-year inventory surveys in Marin County Parks (Gardali et al., 2010) and National Park Service lands (e.g., Gardali & Geupel, 1997; Gardali et al., 1999; Humple & Gardali, 2006). Arising from that data gap, surveys were repeated at historic inventory and monitoring locations across multiple habitats and jurisdictions (DiGaudio and Humple 2019); however, trends from those sites remain unknown. The previously mentioned DiGaudio and Humple (2019) recommendation to revisit these historical sites would also help broaden the geographic scope of our dataset (e.g., in French Ranch and Roy's Redwoods Open Space Preserves and Golden Gate National Recreation Area). (See Future Actionable Items for detailed monitoring recommendations.)

Seasonality: The One Tam area of focus has a diverse wintering-bird community, with many species present in the non-breeding season for six or more months. Winter is a critical part of their annual cycle and thus, conditions here have an impact on population trends. Data on birds' winter status is, therefore, critical to their conservation (Dybala et al., 2015). However, we have minimal information on these populations in the One Tam area of focus (but see Gardali et al., 2020 for winter monitoring in the Bolinas Lagoon Open Space Preserve; Audubon's Christmas Bird Count; and Point Blue's Palomarin Field Station Data Explorer);. Additionally, the area of focus provides important resources for migrating birds that stopover briefly during spring and fall. Currently, bird migration trends are only known for riparian areas (Humple & Porzig, 2014, Gardali et al., 2020). Finally, we know relatively little about the migratory connectivity – the spatial connection between overwintering sites, stopover sites, and breeding locations for a given population – of many of the species that occur in the area of focus and the surrounding region (but see Nelson et al., 2016; Humple et al., 2020; Saracco et al., 2022). It is therefore difficult to determine how migratory species are influenced by what is happening in the areas to which they migrate (Humple et al., 2020). Identifying these locations and evaluating conditions there (Saracco et al., 2022) for more of our species that spend just part of their year in the One Tam area of focus and the surrounding region would likely provide valuable insights into the causes of some of the trends we report here. (See Future Actionable Items for more detailed monitoring recommendations.)

Demography: Understanding abundance trends is crucial to conserving bird populations. Demographic data (e.g., survival, reproductive success) provide additional insight into the mechanisms underlying observed trends and inform conservation actions. Within the area of focus, studies and indices exist for reproductive success from banding data in riparian habitat on National Park Service and Marin County Parks lands (Humple & Porzig, 2014; Gardali et al. 2020), and from Spotted Owl monitoring efforts (Chapter 20), but data is lacking for most species elsewhere. (See Future Actionable Items for more detailed monitoring recommendations.)

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Data-Gap Bird Monitoring: As previously mentioned, Golden Gate National Parks Conservancy supported new cross-jurisdictional monitoring efforts by Point Blue to fill data gaps identified in the 2016 report. This included establishing new grassland survey locations, and re-inventorying historic survey locations in coastal scrub areas undergoing habitat succession and coniferous forests that were last surveyed approximately two decades earlier. These surveys have allowed us to evaluate the condition of some coastal scrub and grassland species, which were previously underrepresented in monitoring efforts. Surveyed areas included lands managed by all One Tam agencies as well as private lands. A suite of monitoring recommendations came out of this effort (DiGaudio & Humple, 2019), many of which are summarized in the Future Actionable Items section. This included a recommendation for long-term monitoring of some of these new grassland monitoring stations; a subset of them have been added to the ongoing Point Blue/Marin Water landbird monitoring program (Cormier et al., 2023).

Vegetation Management: Various agencies and landowners (e.g., Marin County Parks, Marin Water, Audubon Canyon Ranch) are working to reduce fuel loads and improve forest health and that of other habitats in the area of focus. Marin Water's Biodiversity, Fire, and Fuels Integrated Plan focuses on active fuel-break vegetation management (Panorama Environmental, 2019) to reduce catastrophic wildfire risk and improve water quality. Birds will benefit from this attention to healthier forests and other habitats, as well as the lower risk of catastrophic fire. Mitigating the impacts of treatments conducted during the bird-nesting season is also critical. For example, since 2018, Marin Water has been collaborating with Point Blue and others to develop best practices for breeding-season vegetation management and to conduct nesting-bird surveys to minimize impacts and as much as possible avoid disturbing nest sites. Marin County Parks has a similar program.

Related Research:

- In 2021, evidence from long-term population trends (publication brief found here) demonstrated the contributions of protected areas in Marin County, including some sites in Golden Gate National Recreation Area and Mount Tamalpais State Park within the area of focus and others nearby (Dettling et al., 2021). The primary finding was that many bird species had better long-term population trends in the protected areas than in surrounding regions. However, the benefits of protected areas were not universal, suggesting that habitat protection alone is not the conservation solution for all species. Additional research evaluating the effectiveness of habitat protection, specific management actions, and long-term monitoring are also critical for successful conservation planning.

- In 2022, Point Blue and collaborators published a study seeking to understand Black-headed Grosbeak population dynamics. The study consolidated archival GPS-tagging, climate, remote-sensing vegetation, and bird-banding data –the latter from multiple study sites (statewide, regionally, and within the area of focus. The study demonstrated that in our region, population size is variable and largely driven by recruitment, which is higher when weather on molting and winter grounds were relatively cool and wet. Migratory connectivity was determined for one local grosbeak from this study, which bred at Redwood Creek in Golden Gate National Recreation Area and wintered in western Mexico (Saracco et al., 2020). The coastal component of this study was built using intensive long-term demographic monitoring conducted at Redwood Creek and elsewhere in the county by Point Blue's Palomarin Field Station in collaboration with multiple land managers (Gardali et al., 2020), as well as a suite of associated migratory connectivity studies published over the last decade (e.g., Humple et al., 2020; see here for a *Nature* blog summarizing that study).

- The second Marin County Breeding Bird Atlas, a primarily volunteer-driven effort under the sponsorship of Marin Audubon Society to update a 40-year-old effort (Shuford, 1993), is currently ongoing. Its evaluation of the changes in the occurrence and distribution of Marin's breeding birds will provide valuable data for bird conservation and management.

Past Work

Following are some of the previous stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Restoration: There has been over 20 years of invasive plant removal and revegetation in the Redwood Creek Watershed. In this area Point Blue conducts breeding-season and fall-migration monitoring of riparian landbirds, and associated public outreach, in collaboration with National Park Service and California State Parks.

Monitoring: Since the 1990s, ongoing landbird and Spotted Owl monitoring (discussed elsewhere in this chapter) has been conducted. Since the 1970s, an ongoing bird monitoring effort at Bolinas Lagoon has occurred (across a wider range of taxa through 2009, and since 2010 as part of the broader Pacific Flyway Shorebird Survey, which focuses on shorebirds and raptors (coordinated by Audubon Canyon Ranch in collaboration with Point Blue).

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as a part of the development of this report. These are actions not currently funded through agency programs, and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Inventory and Monitoring:

- **Long-Term Monitoring at Grassland Sites on National Park Service/California State Park Lands:** DiGaudio and Humple (2019) strongly recommended incorporating several of the grassland monitoring points first surveyed in 2018–2019 into long-term monitoring; to date, only those on Marin Water lands have been added (Cormier et al., 2023). Additionally, if funding allows, surveying annually rather than every third year would increase our understanding of how grassland specialists use these habitats, given how these birds occur in relatively low densities and can be irruptive (e.g., Grasshopper Sparrows). Given that the grassland bird guild is declining faster than any other group of birds in North America (Rosenberg et al., 2019; NABCI 2022), monitoring them both in the One Tam area of focus and the surrounding region (see next item) would align with broader conservation efforts aimed at understanding and reversing these population declines.
- **Monitoring Grasslands Outside of the One Tam Area of Focus:** Larger grassland complexes in Marin County's public lands beyond the area-of-focus boundary are also known, through historic point count surveys or anecdotal observations, to host

grassland specialists. As these areas are connected through larger grassland patch "archipelagos," they may host even more grassland-specialist potential than within the area of focus. DiGaudio and Humple (2019) recommended monitoring for grassland birds and long-term trends in these areas, including portions of Golden Gate National Recreation Area along the Highway 1 corridor; the Bolinas area; Point Reyes National Seashore's outer point and Tomales Point; and possibly areas to the east, including Mount Burdell Open Space Preserve (the location of a Point Blue/Marin County Parks 2018–2019 study; DiGaudio et al., 2020).

- **Long-Term Bird Monitoring in Other Underrepresented Habitats and Areas:** Expanding monitoring within the area of focus into areas beyond those managed by Marin Water will contribute to a better understanding of how birds are doing across habitats, jurisdictions, and geographies (see recommendations in DiGaudio & Humple, 2019). Additionally, special attention should be given to coastal scrub in the area of focus, for which we lack adequate data to determine bird status and trends; it is experiencing unique management concerns (e.g., Douglas-fir encroachment) and is critical to coastal-scrub-dependent species (e.g., Nuttall's White-crowned Sparrow; Porzig et al., 2018). This approach takes advantage of historical monitoring data, including that from Roy's Redwoods and French Ranch Open Space Preserves, Golden Gate National Recreation Area, Muir Woods National Monument, and private lands. Novel coastal scrub sites should also be considered to supplement these historical sites.
- **Continuation and Expansion of Ongoing Long-term Bird Monitoring Efforts:** Ongoing work, including the continuous monitoring programs whose data contributed to this chapter (Gardali et al., 2020, Cormier et al., 2023, Chapter 20), must continue to be funded in order to track changes in bird populations over time. We should also explore if and how such bird monitoring efforts can be expanded to address contemporaneous management concerns, such as those related to the Marin Regional Forest Health Strategy (GGNPC, 2023) and vegetation management.

Research and Data Analysis:

- **Additional Metrics:** In future Peak Health Reports, or in other data summaries, explore not only trend but also the distribution of birds to identify vulnerabilities (e.g., species associated with more restricted or declining habitats, or found in only a portion of the range in the area of study).
- **Benefits of Fuels Treatment**: Research and monitoring into short- and long-term impacts to birds of fuels treatment management actions should be conducted, during both breeding and nonbreeding seasons, expanding beyond monitoring intended to reduce deleterious impacts to nesting birds. Specifically, explore how birds may benefit from attention to healthier forest and other habitats such as through Marin Water's Biodiversity, Fire, and Fuels Integrated Plan, which focuses on active fuel-break vegetation management (Panorama Environmental, 2019) to reduce catastrophic wildfire risk and improve water quality.

- **Migratory Connectivity and Overwintering Populations:** Additional research could build off pre-existing studies on the breeding and wintering provenance of migratory songbirds and other species at study sites in the One Tam area of focus (Humple et al., 2020; Saracco et al., 2022) and nearby (Nelson et al., 2016; Cormier et al., 2016; Fraser et al., 2018). If possible, it would be advantageous to emphasize regional taxa of concern and incorporate additional technologies (e.g., Motus, given that new towers have recently been or soon will be added in the region). This will help determine how habitat and land use changes in other regions also influence the full life cycle of species that spend only a portion of their year here, and may inform local management of these bird species (Humple et al., 2020). In addition, consider expanding monitoring efforts into the winter and collating more information for wintering birds into the next iteration of this report.
- **Support to Analyze Existing Demographic Data.** Constant-effort mist-netting data collected as part of Point Blue's Palomarin Field Station and the National Park Service's riparian landbird monitoring program (Gardali et al., 2020) contains a wealth of demographic information. The data are contributed to the Institute for Bird Population's Monitoring Avian Productivity and Survivorship Program for inclusion in wider regional data summaries. Funding to support further analyses beyond those conducted to date would provide important insights into the mechanisms and consequences of observed change and should be repeated.

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CHAPTER 20. NORTHERN SPOTTED OWL (*STRIX OCCIDENTALIS CAURINA*)

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

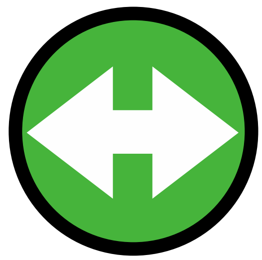
2016

Condition: Good

Trend: No Change

Confidence: High

2022



Condition: Good

Trend: No Change

Confidence: High

FIGURE 20.1 CONDITION, TREND, AND CONFIDENCE FOR THE NORTHERN SPOTTED OWL, ONE TAM AREA OF FOCUS

The Northern Spotted Owl population of Marin County, including in the One Tam area of focus, appears to be stable. The species' overall condition was determined to be good in both the 2016 report and in this update. This holds true even when updated thresholds for a change in condition or trend developed for this version are applied to 2016 data.

Other key findings for this update include:

- Pair occupancy has remained high and close to the 1999–2021 study average. The condition metric remained above the good threshold.
- Fecundity, a measure of reproductive success, varied annually but was higher in the most recent five years compared to the 1999–2021 study average as a whole. The condition metric remained above the good threshold.

- The current number of a known competitor species, the Barred Owl (*S. varia*) in Marin County is low, but the species was detected at two to five Spotted Owl sites per year between 2018 and 2022. However, this metric remained above the good threshold.

METRICS SUMMARY

Metrics in Table 20.1 were used to assess Northern Spotted Owl health in the One Tam area of focus using a county-wide dataset from long-term monitoring throughout Marin County. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain an overall condition, trend, and confidence. Each metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 20.1 ALL NORTHERN SPOTTED OWL METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1: Pair Occupancy		
	2016	**2022**
Condition	Good	Good
Trend	No Change	No Change
Confidence	High	High
Metric 2: Fecundity (Reproductive Success)		
	2016	**2022**
Condition	Good	Good
Trend	No Change	No Change
Confidence	High	High
Metric 3: Barred Owl Presence		
	2016	**2022**
Condition	Good	Good
Trend	Improving	No Change
Confidence	High	High

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

Iconic and charismatic, the Northern Spotted Owl lives in forests from southwestern British Columbia to Marin County, California. This subspecies of the Spotted Owl was listed as federally threatened in 1990 under the Endangered Species Act, and as state-threatened in 2016 under the California Endangered Species Act. One Tam land management agencies have a wealth of inventory and long-term monitoring data on this species, covering most public lands and some private lands in Marin County. Data on long-term trends in Northern Spotted Owl territory occupancy, reproductive success, and nesting habitat preferences help managers to not only track population trends and avoid nesting season disturbances, but also have the potential to evaluate the impacts of potential threats, including encroaching Barred Owls, Sudden Oak Death (SOD), and climate change.

The Northern Spotted Owl is a good indicator of Marin County's forest health because their success depends on the presence of older evergreen forested habitat. This species is an important upper-level predator that feeds on a variety of rodents, especially dusky-footed woodrats (*Neotoma fuscipes*) in this part of their range.

CURRENT CONDITION AND TREND

The Northern Spotted Owl has experienced dramatic declines throughout its range, with historic declines primarily attributed to habitat loss. In a recent analysis from 11 long-term study areas in Washington, Oregon, and California, researchers documented declines of between 2% and 9% annually for each study area. As a result, most of the study areas have only 20% to 30% of their 1995 population levels (Franklin et al., 2021). The principal negative factor was the presence of the Barred Owl, a competitor species (see the Stressors section) in Northern Spotted Owl territories. In contrast, Marin's Northern Spotted Owl population appears relatively stable, and Barred Owl numbers in Marin County remain low (Cormier & Duncan, 2021; Ellis, 2020).

In Marin County, the Northern Spotted Owl has been monitored annually since 1999, with the National Park Service primarily covering federal and California State Parks lands, and Point Blue Conservation Science (Point Blue) primarily focusing on Marin Water and Marin County Parks properties and adjacent lands, including municipal and privately owned lands. Long-term National Park Service monitoring efforts are designed to cover a series of randomly selected sites (Press et al., 2010); 39 are currently monitored and additional management sites are added as necessary. Similarly, Point Blue annually monitors a set of historically occupied territories, plus additional Northern Spotted Owl habitat that may be affected by future management actions is added as appropriate; 47 sites were monitored by Point Blue in 2021 (Cormier & Duncan, 2021).

Both the National Park Service and Point Blue follow standard U.S. Fish and Wildlife Service (USFWS) protocols for determining occupancy, and a Marin County-specific protocol is used to determine nesting status (every pair does not nest every year) and reproduction (number of young produced at each site) (USFWS, 2012; Press et al., 2010). As a result of the extensive coverage of known sites throughout Marin County and the similar patterns in occupancy and fecundity between National Park Service and Point Blue datasets, we believe this Marin-wide dataset is a good representation Northern Spotted Owl trends in the area of focus (Figure 20.2). Current monitoring efforts on and around the mountain indicate that Northern Spotted Owl territory occupancy is high and relatively steady, and that fecundity is variable (Cormier & Duncan, 2021; Ellis, 2020).

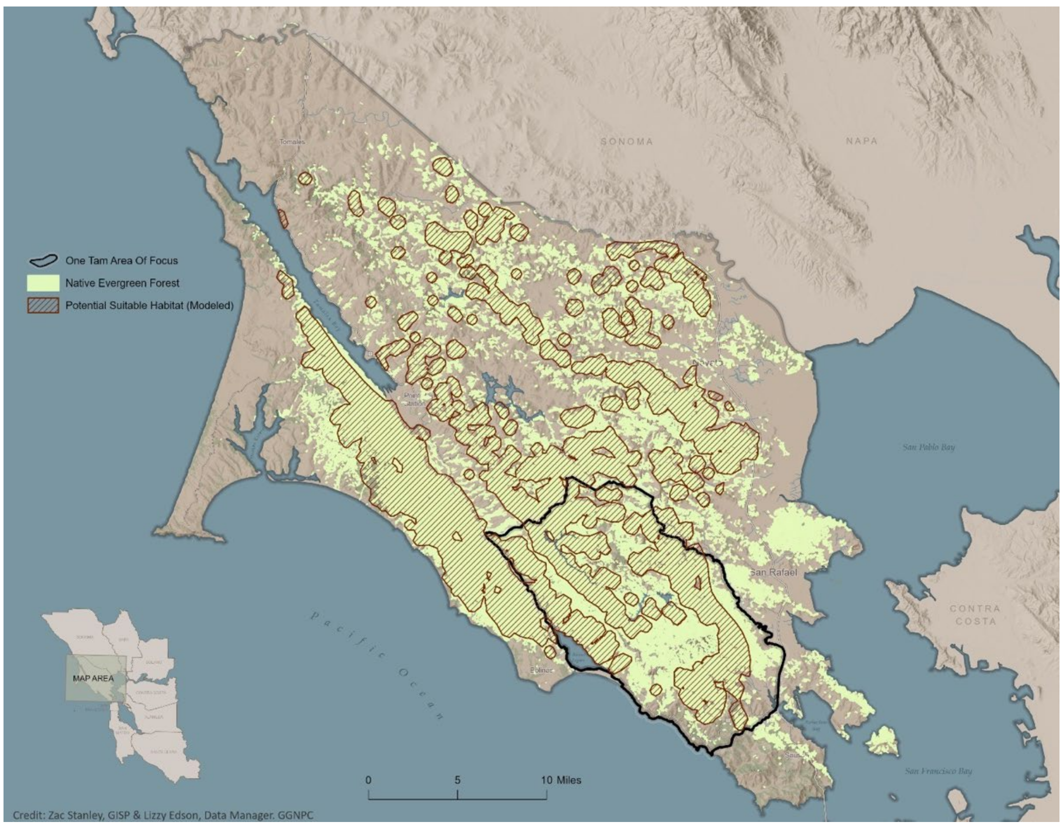


FIGURE 20.2 POTENTIAL SUITABLE NORTHERN SPOTTED OWL HABITAT (BASED ON STRALBERG ET AL., 2009) AND NATIVE EVERGREEN FOREST COVER, MARIN COUNTY (GGNPC ET AL., 2021)

DESIRED CONDITION AND TREND

The desired condition is a healthy population of Northern Spotted Owls that remains stable or increases over time.

Specifically, this requires:

- High pair occupancy.

- Stable or increasing fecundity (within the observed normal range of variability, based on monitoring data).
- Minimal threat from the Barred Owl.

STRESSORS

Historical Impacts: Early declines in the Northern Spotted Owl population were primarily attributed to the loss and adverse modification of suitable habitat throughout their range, which led to their listing as a federally threatened subspecies in 1990 (USFWS, 1990). Although Marin County's old-growth forests were harvested from the late 1880s through the 1950s (Evens, 1993), well before Northern Spotted Owl monitoring began in the late 1990s, it is reasonable to assume that the population was negatively affected by these activities.

Invasive Species Impacts: The Barred Owl, a closely related species to the Spotted Owl, is native to eastern North America but has expanded its range westward, particularly throughout the Pacific Northwest. Its range now overlaps with the entire range of the Northern Spotted Owl, and it is considered an invasive competitor and a primary threat to the latter (Wiens et al., 2021; USFWS, 2011). The Barred Owl's negative impacts on the Northern Spotted Owl, which have been well-documented (e.g., Franklin et al., 2021; Wiens et al., 2021; Dugger et al., 2016; Olson et al., 2005), include reduced rates of territory occupancy, recruitment, and apparent survival, and rates of population change that are indicative of declining populations. Recent research has shown that Northern Spotted Owl populations may be extirpated if the Barred Owl's negative impacts are not ameliorated (Franklin et al., 2021). In a recent study, management of the Barred Owl (removals) was shown to stabilize mean annual Northern Spotted Owl population change rates; in areas without Barred Owl removals, the rates of population change continued to decline (Wiens et al., 2021). In Marin County, the number of Barred Owls has remained relatively low (Cormier & Duncan, 2021; Ellis, 2020; Jennings et al., 2011), but an increase would pose an imminent threat to this relatively small Northern Spotted Owl population.

Climate Vulnerability: A number of studies have evaluated how climate and weather variables affect Northern Spotted Owl populations throughout the subspecies' range. However, the relative importance of different climate and weather metrics varies across sites and studies (e.g., Dugger et al., 2016). While studies differ in the specific metrics evaluated, some have found positive effects of colder and/or drier winters on recruitment (Dugger et al., 2016; Carroll, 2010); negative effects of cold, wet winters on reproductive success at some sites (Glenn et al., 2011); and negative effects of increased precipitation on survival rates (Carroll, 2010). The Northern Spotted Owl was not identified as an at-risk species in a climate vulnerability assessment of California birds (Gardali et al., 2012). However, other potential climate change impacts that may affect this species in Marin County include drought, catastrophic fire, or more frequent large storms, all of which could also influence their habitat and prey.

Fire Regime Change: Decades of fire suppression and the growing influence of climate change have increased the risk of larger and more intense wildfires in California. In the Northern

Spotted Owl range, the proportion of area burned is predicted to increase 10-fold by 2080 (Wan et al., 2019). As a species, the Spotted Owl has been found to use low- and moderate-severity burned areas and avoid large patches of high-severity burns (>75% tree mortality), although it has been documented using smaller patches of forest burned at high-severity (Kramer et al., 2021; Schofield et al., 2020; Roberts et al., 2011). Thus, the severity and extent of wildfire as well as other landscape features (e.g., pre-burn forest patch size) are likely to influence the Northern Spotted Owl's response to future fires in the Mt. Tam region.

Disease: SOD, caused by the water mold *Phytophthora ramorum*, affects many species of native trees in the area of focus. This disease has caused widespread die-off of oak trees and midstory species such as tanoak, changing the structure of forests occupied by the Northern Spotted Owl (Figure 20.2). These changes could have both positive and negative consequences for this species. Research conducted in Marin County demonstrated that increasing SOD disturbance resulted in a decrease in dusky-footed woodrat abundance, likely because the woodrats use oaks for food and shelter (Swei et al., 2011). On the other hand, low to moderate SOD disturbances that open up the forest understory may make it easier for the Northern Spotted Owl to hunt; however, to our knowledge, this has not been evaluated.

Pollution/Contaminants: Ingesting poisoned rodents puts the Northern Spotted Owl at risk. In general, owls living adjacent to residential areas are at greater risk than owls in other parts of their range (Hofstadter et al. 2021). Roughly a decade ago, testing done at the WildCare wildlife hospital revealed that several Northern Spotted Owls had been exposed to rodenticides; the level of impact the rodenticides had on these birds is unknown, and the WildCare testing program is no longer active (M. Piazza/WildCare, personal communication, September 2022). However, even in remote areas of California, the Northern Spotted Owl is exposed to rodenticides; researchers hypothesized that the exposure may be due to illegal marijuana cultivation sites (Gabriel et al., 2018). While less common in Marin County than in other parts of California's Northern Spotted Owl range, illegal cannabis cultivation has been documented on the county's public lands.

Direct Human Impacts: Noise disturbance from vegetation management/landscaping, traffic, construction and maintenance projects, and other human activities may negatively affect the Northern Spotted Owl (Hayward et al., 2011). Ongoing monitoring tracks nest locations to help managers avoid disruptive activities near nests on public lands, and seasonal noise disturbance regulations are in place from February to July (Northern Spotted Owl breeding season). Unfortunately, because public awareness of these noise regulations varies, owls in residential areas are particularly at risk from this kind of disturbance.

Habitat Disturbance/Conversion/Loss: In Marin County, the Northern Spotted Owl lives in a mix of forest types, including Douglas-fir (*Pseudotsuga menziesii*), coast redwood (*Sequoia sempervirens*), bishop pine (*Pinus muricata*), and even hardwoods like California bay (*Umbellularia californica*) and oaks (*Quercus* spp.). Though much of its habitat in Marin County is on protected lands, the Northern Spotted Owl also nests in and adjacent to forested residential areas, which makes both public and private lands important in maintaining habitat quality.

Genetic Isolation: In Marin County, the Northern Spotted Owl appears to be genetically isolated, with very little gene flow between it and populations to the north (Barrowclough et al., 2005). Since immigration from other areas is limited, a significant disturbance to the Marin population from any of the stressors described here could make it particularly vulnerable to declines and make recovery more challenging.

CONDITION AND TREND ASSESSMENT

METRICS

METRIC 1: PAIR OCCUPANCY

Baseline: The National Park Service, California State Parks, Marin County Parks, and Marin Water, in partnership with Point Blue, have monitored the Northern Spotted Owl in Marin County since 1999. This Pair Occupancy metric is defined here as the percentage of surveyed sites occupied by a pair of Northern Spotted Owls (other occupancy categories are Resident Single, Unoccupied, and Unknown). Because not every site is surveyed every year, we updated the methods we used to calculate this metric in 2016.

For this assessment, we only included sites that have been surveyed in at least 12 of the 23 survey years (*n* = 68, with 42–65 sites surveyed each year; Table 20.3; Figure 20.3). We expect this approach to reduce some of the variability that results from including years in which more sites are surveyed for short-term purposes (sometimes in marginal habitat). While not perfect, we believe this measure captures significant changes in Pair Occupancy in our study area. Using this updated site list, Pair Occupancy was 86% from 1999 to 2015 (NPS, 2022; Point Blue, 2021; unpublished data sets; Figure 20.3). Condition goals are the same as used in the 2016 Peak Health Report, but threshold values have been updated slightly (these updates did not change the threshold values assigned in 2016).

The five-year moving average is the average for the most recent five-year period (e.g., in 2020, the five-year moving average is the average for 2016 to 2020, and in 2021, for 2017 to 2021). The five-year moving average is useful for smoothing annual variability in the data and reducing the effects of a single bad year. In the 2016 Peak Health report, thresholds were based on the distribution of five-year-moving-average data compared to data from other studies.

Condition Goals:

- Pair Occupancy rate remains high.
- Pair Occupancy rate remains within the range of variability of the long-term average.
- Pair Occupancy rate remains in the good range.

Condition Thresholds:

- **Good:** The five-year moving average Pair Occupancy rate is >=75%, and no more than one of the five most recent five-year moving averages falls below 75%.
- **Caution:** The five-year moving average Pair Occupancy rate is <75% and >=65%, and/or more than one of the five most recent five-year moving averages is <75% and >=65%.
- **Significant Concern:** The five-year moving average Pair Occupancy rate is <65%, and/or more than one of the five most recent five-year moving averages is <65%.

Current Condition:

2016: Good

The percent of Northern Spotted Owl sites occupied by pairs from 1999 to 2015 ranged from 76% to 93% per year (average 86%; Table 20.2). In 2011–2015, the five-year moving average value was 89%, well above the good threshold, and no years had a five-year moving average below 75%, nor did any individual year have Pair Occupancy less than 75%. These values are different from the Peak Health 2016 report because we changed the number of sites included in the data summary (see the Baseline discussion).

2022: Good

From 1999 to 2021, the average Pair Occupancy rate for the Northern Spotted Owl was 85%, and the most recent five-year average (2017–2021) was 83%. Although these values are above the 75% condition threshold, the most recent five-year Pair Occupancy rate was 6% lower than the rate for 2011–2015 (89%). For 2011–2015, the rate of unoccupied sites was very low (0.3%); the number of unoccupied sites is now closer to the study average (3%). This small decrease in pair status for 2017–2021 was also driven by a slight increase in the proportion of sites classified as occupied by Resident Single owls (Figure 20.3).

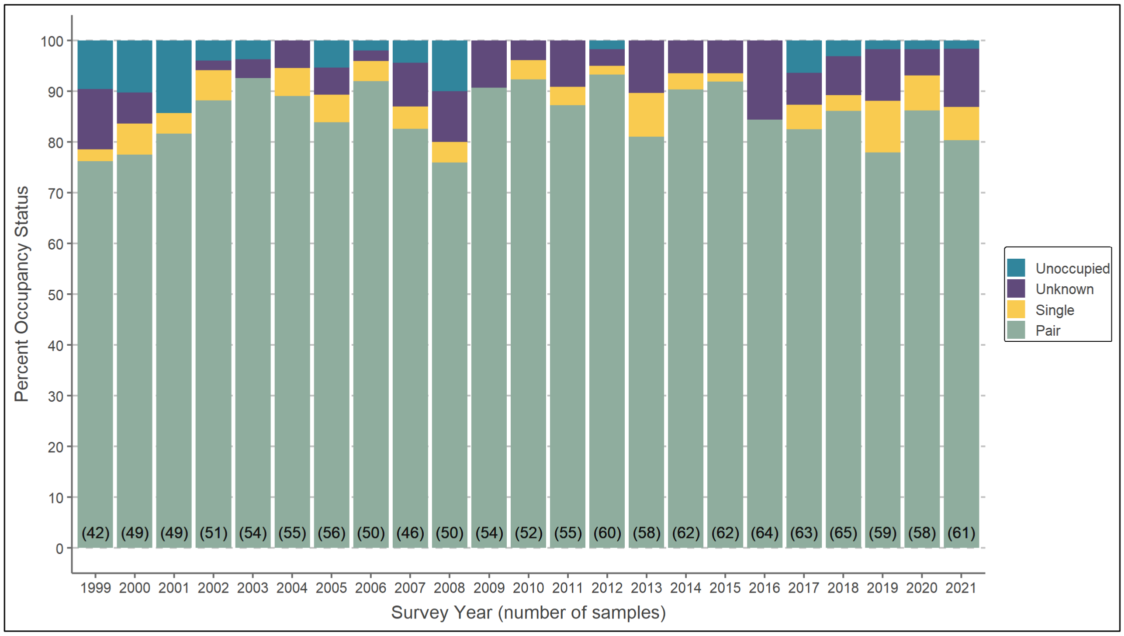


FIGURE 20.3 OCCUPANCY STATUS FOR 68 (N = 42–63 PER YEAR) MARIN COUNTY NORTHERN SPOTTED OWL STUDY SITES SURVEYED BY THE NATIONAL PARK SERVICE AND POINT BLUE CONSERVATION SCIENCE BIOLOGISTS (1999–2021)

Note: This is a subset of all sites monitored each year and represents the longest-surveyed sites (Cormier & Duncan, 2021; Ellis, 2020).

TABLE 20.2 NORTHERN SPOTTED OWL PAIR OCCUPANCY (%) AND FIVE-YEAR MOVING AVERAGE BY YEAR, NATIONAL PARK SERVICE AND POINT BLUE CONSERVATION SCIENCE MONITORING DATA (1999–2021)

Year	Sample Size	Pair Occupancy (%)	Five-Year Moving Average (%)
1999	42	76	-
2000	49	78	-
2001	49	82	-
2002	51	88	-
2003	54	93	83
2004	55	89	86
2005	56	84	87
2006	50	92	89
2007	46	83	88

Year	Sample Size	Pair Occupancy (%)	Five-Year Moving Average (%)
2008	50	76	85
2009	54	91	85
2010	52	92	87
2011	55	87	86
2012	60	93	88
2013	58	81	89
2014	62	90	89
2015	62	92	89
2016	54	84	88
2017	52	83	86
2018	56	86	87
2019	46	78	85
2020	50	86	83
2021	49	80	83
	Average	**85**	**86**
	Standard Deviation	6	2

Note: Pair Occupancy includes data from 68 sites (n = 42–63 per year), a subset of all sites monitored each year (Cormier & Duncan, 2021; Ellis, 2020).

Trend:

2016: No Change

From 1999 to 2015 (with some variation), the Northern Spotted Owl had a high Pair Occupancy rate. The threshold for caution had not been exceeded in 17 years of monitoring (Table 20.2).

2022: No Change

From 1999 to 2021 (with some variation), the Northern Spotted Owl had a high Pair Occupancy rate. The threshold for caution has not been exceeded in 23 years of monitoring (Table 20.2).

Confidence:

2016: High

The Northern Spotted Owl was monitored on an annual basis within and adjacent to the mountain on both National Park Service and California State Parks lands, as well as on and adjacent to Marin Water and Marin County Parks lands, which gave us a high degree of confidence in our condition and trend assessment.

2022: High

Similar to 2016, annual Northern Spotted Owl monitoring within and adjacent to the mountain on both National Park Service and California State Parks lands, as well as on and adjacent to Marin Water and Marin County Parks lands, continues to provide a reliable long-term data set that we can use to assess condition and trend with a high degree of confidence.

METRIC 2: FECUNDITY

Baseline: Fecundity is defined as the number of female young per territorial female (both paired females and Resident Single females). We assume a 1:1 sex ratio for the number of fledged young (total number of young fledged, divided by two), and only include territorial females if the number of young produced is definitive. While fecundity is typically lower for one- and two-year-old females compared to adults (i.e., birds that are ≥three years old; Dugger et al., 2016), we included all age classes for our fecundity calculations. While our estimates of fecundity would likely be higher if we only included data from adults, we chose to include all breeding females in order to assess reproductive success across as many sites as possible and to get a fuller picture of Northern Spotted Owl reproduction in Marin. Average fecundity from 1999 to 2015 was 0.38 (Figure 20.4). We also calculated the five-year moving average (Table 20.2) to reduce the effects of a single bad year. Condition goals are the same as used in the 2016 Peak Health Report, but threshold values have been updated (updates did not change the threshold values assigned in 2016).

Condition Goals:

- Fecundity remains high, within range of long-term average variability, and in the good range.

Condition Thresholds:

- **Good:** Five-year average fecundity is ≥0.30, and no more than one of the past five years with a five-year moving average fecundity value is <0.30.
- **Caution:** Five-year average fecundity is <0.30, and/or two or more of the past five years with a five-year moving average fecundity value <0.30.
- **Significant Concern:** Five-year average fecundity is <0.20, and/or two or more of the past five years with a five-year moving average fecundity value <0.20.

Current Condition:

2016: Good

From 1999 to 2015, Northern Spotted Owl fecundity ranged from 0.04 to 0.73 across all monitored sites, with an average of 0.38 (Figure 20.4). Fecundity typically varies year-to-year for this species. Although it remained above the good threshold, the five-year moving average fecundity values for 2013–2015 approached the 0.30 cutoff for caution, with the 2011–2015 average equal to 0.30.

Thresholds were based on the distribution of five-year moving average data and a comparison with other Northern Spotted Owl monitoring programs. Northern Spotted Owl average adult fecundity in California, Oregon, and Washington study areas ranged from 0.18 to 0.34 for demographic monitoring sites, though one additional study area in Washington had an average adult fecundity of 0.57 (Dugger et al., 2016).

When interpreting these results, it is important to remember that fecundity numbers presented for Marin County's Northern Spotted Owl were for all age classes, not just adults.

2022: Good

From 1999 to 2021, Northern Spotted Owl fecundity was 0.40, and the most recent five-year average (2017–2021) was 0.48. These values are well above the 0.30 condition threshold, and the most recent five-year fecundity rate has increased since the 2011–2015 period.

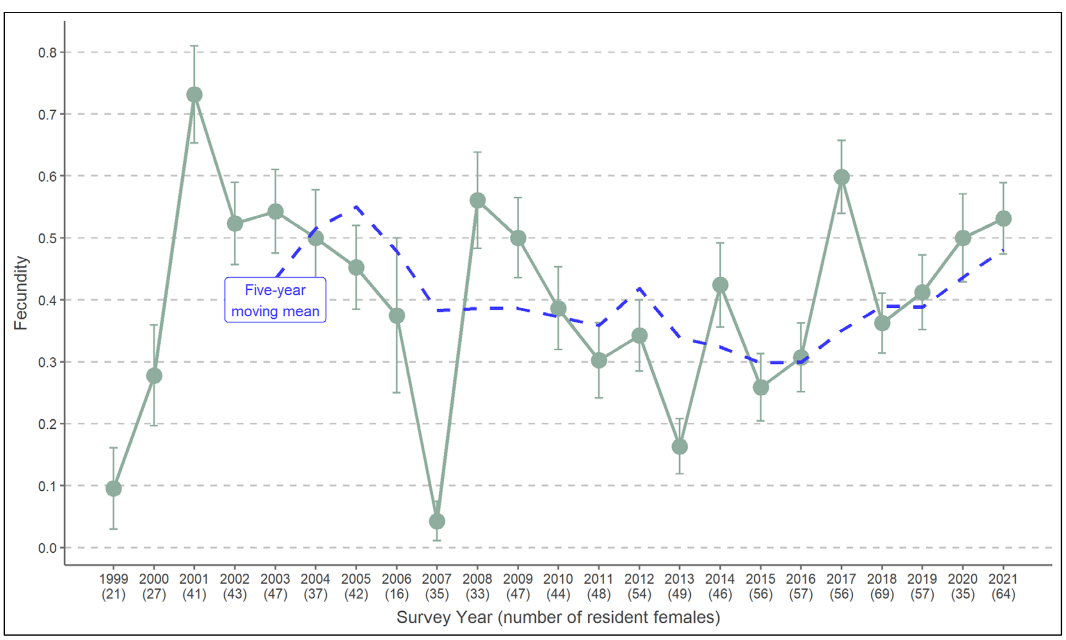


FIGURE 20.4 NORTHERN SPOTTED OWL FECUNDITY FOR 1999–2021 AND THE FIVE-YEAR MOVING AVERAGE FROM 2003–2021 FROM NATIONAL PARK SERVICE AND POINT BLUE CONSERVATION SCIENCE MARIN COUNTY MONITORING DATA

Trend:

2016: No Change

Fecundity appeared to be within the expected range of variation, although 1999 and 2007 were particularly bad years with very few Northern Spotted Owl young fledged. Managers had been concerned that during the 2011–2015 period, only 2014 had a fecundity value above the long-term average, and that annual fecundity and the five-year moving average appeared to be trending downward (Figure 20.4).

2022: No Change

Since the 2016 report, fecundity appears to be within the expected range of variation; four of the last five years had above-average fecundity values. Fecundity has remained in good condition, with the most recent years having higher fecundity than the 2011–2015 period (Figure 20.4).

Confidence:

2016: High

The Northern Spotted Owl was monitored on an annual basis within and adjacent to Mt. Tam on both National Park Service and California State Parks lands, as well as on and adjacent to Marin Water and Marin County Parks lands, providing a reliable long-term data set that gives us high confidence in our assessments.

2022: High

As in 2016, annual Northern Spotted Owl monitoring within and adjacent to Mt. Tam on both National Park Service and California State Parks lands, as well as on and adjacent to Marin Water and Marin County Parks lands allows us to assess condition and trend with a high degree of confidence.

METRIC 3: BARRED OWL PRESENCE

Baseline: The Barred Owl was first detected in Marin County at Muir Woods in 2002, and was first confirmed breeding in Muir Woods in 2007 (Jennings et al., 2011). Two Barred Owls were confirmed in Olema Valley during that period and into the 2010s. In 2015, two Barred Owls were collected from Marin County as part of a research project led by UC Berkeley in partnership with the California Academy of Sciences (Ellis, 2017). Another Barred Owl that had been previously captured and fitted with a radio transmitter was found dead in Muir Woods in 2015. However, based on National Park Service and Point Blue surveys and eBird data (ebird.org), there were no confirmed Barred Owls in Marin County as of the end of the 2015 breeding season (two had been detected earlier that season, as presented in Table 20.3). The condition threshold for

Barred Owl presence has been updated since the first Peak Health Report, to incorporate the five-year average rather than considering only the current year.

We present the number of Northern Spotted Owl sites where Barred Owls had/have been detected each year. In some cases, a single Barred Owl may be detected at more than one Northern Spotted Owl site. We count each Northern Spotted Owl site with a Barred Owl detection because a single Barred Owl could have negative effects on every Northern Spotted Owl it encounters. We recognize that this is an imperfect measure because a pair of Barred Owls occupying one Northern Spotted Owl site most of the time may have a greater negative effect than a single Barred Owl infrequently moving in and out of that territory. We also present the minimum number of known individuals (Table 20.3).

Condition Goal: No Barred Owls present, which is the historic condition for Marin County (Jennings et al., 2011).

Condition Thresholds:

- **Good:** In the most recent year, two or fewer of Marin County's Northern Spotted Owl sites are occupied by Barred Owls and no more than one of the five most recent five-year moving averages is above six Barred Owl-occupied sites.
- **Caution:** In the most recent year, three to six of Marin County's Northern Spotted Owl sites are occupied by Barred Owls, and/or no more than two of the five most recent five-year moving averages are above six Barred Owl–occupied sites.
- **Significant Concern:** In the most recent year, more than six of Marin County's Northern Spotted Owl sites are occupied by Barred Owls and/or more than two of the five most recent five-year moving averages is above six Barred Owl–occupied sites.

TABLE 20.3 NUMBER OF NORTHERN SPOTTED OWL MONITORED SITES WITH BARRED OWL DETECTIONS, FIVE-YEAR MOVING AVERAGE, AND KNOWN MINIMUM NUMBER OF INDIVIDUALS (FROM NATIONAL PARK SERVICE AND POINT BLUE CONSERVATION SCIENCE MONITORING DATA, 1999–2022)

Year	Number of Spotted Owl Sites with Barred Owl Detections	Five-Year Moving Average of Spotted Owl Sites with Barred Owl Detections	Known Minimum Number of Individual Barred Owls
1999	0		0
2000	0		0
2001	0		0
2002	1		1
2003	0	0	0
2004	2	1	2
2005	8	2	4
2006	7	4	3–4

Year	Number of Spotted Owl Sites with Barred Owl Detections	Five-Year Moving Average of Spotted Owl Sites with Barred Owl Detections	Known Minimum Number of Individual Barred Owls
2007	4	4	3–6
2008	8	6	3--6
2009	4	6	4–7
2010	4	5	4–7
2011	4	5	7–8
2012	4	5	5–6
2013	3	4	4–6
2014	2	3	2
2015	2	3	2–3
2016	0	2	0
2017	2	2	1–2
2018	2	2	3–4
2019	4	2	4–5
2020	5	3	5–6
2021	2	3	6
2022	2	3	4
Average	**3**	**3**	
Standard Deviation	2	2	

Note: The minimum number of individuals can be less than the number of Barred Owl sites if Barred Owl detections at nearby Northern Spotted Owl sites are suspected to the be the same individual.

Current Condition:

2016: Good

There were no confirmed Barred Owls within monitored Northern Spotted Owl areas in Marin County in 2015 (the last year included in the first Peak Health report), although Barred Owls had been detected at two sites previously that year, and in low numbers in previous years (Ellis, 2017; Cormier, 2015). The five-year average was less than six sites between 2011 and 2015.

2022: Good

In recent years, Barred Owl detections in Marin County have fluctuated from zero in 2016 to individuals at six different locations in 2020 (five of the six sites being Northern Spotted Owl study sites [Cormier, 2020; Ellis, 2020; NPS, unpublished data]). Four Barred Owls were detected at two sites in Marin County in 2022. All four birds detected in 2022 and six individuals in 2021 were collected as part of a research project led by the University of Wisconsin in conjunction with the California Academy of Sciences (Hofstadter, unpublished data). See Past and Current Management, Restoration, Monitoring, and Research Efforts for more information about this study. The number of known Barred Owls detected at Northern Spotted Owl sites in 2022 and the five-year moving average both remained above the threshold for a good condition.

Trend:

2016: Improving

At least three Barred Owls were thought to occur in Marin County at the start of 2015. However, after the previously described collection and monitoring efforts, no Barred Owls were known to occur in the county.

2022: No Change

The Barred Owl has been detected in low numbers (at two to five Spotted Owl-monitored sites) in the past five years (2018–2022), and their overall numbers are similar to the 2016 Peak Health assessment.

Confidence:

2016: High

Barred Owl detections were recorded during annual Northern Spotted Owl monitoring by the National Park Service and Point Blue. The National Park Service conducted annual Barred Owl surveys in areas outside Northern Spotted Owl monitoring territories in 2012 to 2015. Biologists also monitored Barred Owl reports on eBird.

2022: High

The National Park Service and Point Blue are continuing to record Barred Owl detections that occur during Northern Spotted Owl surveys and monitor eBird for detections reported by the local birding community. In 2020, Point Blue conducted Barred Owl–specific occupancy surveys throughout forested habitat in nine Marin County Parks open-space preserves. These surveys included coverage of Northern Spotted Owl–monitored sites as well as forested habitat within those preserves not surveyed for Spotted Owls and/or not considered Spotted Owl habitat. Only one new Barred Owl site was confirmed through this effort (Duncan & Cormier, 2020). Additionally, the National Park Service has deployed acoustic recording units on their lands to detect the Northern Spotted Owl and Barred Owl (see Current Research for more details). Results from these combined efforts suggest that Barred Owl numbers are still relatively low in Marin County.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

As described, the Northern Spotted Owl has been well studied in Marin County, including within the area of focus. Monitoring objectives include determination of Northern Spotted Owl site occupancy rates and fecundity, and evaluation of nest site characteristics. In addition, information on the Barred Owl is recorded during Northern Spotted Owl surveys; a Barred Owl inventory was conducted on Marin County Parks lands in 2020 (Duncan & Cormier, 2020), and the National Park Service uses acoustic recording units to detect Barred Owls on their lands (Lesmeister et al., 2022; NPS, unpublished data).

INFORMATION GAPS

Survivorship: Survivorship, or the probability that an owl (in this case, the Northern Spotted Owl) survives and stays in the study area from one year to the next, is measured by banding and resighting during annual monitoring. Tracking marked individuals also provides information on territory location shifts over time. Limited resources forced the National Park Service and Point Blue to stop banding the Northern Spotted Owl in 2003; thereafter, survey efforts focused on the continued collection of territory occupancy and fecundity data. Incorporating survivorship into our monitoring program would allow us to evaluate which environmental variables drive survival in Marin. It would also put our results into context when comparing them to other long-term Northern Spotted Owl demographic monitoring areas in which survivorship is measured (Franklin et al., 2021).

Factors Affecting Fecundity: Weather and climate, landscape and habitat, and the presence of the Barred Owl affect Northern Spotted Owl fecundity across the species' entire range, but their effects have not been specifically studied in Marin County or the area of focus. Point Blue and the National Park Service are currently collaborating on an evaluation of the ways weather and climate variables have an impact on whether a site is occupied, and whether or not owls at occupied sites reproduce. Point Blue is also working with a graduate student on an assessment of the impact of habitat features on reproductive success in Marin County.

Barred Owl Information: Understanding the origins of Marin County's Barred Owls (e.g., whether they are offspring of a local pair or immigrated from elsewhere) would increase our understanding of how to manage this species. Collecting data on Barred Owl immigration and genetics would benefit the conservation of Northern Spotted Owls.

Habitat Change (Sudden Oak Death, Climate Change, Wildfire): Northern Spotted Owl habitat in Marin County has and will continue to change over time, but we lack data on how the owls may respond to these changes. For example, it is unclear how observed changes in habitat as a result of SOD may affect the species. We also lack predictions for different levels of wildfire risk in Marin's Northern Spotted Owl habitats; how these forested habitats may be altered by climate change; and how those changes may affect the Northern Spotted Owl.

Dispersal: We lack data on juvenile dispersal (i.e., where young birds go after leaving their natal territory) and where they go while waiting for opportunities to occupy breeding territories. Banding studies (see Survivorship) would increase our understanding of dispersal.

Diet: Understanding how diet affects the Northern Spotted Owl in Marin County can help us predict how the species may respond to changes in its environment as well as aid in its conservation. For example, does diet fluctuate in response to weather and climate; does diet vary geographically (e.g., by forest type, or proximity to urban areas); and/or does diet impact reproductive success, and if so, how?

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Barred Owl Surveys: In 2020, Marin County Parks contracted with Point Blue to conduct Barred Owl–specific occupancy surveys throughout forested habitat in nine of their open space preserves. Surveys included monitored Northern Spotted Owl areas as well as other forested habitat within those preserves not surveyed for the Spotted Owl and/or not considered Spotted Owl habitat. Only one new Barred Owl site was confirmed through this effort (Duncan & Cormier, 2020).

Barred Owl Research: The National Park Service, California Academy of Sciences, and University of Wisconsin initiated a Barred Owl research project in 2021. Objectives of this ongoing project are to study Barred Owl genetics, diet, and exposure to rodenticides. The sampling objectives require the collection of Barred Owls for these analyses. A final objective is to study how the adjacent Northern Spotted Owl responds to Barred Owl collections (e.g., does the Spotted Owl return to the study site if it moved or was not detected when the Barred Owl(s) immigrated to the site?). Six Barred Owls were collected in 2021 and four in 2022. Analysis of the specimens has been initiated, but results have not been completed.

Acoustic Monitoring: In 2021, the National Park Service added annual acoustic recording unit (ARU) monitoring to 28 fixed locations in Northern Spotted Owl habitat in Marin County. This project is coordinated with a regional study led by the U.S. Forest Service's Pacific Northwest Research Station (Lesmeister et al., 2022). In 2021, the National Park Service added an additional 101 ARU sites, and another 92 in 2022 to inventory for the Barred Owl. Results from 2021 indicate that most of the habitat monitored by the National Park Service was occupied by the Spotted, not the Barred Owl, a pattern opposite that determined in study areas north of Marin County. The few sites with ARU-confirmed Barred Owl detections were already known to the National Park Service.

Human Impacts Research: In 2021 and 2022, Point Blue contributed to a research project that aims to understand the Northern Spotted Owl's stress response to anthropogenic proximity. Point Blue biologists collected Spotted Owl fecal samples at sites surveyed for Marin Water and Marin County Parks, and other samples are being collected by survey crews in other parts of the owl's range. This research is led by a University of Oxford graduate student, and data analysis is in progress as of the writing of this chapter.

Status and Vulnerability Assessment: In 2022, the National Park Service contracted with Point Blue to develop a synthesis of the current state of the Northern Spotted Owl in Marin County, to assess their current vulnerability and exposure to threats, and to make conservation recommendations. This work will include the compilation of regional information on the Barred Owl to further assess that particular threat. Other threats to be investigated are likely to include climate change, habitat loss, wildfire, SOD, rodenticide poisoning, genetic isolation, and noise disturbance. This work is scheduled to be completed in 2024.

Regional and Range-Wide Conservation: Dave Press (National Park Service) is a member of the California Department of Fish and Wildlife's Barred Owl Science Team, an advisory group that provides guidance on addressing the threat the Barred Owl poses to the Northern and the California Spotted Owl. Bill Merkle (National Park Service) is a member of a team supporting the USFWS in developing a strategy for managing the Barred Owl throughout the Northern Spotted Owl's range. The USFWS recently published a Notice of Intent to develop a draft Environmental Impact Statement for a Barred Owl management strategy; it is due to be completed by the end of calendar year 2023.

Past Work

Below are some of the previous stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Management: Habitat protections and breeding season noise disturbance avoidance rules were established for the Northern Spotted Owl.

Monitoring:

- Data on territory occupancy rates, fecundity, and nest-site characteristics have been collected.
- Information on Barred Owls is recorded during Northern Spotted Owl surveys.

Inventories: Northern Spotted Owl surveys were conducted by the National Park Service in the late 1980s and early 1990s, with more complete inventories undertaken in 1997, 1998, and 2006 on National Park Service and California State Parks lands.

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as part of the development of this report. These actions are not currently funded through agency programs, and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

- **Survivorship Monitoring:** Add monitoring for key demographic parameters, including adult and juvenile survival, to help assess this at-risk species' most limiting lifecycle stage.
- **SOD Impacts:** Design a study to determine if this disease has had an impact on the owl's behavior, breeding success, nest-site availability, prey species.

- **Diet Analysis**: Assess Northern Spotted Owl prey in Marin County. Determine if there are differences in prey by habitat and/or proximity to urban areas, and if prey selection changes in response to environmental variables (e.g., rainfall, temperature). Additionally, we could assess whether there are prey differences (e.g., species composition, relative abundance, and seasonality of prey) between pairs that nest successfully and pairs that do not produce young. These questions could be informed by analyzing pellets that have been collected over the years during surveys. Further, since dusky-footed woodrats are the primary food item for Northern Spotted Owls in Marin County, research to better understand woodrat distribution and abundance in different forest types would also be an important source of information for understanding the Northern Spotted Owl in Marin County (see Chapter 25, Wildlife Indicator Needs Statements).

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CHAPTER 21. OSPREY (*PANDION HALIAETUS*)

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

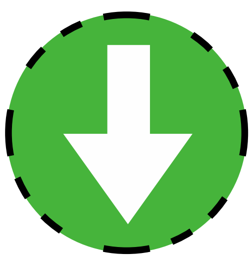
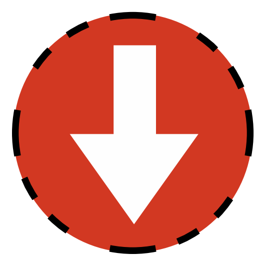
2016	2022
	
Condition: Good	**Condition:** Significant Concern
Trend: Declining	**Trend:** Declining
Confidence: Moderate	**Confidence:** Moderate

FIGURE 21.1 CONDITION, TREND, AND CONFIDENCE FOR THE OSPREY, ONE TAM AREA OF FOCUS

Ongoing, long-term Osprey monitoring at Kent Lake continues to provide data we can use to assess the species' condition and trend with a high degree of confidence. The most notable change since the 2016 report is the decrease in our assessment of its overall condition from good to significant concern. This is primarily as a result of a decrease in reproductive effort (Metric 1), which went from good to significant concern because of a precipitous decline in the number of occupied and active nests between 2017 to 2022. We are not certain what caused this decline but expect that it is due to a number of reasons (including competition with Bald Eagles) rather than a single cause. A less dramatic but still concerning decrease in habitat condition from good to caution was measured by Metric 3, which looks at the number of available nest trees.

METRICS SUMMARY

Metrics in Table 21.1 were used to assess Osprey health at Kent Lake. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 21.1. Each metric is described in the Condition and Trend Assessment section later in this chapter. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 21.1 ALL OSPREY METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE

Metric 1: Measures of reproductive effort		
	2016	**2022**
Condition	Good	Significant Concern
Trend	Declining	Declining
Confidence	High	High
Metric 2: Annual reproductive success		
	2016	**2022**
Condition	Unknown	Unknown
Trend	Unknown	Unknown
Confidence	Low	Low
Metric 3: Habitat		
	2016	**2022**
Condition	Good	Caution
Trend	No Change	No Change
Confidence	High	High

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

The Osprey is a charismatic and iconic raptor species that breeds in lakes and reservoirs in the One Tam area of focus. Because it feeds almost exclusively on fish, breeding success is a good indicator of water quality and fish abundance. The Kent Lake colony was first established in the mid-1960s and has been monitored continuously by Marin Water since 1981, making it one of the longest-running Osprey nesting studies in the Pacific region.

CURRENT CONDITION AND TREND

Following range-wide population declines in the 19th and early 20th centuries caused by persecution and environmental contamination, the Osprey was listed as a California Species of Special Concern. Over the last several decades, the U.S. population has recovered from its historic declines, but the species continues to be protected by the Migratory Bird Treaty Act. Because it is sensitive to environmental perturbations, the Osprey is now considered an ideal worldwide sentinel species (Grove et al., 2009).

The Kent Lake Osprey colony was established after the reservoir was created in the 1950s. The colony grew over the ensuing years, peaking in the mid-1990s. It then entered a period of gradual decline during the subsequent two decades (Figure 21.2) The population has continued to decline, with a notable downward trend since about 2017 (Figure 21.3). From 2020 to 2022, the number of active nests fell to a lower level than in any previous year in the more than three decades this population has been studied (ARA, 2022).

Recent monitoring suggests the colony is currently about one-quarter its former size. The subpopulation on Inverness Ridge, west of Kent Lake, has also declined in recent years (Evens & Brake, 2022). Elsewhere in the San Francisco Bay Area, the number of active Osprey nests has increased over the same period (Evens & Brake, 2022). Given the timing of these shifts, it appears that the Kent Lake colony was foundational and contributed to the overall growth of the regional population.

The causes of the decline seen at Kent Lake are unknown but are likely multifaceted. Possible explanations include: a shift in regional nesting distribution, long-running competition with a pair of nesting Bald Eagles (*Haliaeetus leucocephalus*), changing ecological conditions affecting fisheries and foraging success, changes In the Osprey's wintering grounds, and/or changing patterns of recruitment in the nesting colony. Depredation at nesting trees may also be a contributing factor, at least on Inverness Ridge (Evens, 2022).

DESIRED CONDITION AND TREND

The desired condition for Osprey in the Mt. Tam area of focus is a healthy nesting population that remains stable over time. This requires high levels of pair occupancy and annual reproductive success that is maintained within the normal range of variability, or above long-term average values based on recent historical monitoring.

STRESSORS

Climate Vulnerability: The Osprey requires large, open bodies of water for foraging. Extended periods of drought may cause dramatic and sustained drops in lake levels that could have a negative impact on the species' fledging success. However, the severity of these effects depends on their impact on fish populations; an increase in shallow-water habitat may actually improve the Osprey's ability to catch its prey. The Osprey is also able to range rather far from its nest site to forage, which may provide some resiliency in the face of changes in food availability. For example, Ospreys nesting at Kent Lake may travel to coastal estuaries (e.g., Bolinas Lagoon) or San Francisco or San Pablo Bays to forage. The downside to this strategy is that the increased energy these journeys require may affect the species' reproductive success. The Osprey also needs tall structures for nesting. Increased storm intensity with climate change could increase vulnerability of large trees/snags, causing them to blow down and reducing nest site availability.

Pollution/Contaminants: Osprey populations were seriously affected by contaminants (primarily chlorinated hydrocarbons, but also mercury) in the mid-20th century. Kent Lake Osprey are still potentially threatened by contaminants in nearby areas where they are known to forage. For example, DDT residues continue to be found in the northern San Francisco Bay. Sublethal levels of mercury were also documented in more than one quarter of 3,000 fish sampled in the San Francisco Bay (U.S. EPA, 2015; Ackerman et al., 2014; Buzby et al., 2021).

Predation/Competition: Bald Eagles recolonized Kent Lake in 2008, and there are now several on Inverness Ridge and around San Francisco Bay. These large and aggressive raptors steal fish from Ospreys, increasing the amount of energy the Osprey has to expend to catch and deliver fish to its nest. Nest-site depredation by other predators is poorly documented, but several common local species (e.g., bobcat [*Lynx rufus*], Common Raven [*Corvus corax*], and Great Horned Owl [*Bubo virginianus*]) pose potential threats (Evens, 2022).

CONDITION AND TREND ASSESSMENT

METRICS

METRIC 1: MEASURES OF REPRODUCTIVE EFFORT

Baseline: Osprey reproductive effort is broken into two primary components: number of occupied nests and the nest site occupancy rate (the number of active nests as a percent of occupied nests). When the 2016 baseline was set, annual monitoring showed an average of 38 occupied Osprey nests at the Kent Lake colony between 2003 and 2015. An average of 72% of occupied nests became active (i.e., eggs that reached the incubation stage) (Evens, 2015), with one outlier of low active/occupied nests in 2004 (Table 21.2). In subsequent years (2017–2022), the ratio of occupied to active nests remained relatively stable, but the overall number of occupied and active nests declined rather precipitously (Table 21.2; ARA, 2022; Evens & Brake, 2022).

Condition Goal: Reproductive effort (number of occupied nests and occupancy rate) remains within the range of values recorded over the last decade.

Condition Thresholds:

- **Good:** An average of >25 occupied nests *and* an average nest site occupancy of ≥70% over the previous 10 years, with a <25% decline in nest-site pair occupancy over the previous three years.
- **Caution:** An average of 25 occupied nests *and* an average nest-site occupancy of 50%–70%, or a 25%–50% decline in nest-site pair occupancy over the previous three years
- **Significant Concern:** An average of <25 occupied nests *and* an average nest-site occupancy <50%, or a >50% decline in nest-site pair occupancy over the previous three years.

Current Condition:

2016: Good

Nest site occupancy had been above 75% for all but four of the previous 13 years (Table 21.2).

2022: Significant Concern

The number of occupied nests and active nests declined precipitously between 2017 and 2022 (Figure 21.2), falling >50% for both measures during that six-year period. As mentioned, that decline was ameliorated somewhat by a concurrent increase in the regional population (Evens & Brake, 2022).

TABLE 21.2 MEASURES OF KENT LAKE OSPREY REPRODUCTIVE EFFORT, 2003–2022 (ARA, 2022)

Year	Total Nests	Occupied Nests	Number Active (at least one chick)	Nest-Site Occupancy Rate (active/occupied nests)
2003	49	42	Unknown	Unknown
2004	53	45	18	0.4
2005	59	50	44	0.88
2006	54	44	37	0.84
2007	52	42	29	0.69
2008	50	52	21	0.5
2009	49	43	27	0.63
2010	42	31	27	0.87
2011	46	34	28	0.82
2012	40	32	27	0.87

Year	Total Nests	Occupied Nests	Number Active (at least one chick)	Nest-Site Occupancy Rate (active/occupied nests)
2013	40	28	19	0.68
2014	36	25	14–25	0.56–1
2015	33	28	21	0.75
2016	31	19	16	0.84
2017	38	26	20	0.77
2018	29	19	13	0.68
2019	24	19	12	0.63
2020	20	11	9	0.82
2021	22	13	9	0.69
2022	20	11	8	0.73
Average	**39.4**	**30.2**	**21.3**	**0.72**

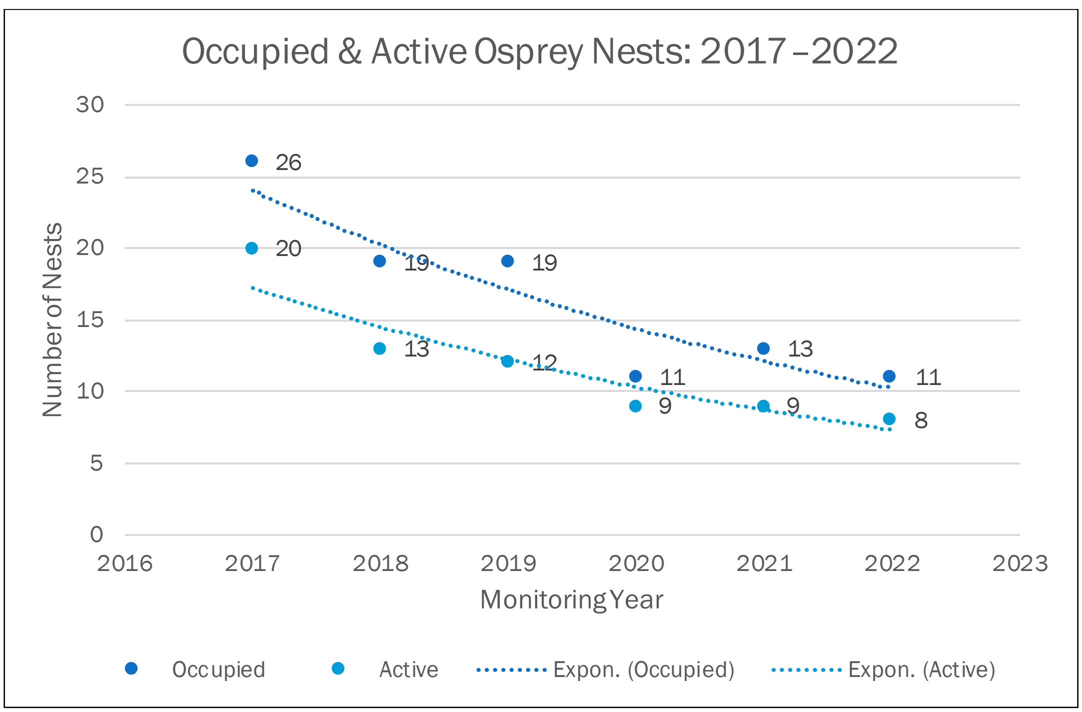


FIGURE 21.2 DOWNWARD TREND IN BOTH OCCUPIED AND ACTIVE NESTS, KENT LAKE, 2017–2022 (ARA, 2022)

Trend:

2016: Declining

The Kent Lake Osprey colony was founded sometime after the original filling of Kent Lake, which was built in 1954. The first nest survey in 1981 showed 11 active nests (Evens, 2015; ARA, 2022). Additional flooding in 1983 killed many of the edge trees, increasing the number of available Osprey nest sites. The number of active nests continued to rise until 1994, when it seemed to plateau at between 35 and 46 active nests. Beginning in 2005, the measure follows a downward trend to 21 in 2015 (Figure 21.3; Evens, 2015).

2022: Declining

Figures 21.2 and 21.3 show a continuing downward trend in nesting pairs following the 2015/2016 monitoring seasons.

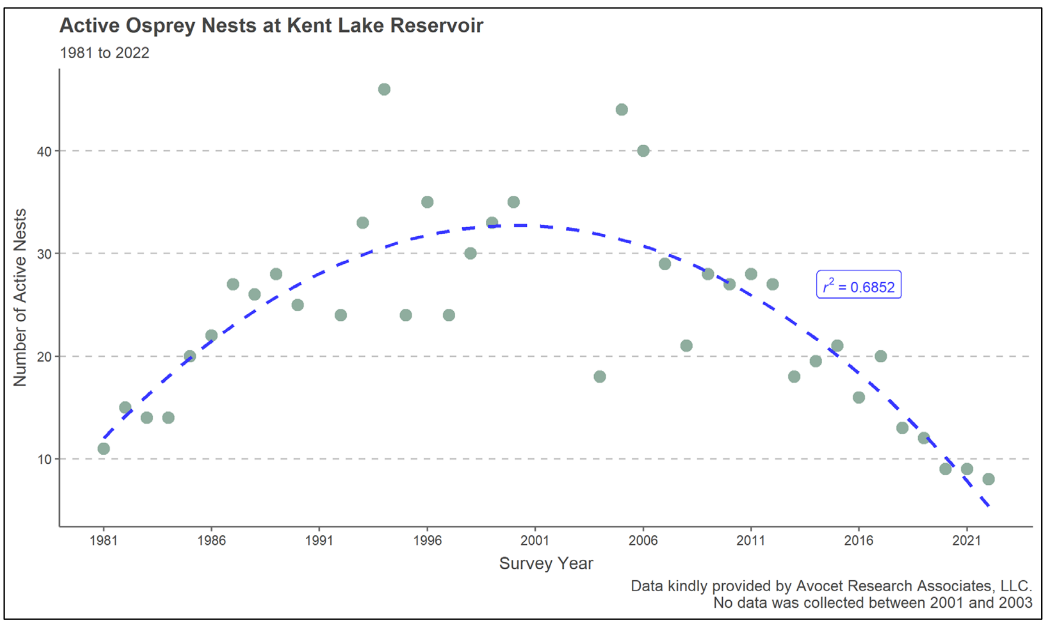


FIGURE 21.3 KENT LAKE OSPREY NESTING PAIRS, 1981–2021 (ARA, 2022)

Confidence:

2016: High

Jules Evens and associates of Avocet Research have conducted annual nest surveys of the Kent Lake colony during 33 nesting seasons since 1981 (excluding 1991, 2001, and 2002), providing reliable data upon which to assess this metric.

2022: High

Annual monitoring has continued through 2022, continuing the long-term data set that gives us high confidence in our results.

METRIC 2: ANNUAL REPRODUCTIVE SUCCESS

Baseline: Reproductive success refers to the number of nestlings fledged from active nests (nests that persist into the incubation stage of the nesting cycle). The reproductive-success threshold for a viable Osprey nesting population throughout their range is 0.8–1.3 chicks per nest per year (Henny & Wight, 1969; Spitzer & Poole, 1980; Poole, 1989). Between 1981 and 2000, minimum reproductive success at the Kent Lake colony averaged 1.4 chicks per nest (+0.37) (Evens, 2001).

Condition Goal: An annual reproductive success rate of good as defined below.

Condition Thresholds:

- **Good:** Annual reproductive success in the range of 0.8–1.3 chicks per nest per year, or higher, or <30% decline in annual reproductive success over a consecutive three-year period.

- **Caution:** Annual reproductive success of <0.8–1.3 chicks per nest per year, or a 30%–50% decline in annual reproductive success over a consecutive three-year period.

- **Significant Concern:** Annual reproductive success declines >50% over a consecutive three-year period.

Current Condition:

2016: Unknown

The reproductive success of the Kent Lake Osprey colony had not been systematically monitored since 2000, and we did not know the actual productivity values (number of fledglings per nest). However, the multiyear presence of approximately 20 active nests late in the nesting season, often with chicks present, suggested some degree of nesting success.

2022: Unknown

As was true in 2016, the reproductive success of the Kent Lake Osprey colony has not been systematically monitored since 2000, and we still do not have actual productivity values (number of fledglings per nest). However, the multiyear presence of approximately 10 active nests late in the nesting season, often with chicks present, suggests the possibility of moderate nesting success.

Trend:

2016: Unknown

A lack of recent observational data made it impossible for us to state a trend for Osprey annual reproductive success. That said, while monitoring efforts had detected early abandonment of the nesting effort at some occupied nests, the persistence of a proportion of nests into the "active" phase of the nesting cycle suggested that some nests had successfully fledged chicks.

2022: Unknown

As with the 2016 assessment, the lack of recent observational data in the fledging phase of the nesting effort makes it impossible for us to state a trend for Osprey annual reproductive success in 2022. That said, while monitoring detected early abandonment of the nesting effort at some occupied nests, the persistence of a proportion of nests into the "active" phase of the nesting cycle suggests that some nests successfully fledged chicks.

Confidence:

2016: Low

Our confidence in this assessment was low because systematic monitoring of reproductive success has not been conducted since 2000.

2022: Low

Our confidence in this assessment remains low for the same reason.

METRIC 3: HABITAT

Baseline: Marin Water currently records nest trees' species and status (i.e., living or dead [snags]). Kent Lake Osprey have nested only in trees since the colony's inception, including coast redwood (*Sequoia sempervirens*), and Douglas-fir (*Pseudotsuga menziesii*). In 2015, "dead redwood" was the most common class of nesting tree, hosting nearly 43% of all Kent Lake Osprey nests (Table 21.3; Evens, 2015). By 2022, the species' nesting-tree preference had shifted, with about 35% in Douglas-fir and 65% in coast redwoods. The use of live trees (60%) outweighed the use of snags (40%).

Condition Goal: Continued availability of suitable nesting sites provided by a mix of live trees and snags, particularly coast redwood.

Condition Thresholds:

- **Good:** Coast redwoods and Douglas-firs, live and snags, at the Kent Lake shoreline are available in numbers comparable to Osprey nesting stands from 2006 to 2015 (Table 21.3).
- **Caution:** There is a loss of many (>30% but <50%) of live trees and snags at the Kent Lake shoreline.
- **Significant Concern:** There is a loss of a significant number (>50%) of live trees and snags at the Kent Lake shoreline.

TABLE 21.3 SPECIES AND STATUS (LIVING/DEAD) OF OSPREY NEST TREES AT KENT LAKE, 2015 (ARA, 2022)

Tree Class	Douglas-fir (% of Total)	Redwood (% of Total)	Unknown	Total (% of Total)
Live	3 (10.7)	10 (35.7)	0 (0)	13 (46.4)
Dead (Snags)	1 (3.4)	12 (42.9)	1 (3.6)	14 (50.0)
Unknown	0 (0)	0 (0)	1 (3.6)	1 (3.6)
Total	**4 (14.1)**	**22 (78.6)**	**2 (7.1)**	**28 (100.0)**

Current Condition:

2016: Good

In 2015, there were 28 nesting trees, which established the threshold for a condition of good for this metric.

2022: Caution

In 2022, there were 20 nesting trees (Table 21.4), a 29% decrease, which shifted the condition from good to caution. It is important to note that although the current Osprey colony at Kent Lake is apparently viable (healthy), the recent reduction in the number of active nests suggests that, realistically, further declines may be expected. For these reasons, it is important that nesting trees remain available for the Osprey, as well as for the Bald Eagle, Purple Martin (*Progne subis*), and perhaps other rare and at-risk species.

TABLE 21.4 SPECIES AND STATUS (LIVING/DEAD) OF OSPREY NEST TREES AT KENT LAKE, 2022 (ARA, 2022)

Tree Class	Douglas-fir (% of Total)	Redwood (% of Total)	Total (% of Total)
Live	7 (35.0)	5 (25.0)	12 (60.0)
Dead (Snags)	0 (0)	8 (40.0)	8 (40.0)
Total	**7 (35.0)**	**13 (65.0)**	**20 (100.0)**

Trend:

2016: No Change

Data on tree species and type going back to 1981 showed no directional trend.

2022: No Change

Data still show no directional trend; at the time of publication of this report, we do not yet know if late-2022 storms brought down more trees.

Confidence:

2016: High

Tree counts and conditions had been assessed as recently as 2015 (Evens, 2015).

2022: High

Current data on tree types with functional nests were used to assess the condition and trend for this metric.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

Two biologists visit the Kent Lake Osprey colony twice annually to determine location and distribution of occupied and active Osprey and Eagle nests in the watershed. These visits are timed to coincide with the height of the nesting cycle (April–June). The entire reservoir is surveyed by boat, and each nest is located and recorded. Tree species and class (i.e., living or dead) are also recorded and mapped. Findings are then summarized in an annual report. (See Evens [2015] and ARA [2022] for a full description of this monitoring program and its methods.)

INFORMATION GAPS

Reproductive Success: An increase in annual monitoring effort would allow us to determine the colony's actual productivity (fledging success). Currently, assumptions are made based on the number of birds that remain on nests late in the season but prior to the fledging period.

Prey Ecology: Foraging patterns, locations, and prey availability are not well known, nor are the ecological dynamics of local prey species (e.g., top smelt). Kent Lake Osprey are known to hunt in adjacent lakes (e.g., Bon Tempe), along the outer coast (e.g., Bolinas Lagoon), and in San Francisco Bay, but there are few observations of foraging at Kent Lake. California Department of Fish and Wildlife fish stocking is a potential data source for Bon Tempe Lake, but Kent Lake Osprey forage more broadly than Bon Tempe. No other data are currently available.

Chemical Threats: Sampling for mercury and other contaminants has not been conducted, although studies in San Francisco Bay indicate that contaminants are present in the food chain, possibly at biologically significant levels. (Buzby et al., 2021).

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Continued Monitoring: The decades-long monitoring program at Kent Lake has provided a robust data set that we can use to see the recent changes previously discussed.

Past Work

Below are some of the previous stewardship and management activities that have been undertaken over the years to monitor, protect, and restore this health indicator.

Monitoring: Two nesting status surveys have been conducted throughout Kent Lake each year (Marin Water and Avocet Research Associates) since 1981.

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as a part of the development of this report. These are actions not currently funded through agency programs, and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Existing Program Support:

- **Reproductive Success:** Reinstate funding for monitoring this important aspect of Osprey health.
- **Environmental Contaminants:** Conduct an analysis to determine constituents, specifically mercury and other fish-related contaminants, present in Ospreys to support further understanding of factors that affect reproductive success.
- **Nest Cams:** Record Osprey nesting to build public awareness and interest, and to document behaviors and fish species being consumed.

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ADDITIONAL REFERENCE MATERIAL OF INTEREST

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CHAPTER 22. BATS (ORDER CHIROPTERA)

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

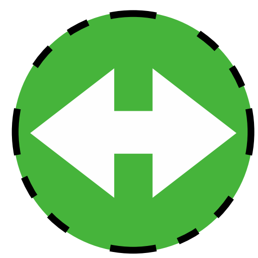
2016	2022
This indicator was not included in the original 2016 report	
Condition: N/A	**Condition:** Good
Trend: N/A	**Trend:** No Change
Confidence: N/A	**Confidence:** Moderate

FIGURE 22.1 CONDITION, TREND, AND CONFIDENCE FOR BATS, ONE TAM AREA OF FOCUS

Lack of data prevented inclusion of bat species in the original 2016 evaluation of Mt. Tam's health. To address this, a Marin County-wide bat monitoring program was initiated in 2017; it has provided the preliminary data used to incorporate them in this 2022 update.

METRICS SUMMARY

The metrics in Table 22.1 were used to assess bat health. The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain the overall condition, trend, and confidence described in Figure 22.1. Each metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 22.1 ALL BAT METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE.

Metric 1: Species richness		
	2016	**2022**
Condition	N/A	Good
Trend	N/A	No Change
Confidence	N/A	Moderate
Metric 2: Species presence and distribution		
	2016	**2022**
Condition	N/A	Good
Trend	N/A	Unknown
Confidence	N/A	Moderate

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

Bats represent one-fifth of the planet's mammal diversity. According to the International Union for Conservation of Nature, globally, 80% of bat species are either not well understood or are in need of conservation. (Frick, Kingston & Flanders, 2019). Mt. Tam supports a diverse bat community; however, until recently, informational studies were limited to small-scale inventories at Muir Woods (Heady & Frick, 2004) and in and around Marin Water structures (GANDA, 2003), as well as a few other very limited monitoring and research efforts. Three local bat species have been designated as state Species of Special Concern, so learning more about these important creatures is especially critical. Because their reproductive rate is low—bats give birth only once a year, usually to just one or two pups—population declines can occur rapidly, and recovery is slow. Table 22.2 shows Marin County bat species and their current listing-status designations.

TABLE 22.2 BAT SPECIES EXPECTED TO BE SEEN IN MARIN COUNTY, AND THEIR CONSERVATION STATUS

Species	Common Name	CDFW Designation*	Other Designations*
Antrozous pallidus	Pallid bat	Species of Special Concern	BLM: Sensitive species FWS Sensitive species WBWG: High
Corynnorhinus townsendii	Townsend's big-eared bat	Species of Special Concern	BLM: Sensitive species FWS: Sensitive species WBWG: High
Eptesicus fuscus	Big brown bat		
Lasionycteris noctivagans	Silver-haired bat		WBWG: Medium
Lasiurus blossevillii	Western red bat	Species of Special Concern	WBWG: High
Lasiurus cinereus	Hoary bat		WBWG: Medium Conservation interest within FWS
Myotis californicus	California myotis		
Myotis evotis	Western long-eared bat		BLM: Sensitive species WBWG: Medium
Myotis lucifugus	Little brown bat		WBWG: Medium Undergoing ESA** species status assessment
Myotis thysanodes	Fringed myotis		BLM: Sensitive species FWS: Sensitive species WBWG: High
Myotis volans	Long-legged myotis		WBWG: High
Myotis yumanensis	Yuma myotis		BLM: Sensitive species WBWG: Medium
Tadarida brasiliensis	Mexican free-tailed bat		

**BLM = Bureau of Land Management, CDFW = California Department of Fish and Wildlife, FWS = U.S. Fish and Wildlife Service, WBWG = Western Bat Working Group*
*** ESA = Endangered Species Act*

In addition to providing valuable ecosystem services, bats are important ecological indicators. They are sensitive to a wide range of environmental factors, including climate change, habitat loss/fragmentation, pesticides/insect availability, disease, drought, wildfires, and human disturbance (especially at breeding colonies). They use a variety of roosting habitats (trees in various stages of decay, fallen wood and snags, rock outcrops, mines, caves, and bridges and other human-made structures) and often return to the same roosts annually. While bats in other areas of the western U.S. have been affected by solar and wind energy development and diseases such as white-nose syndrome (WNS), the biggest threat to Marin County's bats are habitat loss and roost disturbance. Significantly, bats serve as effective proxies in identifying and understanding habitat features available not just for their own species, but for other taxa that depend on them.

CURRENT CONDITION AND TREND

In 2017, One Tam and the U.S. Geological Survey partnered on a pilot acoustic inventory of Mt. Tam's bats. The study monitored bat activity for seven consecutive nights at a time across 50 randomly selected sites covering all four One Tam partner agency jurisdictions. Priorities included understanding species diversity in key habitats (i.e., redwood and Douglas-fir forests, oak woodlands, and riparian and lake habitats); documenting maternity colony presence, locations, and size; and identifying common best practices for vegetation and fuels management. This pilot study was a precursor to developing a more comprehensive monitoring program that included components of the North American Bat Monitoring Program (NABat) (e.g., ways to assess changes in bat distribution and abundance). Currently, the One Tam bat monitoring program uses NABat methodology in conducting winter roost and maternity colony counts, and acoustic surveys at stationary points. These data are then added to NABat's continent-wide effort to detect trends in bat populations and to assist in conserving them.

Throughout their lifespans, bats cover large distances. Many species travel several miles nightly between roosting and foraging habitats, migrate seasonally, or are long-distance migrants. Thus, the One Tam bat monitoring program extends beyond the One Tam area of focus. Because bats are so highly mobile, it is appropriate to use county-wide data rather than restricting observations to the area of focus, which may be too small a lens to determine meaningful annual differences. The movement ecology of bats also highlights the importance of monitoring and management across broad geographic scales. Collaboration between land management agencies facilitates effective bat research, as bats caught in one jurisdiction are often tracked across agency boundaries and into nearby neighborhoods. Additionally, Marin County's bat population is likely linked to other populations through disease transmission and larger-scale human-land-use patterns.

To date, monitoring efforts indicate that bats' current condition within the area of focus and throughout the county is good, based on the following:

- Acoustic monitoring has documented the expected suite of species.
- Summer telemetry has revealed previously undocumented maternity colonies for a variety of species, including pallid bats, big brown bats, and California and Yuma myotis, with some large colonies hosting more than 200 bats.
- Winter telemetry has detected a diversity of bat activity and identified the roosts of several species, including pallid bats, big brown bats, California and Yuma myotis, and a

previously undocumented wintering area for female hoary bats, which is a novel finding throughout this species' range.

- WNS has not been found in Marin County, despite recent documentation of the disease's causative fungal pathogen *Pseudogymnoascus destructans* (Pd) at several locations across California. WNS is a fast-spreading fungal disease that has decimated populations of some North American bat species.

DESIRED CONDITION AND TREND

- The full suite of expected bat species is present.
- Species diversity is high and distributed at stable or increasing levels in appropriate habitats across the landscape.
- Local populations remain stable or improve within a range of expected natural fluctuations and are resilient to ongoing and emerging stressors.
- Suitable habitat diversity is protected or enhanced through actions to maintain landscape connectivity and mosaics that support resident and migratory species, maternity roosts, and foraging.

STRESSORS

Invasive Species Impacts: The barred owl (*Strix varia*), an invasive species, has a varied diet that has been known to include bats (Bergstrom and Smith, 2017). While barred owl numbers are currently low, we do not know what effect an increase in their population might have on bat species.

Climate Vulnerability: Extended drought conditions may reduce the amount and quality of available bat foraging habitat, insect food sources, and drinking water. Some species (e.g., Yuma myotis) are particularly reliant on habitats that include open water. However, all of Marin County's bat species need open water to drink, and this demand increases during the maternity season (Adams and Hayes, 2008). Species that are especially reliant on open water may be particularly vulnerable, but all species are susceptible to the effects of a changing climate (Adams and Hayes, 2021).

Fire Regime Change: Fire suppression can lead to woodland and forest habitats becoming increasingly dense and monotypic, reducing habitat diversity and making it difficult for bats to forage effectively. In addition, the common fire-prevention practice of clearing snags and downed trees may reduce suitable roosting habitat. Fire suppression can also ultimately result in high-intensity blazes that further reduce available habitat. The historic fire regime in the One Tam area of focus—including the cultural burning practices of the Coast Miwok people—maintained a mosaic of habitat types (Long et al., 2021) that created roosting and foraging habitats for a diverse bat community. Although fire can sometimes be an immediate stressor, returning to a moderate-intensity fire regime would likely benefit Marin County's bat community (Steel et al., 2019).

Disease: Like all wildlife, bats can be resilient to diseases with which they have co-evolved if they are part of an otherwise healthy population in a healthy and intact ecosystem. However, habitat fragmentation and pressure from other stressors may reduce bats' ability to counteract endemic diseases, as well as make them more susceptible to novel and/or recurring introduced diseases. WNS is one such introduced disease that could be a potential future threat if it continues to spread westward. Pd has been detected at several sites in California (White-Nose Syndrome Response Team, 2022a). So far, six of the species that occur in Marin County have proven to be susceptible to the disease (White-Nose Syndrome Response Team, 2022b). WNS has already wiped out 90% of the U.S. population of little brown bats (Cheng, et al., 2021). However, coastal northern California's mild winter conditions may help Marin County's bats be more resilient to WNS than populations in other parts of the country.

Pollution/Contaminants: Bats can suffer from insecticides in two ways: directly, by eating contaminated prey, or indirectly, through a loss of food sources. However, this may not be as great a problem in Marin County, which is not as highly agricultural as other areas of the state. In addition to the other negative impacts described earlier, drought concentrates heavy metals in the water bats depend upon, which in turn increases toxin bioaccumulation in their insect prey. High mercury levels have been shown to affect bats' immune systems, which may increase their susceptibility to disease (Becker et al., 2021). Finally, it is possible that light pollution from urban areas and high audio frequency pollution from electronic devices could have a detrimental effect on the amount and quality of suitable habitat.

Habitat Disturbance/Conversion/Loss: Roosting habitat disturbance or removal reduces available bat habitat and can be especially harmful to maternity colonies.

Predation/Competition: Where Marin County's public lands interface with urban areas, cats can prey on bats, especially where the latter roost in built structures (The Bat Conservation Trust, nd). Overall, bats in Marin County have evolved to co-exist with one another through niche partitioning, which reduces direct competition. However, some bat species are dietary and habitat generalists. Habitat loss or homogenization could result in the replacement of specialist species by generalists better able to make use of a wider range of habitats.

CONDITION AND TREND ASSESSMENT

METRICS AND GOALS

METRIC 1: SPECIES RICHNESS

This metric measures the number of species represented in Marin County's bat community using a combination of acoustic monitoring, roost monitoring, mist netting, and telemetry (varying call sound volumes mean that not all bats can always be reliably detected using just acoustic monitoring).

Baseline: All 13 expected species were detected acoustically during the 2017 pilot monitoring project.

Condition Goal: Bat species richness continues to include those expected (based on known lists from range maps and other evidence). Mt. Tam experiences no species loss.

Condition Thresholds:

- **Good:** Using various methods (i.e., mist netting, acoustic detectors, and roost observations), all species are detected, with no species undetected across a three-year time span.
- **Caution:** Using various methods, 11 of 13 species are detected, with two expected species not detected across a three-year time span.
- **Significant Concern:** Using various methods, more than two expected species are not detected across a three-year time span.

Current Condition:

2016: N/A

2022: Good

We consider the overall condition of bats in Marin County to be good because all species were detected in the three-year window between 2019 and 2021. Even though 2018 was the first year of monitoring after the pilot study—and the only year so far where call identifications have been fully verified by biologists—acoustic monitoring that year detected all 13 expected species.

Figure 22.2 shows species detected through acoustic monitoring for each year of the project to date. A “verified” status means that the call file identification was confirmed by a bat biologist. A “provisional” status means that the species was detected acoustically and identified by the SonoBat software but has not yet been confirmed by a bat biologist. Figure 22.3 shows species visually identified by a bat biologist through other monitoring efforts (e.g., mist netting, telemetry, roost monitoring).

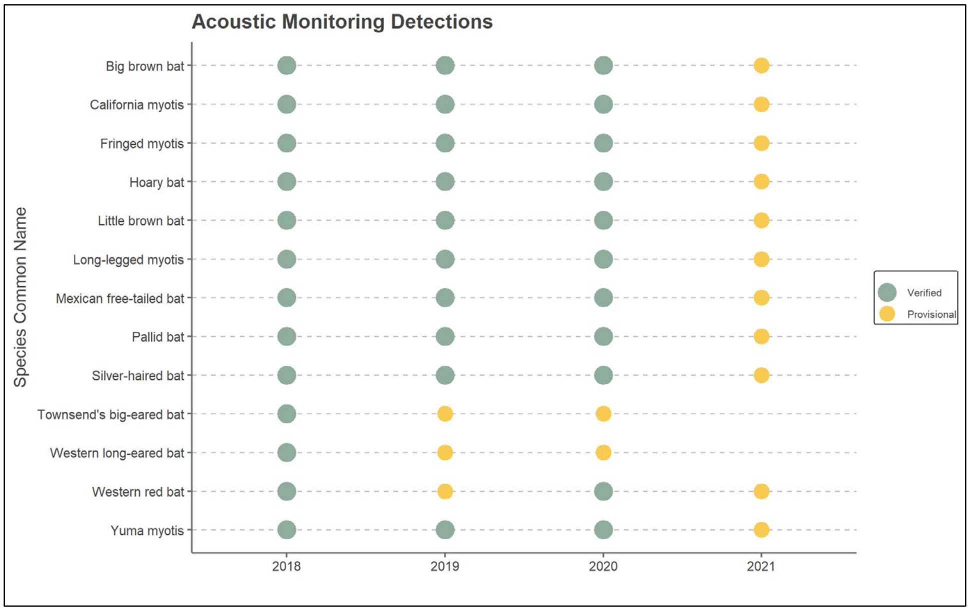


FIGURE 22.2 BAT SPECIES PRESENCE DETECTED ACOUSTICALLY BY SURVEY YEAR YEAR

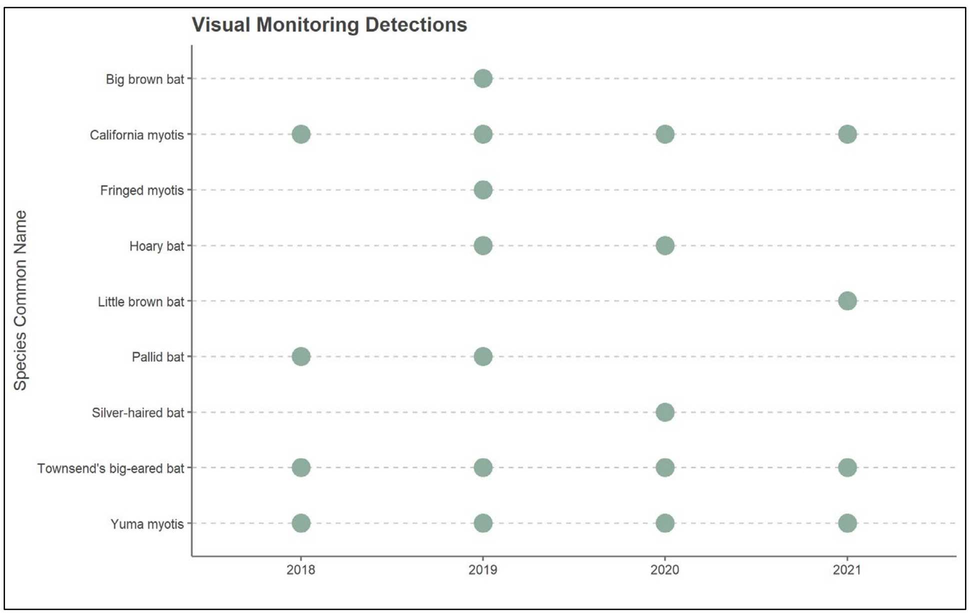


FIGURE 22.3 BAT SPECIES PRESENCE DETECTED VISUALLY BY SURVEY

Trend:

2016: N/A

2022: No Change

Through 2021, the trend is not changing because there has not been a decline in species (i.e., no species is missing for three years). These trends may be adjusted as manual verification of acoustic data changes them from provisional to verified.

Confidence:

2016: N/A

2022: Moderate

Monitoring effort may fluctuate from year to year. Reduced effort would lower our confidence in the metric for a given year as we would be less certain that we have observed all species present on the landscape. Furthermore, identifying bat species by their acoustic call files is sometimes a challenge, even for a bat biologist. Classification software such as SonoBat uses highly sophisticated models to identify the species captured in the acoustic file, but still requires an expert to fully confirm the identification with a high level of confidence.

Our current confidence is moderate, because acoustic data from 2019 to 2021 have not yet been fully verified by a bat biologist. Additionally, the western long-eared bat was not acoustically detected by the SonoBat software in 2021, and was only provisionally detected in 2019 and 2020. It was also not detected using in-person monitoring methods; however, this is not a cause for concern at this time, because this species is not commonly detected in Marin.

METRIC 2: SPECIES PRESENCE AND DISTRIBUTION

This metric determines where bats are found across the landscape by counting how many acoustic monitoring sites each species is detected at (Figure 22.4). It also looks at the number of bat species detected (diversity) at each acoustic monitoring site (Figure 22.5).

Baseline: The baseline for this metric is the average of the first three years of data (2018 to 2020) collected under NABat guidelines.

Condition Goal: Stable or increasing trends in species detection across acoustic sites.

Condition Thresholds:

- **Good:** Three-year moving average of site detections/species remains stable (< 30% fluctuation) or improves over time.
- **Caution:** Number of site detections/species declines > 30% for one to three species or sites for three consecutive averages.
- **Significant Concern:** Number of site detections/species declines > 30% for four or more species or sites for three consecutive averages.

Current Condition:

2016: N/A

2022: Good

The condition for this metric is good because fluctuations for the number of acoustic detector locations per species (Figure 22.4) and the number of species per grid cell (Figure 22.5) were stable each year for three years.

Figure 22.4 shows the three-year average (mean) number of sites in which each species has been detected to date. The 2020 points are the mean for years 2018, 2019, and 2020. The 2021 points are the mean for years 2019, 2020, and 2021. To account for differing levels of monitoring efforts each year, percentages rather than raw numbers were used. Figure 22.5 shows the three-year mean of species detected within each 10 km grid cell. Both charts show the level of fluctuation between the three survey years as vertical range line.

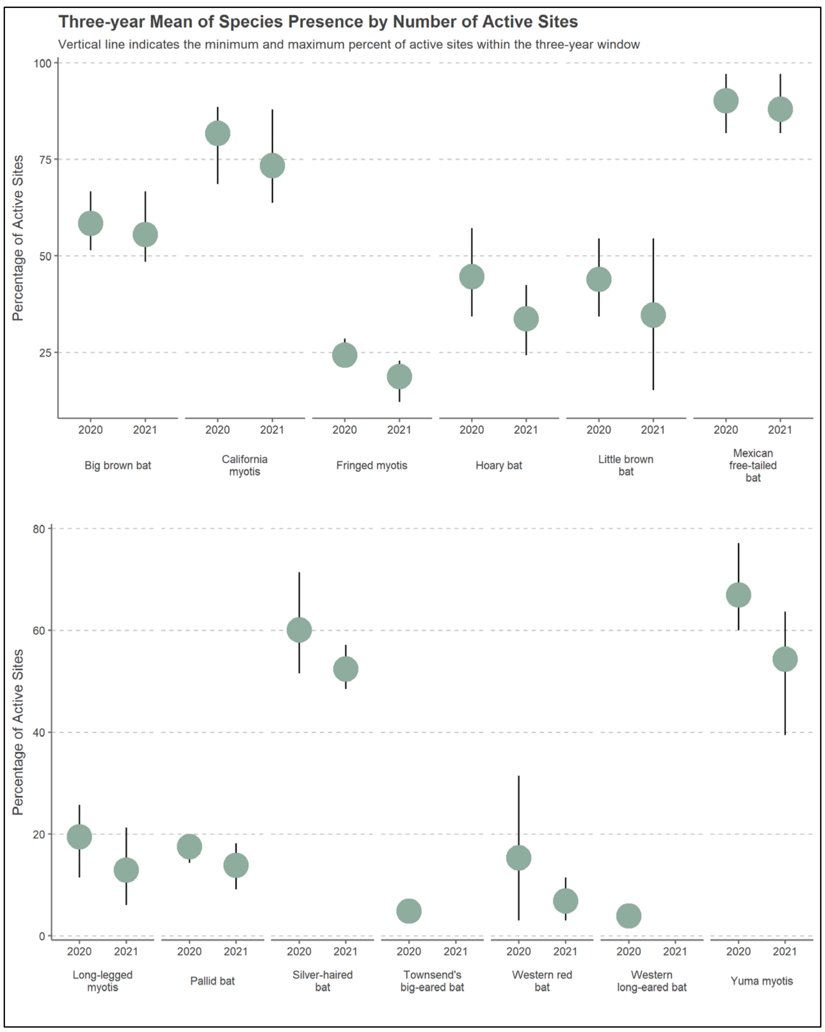


FIGURE 22.4 BAT SPECIES PRESENCE BY NUMBER OF SITES, AND PERCENTAGE FLUCTUATION OF NUMBER OF SITES FROM THE PREVIOUS YEAR

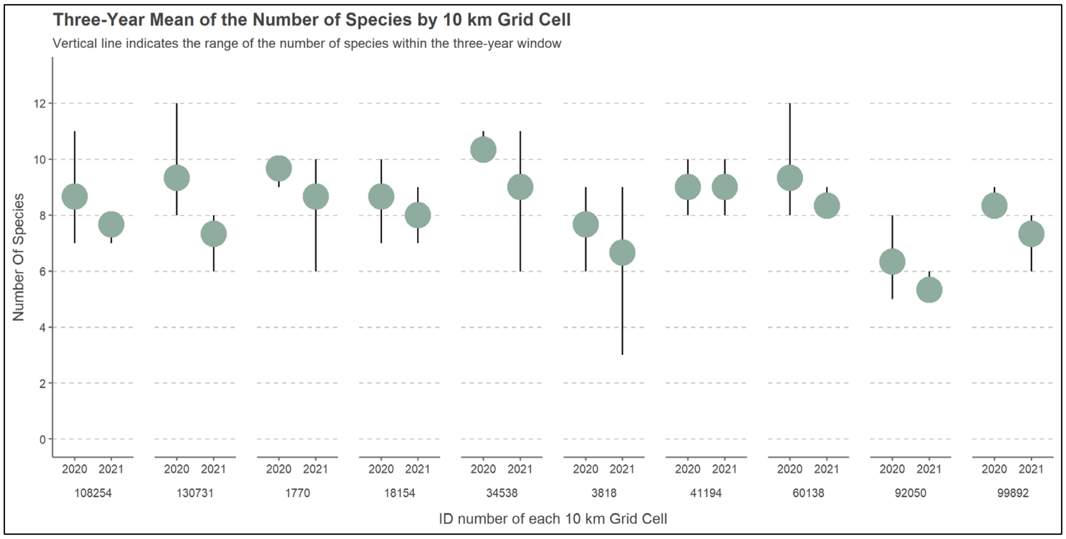


FIGURE 22.5 NUMBER OF BAT SPECIES DETECTED AT EACH 10 KM GRID CELL BY YEAR; PERCENTAGE FLUCTUATION IN SPECIES

Trend:

2016: N/A

2022: Unknown

The trend is unknown until at least three years of data have been fully processed.

Confidence:

2016: N/A

2022: Moderate

Our confidence in this assessment is moderate because we do not yet have three full years of change data, and the records of some species detected in 2019, 2020, and 2021 are still provisional.

As with Metric 1, monitoring effort may fluctuate from year to year. A reduction in the number of sites monitored—and thus, a reduction in the quantity of data available to compare against previous years—would lower our confidence in the metric for a given year. In addition, some species are less common and so may inherently have more variability. A decrease in the number of sites for a rare species may be less concerning than a decrease for a common species. The higher the number of rarer bat species associated with the threshold, the lower our overall confidence would be. Furthermore, as mentioned, identifying bat species by their acoustic call files can be a challenge, even for a bat biologist. Classification software, such as SonoBat, uses highly sophisticated models to identify the species that made the acoustic file, but an expert still needs to fully confirm the identification with a high level of confidence.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

SUPPORTING DATA

- Marin County bat acoustic pilot study 2017.
- Marin County bat monitoring data 2018–2021.
- Annual monitoring of maternity roosts, including Townsend's big-eared bat roosts.

INFORMATION GAPS

Distribution and Abundance: The overall population size for Marin County's bat species is unknown. We also do not know whether species currently described as rare were previously widespread, or if for some species, the county is marginal habitat and/or at the edge of their range.

Habitat Use: How migratory bats, including hoary bats, western red bats, and silver-haired bats are using this landscape to support their overall lifecycles.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Past Work

Following are some of the stewardship and management activities that have been undertaken to monitor, protect, and restore this health indicator.

Monitoring and Surveys:

- A one-week acoustic monitoring pilot study was done at 50 randomly selected sites on public land in Marin County, 2017.
- Summer acoustic monitoring was conducted at 36 locations throughout Marin County, 2018–2019.
- Winter and summer mist-netting and telemetry were conducted at Olema (National Park Service land) and Samuel P. Tylor State Park in year one (July 2018, March 2019).
- Winter and summer mist-netting and telemetry were conducted at Cascade Canyon (Marin County Park land) and Lake Lagunitas (Marin Water land) in year two (July 2019, March 2020).
- Winter and summer mist-netting and telemetry were conducted at Deer Island (Marin County Park land) in year three (July 2021, March 2022).

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as part of the development of this report. These actions are not currently funded through agency programs, and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Develop Additional Metrics: To define bats by geographic distribution and activity, a third metric under consideration aims to create a matrix of species presence in the Marin County through a combination of manually vetted calls and auto-identification.

Resource Management and Monitoring: Volunteer roost surveys could be developed and implemented in conjunction with the U.S. Geological Survey and NABat as a collaborative community science effort.

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ADDITIONAL REFERENCE MATERIAL OF INTEREST

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CHAPTER 23. MAMMALS

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UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

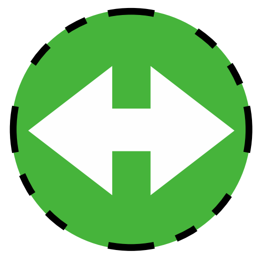
2016

Condition: Caution

Trend: Unknown

Confidence: Low

2022



Condition: Good

Trend: No Change

Confidence: Moderate

FIGURE 23.1 CONDITION, TREND, AND CONFIDENCE FOR MAMMALS, ONE TAM AREA OF FOCUS

Mt. Tam's mammal community appears to be doing better than it was in 2016, with a condition that went from caution to good between 2016 and 2022 and with no change for the trend assessment. Our confidence in this assessment has also increased. In 2016, we had access to a limited amount of wildlife camera data. Since then, we have increased both the number of wildlife cameras and the areas they cover. These data have allowed for additional analysis in this update—in particular, Metric 3: Wildlife Picture Index—for key groups. Some of the improvement in the condition and trend of this mammal community indicator is undoubtedly due to having more data available to work with. Also, as our knowledge of the species that occur here changed, we reassessed some of the condition thresholds we used for each metric.

METRICS SUMMARY

Metrics in Table 23.1 were used to assess mammal community health in the One Tam area, primarily using data from Marin Wildlife Watch (MWW, formerly known as the Marin Wildlife Picture Index Project; see O'Brien et al., 2010). The condition, trend, and confidence for each metric was then given a score. These scores were combined and averaged to obtain an overall condition, trend, and confidence. Each metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 23.1 SUMMARY OF MAMMAL ASSESSMENT METRICS, WITH THEIR RESPECTIVE CONDITION, TREND, AND CONFIDENCE FOR 2016 AND 2022

Metric 1: Native species richness		
	2016	**2022**
Condition	Good	Good
Trend	Unknown	Improving
Confidence	Moderate	High
Metric 2: Presence and distribution of rare species		
	2016	**2022**
Condition	Significant Concern	Good
Trend	Unknown	Improving
Confidence	Low	Moderate
Metric 3: Wildlife Picture Index for key groups		
	2016	**2022**
Condition: Species-Specific Abundance and Stability	Unknown	Good
Condition: Aggregated Mammals	Unknown	Caution
Trend: Species-Specific Abundance and Stability	Unknown	No change
Trend: Aggregated Mammals	Unknown	Declining
Confidence: Species-Specific Abundance and Stability	Low	Moderate
Confidence: Aggregated Mammals	Low	Moderate
Metric 4: Non-native, invasive mammal species		
	2016	**2022**
Condition	Good	Good
Trend	Unknown	No Change
Confidence	Moderate	Moderate

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

Mammals are good indicators of ecological condition because they are "energetically expensive," relying on healthy lower trophic levels; they are also responsive to habitat changes (Andren, 1994). Species that cannot fly also rely on suitable, connected habitats. This chapter focuses on mouse-size and larger terrestrial mammals that we can assume are reliably detected by MWW cameras. MWW Phase I (the North Array) was implemented in September 2014, when One Tam partners established a grid of 128 cameras in a variety of habitat types throughout the Lagunitas Creek corridor (Figure 23.2; Townsend, 2015, 2018). In MWW Phase II (the South Array), which was implemented in June 2017, 80 cameras were added in the Redwood Creek Watershed (Figure 23.2).

Thanks to MWW, we have the potential to detect 22 mammals (five small-rodent species are aggregated in one category). Not all are covered in this chapter, however. Of the mountain's 46 native mammal species (see Appendix 9, Mammal Species), 13 are bats (see Chapter 22) and four are insectivores, which are not included because they are not reliably detected by camera traps, and the North American river otter (*Lontra canadensis*) is covered with additional detail in Chapter 24. (The need for future monitoring programs for small mammals is described in Chapter 25.)

Some of Mt. Tam's mammals have special conservation status, though none are listed as a state or federally endangered species. The California Department of Fish and Wildlife (CDFW) has classified the ringtail (*Bassariscus astutus*) as a fully protected species and the American badger (*Taxidea taxus*) as a Species of Special Concern. The ringtail has been documented in Point Reyes National Seashore (Evens, 1983), but not within the One Tam area of focus. Although the mountain lion (*Puma concolor*) is a candidate for listing under the California Endangered Species Act, the listing petition does not include the North Coast Evolutionarily Significant Unit in which Marin County is located.

In October 2020, the State of California enacted Executive Order N-82-20 to combat the biodiversity and climate crises. This executive order includes guidance for establishing baseline assessments of California's biodiversity (Order 1a) as well as provides indicators and tools to monitor, track, and protect the state's biodiversity (Order 1c-e). The MWW helps support this goal by providing both a baseline assessment and ongoing mammal community status and trend-monitoring. This includes species richness; occupancy; and the Wildlife Picture Index (WPI), which allows us to assess mammal community condition and trend. The WPI was established by a consortium of international conservation organizations to measure biodiversity trends in support of the Convention on Biological Diversity (see also O'Brien et al., 2010); the United States is not a signatory to this international treaty.

The MWW, along with other documented sources (including earlier agency inventories), provided the information used to develop this chapter. Reliable information about mammal abundance and distribution, community structure, trophic-level health, and abundance trends is needed to understand these important metrics of overall ecosystem health. In the past, the level of effort required to obtain these kinds of data was generally beyond the capacity of most land management agencies. However, landscape-level camera trapping is a non-invasive way to obtain these metrics and reliably measure change over time. Networks of remote cameras have proven very effective in gaining valuable information on mammal diversity, distribution, and abundance (O'Brien et al., 2010; Ahumada et al., 2011). Additionally, photographs can be shared with the public, which provides the community with a chance to learn about mammals that live here but that they may rarely see.

Monitoring the entire mammalian community—rather than the more common practice of focusing on one or more single sensitive species—has a number of benefits: Trends in common species may be easier to detect than those for rare species, changing trends in common species may provide early indications of environmental fluctuations, and examining trends for various trophic levels can provide insight into overall wildlife community status.

By deploying many wildlife cameras and systematically spacing them across the landscape, data can be captured and then aggregated or disaggregated to measure the abundance of individual species or trophic levels over a span of seasons and years. This approach helps achieve the goal of understanding both the condition (i.e., presence, abundance, and diversity) and trend of the mammalian community as a whole. This community can also be studied by guilds or trophic levels (e.g., carnivores or prey) and individual species (e.g., American badger or black-tailed deer [*Odocoileus hemionus*]). Finally, MWW-acquired data can also be used to determine how management changes and environmental stressors such as drought affect mammals.

CURRENT CONDITION AND TREND

Mammalian inventories have been completed on some of lands within and adjacent to Mt. Tam (Howell et al., 1998; Fellers & Pratt, 2002; Semenoff-Irving & Howell, 2005). However, these inventories were not systematic and did not provide information about mammalian abundance.

In the Mammal chapter in *Measuring the Health of a Mountain* (Edson et al., 2016), findings indicated that most native mammal species—15 of which had been detected—were present in the North Array study area (Townsend, 2015), which was above the good threshold. A few rare species were not detected, raising significant concern about this metric at the time. Preliminary occupancy results in 2016 suggested a relatively healthy level of mammal diversity, with an abundance of small mammals (prey species). However, the data and analyses necessary to assess this metric were not sufficient, so it was determined to be unknown. The opossum (*Didelphis virginiana*) and domesticated cattle (*Bos taurus*) were the only non-native mammals observed, which was above the good threshold. Overall, the condition assessment for mammals was caution, with an unknown trend.

In this chapter, we are able to update these findings with a three-year data analysis from the North Array (2014–2017) and a three-season data analysis from the South Array (summer, fall, and winter 2017). The South Array, which covers parts of Muir Beach and extends north, is divided into four subarrays (Beach, Tam, Wood, and East; Figure 23.2 [Townsend, 2018, 2020]). Based on the increased amount of data and greater coverage of cameras around Mt. Tam, we increased our understanding of the mammal community as well as our confidence in the assessment. Native species richness remained in good condition and improving trend as we added two new native species since 2016, long-tailed weasel (*Mustela frenata*) and American black bear (*Ursus americanus*). In 2022, we were able to calculate species occupancy estimates and the Wildlife Picture Index (a way of measuring trend in biodiversity from wildlife camera data). Species-specific abundance and stability were rated as good, and the Wildlife Picture Index was rated as caution. Our rare species metric moved from a condition of significant concern to good. The invasive species metric remained in good condition with no change in trend in 2022.

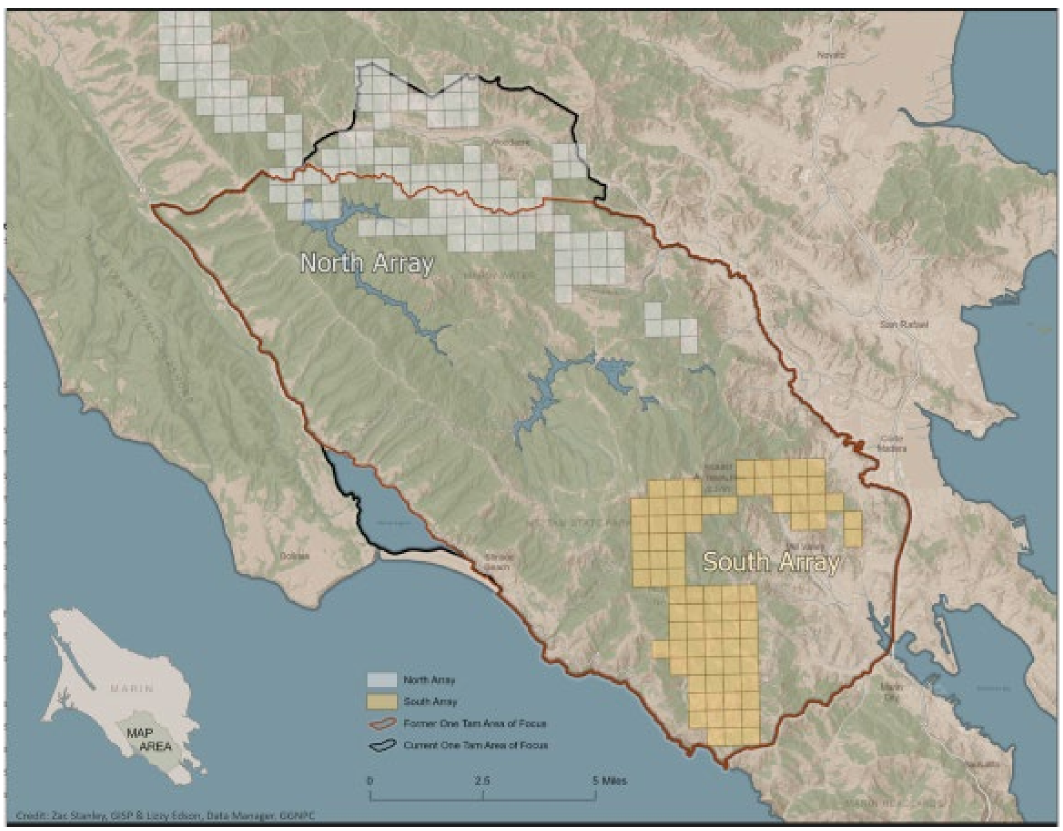


FIGURE 23.2 MWW NORTH AND SOUTH ARRAYS

Note: The North Array (2014 to present) and the South Array (2017 to present) cameras are 0.5 km apart.

DESIRED CONDITION AND TREND

The desired condition for the mammalian community within the study area (which extends beyond the One Tam area of focus to the north) is to maintain and, where able, improve native biodiversity, abundance, and the habitats that support this community. More specifically, this entails the following:

- The full suite of expected native mammals is present.
- Native species diversity is high and stable (or increasing); mammals are well represented across trophic levels and are distributed across the landscape.
- Rare species are present within our study area and, ideally, are detected by both North and South Array cameras. Increasing occupancy by these rare species is also desired.
- Non-native mammals, especially species such as feral pigs (*Sus scrofa*) that have large ecosystem impacts, are not present.
- Wildlife habitat is protected or enhanced through actions such as maintaining patch sizes of diverse habitat types and landscape connectivity. (Note: Habitats and patch-size needs will differ by species.)

STRESSORS

Historical Impacts: Although most of the One Tam area of focus is protected, past land uses continue to affect habitat quality and quantity. Certain species of mammals were also the targets of hunting and trapping for centuries, the results of which may still be affecting regional mammal numbers and diversity (see Chapter 12, Extirpated Species section).

Invasive Species Impacts: Invasive plants and animals can have far-reaching and detrimental effects on ecosystems. Invasive plants may dramatically alter wildlife habitat. Some invasive animals outcompete native species for food, water, nest or burrow sites, and shelter, or prey on native wildlife. Other species, such as feral pigs, do great damage as they trample foliage and upturn soil while rooting and foraging for food.

Climate Vulnerability: A warmer climate subject to periods of drought and flashier storms will alter plant communities that comprise wildlife habitat in the One Tam area of focus. However, most mammals tend to be well distributed across habitat types and may be somewhat resilient to shifting plant communities. The coastal influence and fog, along with a variety of microclimates, could make this area a potential climate refuge for wildlife that find other parts of the North Bay less hospitable.

Fire Regime Change: The potential for increased fire activity will threaten mammals. High-intensity fires can make some areas unsuitable for periods of time and reduce habitat connectivity. Fast-moving fires cause direct mortality, especially for dusky-footed woodrats

(*Neotoma fuscipes*) and other small mammals. In addition, fires may burn woodrat houses, which are often used by a variety of other taxa as well.

Disease: Mammals are subject to a range of diseases. Many, such as canine distemper, canine parvovirus, leptospirosis, and feline leukemia, are spread by contact with pets (Riley et al., 2004). A canine distemper outbreak dramatically affected Marin County's gray fox (*Urocyon cinereoargenteus*) populations in the mid-1990s. The CDFW has recently documented adenovirus, a viral disease that affects deer, in Marin County. Rabbit hemorrhagic disease has been documented in California and was recently confirmed in black-tailed jackrabbits (*Lepus californicus*) in Marin. Disease is also likely a factor in the range-wide decline of western spotted skunks (*Spilogale gracilis*). Studies suggest that wildlife disease outbreaks may become more common with climate change.

Pollution/Contaminants: Mammals are at risk of potentially deadly rodenticide exposure, especially when they live adjacent to residential areas. Additionally, rodenticide exposure has been linked with susceptibility to mange in bobcats (*Lynx rufus*) (Riley et al., 2007). Recent research projects focusing on the Turkey Vulture (*Cathartes aura*) and Barred Owl (*Strix varia*) may provide information on the potential exposure of the mountain's mammals to rodenticides. Ongoing efforts to ban anti-coagulant rodenticides in Marin County would benefit mammals.

Direct Human Impacts: Studies have documented that recreational activities alter the way carnivores use protected areas (George & Crooks, 2006; Reed & Merenlender, 2011); the impacts of these activities vary by species (Townsend et al., 2020; Reilly et al., 2017). The presence of dogs can also affect the abundance and behavior of mammal communities near trails (Lenth et al., 2008).

Habitat Disturbance/Conversion/Loss: The mountain's contiguous open spaces are threaded with trails and roads and surrounded by a mix of agricultural, suburban, and urban areas. Resulting habitat loss and fragmentation may have a negative effect on mammal numbers and diversity and can be particularly detrimental to species like mountain lions, which require large home ranges. Mammals are particularly susceptible to vehicle strikes as they attempt to cross roads.

CONDITION AND TREND ASSESSMENT

METRICS

METRIC 1: NATIVE SPECIES RICHNESS

Baseline: In 2016, we assessed native species richness as good, with most (15) expected species detected. (American badgers were detected outside of the area of focus, so they were not included.) At that time, we noted six additional species that could potentially be detected with camera traps, including the ringtail cat, ermine (*Mustela ermine*), long-tailed weasel, Point Reyes mountain beaver (*Aplodontia rufa phaea*), American black bear, and muskrat (*Ondatra zibethicus*).

For this update, we increased the analysis' geographic footprint beyond the area of focus to the entire MWW study area extent, including the full North and South Arrays (Figure 23.2). Available data include images from 2014–2017 for the North Array and from three seasons in 2017 for the South. (The lag in data intervals is due to the time it takes to process millions of photos and verify results.) We currently expect 17 native mammal species to be detectable by MWW cameras. Six additional non-native species have occurred (or have the potential to occur) in the study area, including domestic cats and cattle.

Since 2016, we have detected the American badger, long-tailed weasel, and American black bear (Table 23.2). These new sightings could be a result of the increased geographic area and additional cameras as well as having a longer data-collection interval. Recent documentation of the American black bear on Mt. Tam and elsewhere in Marin County may indicate re-colonization, and we will begin tracking them as a rare species. And, based on detections from the South Array, we have also added the long-tailed weasel to our rare species list.

We now have six species of unknown status, including two additions: the California ground squirrel (*Otospermophilus beecheyi*) and the porcupine (*Erethizon dorsatum*). The others are ermine, ringtail, mountain beaver, and muskrat (Table 23.2). Unknown can mean several things, but generally it refers to species that are data-deficient (i.e., we are not clear on their current range) and have spotty historical occurrence data (few records near the area of focus, or that existing records are anecdotal).

Mammalian species that may have been extirpated from the area include those that have significant effects on ecological health: the grizzly bear (*Ursus arctos*), an apex predator, and grazing ungulates such as the tule elk (*Cervus canadensis nannodes*) (see Chapter 12, Table 12.1). A few organizations are exploring the feasibility of returning one lost keystone species: the beaver, an ecosystem engineer that could help improve wetland function in select areas.

TABLE 23.2 MAMMALS EXPECTED TO OCCUR IN MARIN COUNTY, CALIFORNIA, COUNT OF SPECIES DOCUMENTED BY MWW, SCIENTIFIC NAME, COMMON NAME, DETECTIONS IN NORTH (2014–2017) AND SOUTH ARRAYS (2017)

Taxon	Count	Scientific Name	Common Name	Array	Status as of 2017
Marsupialia	1	*Didelphis virginiana*	Opossum	Both	Detected
Carnivora	2	*Lontra canadensis*	River otter	North	Detected
Carnivora	3	*Urocyon cinereoargenteus*	Gray fox	Both	Detected
Carnivora	4	*Canis latrans*	Coyote	Both	Detected
Carnivora	5	*Ursus americanus*	Black bear	North	Detected (2021) *

Taxon	Count	Scientific Name	Common Name	Array	Status as of 2017
Carnivora	6	*Mephitus mephitus*	Striped skunk	Both	Detected
Carnivora	7	*Spilogale gracilis*	Western spotted skunk	Both	Detected
Carnivora		*Mustela erminea*	Ermine	-	Unknown
Carnivora	8	*Mustela frenata*	Long-tailed weasel	South	Detected*
Carnivora	9	*Taxidea taxus*	Badger	Both	Detected*
Carnivora	10	*Lynx rufus*	Bobcat	Both	Detected
Carnivora	11	*Puma concolor*	Mountain lion	Both	Detected
Procyonidae	12	*Procyon lotor*	Raccoon	Both	Detected
Procyonidae		*Bassariscus astutus*	Ringtail	-	Unknown
Artiodactyla		*Sus scrofa*	Feral pigs	-	Unknown
Artiodactyla	13	*Odocoileus hemionus columbianus*	Black-tailed deer	Both	Detected
Rodentia		*Aplodontia rufa*	Mountain beaver	-	Unknown
Rodentia		*Ondatra zibethicus*	Muskrat	-	Unknown
Rodentia	14	*Neotoma fuscipes*	Dusky-footed woodrat	Both	Detected
Rodentia	15	*Tamias sonomae*	Sonoma chipmunk	Both	Detected
Rodentia		*Otospermophilus beecheyi*	California ground squirrel	-	Unknown
Rodentia	16	*Sciurus griseus*	Western gray squirrel	Both	Detected
Rodentia	17	*Sciurus carolinensis*	Eastern gray squirrel	South	Detected
Rodentia	18	*Sciurus niger*	Fox squirrel	Both	Detected
Rodentia		*Erethizon dorsatum*	North American porcupine	-	Unknown
Lagomorpha	19	*Lepus californicus*	Black-tailed jackrabbit	North	Detected
Lagomorpha	20	*Sylvilagus bachmani*	Brush rabbit	Both	Detected
Domestic	21	*Felis catus*	Domestic cat	Both	Detected
Domestic	22	*Bos taurus*	Cattle	North	Detected

Blue font = unknown, red font = non-native
**New since 2016*

Note: Since the American black bear was detected with photos in 2021, that was noted. A total of 22 species have been detected, including 16 expected native species, one unknown-status species (American black bear), and five non-native species.

Condition Goals:

- Maintain the full suite of expected native mammal species (not including species of unknown status).
- Lose no additional native mammal species from the study area.

Condition Thresholds:

- **Good:** Two or fewer expected native species fail to be detected in a given year, or the number of native species detected is stable or increasing from the baseline (or the previous measurement cycle).
- **Caution:** Three expected native species fail to be detected in a given year, or the number of native species detected declines by one from the baseline (or the previous measurement cycle).
- **Significant Concern:** More than three expected native species fail to be detected in a given year, or the number of native species detected declines by >1 from baseline (or the previously measurement cycle).

Current Condition:

2016: Good

MWW detected 15 native mammal species for this preliminary analysis. (The American badger, which was detected just outside the area of focus boundary, was not included.)

2022: Good

We have increased the number of native species detected to 17 from the 15 counted in 2016, including the American black bear and long-tailed weasel. We now have more badger detections, including within the original One Tam area of focus, on both the North and South Arrays. The long-trailed weasel was only detected on South Array cameras added in 2017. The American black bear was detected recently on two North Array cameras, and several other occurrences have been documented (primarily by regional wildlife cameras not part of MWW) over the past two years.

Trend:

2016: Unknown

Using MWW camera data available from the North Array, the 2016 mammal chapter analysis established a baseline; however, there were not enough data over time to establish a trend.

2022: Improving

Based on 2014–2017 North Array data, recent analysis of 2017 South Array data, and later detections of select species (mountain lion and black bear; Table 23.3), we detected all the expected native species. Non-native wildlife species include the fox squirrel (*Sciurus niger*), opossum, eastern gray squirrel, and non-native domestic species (e.g., cats and cattle).

While the condition remained good from 2016 to 2022, the detection of two additional expected native species means the trend is improving from the 2016 baseline. This result is somewhat expected, as we have added three years of sampling from the North Array and an entire new area of sampling with the South Array.

Confidence:

2016: Moderate

Our confidence in the metric assessment was moderate, as the aggregated existing data was limited and only preliminary MWW results were available at the time.

2022: High

Our confidence in the measurement of native species richness is now high. We have analyzed data from thousands of trap nights from North Array cameras (2014–2017) and added three seasons of 2017 data from South Array cameras. In addition, new artificial intelligence software that provides an initial image classification for photos uploaded to the cloud database has allowed us to search for rare species and then confirm their identification. Most of our South Array data has been uploaded to this cloud database, but several years of North Array images still have not been added (this work is in progress).

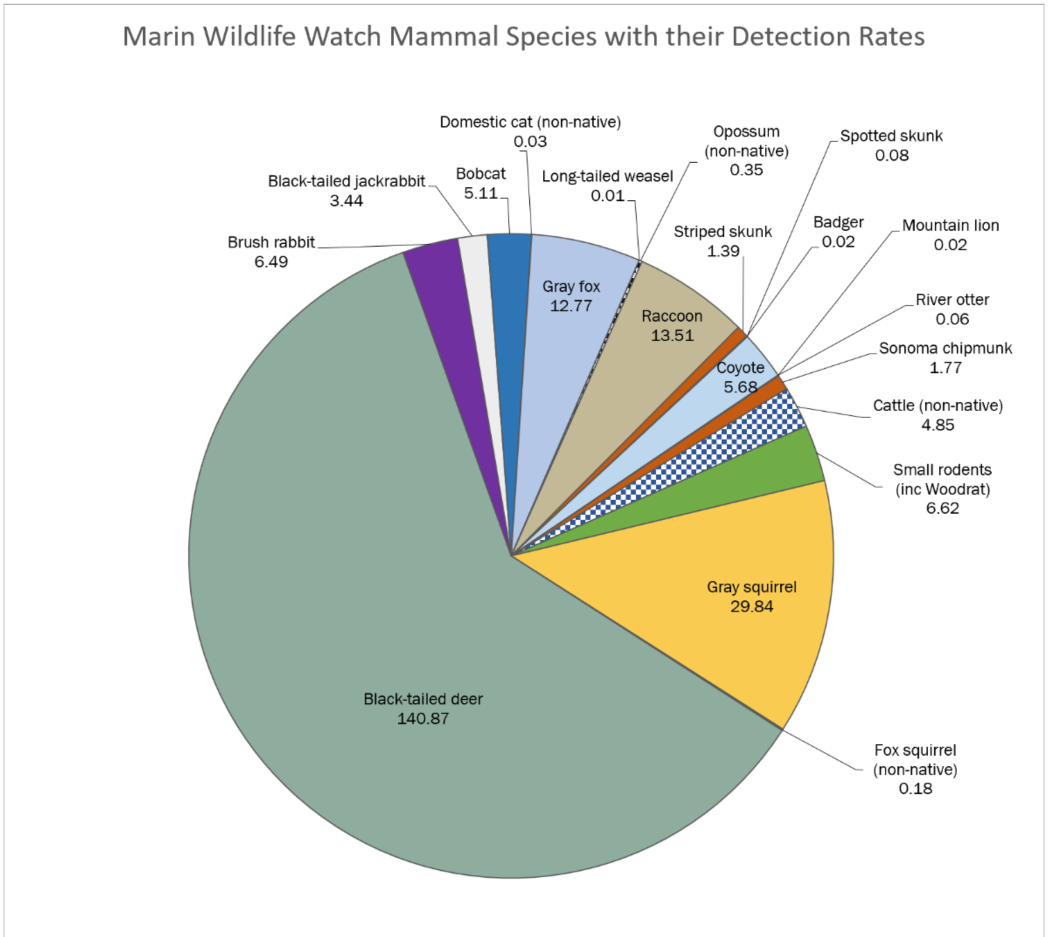


FIGURE 23.3 MAMMAL SPECIES DETECTED AND DETECTION RATES (DETECTIONS PER 100 TRAP NIGHTS) FROM MWW NORTH ARRAY (2014–2017) AND SOUTH ARRAY (2017)

Note: Only fully cataloged and verified data were included in this figure.

METRIC 2: PRESENCE AND DISTRIBUTION OF RARE SPECIES

Baseline: Rare species such as the western spotted skunk, American badger, and mountain lion, are important components of Mt. Tam's mammalian diversity. The western spotted skunk is reported to be in decline in the central coast of California. This species was detected during Muir Woods inventories (Howell et al., 1998), and a single animal was detected at Point Reyes National Seashore (Fellers & Pratt, 2002). The American badger is fairly common in Point Reyes grassland and coastal scrub habitats (D. Press, personal communication, 2016). It was detected in the Marin Headlands during the 2014 BioBlitz (a communal citizen-science effort), and Marin County confirmed badgers in the Lucas Valley Preserve just to the north in 2016. The mountain lion has a large home range (generally more than 100 sq km), which likely allows only a few individuals to inhabit the 213 sq km area of focus. In a two-and-a-half-year study of Marin County camera traps, 55 lion detections, including at least two males, were recorded. One easily identified male (he only had one eye) accounted for 40 of those detections (Fifield et al., 2015).

Based on new observations, the American black bear and the long-tailed weasel have been added to our list of rare species (Table 23.3). Black bears were known as rare vagrants only periodically seen in Marin County. However, a series of recent documented occurrences over the last two years, including one of two bears together, indicates a possible recolonization. Increases in the number of bear observations in Sonoma and Napa Counties support the idea that this recolonization may be sustained by bears dispersing from immediately north of the area of focus. The long-tailed weasel was known to occur at both Point Reyes National Seashore and Golden Gate National Recreation Area. We have now identified two photos of long-tailed weasels from cameras in the MWW South Array.

The ringtail cat, a rare and elusive species, has not been detected on Mt. Tam but has been seen at nearby Point Reyes National Seashore (Evens, 1983). Additional surveys in appropriate areas, or follow-up on observations, may allow us to confirm its presence and get a better idea of its distribution in Marin County. Since the 2016 report, we have moved the ringtail from an expected rare species to unknown status.

TABLE 23.3 ONE TAM RARE SPECIES LIST

Rare Mammal Species on Mt. Tam	
Species	**Common Name**
Ursus americanus	American black bear
Spilogale gracilis	Western spotted skunk
Mustela frenata	Long-tailed weasel
Taxidea taxus	American badger
Puma concolor	Mountain lion

Condition Goals:

- Rare species are detected in study area, and (ideally) in both MWW's North and South Arrays.
- Maintain rare species presence and distribution based on improved documentation of their current ranges.

Condition Thresholds:

We adjusted these thresholds from those used in 2016, changing the criteria from detection in appropriate habitat types to detection within a five-year window. This adjustment reflects the fact that we are not seeing consistent habitat associations for these rare species. This may be because they are passing by MWW cameras as they move between suitable areas across the mountain's patchy habitats.

- **Good:** Detect all five of the rare species listed in Table 23.3 within the most recent five-year window within the area of focus. Three or fewer rare species are only detected at one of the camera arrays (i.e., only North or only South).
- **Caution:** One of five rare species listed in Table 23.3 is not detected within the most recent five-year window within the area of focus. More than three rare species are only detected at one of the camera arrays (i.e., only North or only South).
- **Significant Concern:** More than one rare species is not detected within the most recent five-year window.

Current Condition:

2016: Significant Concern

Photos of the western spotted skunk were rare, and only a few mountain lions had been captured on camera as of the 2016 report. The badger was detected just north of the original One Tam area of focus. The ringtail cat had not been detected, and although we followed up on some credible sightings, we were not able to confirm its presence. It is possible that the ringtail is not present in our study area, or it may be that it is just extremely rare and elusive, and difficult to capture on wildlife cameras. Nearly all rare-species detections seem to have been made in locations away from more developed areas.

2022: Good

Since 2016, we have expanded the MWW and analyzed more images (Figure 23.2). As a result, we can now say that rare mammals are present and have been seen across the landscape on both camera arrays, giving us a condition of good for this metric. Reasons for this status include:

- Seven badger observations within the study area, with four from the North Array and three from the South (Figures 23.4 and 23.5). The badger is typically associated with larger patches of grassland habitat. Five badgers were detected in grassland or coastal scrub habitat, and two were detected in other habitat types, including redwood forest (Figure 23.5).
- Two black bear photos from the North Array (as well as several other documented occurrences within Marin County).
- Ten mountain lion observations, seven from the North Array and three from the South.
- Eighteen western spotted skunk sightings, eight from the North Array and 10 from the South.
- Two long-tailed weasel observations from the South Array.

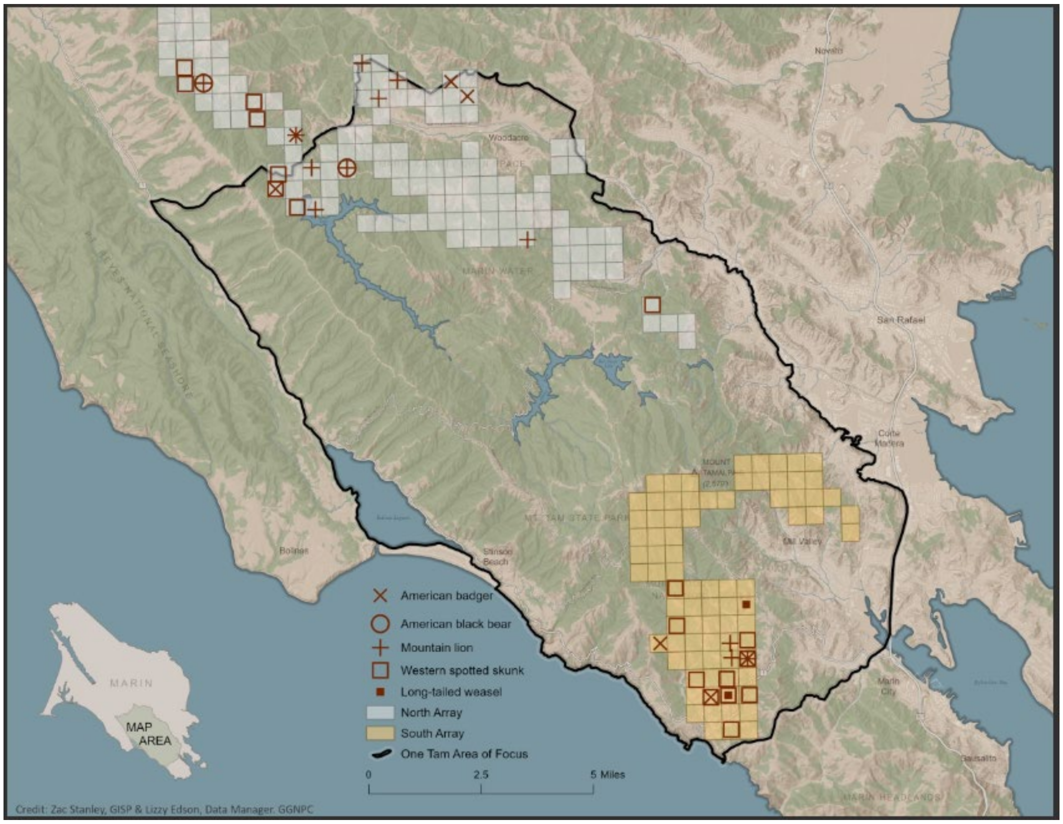


FIGURE 23.4 CAMERA GRID LOCATIONS WITH RARE-SPECIES DETECTIONS FOR MWW STUDY AREA

Note: North Array data are from 2014 through fall 2017 and South Array data are from 2017 (summer, fall, and winter seasons). Black bear locations from the North Array and mountain lion locations from the South Array were added from 2021 data.

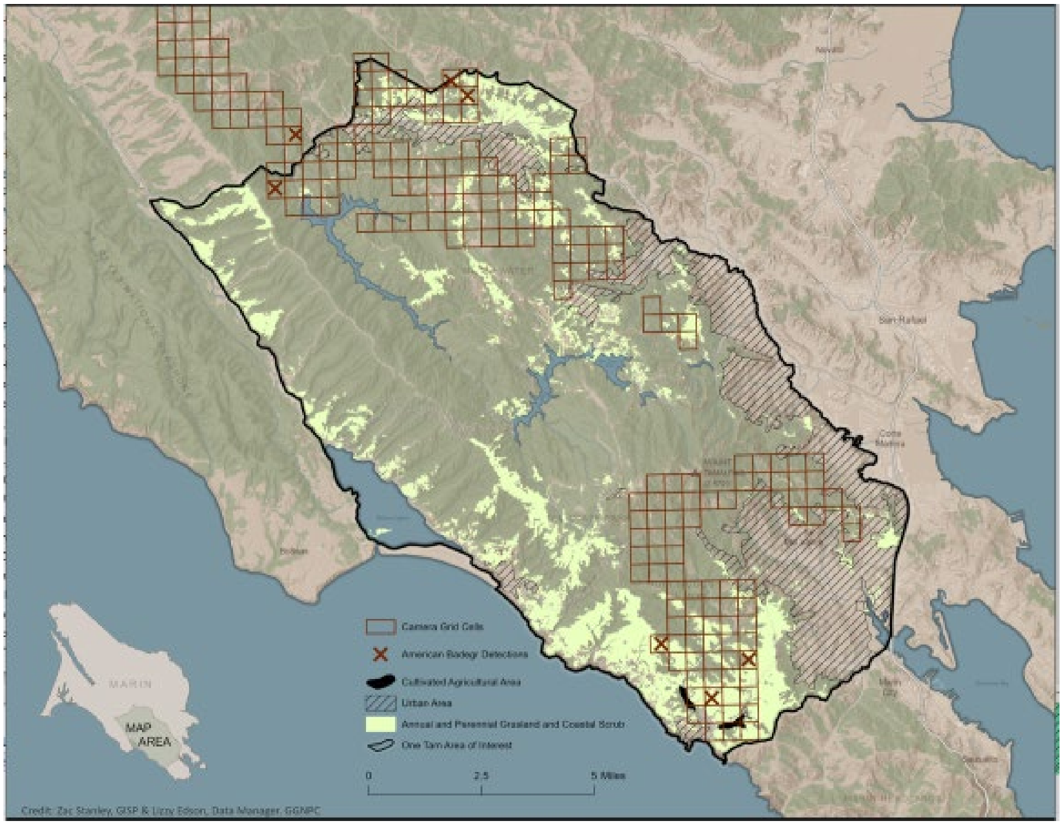


FIGURE 23.5 GRASSLAND AND COASTAL SCRUB HABITAT, ONE TAM AREA OF FOCUS, WITH MWW NORTH AND SOUTH ARRAY CAMERA GRIDS AND AMERICAN BADGER DETECTION LOCATIONS

Trend:

2016: Unknown

Because we had limited MWW camera data available from the North Array, the 2016 analysis was establishing a baseline. The trend for rare species was unknown at that time.

2022: Improving

Since the 2016 report, we have added observations for all of our rare species except the ringtail. In addition, we were able to add two species (the black bear and the long-tailed weasel) to our rare species list. By adding observations at new locations, we are increasing our understanding of the areas these species may be using.

Confidence:

2016: Low

We only had limited data for the initial analysis, so our confidence in our ability to adequately assess the presence of rare mammals was limited.

2022: Moderate

We have expanded both the area and the amount of time we have sampled for rare species since 2016. However, despite increased levels of effort and coverage, we still have a large number of images that have not been processed for a more up-to-date rare-species evaluation. In addition, documenting rare species takes more time because there are fewer photos of them amongst the many images the cameras take. Therefore, our confidence that we have adequately sampled for rare species is moderate.

METRIC 3: WILDLIFE PICTURE INDEX (WPI) FOR KEY GROUPS

Baseline: Use species-specific occupancy estimates to measure trends in seasonal abundance for different mammal trophic levels, including:

- Top predators (e.g., mountain lion and coyote [*Canis latrans*]).
- Mesocarnivores (e.g., bobcat, gray fox, American badger, and western spotted skunk).
- Other native mesocarnivores (e.g., raccoon [*Procyon lotor*] and striped skunk [*Mephitis mephitis*]).
- Large-bodied native grazers (e.g., black-tailed deer).
- Small-bodied prey (e.g., dusky-footed woodrat, Sonoma chipmunk [*Tamias sonomae*], western gray squirrel [*Sciurus griseus*], black-tailed jackrabbit, and brush rabbit [*Sylvilagus bachmani*]).

The MWW was designed to provide data that could be used to assess changes in condition of the mammal community over time and establish a trend. In 2016, the MWW was underway, but few data were available. Now, results from the North Array (2014 to 2017) and from the South Array (2017) are available to assess conditions for this metric. These data were used to generate species' occupancy assessments and biodiversity trend in WPI for the North Array only.

Condition Goals:

- Common species are present, abundant, and stable.
- Recognizing that rare species are expected to be at lower "prevalence and abundance" than common species, they are present and stable.
- Each species and/or each trophic group is stable or increasing in occupancy.
- The WPI, a biodiversity metric of trend using aggregated mammal occupancy estimates, is stable in comparison to the baseline year (first year of monitoring).

Condition Thresholds:

- **Good:** Fewer than five species' specific seasonal occupancy estimates are declining compared to the baseline (year one: 2014 for North Array and 2017 for South Array). Each trophic level has expected diversity levels, and mesocarnivores are "balanced." The WPI is stable or increasing.

- **Caution:** Between five and nine species' specific occupancy estimates are declining compared to the baseline (year one: 2014 for North Array and 2017 for South Array). More than one trophic level (or an important constituent member of a trophic level) and/or the WPI are declining over the most recent three-year period.

- **Significant Concern:** Ten or more species' specific occupancy estimates are declining compared to the baseline (year one: 2014 for North Array and 2017 for South Array). More than one trophic level continues to decline after three years. The WPI declines for more than three years.

Current Condition:

2016: Unknown

As of 2016, most native mammals had been detected (Townsend, 2015), although there was some concern about low detections for certain rare species. Deer were the most commonly detected species (Townsend, 2015). Corroborating this finding, a 2020 CDFW study estimated the density of deer in Marin County at 18.3 deer per sq km, higher than any other published deer density estimate for California. Due to limited data for analysis, the condition for this metric was assessed as unknown in 2016.

2022:

Good (for species-specific abundance and stability)

Caution (for aggregated trends in mammal biodiversity)

Available datasets were used to assess the current condition for most mammals in the One Tam area of focus (Figure 23.2). Analyses from the North and South Arrays were used to establish baselines and, when possible, also establish trends based on seasonal occupancy estimates (i.e., the probability that a site is occupied by a target species, with numbers ranging from 0 to 1.0). Seasonal analyses include summer (June 1 to August 31), fall (September 1 to November 30), winter (December 1 to February 28), and Spring (March 1 to May 30).

Occupancy accounts for variable species detectability caused by things like habitat type or survey conditions (e.g., lighting or weather). Each day a camera was operating was considered a resurvey ("trap night"; Townsend, 2018). Species-specific occupancy numbers closer to 1.0 (e.g., black-tailed deer in Figures 23.6 A–D) indicate that a species is highly likely to be present at each camera on most trap nights. Numbers closer to zero (e.g., puma in Figures 23.6 A–D) indicate rare species that are only detected at a few cameras on a few trap nights. Occupancy in the middle range (e.g., coyotes in Figures 23.6 A–D) indicate presence at most of the cameras and on many trap nights. Although occupancy and abundance are different measures, a species increasing in abundance is typically increasing in occupancy, while a species declining in abundance tends to be declining in the number of sites it occupies (Gaston et al., 2000).

The WPI is a biodiversity metric (i.e., a measure that looks at both species richness and abundance, or, in our case, occupancy) that aggregates occupancy estimates across species using the geometric mean (O'Brian et al., 2010; Buckland et al., 2005). We need three or more years of data to calculate a WPI trend, so this was done only for the North Array data set. Year one WPI is scaled to 1.0, and subsequent years are calculated and scaled to the year-one reference. Thus, an increasing WPI trend (a WPI greater than 1.0 for years following the baseline) indicates increasing biodiversity, while a declining WPI trend (a WPI less than 1.0 for years following the baseline) indicates declining biodiversity.

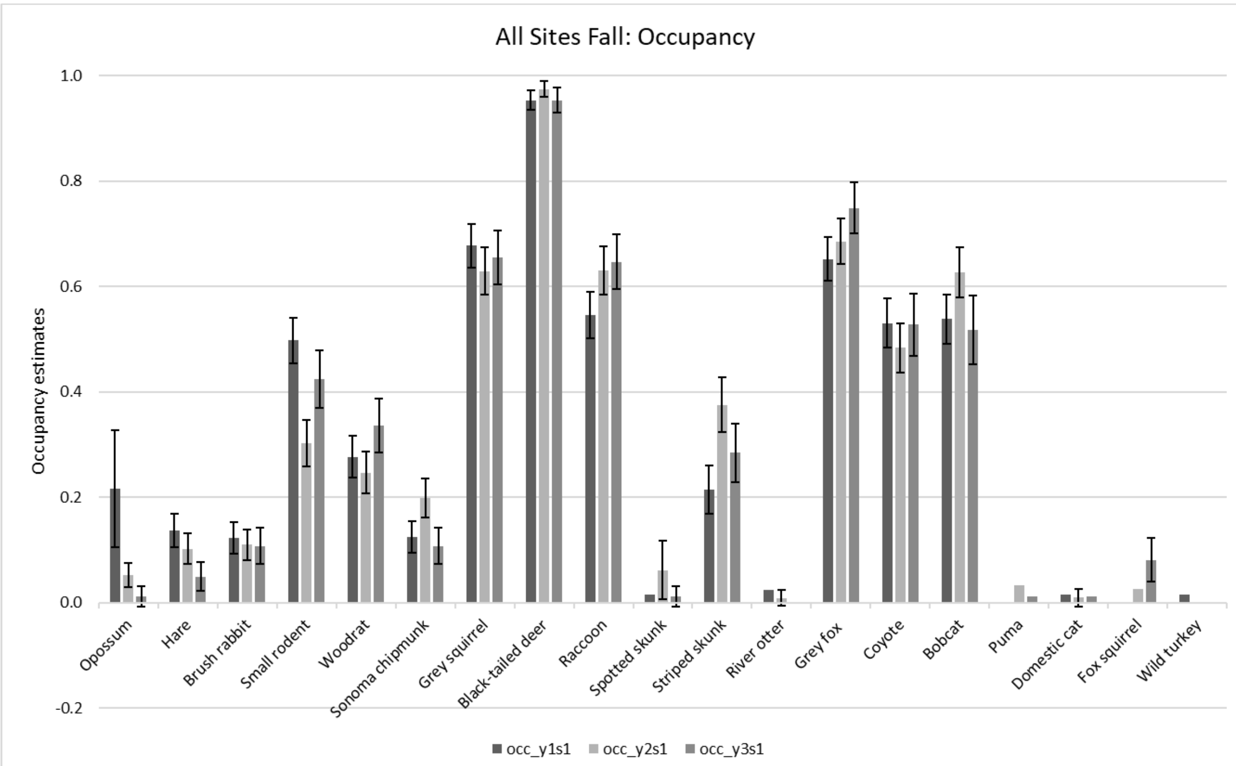
For the North Array, stable occupancy estimates for most mammal species were observed in all v seasons from 2014 to 2017 (Figures 23.6 A–D), with the exception of a slight downward trend in the summer estimates for the gray fox, bobcat, and coyote (Figure 23.6 D). Additionally, mesocarnivore occupancy estimates were balanced at generally 0.5 or higher for the raccoon, gray fox, coyote, and bobcat (Figures 23.6 A–D). The absence of a disproportionately high occupancy estimate for any single mesocarnivore supports the idea of a "mesocarnivore release," in which the numbers of smaller predators increase in the absence of larger predators. In addition, stable and similar relative abundances among common species and within trophic levels can be an indicator of a healthy ecosystem. In the area of focus, small herbivores were diverse and well represented and deer continued to have high occupancy estimates (close to 1.0) from 2014 to 2017. Combined, these results gave a condition of good for species abundance and stability.

In addition to looking at individual species, the WPI was plotted from year one (2014/2015, baseline) to year three (2016/2017) for each season. Comparing year three to year one indicated declines in the fall (-13%, 2014–2016) and winter (-11%, 2014–2016/17), but stable trends for spring (-1%, 2015–2017) and summer (-0.4%, 2015–2017) (Figures 23.7 A–D). The declines led us to assign a condition of caution for biodiversity trends overall.

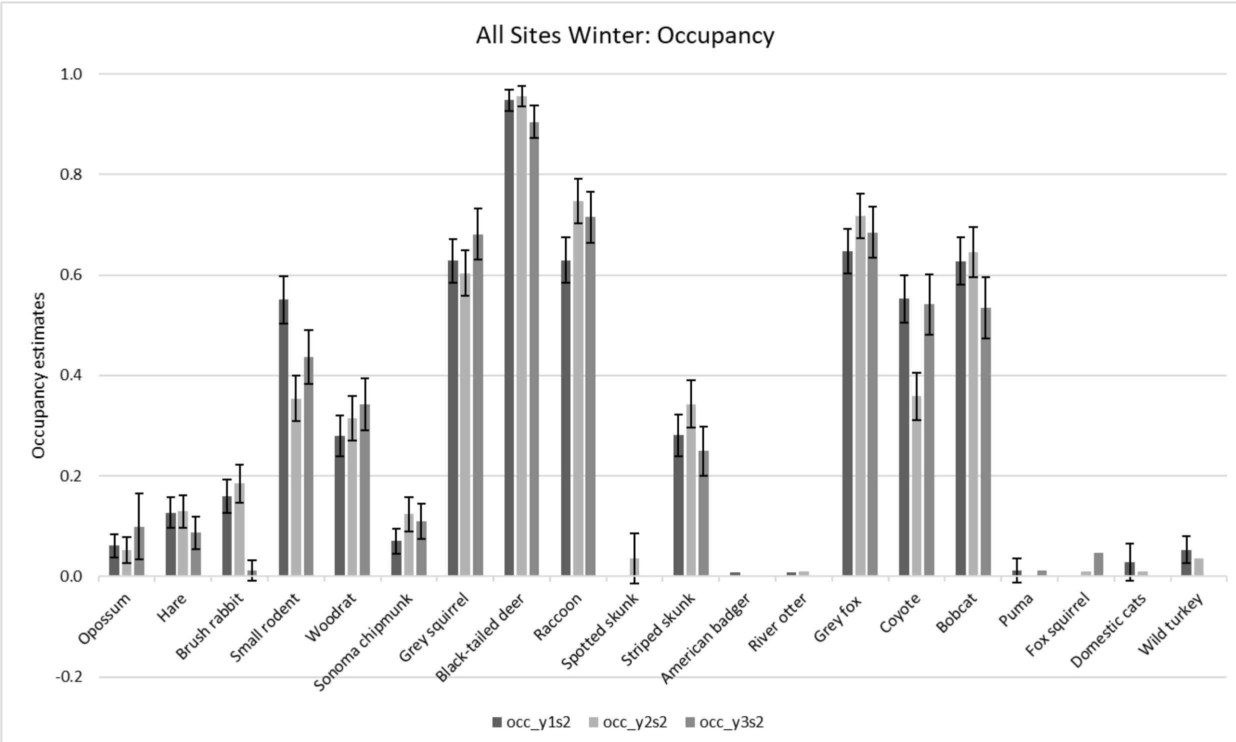
Aggregated South Array occupancy estimates across the summer, fall, and winter seasons in 2017 indicated stable and healthy abundance for common species (Figure 23.8). Occupancy estimates for the less-common species indicated spotty presence and abundance for the opossum, jackrabbit, fox squirrel, and badger; the western spotted skunk was reliably present at low occupancy (0.05) each season. Both the North and South Arrays had robust and balanced carnivore communities. Therefore, the condition is good for stable and balanced occupancy estimates for most to all species. The condition is caution for two (fall and winter) of the four seasons, with a declining WPI for the North Array during 2014–2017.

Abbreviations: occ_y1s1 = 2014/2015; occ y2s2 = 2015/2016; occy3s3 = 2016/2017. **Species names**: Hare = black-tailed jackrabbit; woodrat = dusky-footed woodrat; grey squirrel or gray squirrel = western gray squirrel; spotted skunk = western spotted skunk; grey fox = gray fox; and puma = mountain lion.

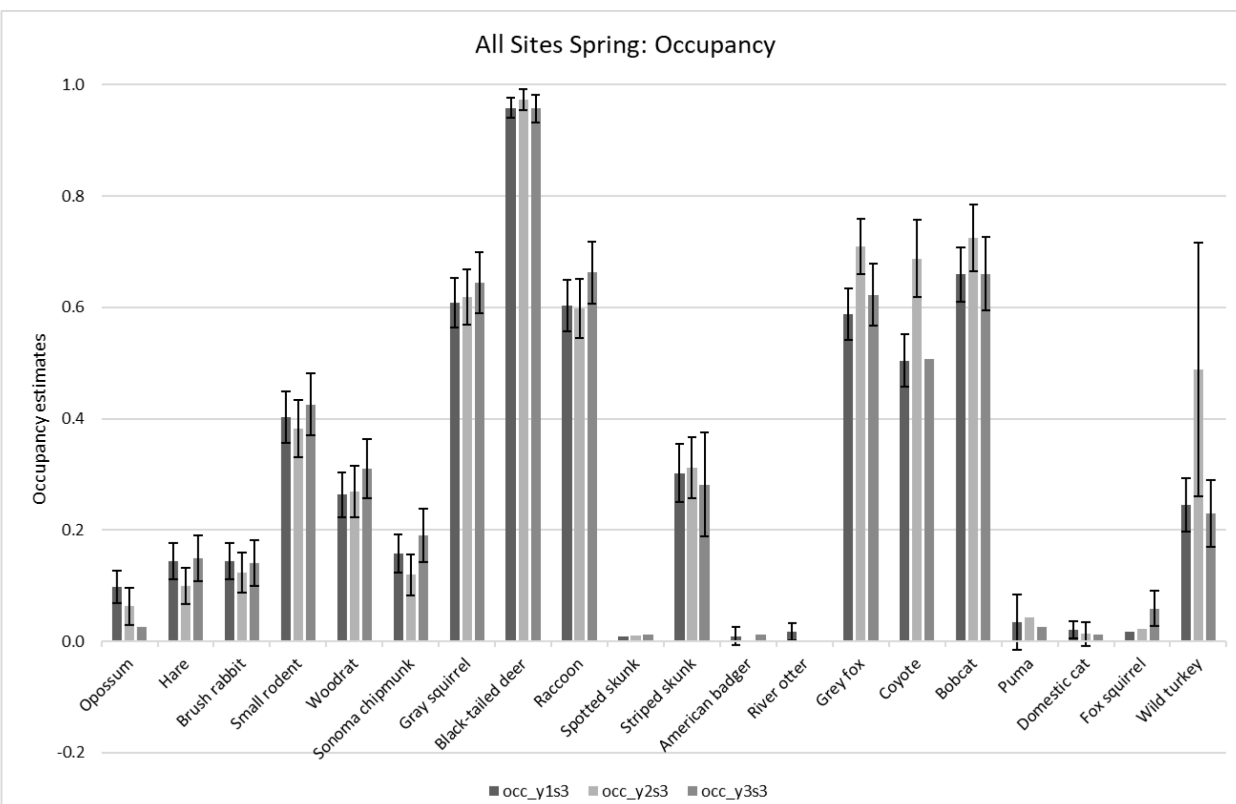
a) Fall 2014, 2015, 2016



b) Winter 2014/2015, 2015/2016, and 2016/2017



c) Spring 2015, 2016, 2017



d) Summer 2015, 2016, 2017

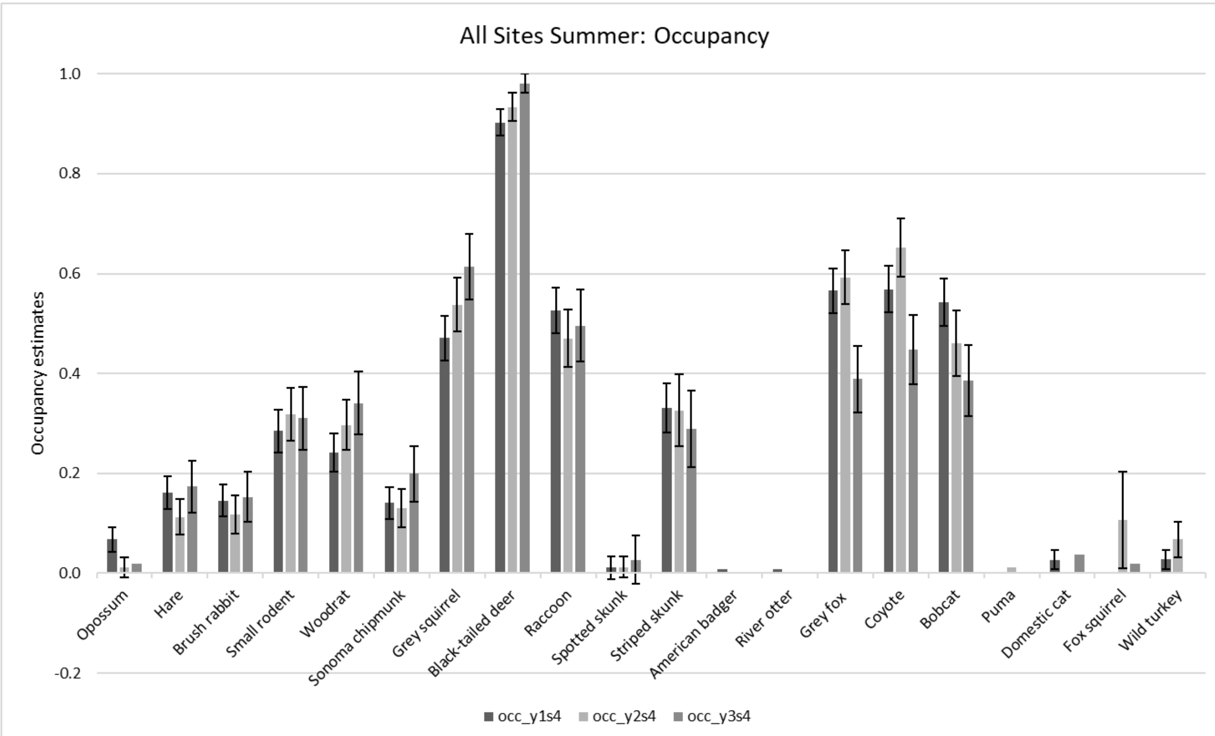
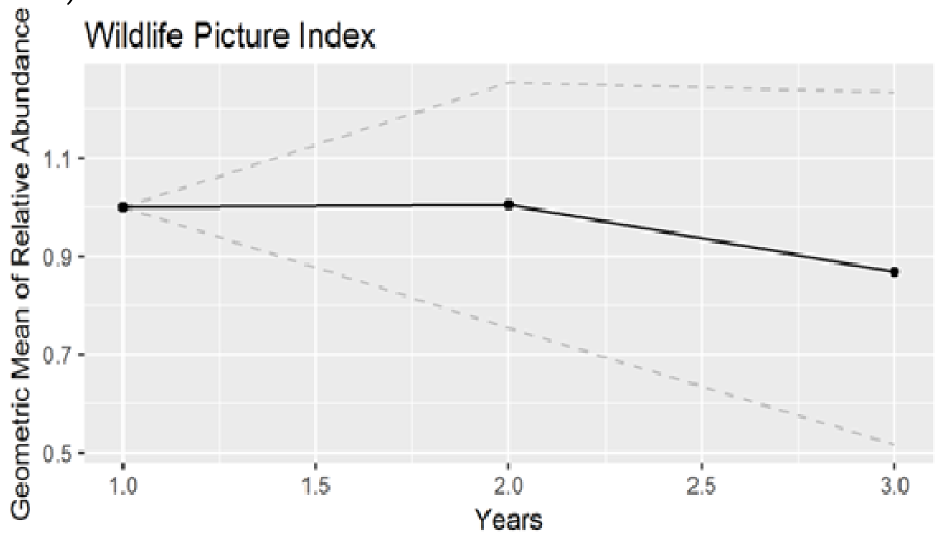


FIGURE 23.6, A–D SEASONAL OCCUPANCY ESTIMATES +/- SE FOR INDIVIDUAL SPECIES, MWW NORTH ARRAY, FALL 2014–SUMMER 2017 (TOWNSEND, 2018)

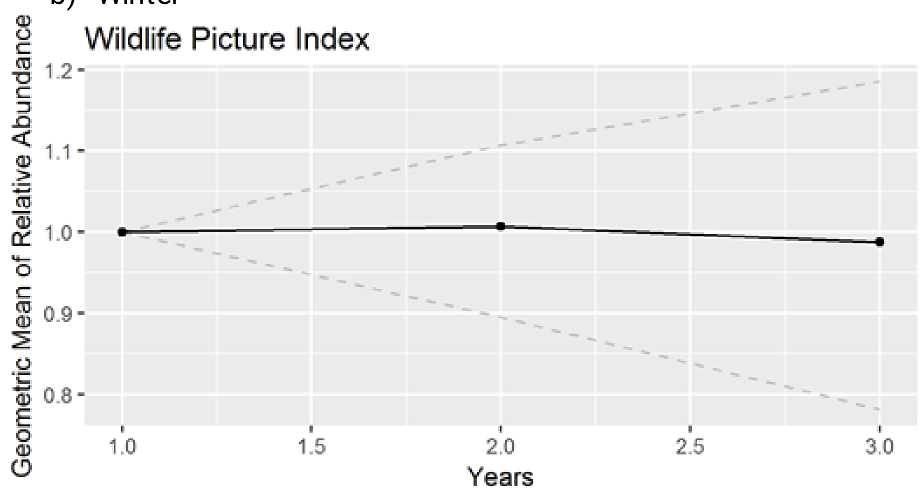
Note: *The Wildlife Picture Index (WPI) is calculated for each season and is the geometric mean of the sum of the species' specific occupancy estimates. It is set to one for the first season, with subsequent years scaled to the year-one estimate. When WPI is increasing, year two and three WPI estimates will be greater than 1.0. The Y-axis in figures is the WPI. The confidence interval (CL) is shown with dotted lines.*

a) Fall



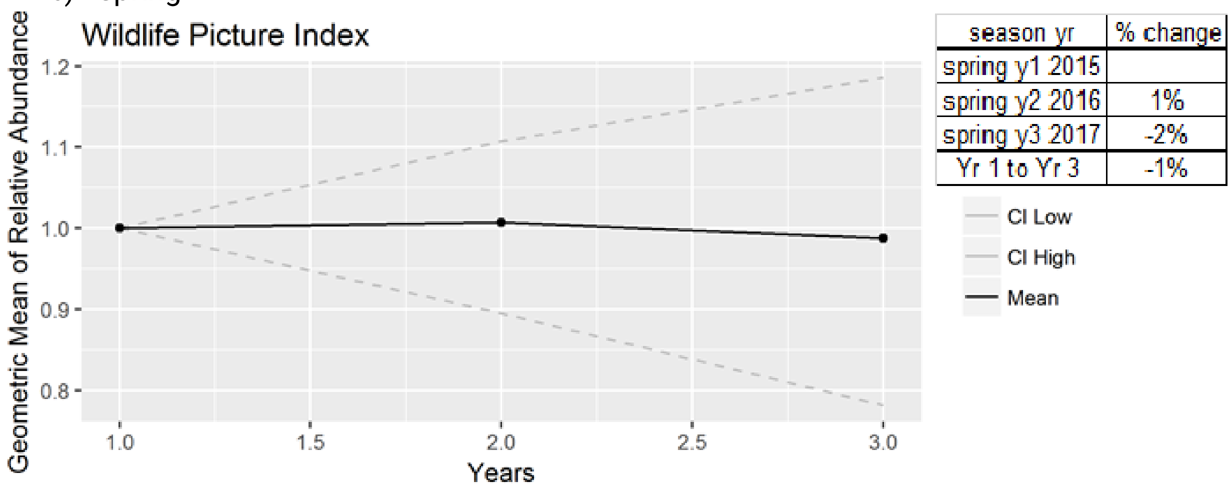
All Sites	% change
Fall y1 2104	0%
Fall y2 2015	1%
Fall y3 2016	-14%
Total change	-13%

b) Winter



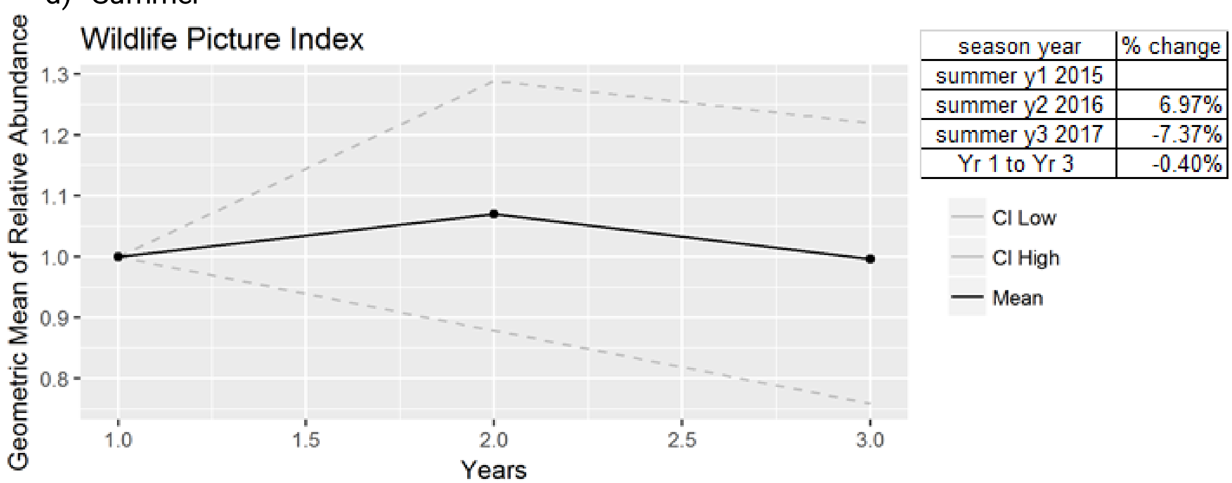
season year	% change
winter y1 2014	
winter y2 2015	-1%
winter y3 2016	-11%
Yr 1 to Yr 3	-11%

c) Spring



season yr	% change
spring y1 2015	
spring y2 2016	1%
spring y3 2017	-2%
Yr 1 to Yr 3	-1%

d) Summer



season year	% change
summer y1 2015	
summer y2 2016	6.97%
summer y3 2017	-7.37%
Yr 1 to Yr 3	-0.40%

FIGURE 23.7, A–D WILDLIFE PICTURE INDEX WITH CONFIDENCE INTERVALS FOR MWW NORTH ARRAY, 2014/15–2016/17 (TOWNSEND, 2018)

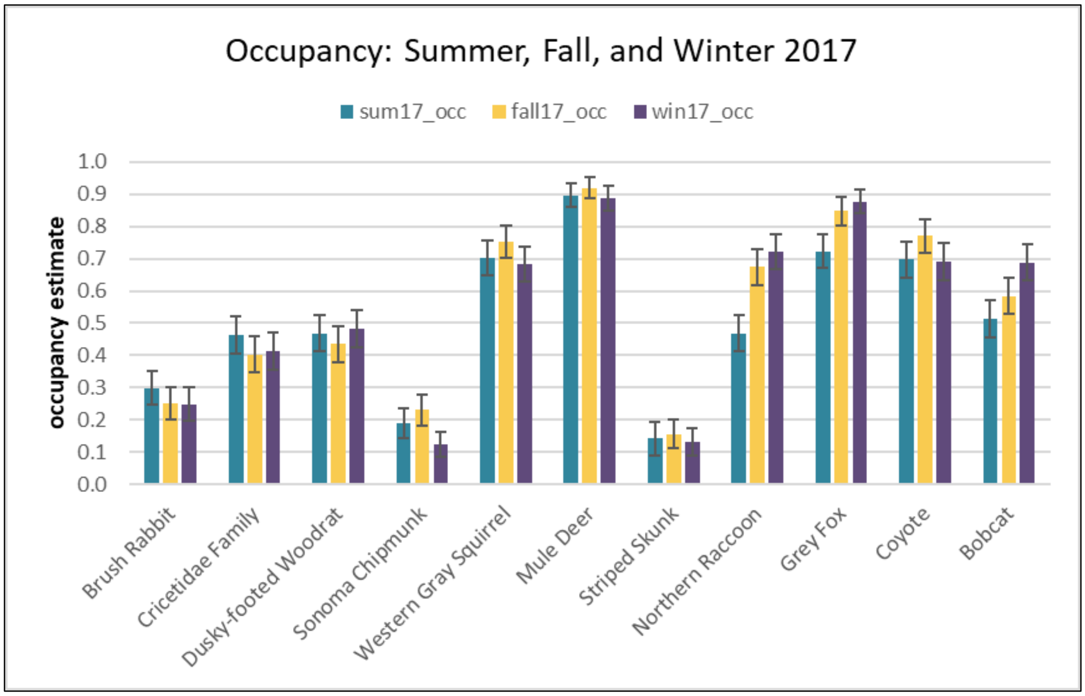


FIGURE 23.8 OCCUPANCY ESTIMATES +/- STANDARD ERROR, COMMON SPECIES, MWW SOUTH ARRAY, SUMMER, FALL, WINTER 2017 (TOWNSEND, 2020)

Abbreviations: *sum17_occ = occupancy estimate summer 2017; fall17_occ = occupancy estimate for fall 2017; and win17_occ = occupancy estimate for winter 2017.* ***Species naming:*** *Cricetidae family = small mammals; mule deer = black-tailed deer; northern raccoon = raccoon; grey fox = gray fox.*

Trend:

2016: Unknown

There was insufficient MWW data to assess the condition and trend in 2016.

2022:

Species abundance and stability: No Change

Biodiversity: Declining

Occupancy for most species and guilds was stable and balanced. Trends in the WPI warranted a caution assessment. We will continue to generate seasonal biodiversity measures on an annual basis to track trends for this metric.

Confidence:

2016: Low

In 2016, we had only three months of North Array camera data, so occupancy and WPI analyses could not be conducted. As a result, our confidence was low.

2022: Moderate

The analyses for this metric were based on reliable data from a wide geographic area for 2014 through 2017 from the northern portion of the study, and additional data for 2017 from the Southern Array. Images from these arrays have been and continue to be collected for processing and analysis but were not ready at the time of this writing. Additional years of data will increase our confidence about WPI estimates and provide more years to establish trends for individual species in the area of focus.

METRIC 4: NON-NATIVE, INVASIVE MAMMAL SPECIES

Baseline: Non-native, invasive mammals in the One Tam area of focus and its surroundings include:

- The red fox (*Vulpes vulpes*), an introduced species, is not commonly seen in Marin County. Invasive red fox affect a broad range of native prey species because of their omnivorous diet. Although best known for preying upon birds and eggs, red fox also prey upon small mammals and reptiles.
- Domestic cats are present in some areas, usually focused around human developments. Where present, they have a significant detrimental effect on birds, small mammals, reptiles, and amphibians (Trouwborst et al., 2020).
- The fox squirrel is an eastern species that is spreading westward, particularly in urban areas (Muchlinski & King, 2010). In southern California, fox squirrels may be displacing native western gray squirrels.
- The eastern gray squirrel (*Sciurus carolinensis*) is known to be in Marin County. We need to do additional work to determine its distribution and relative abundance on the mountain. This species may compete with the native western gray squirrel (Johnston, 2013).
- The opossum is established in Marin County, but at relatively low densities. A southern California study found that they can have a negative impact on landbird communities (Crooks & Soulé, 1999).
- The feral pig was largely eradicated from Marin County in the late 1980s because of the dramatically detrimental effects they have on terrestrial ecosystems.
- The black rat (*Rattus rattus*) and the Norway rat (*R. norvegicus*) are commonly found in and near human developments. In wildlife camera images, we cannot reliably distinguish these invasive rats from other small mammals.
- Cattle (*Bos taurus*) are present in some specific areas due to land management decisions.

We have detected six of the eight species listed above through our MWW project (Table 23.4). We need more information on the invasiveness of some of the San Francisco Bay Area's non-native species to better assess this metric.

TABLE 23.4 NON-NATIVE MAMMALS DETECTED BY MMW IN THE ONE TAM AREA OF FOCUS

Non-Native Mammals in the One Tam Area of Focus	
Species	**Common Name**
Didelphis virginiana	Opossum
Sus scrofa	Feral pig
Sciurus carolinensis	Eastern gray squirrel
Sciurus niger	Fox squirrel
Felis catus	Domestic cat
Bos taurus	Cattle

Condition Goal: An absence of non-native mammals, especially feral pigs or cats, which can have outsized and detrimental impacts on native biodiversity.

Condition Thresholds:

- **Good:** The feral pig is not detected in the study area. Domestic cats are at low abundance and only detected around developed areas. Other non-natives (aside from cattle) are present at low densities of <0.5 detections per 100 trap nights.

- **Caution:** The feral pig is not detected in the study area. Non-native species (aside from cattle) are present at moderate densities of ≥0.5 detections per 100 trap nights.

- **Significant Concern:** All five non-native species are detected; domestic cats are detected by cameras at a distance from developed areas; there is evidence of a non-native mammal displacing a native species.

Current Condition:

2016: Good

Based on data available at the time of the analysis, opossums and cattle were the only non-native mammals detected.

2022: Good

Through MWW data analysis, we have detected cattle, domestic cats, opossums, fox squirrels, and eastern gray squirrels. Cattle are used for grassland management and so are expected in areas where grazing happens. Cat detections tended to be near developed areas. Other detections of non-native species were at low densities.

Trend:

2016: Unknown

Our 2016 assessment of invasive species was based on a few months of MWW North Array data, and we were not able to determine a trend at that time.

2022: Decreasing

With a longer time period and a larger sampling area, the number of detected non-native species in our study area increased to six. The extent of invasiveness for some of these non-natives is unclear, and more information would help us make a better assessment of the threats they pose to native mammals. What we do know is that omnivorous opossums prey upon landbird nests (Crooks & Soulé, 1999), though their impact on the study area is unknown. Fox squirrels have been shown to compete with western gray squirrels in some places (Muchlinski & King, 2010), but it is unclear if they have expanded beyond the mountain's urban edge. Introduced eastern gray squirrels have also been detected (Trouwborst et al., 2020), and we are currently developing a project to better understand their distribution, abundance, and possible effects on the native western gray squirrel. Domestic cats were detected on our MWW cameras in both the North and South Arrays.

Confidence:

2016: Moderate

Based on the limited quantity of data from the North Array cameras available at that time, our confidence was moderate.

2022: Moderate

Our confidence remains moderate. Although we have increased MWW's geographic scope and duration, we are still determining the extent of some of these non-native species. Also, their impacts on the mountain's ecosystems are not well known.

SUPORTING DATA, OBSERVATIONS, AND RESEARCH

MARIN WILDLIFE WATCH (MWW)

The MWW study area is approximately 32 sq km. In fall 2014, 128 camera stations were deployed at 0.5 km intervals in roughly north-south–oriented grids (North Array). An additional 80 cameras were installed south of that (South Array; Figure 23.2). In 2018, the North Array was reduced to 36 cameras at 1 km intervals, but covered essentially same study area extent. Both arrays continue to collect data. Camera stations are set to maximize the likelihood of mammal detections, including small mammals, and standardized to a height that allows them to detect the gray fox at a distance of roughly .91 to 1.2 m.

Images from the camera's memory cards are downloaded and reviewed to identify species. Trained staff and supervised volunteers record the species and number of individuals for each image. This data was used for this chapter's analyses. Full methods and results, including the species detected, how often, and other data, were compiled and analyzed and are available in Townsend, 2015, 2018 (administrative drafts). Methods are also included in published papers (O'Brien et al., 2010; O'Brien, 2010; see also Townsend et al., 2020).

NATIONAL PARK SERVICE TERRESTRIAL VERTEBRATE INVENTORY WORK

The National Park Service has completed terrestrial vertebrate inventory work at Muir Woods (Howell et al., 1998), Point Reyes National Seashore (Fellers & Pratt, 2002), and Golden Gate National Recreation Area (Semenoff-Irving & Howell, 2005).

OTHER SUPPORTING DATA SOURCES

Information for this chapter also came from staff and visitor observations, as well as observations and data from others, including:

- **The River Otter Ecology Project** initiated a study of North American river otters in Marin County in 2012. It performs non-invasive camera trapping and scat collection in coastal, wetland, riverine, pond, and reservoir environments, including some in the One Tam area of focus. The collected scat is analyzed to determine what the otter is consuming and, in selected areas, efforts are made to document otter breeding. The results of this camera trapping facilitate family structure analysis and vocalization studies and provide basic abundance information. River otters are described in more detail in Chapter 24.
- **The Felidae Conservation Fund** conducted a San Francisco Bay Area bobcat study that has found large numbers of this species in Marin County. It has also placed wildlife cameras in Marin to study mountain lion numbers; it is believed that there are likely one transient and one resident male in the area. Through the Bay Area Puma Project, the fund is working with others to initiate a mountain lion telemetry study in the county and the northern San Francisco Bay Area more generally.
- **The California Department of Fish and Wildlife** (CDFW) estimated the density of deer in Marin County at 18.3 deer per sq km, which is 1.7–6.1 times higher than published deer abundance estimates elsewhere in the state. The highest deer densities, up to 44 deer per sq km, were found in areas with intermediate human densities and higher densities of oaks and hardwoods. The overabundance of deer in Marin County is possibly associated with a paucity of large predators (though an apparent increase in coyotes

was reported from 2007 to 2016). CDFW did note that although deer densities in Marin were high, they were at the low end compared to other places in North America experiencing overabundant deer densities (Furnas et al., 2020). Overabundance is defined as when deer numbers exceed ecosystem carrying capacity, and the deer are malnourished or experience die-off. To date, deer appear to be largely healthy in our camera images, and occupancy estimates (close to 1) are similar to those from other parts of the Bay Area (e.g., Napa and Sonoma Counties).

INFORMATION GAPS

Climate Change: We do not know how the effects of climate change will affect (or alter) the mountain's mammal habitats. Because the habitats are diverse and patchy and exist along a variety of elevation gradients, it is possible that they will serve as a climate refuge for some species. We are currently working to better determine whether mammal species in the area of focus have been found to be vulnerable to climate change, either regionally or in the state.

Marin Wildlife Watch (MWW) Workflow: We continue to run wildlife cameras at both the North and South Arrays and have transitioned to a cloud database, where artificial intelligence (AI) is used to assist in cataloging images. Once the images are run through AI, we verify that the computer assignments are correct. The sheer volume of images means that confirming and/or identifying the species is quite time-consuming, which results in an information gap. Focusing our efforts on this part of the workflow is a priority.

Small Mammal Diversity and Population Information: We currently have very little population data for native small-mammal species, apart from incidental sightings and a few limited inventories. In particular, we would like to better understand dusky-footed woodrat distribution and abundance (a dusky-footed woodrat study is also identified as a priority for Northern Spotted Owls; see Chapter 20). Woodrat occupancy estimates (along with small rodents) from MWW arrays provide some abundance and distribution trend data, at least within the camera study areas. Currently, camera images lack the resolution to identify small rodents to the species level. A needs statement to develop an assessment program for small mammals is included in Chapter 25 of this report.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Coyote Study: Golden Gate National Recreation Area (National Park Service) initiated a coyote coexistence project in 2020 in partnership with the Presidio Trust and UC Davis. The objectives of this project are to study coyote movement patterns along a gradient of human development, mark individual coyotes with unique combinations of colored ear tags, and provide information to develop outreach materials to educate people on the dangers of feeding and approaching coyotes. The project also includes studying coyote genetics, diet, and disease exposure. In 2020, seven coyotes were captured and collared; three were later killed by vehicles on Highway 101, and two successfully dispersed north in Marin. Two adult coyotes stayed in the Marin Headlands area where they were captured. A Tracking Coyotes in Marin iNaturalist project was established, and the public was encouraged to contribute photographs. Additionally, a few management actions were undertaken to restrict access to some feeding locations through installing traffic cones and signage. No coyotes were captured during trapping in 2021. At the time of this report, efforts are being made to capture more coyotes for study.

Point Reyes Mountain Beaver Study: Point Reyes National Seashore (National Park Service) wildlife staff is assisting UC Berkeley research into the little-studied Point Reyes mountain beaver (*Aplodontia rufa phaea*). This subspecies of mountain beaver, which is endemic to Point Reyes, is threatened by its limited range and wildfire. Staff will be assisting with a nearly parkwide inventory, searching for the burrows of the elusive species. The goal is to produce a habitat model that shows where it is most likely to occur. This information will be used to guide future management actions in that habitat, especially in the event of fire (and fire response), and to minimize disturbance to this unique animal. Information from this study may help identify suitable mountain beaver habitat on areas adjacent to Point Reyes.

Past Work

Following are two of the previous stewardship and management activities undertaken over the years to monitor, protect, and restore this health indicator.

Monitoring: Long-term MWW data collection was initiated to assess condition and trends (2014 to the present/ongoing).

Inventories: Mammal inventories were undertaken by the National Park Service and Marin Water (1990–1997 and 2014).

FUTURE ACTIONABLE ITEMS

This section includes needs identified by agency and local scientists as part of the development of this report. These are actions not currently funded through agency programs and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Research: Continue MWW and work through the image backlog to bring the data up to date to assess current conditions more effectively. Continue monitoring trends and capturing the effects of drought, wildfire, and management practices. Also, continue the coyote coexistence project and outreach on reducing coyote (and other wildlife) feeding. Initiate work on eastern gray squirrels and their potential impact on native western gray squirrels.

Roadkill Research and Interventions: Increase contributions to the UC Davis California Roadkill Observation System. Work is needed to identify Marin's roadkill hotspots and species, which will enable us to identify projects that will mitigate roadkill in these areas.

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CHAPTER 24. NORTH AMERICAN RIVER OTTER (*LONTRA CANADENSIS*)

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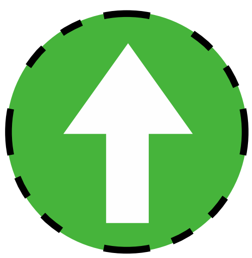
UPDATE AT A GLANCE

SUMMARY OF CHANGES IN THIS INDICATOR SINCE 2016

2016



Condition: Good

Trend: Improving

Confidence: Moderate

2022

Condition: Good

Trend: Improving

Confidence: Moderate

FIGURE 24.1 CONDITION, TREND, AND CONFIDENCE FOR THE NORTH AMERICAN RIVER OTTER, ONE TAM AREA OF FOCUS

The North American river otter population of Marin County, including the One Tam area of focus, appears to continue to improve, and its overall condition remains good. Key findings for this 2022 update are that river otters are continuing their decade-long increase in Marin and the broader San Francisco Bay Area, and that they now occupy most suitable water bodies within the area of focus.

METRICS SUMMARY

The metric in Table 24.1 was used to assess North American river otter health. The condition, trend, and confidence for this metric was then given a score, which determined the overall condition, trend, and confidence described in Figure 24.1. This metric is described in the Condition and Trend Assessment section later in this document. (See Chapter 2 for definitions of terminology used throughout this chapter, how metrics are being used to evaluate the health of each indicator, and other project methodology details.)

TABLE 24.1 NORTH AMERICAN RIVER OTTER METRIC, WITH CONDITION, TREND, AND CONFIDENCE

Metric 1: North American river otter presence		
	2016	**2022**
Condition	Good	Good
Trend	Improving	Improving
Confidence	Moderate	Moderate

INTRODUCTION

WHY IS THIS AN IMPORTANT INDICATOR?

As an apex predator that uses a variety of terrestrial and aquatic habitats, the North American river otter is a sentinel indicator of watershed function and health (Larivière & Walton, 1998). It plays a key role in both marine and freshwater ecosystems, as it feeds upon a wide variety of native and non-native species (Penland & Black, 2009; Garwood et al., 2013). It is also an indicator of water quality because it is susceptible to potential pathogens such as *Cryptosporidium*, *Giardia* (Gaydos et al., 2007), and *Vibrio* spp. (Bouley et al., 2015), and bioaccumulates environmental contaminants such as mercury, metals, organochlorines, and hydrocarbons (Francis et al., 1994; Halbrook et al., 1996; Bowyer et al., 2003).

Furthermore, understanding river otter ecology and population status is an important element of ecosystem management (Bowen, 1997; Kruuk, 2006; Ben-David & Golden, 2009). The river otter transports aquatic nutrients to land (Ben-David et al., 2004); plays a key role in aquatic and terrestrial food webs (Crait & Ben-David, 2007); and affects the composition and abundance of prey species (Garwood et al., 2013). This charismatic megafauna, which is regularly and easily seen in Mt. Tam watersheds, is popular with the public, and its resurgence is a source of inspiration. Once extirpated from this region, the return of river otters to Marin County waters is a wildlife recovery success story.

CURRENT CONDITION AND TREND

Historically present but extirpated from most of the San Francisco Bay Area, the North American river otter has significantly increased in both number and distribution over the last 30 years (Bouley et al., 2015; Carroll et al., 2020; CDFW, 2019). Currently, it can be found in watersheds from Mt. Tam's headwaters to the coast and as far as San Francisco Bay (Figure

24.2; Bouley et al., 2015). Observational data from the River Otter Ecology Project (ROEP) also indicate the presence of otters in most water bodies in the area of focus (Bouley et al., 2015; Carroll et al., 2020; River Otter Ecology Project, 2022). North American river otter health was assessed using a single metric: presence in suitable water bodies. Data collected and compiled by ROEP used for this assessment include observations from ROEP staff and volunteers, wildlife camera data, and community science data reported online through the ROEP Otter Spotter project.

FIGURE 24.2 DOCUMENTED PRESENCE OF THE NORTH AMERICAN RIVER OTTER (ROEP DATA)

DESIRED CONDITION AND TREND

The desired condition is that the North American river otter is present in all suitable water bodies in the area of focus.

STRESSORS

Historical Impacts: Historical persecution in the form of fur trapping and predator removal, habitat loss, and poor water quality were probably major factors in the extirpation of the North

American river otter from the San Francisco Bay Area. Fur trapping, a practice that was not outlawed in California until 1961, may have also contributed to its decline.

Climate Vulnerability: This species will be affected by climate change everywhere it lives (Cianfrani et al., 2018), with mean annual temperature being the most important variable determining its eventual distribution. Models predict habitat loss in the southern segment of its range (including central California) and range expansion in the northern segment through 2050. The North American river otter consumes a wide array of prey, which may provide the species with some resilience to climate change. However, its prey species are also vulnerable to drought and flooding, and changes in prey composition and abundance could challenge that resilience. The decline of large prey in Marin's watersheds, particularly salmonids (see Anadromous Fish, Chapter 14), may also have detrimental effects.

Fire Regime Change: Removing riparian vegetation for fire mitigation may have negative impacts on the river otter's habitat quality (Prenda et al., 2001); however, most fire fuels reduction work in Marin County will likely be outside of riparian corridors.

Disease: North American river otters are susceptible to diseases such as canine distemper, feline and canine parvovirus, and rabies (Gaydos, 2014).

Pollution/Contaminants: This species is vulnerable to aquatic pollution from spills and other sources, as well as secondary exposure to rodenticides. It may also be susceptible to mercury poisoning from the fish it eats (Gaydos, 2014).

Direct Human Impacts: North American river otters are susceptible to car strikes as they traverse terrestrial habitats (Bouley et al., 2015).

Habitat Disturbance/Conversion/Loss: Because of their dependence on aquatic ecosystems, the North American river otter is directly and negatively affected by the loss or degradation of these habitats as a result of human development or land-use changes.

Predation/Competition: The impacts of predation or competition on the North American river otter is uncertain, but any effects could be exacerbated by drought (Gorman et al., 2006).

METRIC

METRIC 1 (OF 1): NORTH AMERICAN RIVER OTTER PRESENCE

Baseline: North American river otter numbers have increased dramatically over the last decade, and this species now occupies most of the suitable water bodies within the One Tam area of focus (Figure 24.2, Bouley et al., 2015).

Condition Goal: North American river otters are present in all suitable water bodies.

Condition Thresholds:

- **Good:** The North American river otter is present in >80% of suitable water bodies.
- **Caution:** The North American river otter is present in <80% and ≥60% of suitable water bodies.
- **Significant Concern:** The North American river otter is present in <60% of suitable water bodies.

Current Condition:

2016: Good

Observational data from ROEP indicated the presence of the North American river otter in most suitable water bodies (Bouley et al., 2015).

2022: Good

ROEP analysis of observational data shows that the North American river otter is present in approximately 75% of lentic water body areas (e.g., ditches, seeps, ponds, seasonal pools, marshes, and lakes) and 25% of perennial stream reaches. Because the data are based on opportunistic sightings, they likely understate the true presence of the North American river otter in the area of focus.

Trend:

2016: Improving

In 2016, the status of the North American river otter had shifted from extirpation in the San Francisco Bay Area to being present in most suitable water bodies in the area of focus (Bouley et al., 2015).

2022: Improving

Statistical modeling of ROEP camera trap data shows increasing North American river otter abundance in Mt. Tam's reservoirs and in the portion of Lagunitas Creek immediately downstream of Kent Lake. While the same modeling suggests that abundance is not increasing in the coastal areas around Bolinas Lagoon and Muir Beach, the overall trend in the area of focus is improving.

Confidence:

2016: Moderate

Additional data were needed to determine the species' presence in all suitable water bodies in 2016.

2022: Moderate

Analysis of opportunistic sighting reports is subject to a high degree of uncertainty. Modeling of camera trap data uses median values that may have considerable margins of error. In both cases, additional data collected over time may give us more accurate estimates.

SUPPORTING DATA, OBSERVATIONS, AND RESEARCH

RIVER OTTER ECOLOGY PROJECT

Since 2012, ROEP has been collecting North American river otter observations and monitoring coastal and riverine populations in Marin County via non-invasive camera trapping and scat collection (Bouley et al., 2015; Carroll et al., 2020; River Otter Ecology Project, 2022). In 2019, the California Department of Fish and Wildlife (CDFW) updated the North American river otters' range map. This update, based largely on data provided by ROEP, added 4,100 square miles, including all of Marin County, to the species' known range (a comparison of the previous and updated range maps is available at https://riverotterecology.org/otter-spotter-community-based-science).

In 2018, a San Francisco State University Genomics/Transcriptomics Analysis Core lab analysis of North American river otter mitochondrial DNA derived from fecal samples indicated that there are four major haplotypes present in Marin County. This level of genetic diversity is a positive indicator for species recovery. Ongoing analysis of fecal-derived DNA may yield additional information on sex ratios, abundance, and dispersal patterns.

Yearly analyses of bacterial cultures for *Salmonella* and *Vibrio* have revealed four species of *Vibrio* and no *Salmonella*, both of which can be pathogenic, in the samples tested so far.

INFORMATION GAPS

Population Data: While the North American river otter has been documented in Mt. Tam's watersheds, little is yet known known about its population demographics beyond its presence and limited abundance data. Data on its home range and dispersal patterns are also lacking, and the distribution and abundance of prey are poorly understood. ROEP observational and genetic work-in-progress should ultimately help answer some of these questions.

Water Quality Impacts: Insufficient information is available about how the health of the North American river otter is linked to water quality indicators for toxins and pathogens.

PAST AND CURRENT MANAGEMENT, RESTORATION, MONITORING, AND RESEARCH EFFORTS

Resource Protection and Stewardship Successes Since the 2016 Peak Health Report

Habitat Restoration: As a part of its Redwood Renewal work, the National Park Service implemented a restoration project in Redwood Creek at Muir Woods in 2019 to improve creek function, with particular benefits for threatened and endangered salmonids. Phase II of this project will be implemented in 2023. In addition, since 2016, Marin Water has implemented several projects in Lagunitas Creek to improve creek function and benefit salmonids.

Team River Otter: ROEP has partnered with CDFW and California Academy of Sciences to form a salvage team that collects river otter carcasses; these carcasses are necropsied to better understand the animals' condition and cause of death, and to support the academy's specimen collection. More information is available through ROEP's Story Map.

Monitoring Approach: ROEP developed an analytical framework for estimating local change in river otter abundance over time (Carroll, et al., 2020).

Past Work

Following are two previous stewardship and management activities undertaken over the years to monitor, protect, and restore this health indicator.

Restoration: The National Park Service completed a riparian habitat restoration project primarily focused on benefiting salmonid populations at Muir Beach in 2014. A major component of this project was to create over one acre of off-channel aquatic habitat and introduce more woody debris into the creek system to provide essential resting and feeding habitats for juvenile coho salmon and steelhead trout. This project improved conditions for river otters by increasing the salmonid prey base and by creating new areas of aquatic habitat.

Management: "Otter crossing" signs were installed near Muir Woods National Monument to help reduce road kills (National Park Service and California State Parks).

FUTURE ACTIONABLE ITEM

This section includes a need identified by agency and local scientists as a part of the development of this report. This action is not currently funded through agency programs and will be further evaluated and prioritized for future funding and implementation outside of this health assessment process.

Programs to Reduce Road Kills: Vehicle/wildlife collisions are a significant population threat for river otters, as they are for many other types of wildlife, especially mammals. There should be future opportunities to partner with other groups and agencies to make progress on this issue that would benefit multiple species, including otters.

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CHAPTER 25. WILDLIFE HEALTH INDICATOR NEEDS

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Many things remain unknown about Mt. Tam's wildlife, as evidenced by the information gaps identified in each indicator chapter of this report as well as by the 2016 proposed indicators that we have not yet been able to assess (see Appendix 1). For example, a lack of information prevented us from including small mammals and invertebrates, two important taxonomic groups. The few inventory efforts of the mountain's small mammals that have been carried out were too limited in scope and scale to be useful. And, aside from some work on butterflies and bees, invertebrates have not been well studied at all.

This chapter summarizes some of these more pressing information gaps, the current state of our knowledge about them, and what it might take to gather enough additional information to include them in the next iteration of this assessment. For a few of them, the missing data are available but come from multiple sources and would require a dedicated effort to retrieve, collate, and analyze. In some cases, plans are in place to collect this data soon; in others, a whole new data-collection effort will be needed.

WILDLIFE MANAGEMENT AND MONITORING

Although a few programs cross jurisdictional boundaries, each One Tam partner agency has conducted its own wildlife inventories, monitoring programs, surveys, and management activities over the years. Many academic and nonprofit partners have also contributed to this work. Consequently, data used to inform the wildlife condition and trend assessments in this report came from a large number of sources.

Each chapter in this report describes the information sources used to evaluate the respective indicator in detail. Also included are management, monitoring, restoration, and other efforts to support that indicator, as well as ways to fill key data gaps. The following section, therefore, focuses on information gaps that apply to multiple health indicators.

INVENTORY, MONITORING, AND ASSESSMENTS

- **Complete Historical Conditions Analysis for Priority Taxa:** Many of our condition assessments are based on comparisons to historical range or population statuses. For some species, especially rare ones, this information is available electronically and has been incorporated. Often, though, the amount of museum collection information that has been gathered or can be readily accessed is limited. Historical field notes and notebooks are rarely searchable online, and old reports are often on shelves, not servers. Partnering with natural history museums to make collections data computer-searchable for taxa such as plants and insects and tracking down historical notes and reports will allow us to compare the past to the present and paint a more complete picture as we look to the future.

- **Conduct a Mt. Tam Wildlife Vulnerability Analysis Specific to Climate Change:** The San Francisco Bay Area's climate is changing in ways that will likely affect the spatial patterns or distributions of native plant communities. We are already experiencing higher temperatures, higher levels of climatic water deficit that impose drought stress on plants, reduced rainy-season duration, flashier rain events, and longer dry periods between rains. Climate change is likely intensifying the drought currently afflicting the southwestern United States, which has been assessed as the most severe in more than 1,200 years (Williams et al., 2022). After being perennial for decades, some local streams went dry in 2021, resulting in the death of endangered salmonids and other aquatic life. Several recent studies and predictive modeling efforts (Ackerly et. al., 2012; Thorne et. al., 2017) provide insights into distribution and associated vulnerabilities faced by vegetation communities under various climate futures. These changes to community composition and landscape-scale habitat connectivity may have effects on wildlife presence, movement, and population viability. Gaining a better understanding of species' vulnerability and habitat connectivity is critical to sustaining healthy wildlife communities. Existing models such as the TNC Omniscape and/or other permeability and wildlife connectivity data methodologies (Gray et al., 2020) could be leveraged and combined with climate vulnerability layers to do a regional habitat assessment. This would enable us to prioritize areas to reduce anticipated climate-related stressors. Findings from such an assessment could also provide guidance on where to focus limited resources, how to reduce non-climate stressors that are within our control, and how to facilitate habitat connectivity to allow species movement. (The Golden Gate Biosphere has just initiated a biosphere-wide climate vulnerability assessment that will include important information about Marin County's wildlife and habitats.)

- **Leverage Forest Health and Resilience Projects for Wildlife Assessments:** Guided by the Marin Regional Forest Health Strategy, agency partners are pursuing projects to improve these habitats and increase resilience in the face of threats such as climate change, among others. As part of this strategy, these projects are designed to avoid or minimize impact to wildlife and their habitats. These projects present new opportunities for studying the relationship between forest treatments and effects on target wildlife taxa, such as bats, woodrats, and birds. In addition, further investment in existing inventory and monitoring efforts could help leverage those programs to help us understand how those taxa respond to forest treatments. Such assessment could help inform the design of future forest health projects.

- **Assess Invasive Wildlife Impacts**: The **Barred Owl** (*Strix varia*) is being reassessed as an invasive species in the Pacific Northwest, and a U.S. Fish and Wildlife Service–led effort to develop a Barred Owl management strategy throughout the Northern Spotted Owl's (*S. occidentalis caurina*) range is expected in 2023. The **eastern gray squirrel** (*Sciurus carolinensis*) and **fox squirrel** (*S. niger*) were introduced to several urban parks in the Pacific Northwest. Recent observations on Mt. Tam indicate that these two species have also spread out from urban areas. More work needs to be done to determine the extent of this spread and whether these invasive squirrels pose a threat to our native western gray squirrels (*Sciurus griseus*). **New Zealand mud snails** (*Potamopyrgus antipodarum*) are a non-native grazing snail that is now found in Lagunitas and Redwood Creeks; however, we have no information on the extent of their impact on local food chains.

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MIGRATORY SPECIES

WHY IS THIS AN IMPORTANT INDICATOR?

Mt. Tam provides habitat for an amazing diversity of both resident and migratory wildlife species. For example, its location along the Pacific Flyway means that we have both fall and spring migrating birds in addition to those that live here year-round.

Migratory species pose special management challenges, as they rely on a range of landscapes that fall under many land-ownership jurisdictions and have various levels of protection. In some cases, they are also dependent on the connectivity of these lands, decisions about which are made by many people or even by many countries. These migratory patterns, which have evolved over thousands of years, are essential to supporting the mountain's biodiversity and need to be protected. Acquiring more data on migratory species' seasonality and movement patterns will help us do this.

MONITORING AND DATA COLLECTION NEEDS

Studying migratory animals as they travel across sometimes great distances can be difficult. However, if tagged with a tracking device, species such as birds, bats, and even monarch butterfly (*Danaus plexippus plexippus*) can be detected as they pass by towers connected to the Motus Wildlife Tracking System network. Motus towers are essentially long-range receivers (up to 15 km, depending on topography and vegetation) that recognize the passage of radio-tagged wildlife. Data can be retrieved for animals of any size or taxonomy that have been fitted with suitable activated radio-tags. These towers are used by an international network of researchers, facilitating the aggregation of data on aspects such as presence/absence and migration routes from many different studies into a single database that members can access.

Joining the Motus network is free, but acquiring data from Mt. Tam requires the installation of multiple towers. Through a joint National Park Service/One Tam bat project, we have purchased equipment and will be installing three to four Motus towers in Marin County. Audubon Canyon Ranch has installed two towers on their Marin properties, and Richardson Bay Audubon has installed one. In addition, the California Department of Fish and Wildlife is planning to install more than 50 Motus towers across the state. Data from these towers will increase our understanding of existing ecological health indicators (e.g., bats) and provide information on potential new future indicators (e.g., monarch butterfly and raptors). Furthermore, having a broad array of locally, regionally, nationally, and even in some cases internationally coordinated Motus towers provides the most data-rich return on our investment. Our One Tam studies will benefit from data from outside Marin County, and data from our towers will benefit studies in other areas. Candidate species include:

- **Hoary bat** (*Aeorestes cinereus*) is a migratory species known to spend time in the One Tam area of focus. Learning more about its migration patterns will be important to protecting this bat, including tracking the risk and/or spread of white-nose syndrome, a disease decimating bat populations in the eastern and midwestern U.S., which is likely coming our way. The National Park Service has begun funding migratory studies of hoary bats with our U.S. Geological Survey bat research team.

- **Monarch butterfly** winters and breeds in Marin County. Its populations are extremely low nationwide, and western monarchs are at risk of extinction. Nano radio-tags are used to track the monarch's migration patterns and how it searches out and moves between overwintering groves. Initially, we will rely on having our towers contribute to information on monarchs tagged through other programs. Going forward, we are investigating the possibility of starting a monarch capture-and-tagging program of our own. (See additional information on this species later in this chapter.)

- **Raptors** have been studied by the Golden Gate Raptor Observatory (GGRO), a program of GGNPC and NPS, since 1984. Its fall-migration raptor-banding program provides a convenient opportunity to put radio tags on species for which we want to learn more about movement patterns. GGRO has previously tagged raptors with radio transmitters, but a major staff and volunteer effort was required to track radio-tagged birds over large areas with hand-held receivers. Using Motus towers starting in 2023 will not only allow us to collect more data, but also, to do it without such a heavy lift.

INSECTS

WHY IS THIS AN IMPORTANT INDICATOR?

Insects represent the largest part of the Earth's known biological diversity, comprising more than half of all named species (Grimaldi & Engel, 2005). In terrestrial ecosystems, they are well known for performing many important functions, including herbivory, predation, parasitism, pollination, and decomposition. These ecosystem services are critical to sustaining healthy plant diversity and soil composition. As a food source for many other species, insects also constitute a vital part of the food web.

Unfortunately, there are few complete summaries of the insect components of most ecosystems—including those found on Mt. Tam—due to their unparalleled diversity, small size, and the cryptic habits of the vast majority of species. In the absence of baseline information from detailed insect surveys, only the roughest estimates about insect diversity can be made. Given Mt. Tam's complex and varied topography, geology, vegetation communities, and microclimates, some experts suggest that the number of insects could be six to 10 times greater than the number of plants found here (P. DaSilva, personal communication, 2016).

MONITORING AND DATA COLLECTION NEEDS

COLLECTIONS ANALYSIS

Over time, Mt. Tam–focused research by individual entomologists and scientific institutions—e.g., California Academy of Sciences, Essig Museum of Entomology, and College of Marin—has resulted in published articles and preserved specimens. Data from these efforts should be analyzed and consolidated, a crucial step in the development of monitoring programs for the taxonomic groups of greatest concern. Digitizing specimen records would also greatly facilitate input from the broader research community and could potentially yield updated and expanded species lists. Additionally, specialist help with direct examination of collections of specific taxa that have not yet been digitized would also expand our knowledge base. (A literature review was conducted for this report's new chapter on bees; however, no similar effort has been made for other insect groups.)

Finally, the use of iNaturalist as a tool for community science and crowd-sourced data has grown tremendously since the first iteration of this report in 2016. However, the availability of expert taxonomic knowledge and challenges in making species-level identifications (which, in some cases, cannot be done from a photograph) continues to limit the utility of iNaturalist.

INVENTORIES AND FIELD WORK

Additional inventories and collections are essential to update information available from extant collections and publications. Workshops with local entomologists would help determine the orders or individual species that would best serve as habitat or ecosystem indicators as well as how to address species richness and population trends data gaps most effectively.

Targeted surveys of selected taxa on Mt. Tam—conducted by specialists who could help interpret the results within the context of larger-scale patterns of richness and population fluctuation—would provide valuable information. Taxa-specific inventories might include dragonflies and damselflies (Odonata), ground beetles (Carabidae), butterflies and moths (Lepidoptera), and ants (Formicidae).

All-taxa bioblitzes that engage both experts and interested community members could also produce valuable information on the insect fauna of select habitats of interest over time, as could encouraging the public to add observations to iNaturalist.

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MONARCH BUTTERFLY (*DANAUS PLEXIPPUS PLEXIPPUS*)

WHY IS THIS AN IMPORTANT INDICATOR?

The large and colorful monarch butterfly is found throughout much of the country. The species' two-way migration and colonial use of overwintering groves makes it unique among butterflies. Multiple generations hopscotch from wintering to breeding sites using milkweed as their caterpillar host plant. Pupae that emerge from August through October migrate to overwintering sites, then, in late spring, seek out milkweed to lay their own eggs. Most monarchs west of the Continental Divide (the western monarch population) migrate to the California coast to overwinter (Pelton et al., 2016). Marin County has both significant overwintering groves and breeding habitat with patches of narrowleaf milkweed (*Asclepias fascicularis*) host plants. One Tam received a grant from the Wildlife Conservation Board to assess and enhance monarch overwintering and breeding habitat in Marin County, and the National Park Service received additional funds to enhance monarch overwintering groves.

Monarch butterfly, which has been declining throughout its range, was listed in 2014 as a candidate species under the Federal Endangered Species Act. The western monarch is in serious decline, with overwintering populations falling by more than 99% since the mid-1980s (Pelton et al., 2019). (The overwintering phase [and perhaps the early spring period] has been identified as the most limiting part of the monarch lifecycle [Pelton et al., 2019].) Several National Park Service sites in Marin have been listed in California's top 50 monarch overwintering sites. However, these sites are also in serious decline (Pelton et al., 2016). The ideal monarch overwintering grove acts as a windbreak against winter storms, has a range of sun exposure from full to filtered to shaded, and includes nectar sources. California's overwintering groves are largely made up of non-native trees (Longcore et al., 2020); their senescence, especially in protected areas, is a serious threat to monarch viability, and managing the groves has been identified as a critical short-term action (Longcore et al., 2020; WMWG, 2019).

Patches of narrowleaf milkweed, the native host plant for monarch butterfly in Marin County, can be found on Marin Water and Marin County Parks lands. Enhancing both the extent and quality of narrowleaf milkweed patches will benefit monarch butterfly populations.

MONITORING AND DATA COLLECTION NEEDS

While each of the following activities is already underway to some extent, the need to support and expand them, and then to collect and analyze the accumulated data, continues.

COMMUNITY SCIENCE

Community science–led monarch counts at Marin County overwintering groves at key points during the season (Thanksgiving and around New Year's Day) carried out in coordination with the Xerces' Society should continue, as should encouragement of annual agency participation in the Western Monarch Milkweed Mapper, Western Monarch Mystery Challenge, and/or International Monarch Monitoring Bioblitz. In addition, we should encourage the public to upload monarch and narrowleaf milkweed photos to iNaturalist.

HABITAT ASSESSMENT AND ENHANCEMENT

In 2022, we initiated a project to assess four priority monarch overwintering groves and to develop management plans for three of them. Scientists will be using lidar, fish-eye photography, and site visits to assess the groves and develop management plans. In 2022, we also initiated work to assess and enhance priority patches of narrowleaf milkweed.

MIGRATION STUDIES

See the Migratory Species section earlier in this chapter.

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SMALL MAMMALS

Small mammal studies typically require trapping and are therefore time- and resource-intensive. This is among the primary reasons Mt. Tam's small mammal communities have not been well studied. While vertebrate inventories of Golden Gate National Recreation Area (Semenoff-Irving & Howell, 2005), Muir Woods National Monument (Howell et al., 1998), and Point Reyes National Seashore (Fellers & Pratt, 2002) have been completed, they have yet to be updated.

Additional documentation of Mt. Tam's small mammal population includes an inventory at Muir Beach (Takekawa et al., 2003) and Sudden Oak Death (SOD) research on deer mice and woodrats (Swei et al., 2011). The Marin Wildlife Watch project is providing information on the >1 kg terrestrial mammal community; more information on mammals too small to be reliably detected by these cameras would complement that project.

WHY IS THIS AN IMPORTANT INDICATOR?

Small mammals are sensitive to habitat change, are an important food resource for predatory species, and have an impact on vegetation by consuming and dispersing seeds (Converse et al., 2006). For example, dusky-footed woodrats (*Neotoma fuscipes*) are the primary food item of the federally threatened Northern Spotted Owl. Research conducted in Marin County, including on Mt. Tam, demonstrated that SOD has led to an increase in deer mice (*Peromyscus maniculatus*) and decrease in dusky-footed woodrats (Swei et al., 2011).

MONITORING AND DATA COLLECTION NEEDS

The goal of small mammal monitoring would be to inventory priority habitat types, which includes updating the monitoring work described earlier. Particular attention needs to be directed to making sure we know what species are present so we can tell if they are disappearing from or moving into the One Tam area of focus. Particular attention should also be paid to habitat types that are rapidly changing.

Such a program would include:

- Identifying priority habitats for small mammal inventory work.
- Developing a study plan that includes areas to trap, number of traps and trap nights, and trap-revisit frequency.

A separate effort should be undertaken to develop a study plan for the dusky-footed woodrat to determine woodrat density by habitat type. This work would potentially include woodrat house counts that determine occupancy and mark-recapture trapping. Specific woodrat data could be compared with Marin Wildlife Watch data to model how accurately wildlife camera results reflect woodrat-density field-study estimates.

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TREE SQUIRRELS

WHY IS THIS AN IMPORTANT INDICATOR?

Recent observations indicate that the invasive eastern gray squirrel (*Sciurus carolinensis*) may be more widespread in wildlands than previously known. This species was introduced to many urban environments in the San Francisco Bay Area and appears to be spreading. Some areas report declines in western gray squirrels in areas with eastern gray squirrels (Johnston, 2013). We need to conduct a study to understand the extent of the eastern gray squirrel in Marin County, to see if it is threatening the native western gray squirrel, and to determine whether we can reliably distinguish these species in wildlife camera photos. The invasive eastern fox squirrel (*Sciurus niger*) is also in Marin, and some southern California studies show that it is negatively affecting western gray squirrels there (Cooper & Muchlinski, 2015).

The western gray squirrel is Marin County's native tree squirrel, and its loss would be a loss to Mt. Tam's native biodiversity. These squirrels are seed predators (acorns are among their favorites), but they also play an important role in seed dispersal, as they rarely collect from all of their caches. Based on Marin Wildlife Watch data, the western gray squirrel is one of the mountain's most commonly detected species, second only to black-tailed deer.

MONITORING AND DATA COLLECTION NEEDS

The goal of this work would be to document the extent and density of western, eastern gray, and fox squirrels and the degree to which their ranges overlap. We would also examine whether these invasive squirrels are excluding native western gray squirrels. In addition, we would be interested in using genetics to help confirm species identifications and, ideally, to establish criteria to distinguish them in wildlife camera images.

Such a program would include:

- Developing and implementing a study plan that included identifying areas to place fur traps, installing the traps, placing additional wildlife cameras in key areas across the landscape, and using genetic studies to document the distribution and abundance of the three tree squirrel species.
- Analyzing existing tree squirrel images to verify their classification and developing criteria to distinguish these images, if possible.

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CHAPTER 26. ROLLING IT UP: AN OVERVIEW OF MT. TAM'S ECOLOGICAL HEALTH

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The preceding chapters have described how certain species, taxonomic groups, or vegetation communities can be used to measure Mt. Tam's health. Tracking these important indicators is one way to understand and evaluate how the mountain's natural resources are functioning. However, these individual indicators represent only a portion of the ecological communities and natural processes of which they are a part.

Combining them—or "rolling them up"—in different ways allows us to develop a more complete understanding of how well ecological systems and landscape-level processes are functioning within the One Tam area of focus. Although not an exact science, this approach gives land managers new ways to understand what is happening and make decisions based on that broader understanding.

Because the interplay among human use, health indicators, and ecosystem processes and stressors is complicated and important details may be obscured, it is important to interpret the results of these roll-ups carefully. For example, combining individual species and community-level indicators may result in an ecosystem being described as doing well overall despite some species within it doing poorly. Given the range of possible contributing factors in any given ecosystem, it can also be challenging to decide what to include and what to leave out.

The 2016 version of this report considered a number of ways that indicators could be combined to communicate broader ecosystem health in a meaningful way. At the time, we only had enough information to pursue the question of the mountain's overall health and that of select ecological communities (e.g., oak woodlands, grasslands, shrublands, and redwoods). Using what we knew from existing models, we also looked at climate-vulnerable species and communities. All of those analyses have been updated here, and include a look at how these indicators and ecosystems might fare under recent regional climate models by Pepperwood Preserve climate scientists.

A LANDSCAPE-LEVEL LOOK AT ECOLOGICAL HEALTH

In the 2016 report, each indicator used for a roll-up had to have a condition, trend, and certain level of confidence in the data. In many cases, only vegetation communities and bird guilds were included because their associations were much more well established than those of other taxonomic groups. Habitat generalists (e.g., some mammals) were not included because they do not reveal anything in particular about specific plant communities. Roll-ups were based on the overall condition, trend, and confidence of the individual indicators, using the same scoring and averaging methodology employed for the rest of the project (see Chapter 2).

The pie charts presented in this chapter (Figures 26.2–26.7) update those included in the 2016 report. The color of the center circle represents the overall condition, and the line around the circle indicates our level of confidence in the data (Figure 26.1). Individual segments around the edge of each pie chart represent the condition of each component of the roll-up. It is important to note that these are not weighted. While these roll-ups included a trend in 2016, we decided against doing so now because new data from the 2018 Marin Countywide Fine Scale Vegetation Map make it difficult to infer trends between 2016 and 2022.

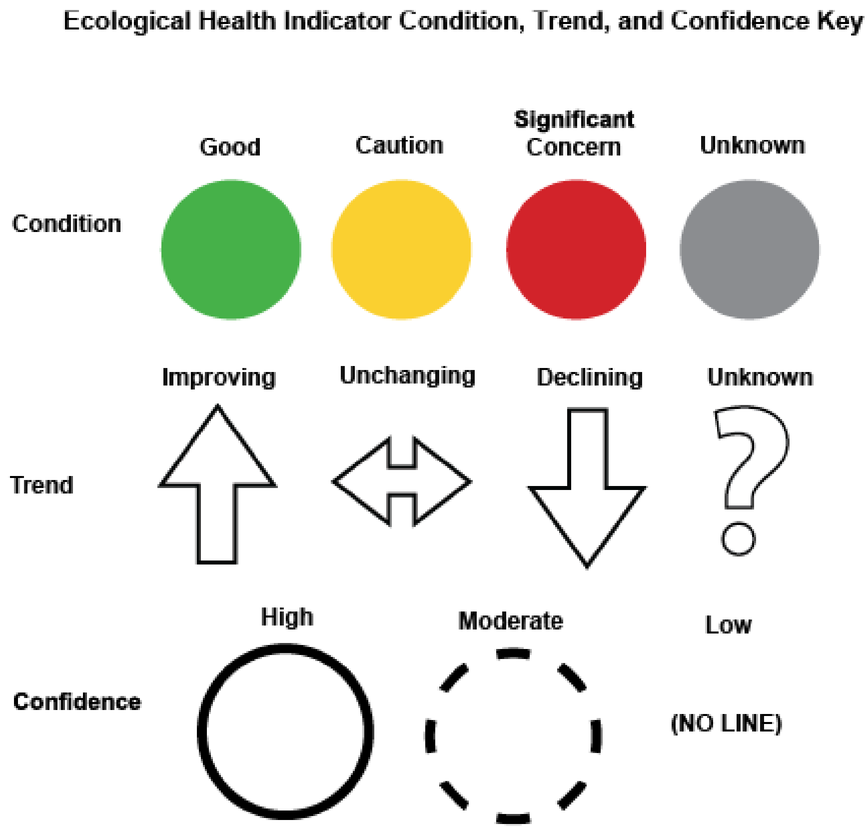


FIGURE 26.1 SYMBOLOGY USED TO SHOW OVERALL CONDITION, TREND, AND CONFIDENCE OF EACH INDICATOR

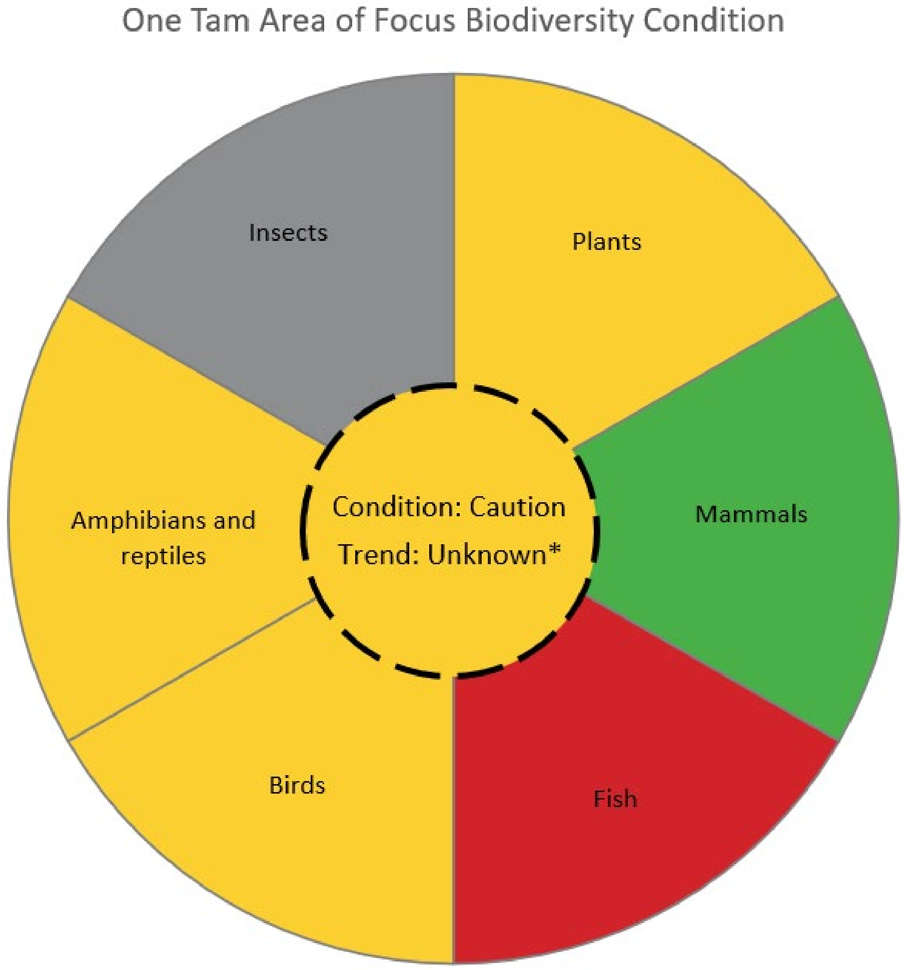


FIGURE 26.2 BIODIVERSITY CONDITION, ONE TAM AREA OF FOCUS

**We did not establish a trend in the overall condition for Mt. Tam between 2016 and 2022 because of the addition of new indicators since 2016, an expanded geography, and a major new vegetation mapping effort that parses those communities differently than before. In addition, some indicators improved while others declined or did not see a change in condition.*

Condition: Caution

Confidence: Moderate

Trend: Unknown

Extrapolating from the area of focus and assessed by looking at a collection of the key taxonomic groups shown in Figure 26.2, the condition of Mt. Tam's overall health is judged to be caution, with an unknown trend. This evaluation reflects the challenge of identifying trends over time when new elements—the addition of indicators (bats, bees, and the California giant salamander [*Dicamptodon ensatus*]), the removal of an indicator (the American badger [*Taxidea taxus*]), and the use of new classifications and techniques in the 2018 Fine Scale Vegetation Map—have been introduced. Each group has one equal segment, and each segment was given its own condition and confidence score by averaging those of the indicators within them (Figure 26.2). For example, the mammal grouping included native mammal diversity, bats, and the North American river otter (*Lontra canadensis*). Future work to refine this overall biodiversity assessment could include other important taxonomic groups currently lacking data (e.g., fungi, lichens, and invertebrates).

Some taxonomic groups included in Figure 26.2 have experienced local or global extirpations and include species that are in perilous condition, while others with limited extinctions and generally healthy populations are faring better. In most cases, a much more complex reality underlies each segment of this figure. For example, there are more than 750 known native plant species and in excess of 300 known non-native species. While some non-native species have limited distribution and impact, many are noxious invasives that affect native species and processes by outcompeting and displacing native species, altering habitats and fire regimes, and requiring significant resources to control and eradicate (Mack & D'Antonio, 1998; Hobbs & Mooney, 2005; Pimentel et al., 2005). In addition, 65 likely plant extirpations have been documented (Appendix 4). Of the known extant native plant species, more than 40 are considered rare, threatened, or endangered. These special-status plants are susceptible to stochastic events and existing stressors that could lead to further imperilment, and even local or global extinction.

Despite losses and threats from non-native species and other environmental pressures, the floristic biodiversity of the area is high and supports an equally high diversity of habitats that host dozens of wildlife species. These vegetation and habitat types are defined by high variability in topography, temperature, precipitation, and soils within the One Tam area of focus (see Chapter 1).

ECOLOGICAL COMMUNITIES

Each ecological community or ecosystem roll-up was created by aggregating all pertinent vegetation and wildlife metrics from individual indicators. Each metric has its own condition, trend, and confidence level (as determined in the individual indicator assessment).

In order to focus more upon what *could* be said about the state of the ecosystems on Mt. Tam, large data gaps were omitted. However, if a metric had already been described and assessed in one of the chapters in this report, it was included in the roll-up regardless of whether or not there was currently enough data to assign a condition or trend score. Consequently, some taxonomic communities, such as invertebrates, are currently underrepresented, even though they are incredibly important to the mountain's overall health. Omissions are due only to a lack of analyzable data, and as data gaps are filled, these ecosystem roll-ups will be further refined.

Using the grasslands ecosystem (Figure 26.5) as an example of how different components were rolled up, four metrics are taken from the grassland vegetation indicator, one from the native mammal diversity indicator, and one from grassland birds. (Note: The *State of Mt. Tam Bird Species Traits & Status Database* was used to determine bird species with strong affiliation to a particular habitat type.) This approach allows for the future addition of segments from other taxonomic groups as strong habitat affiliations are uncovered and more data are gathered.

Figure 26.3 summarizes the overall condition of the four ecological communities included in this chapter, all of which have a condition of caution. Detailed roll-ups that show how that conclusion was arrived at for each community follow.

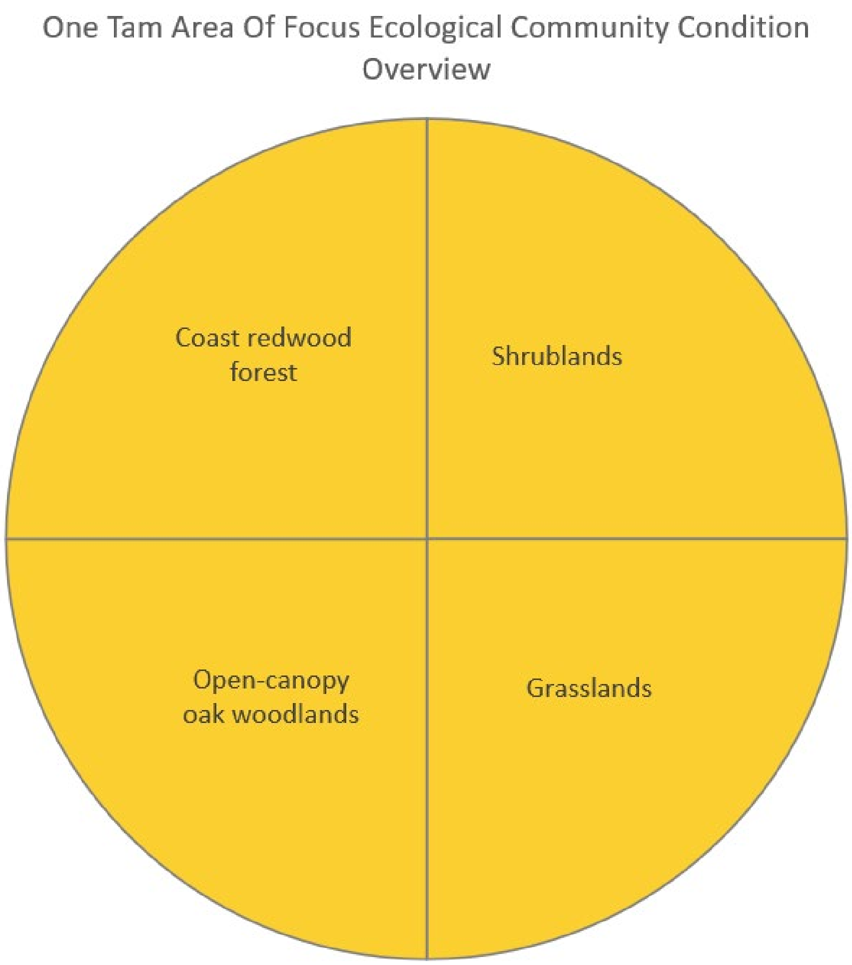


FIGURE 26.3 CONDITION OVERVIEW, MT. TAM ECOLOGICAL COMMUNITIES

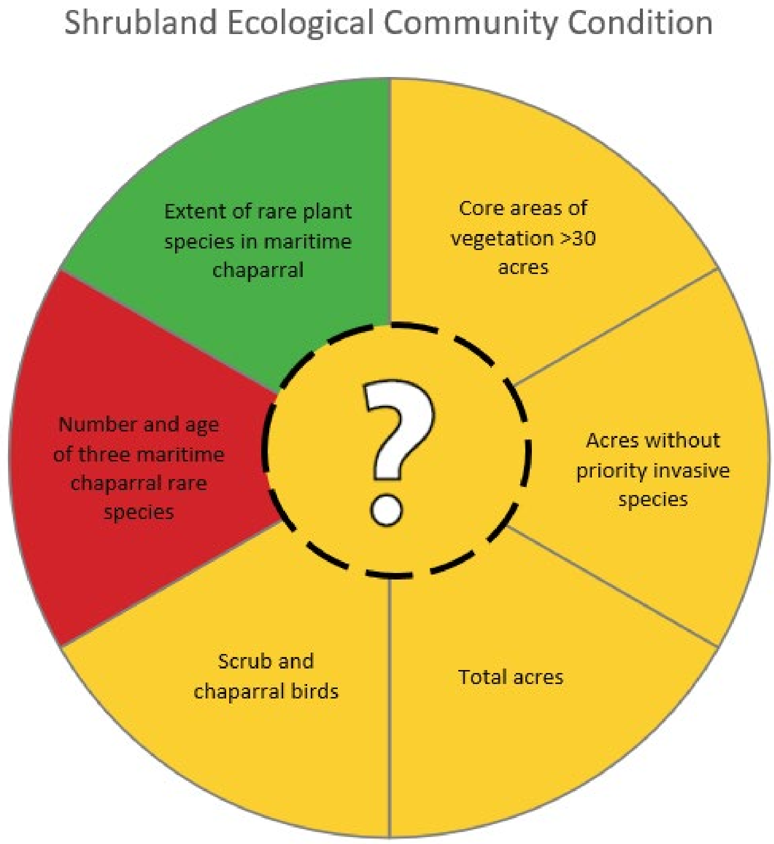


FIGURE 26.4 SHRUBLAND COMMUNITY CONDITION, ONE TAM AREA OF FOCUS

Condition: Caution

Confidence: Moderate

Trend: Unknown

The current condition of shrubland communities, evaluated as good in 2016, is now caution. This is in part because new data and analyses indicate a higher level of threat from invasive species and greater forest succession due to fire suppression. However, these results need to be considered with the understanding that comparing 2016 and 2022 is complicated by two important factors: revised shrublands metrics and the previously described challenges presented by the updated vegetation map. The number of certain rare maritime chaparral species remains of significant concern; although the extent of those species remains good, the overall bird community is in a state of caution. (See Chapter 7 for more about the mountain's shrublands, Chapter 8 for maritime chaparral species, Chapter 18 for birds, and Chapter 23 for mammals.)

Projected future vegetation changes for the San Francisco Bay Area include increases in shrublands, especially chamise-dominated chaparral (Cornwell et al., 2012; Ackerly et al., 2015).

Yet even chaparral species that are adapted to—or tolerant of—very dry conditions are not immune to drought stress, and may suffer under hotter, drier climate scenarios in their current distributions (Jacobsen et al., 2007; Paddock et al., 2013). As a result, these shrub-dominated vegetation types are expected to shift toward the coast at lower elevations. (See the Climate Change and Vegetation Indicators section at the end of this chapter for additional details.)

GRASSLANDS

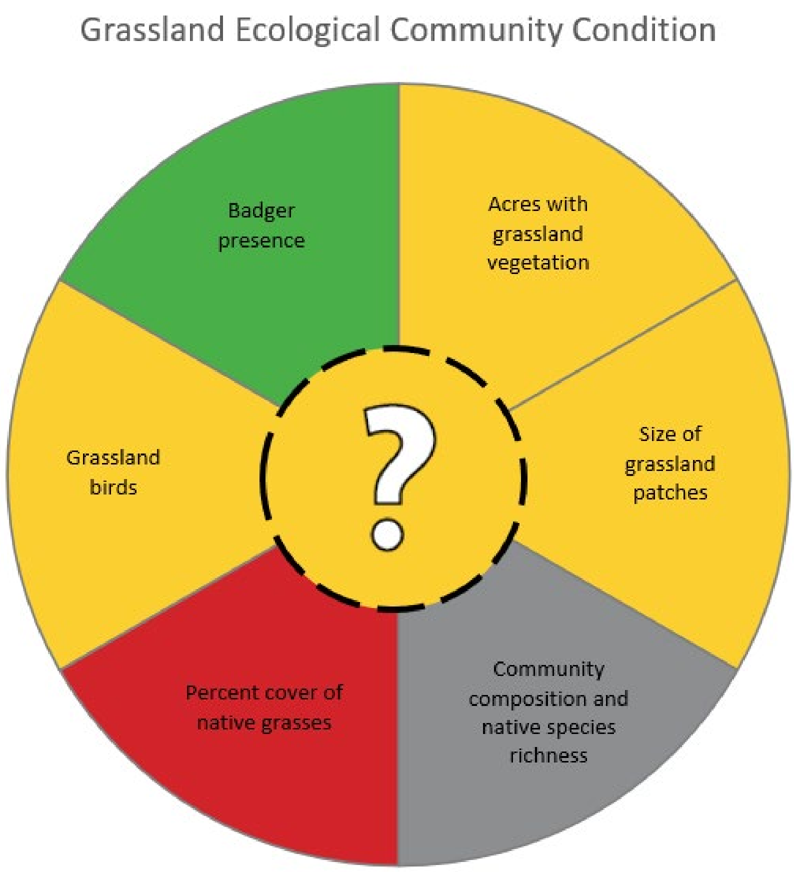


FIGURE 26.5 GRASSLAND COMMUNITY CONDITION, ONE TAM AREA OF FOCUS

Condition: Caution

Confidence: Moderate

Trend: Unknown

Grassland communities on Mt. Tam are in a condition of caution. Douglas-fir (*Pseudotsuga menziesii*) and coyote brush (*Baccharis pilularis*) recruitment into the edges and interiors of some patches means that the overall patch size and number of large patches are below the desired condition. The presence and relative dominance of non-native, invasive grasses and forbs is further causing grassland habitat quality to suffer. However, since the last Peak Health report, badgers have been documented as present within the One Tam area of focus. Grassland bird monitoring also started after a data gap was identified in 2016, which changed their condition from unknown to caution for this report. (See Chapter 9 for more information about Mt. Tam's grasslands, Chapter 19 for birds, and Chapter 23 for mammals.)

In the future, Thorne et al. (2016) concluded that grasslands had mid-to-high climate vulnerability, with much of the north coast becoming unsuitable for grasslands in a warmer and wetter future. Thus, grasslands will be expected to shift across the landscape and change in composition and quality. Near the coast, some grasslands may be lost to coyote brush, while away from the coast, they could expand at the expense of forests and woodlands (Cornwell et al., 2012; Ackerly et al., 2015). In the absence of periodic wildfires, these habitats are also vulnerable to succession. (See the Climate Change and Vegetation Indicators section at the end of this chapter for additional details.)

OPEN-CANOPY OAK WOODLANDS

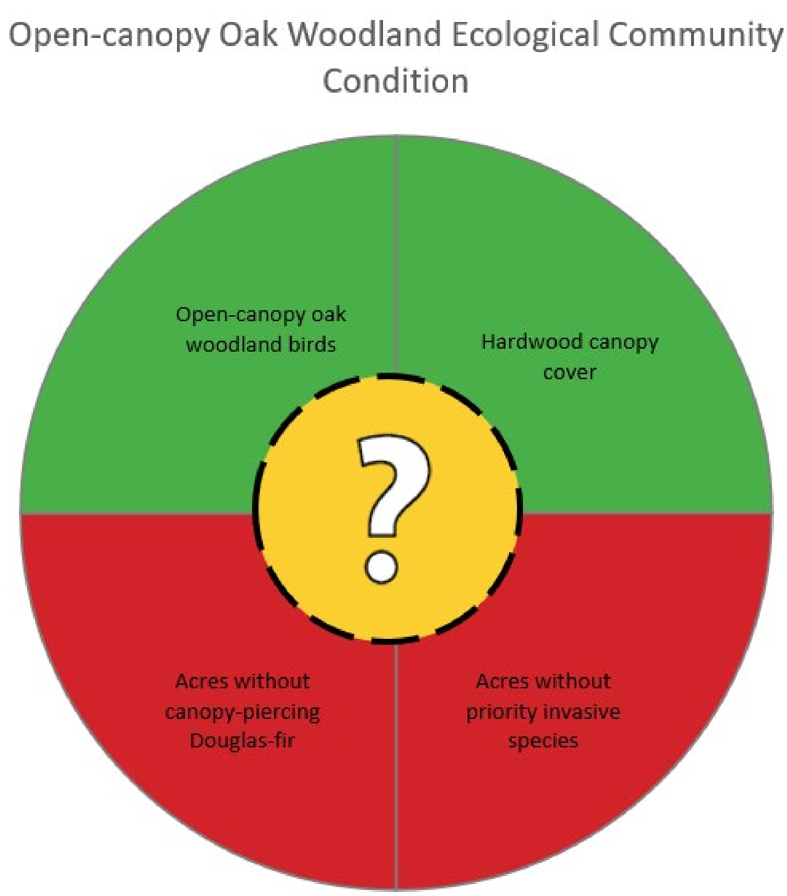


FIGURE 26.6 OPEN-CANOPY OAK WOODLAND COMMUNITY CONDITION, ONE TAM AREA OF FOCUS

Condition: Caution

Confidence: Moderate

Trend: Unknown

Open-canopy oak woodlands are in a condition of caution, mostly due to invasive species, Sudden Oak Death (SOD), and Douglas-fir encroachment. Douglas-fir recruitment, which is slowly leading to mixed-conifer hardwood woodlands, is likely driven by fire suppression. Furthermore, several species of broom continue to rapidly invade and colonize many of Mt. Tam's oak woodlands. This has also likely led to a reduction in the diversity and abundance of birds and mammals (Freed & McAllister, 2008). SOD continues to be the major stressor in this community. A 2014 Marin Water survey found that more than 90% of open-canopy oak woodlands were affected by the pathogen (AIS, 2015). This disease, which is expected to continue to kill oaks, may eventually transform these oak woodlands into woodlands or forests with very minor oak components.

Oak woodlands are known centers of high avian diversity (Zack et al., 2002). The condition of the oak woodland bird guild stayed in the good range, and the trend went from no change to improving. This may be in part because the number of species included increased, with a few species assigned to this habitat in 2022 that were either not previously included or were included but for which we lacked adequate data to analyze a trend. (See Chapter 6 for more information about oak woodlands and Chapter 19 for additional details about birds.)

The future of oak woodlands under potential climate change scenarios is uncertain (Ackerly et al., 2012; Ackerly et al., 2015; Cornwell et al., 2012). However, a warmer future is likely to increase both the prevalence of SOD and its effects on coast live oak and black oak types. (See the Climate Change and Vegetation Indicators section at the end of this chapter for additional details.)

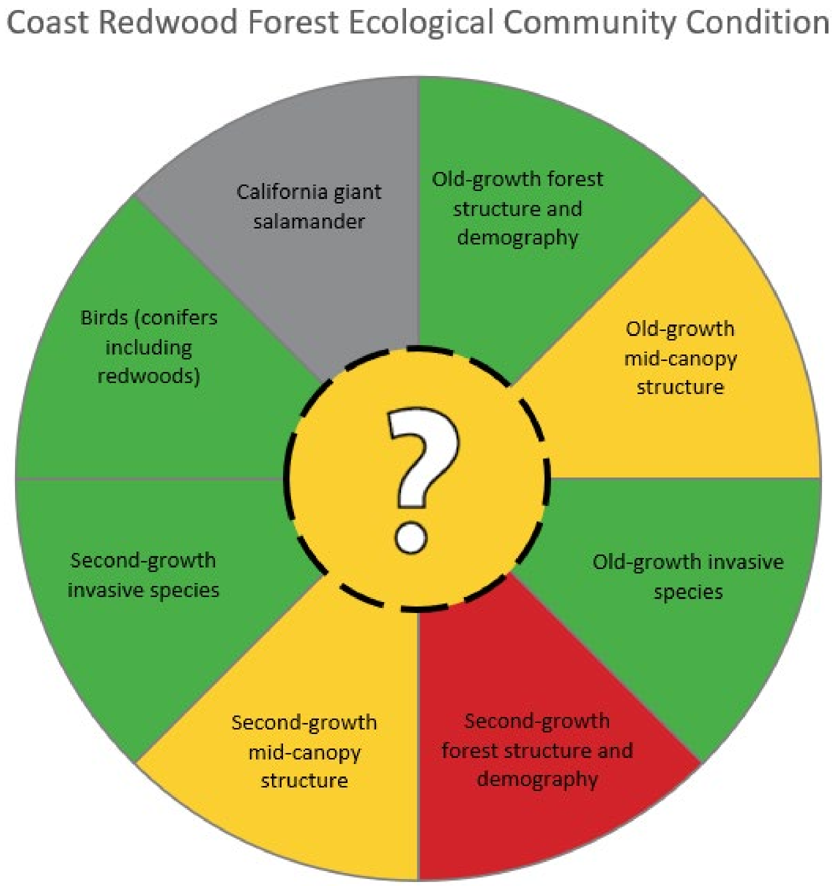


FIGURE 26.7 COAST REDWOOD FOREST COMMUNNITY CONDITION, ONE TAM AREA OF FOCUS

Condition: Caution

Confidence: Moderate

Trend: Unknown

While old-growth redwood forests are in good condition, the condition of second-growth forests, which make up the majority of these communities on Mt. Tam, is caution. Second-growth forests are largely a result of historical logging in the area. Although they vary widely in their characteristics and in the degree to which they have recovered from the impacts of logging, Mt. Tam's second-growth stands generally exhibit a greatly simplified structure: an absence of larger trees in the canopy, a more basic understory, and a higher density of small-diameter trees.

Currently, SOD is the major stressor of both old- and second-growth forest structure, particularly its impact on tanoaks, which are common redwood-forest understory associates. Estimates across Marin County put total tanoak mortality at about 50% or greater (McPherson et al., 2010;

Swiecki & Bernhardt, 2013). In many stands within the One Tam area of focus, close to 100% of the tanoaks have been affected.

An assessment of the avian community associated with coast redwood forests indicates that it is in good condition; Northern Spotted Owls (*Strix occidentalis caurina*) are doing well across the region in this habitat type. (See Chapter 4 for more details about redwoods and Chapters 19 for birds and 20 for the Northern Spotted Owl.)

The fate of Marin County's redwood forests may very much depend on whether climate change produces overall wetter or drier conditions. Bay Area redwoods occupy relatively low climatic-water-deficit zones, but as water deficits increase, some populations currently near the drier edge of the range could end up in unsuitable conditions. A statewide model of climate exposure suggests that about 45% of redwood forests in the One Tam area of focus are in a "high exposure" category and thus may not be able to adapt (Thorne et al., 2017; GGNPC et al., 2021). (See the Climate Change and Vegetation Indicators section that follows for additional details.)

CLIMATE CHANGE AND VEGETATION INDICATORS

PROJECTING CLIMATE CHANGE IMPACTS ON VEGETATION TO INFORM LONG-TERM MONITORING

Pepperwood Preserve scientists provided another way to look at overall health by using models that provide a broader view of how climate change may affect different communities. These three different resources can be used to inform key hypotheses about potential climate impacts and to prioritize indicators for long-term vegetation monitoring on Mt. Tam. All three rely on the U.S. Geological Survey (USGS) Basin Characterization Model (BCM) introduced in Chapter 1 (Flint et al., 2013). This gridded climate-hydrology model is now used internationally to calculate monthly water balance variability based on historical or projected weather and landscape features within hydrologic basins. A key watershed parameter, Climatic Water Deficit (CWD), measures the limits of soil moisture available to plants and can help predict current plant ranges and drought stress. CWD projections can also be used to define potential zones of climate vulnerability and to project potential species composition shifts.

As the BCM considers the impact of local weather, topography, and geology on the balance of energy and water, CWD assessments can identify relatively arid locations where vegetation may be more vulnerable, such as south-facing slopes on or near hilltops with thin soils. This information can be useful to identify vulnerable vegetation stands that may require extra management or monitoring to evaluate mortality, manage soil-moisture retention, or restore hydrological function.

The three approaches are:

1. Bay Area Conservation Lands Network products (BAOSC, 2019) define climatic water deficit suitability, or "comfort zones," that can be investigated as part of the Conservation Lands Network explorer tool function. This approach relies on defining the

upper limits of CWD tolerance for different plant communities and evaluating where they are close to the edge of their drought tolerance and are therefore vulnerable to increasing aridity trends. Based on current conditions alone, including iconic redwoods and Douglas-fir, 10 plant communities (Figure 26.8) in the One Tam area of focus were identified as vulnerable.

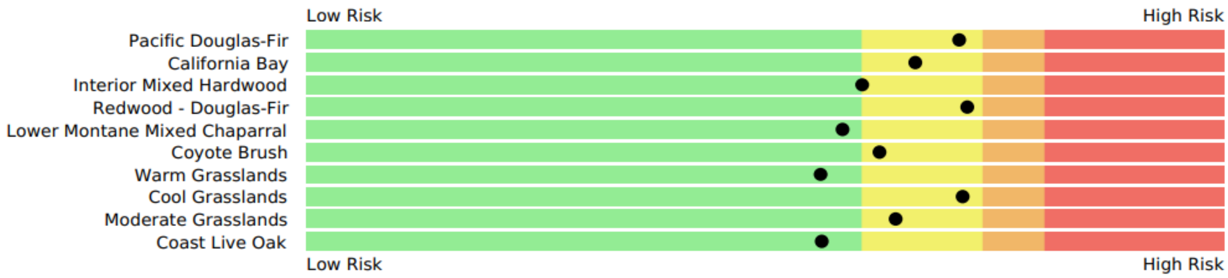
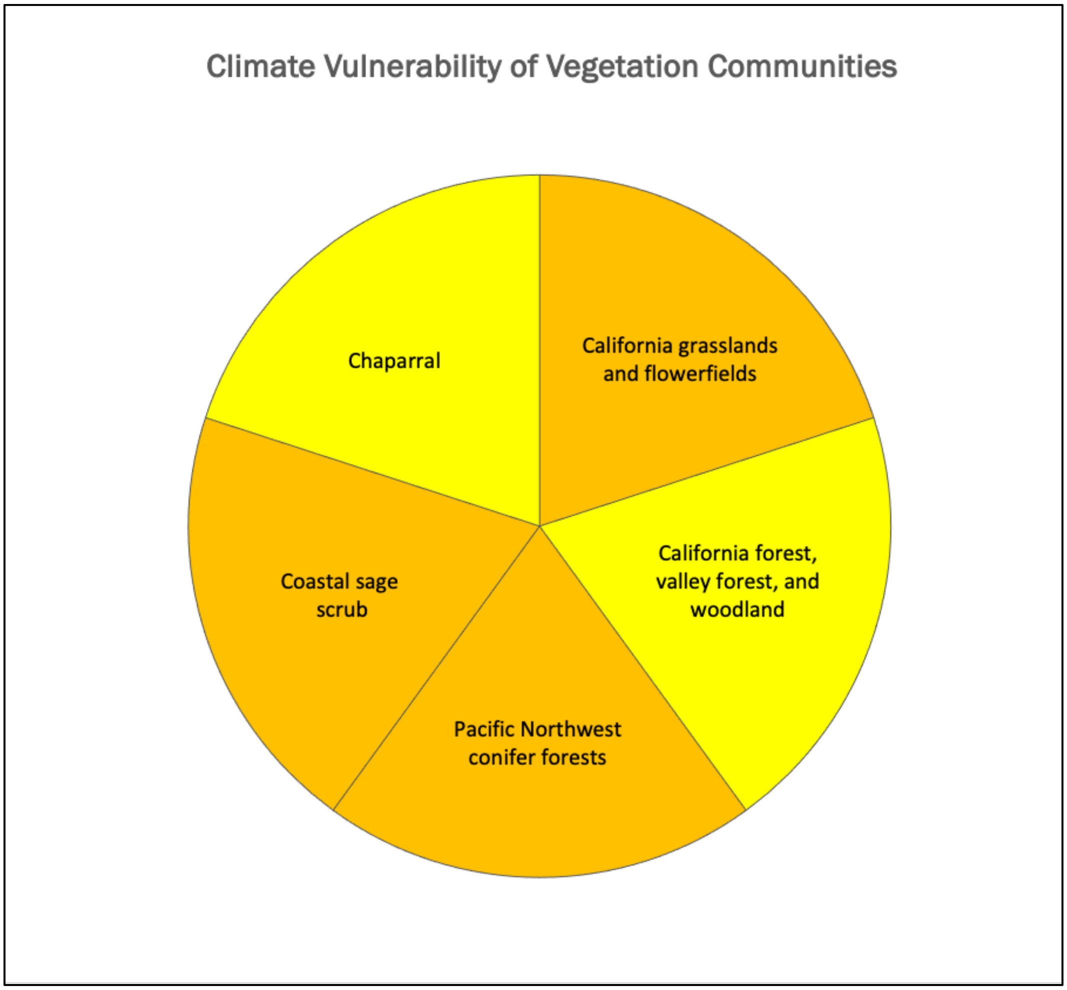


FIGURE 26.8 TEN PLANT COMMUNITIES CLOSE TO THE EDGE OF THEIR DROUGHT TOLERANCE UNDER CURRENT CONDITIONS (BAOSC, 2019)

Note: The black dots show the average CWD value for each vegetation type relative to its "comfort zone," which is indicated in green. As the average CWD value approaches the yellow, orange, and red zones, climate risks increase.

2. The California Department of Fish and Wildlife (CDFW) and Thorne Lab at UC Davis did statewide assessments using CWD as well as other climate parameters to assign climate vulnerability rankings for 31 vegetation types (macrogroups) (Thorne et al., 2016). They estimated plant types' sensitivity and adaptive capacity based on expert assessments of their life-history traits. The resulting climate vulnerability categories combine climate exposure, sensitivity, and adaptive capacity and are ranked as moderate, mid-to-high, or high. Most of the selected vegetation community indicators for Mt. Tam have a comparable match to assessed CDFW macrogroups, except for serpentine barrens, which are not included in this assessment (Figure 26.9).



Key to mean climate vulnerability rank:

Moderate

Mid-to-High

High

FIGURE 26.9 CLIMATE VULNERABILITY OF SELECTED VEGETATION COMMUNITIES (THORNE ET AL., 2016)

3. For the Climate Ready North Bay: Vegetation Reports, Ackerly et al. (2015) used a probabilistic logistic regression to model potential extents of plant distributions based on projected future climate changes. A difference in this approach compared to the previous two is that this model estimates not just what vegetation types are vulnerable to decline, but also, which types may expand. The results are also different in that they are summarized at the scale of landscape units defined for the Conservation Lands Network. Based on 54 different future climate scenarios applied to 22 major vegetation types, Figure 26.10 displays a visualization for the projected future relative spatial

extents of 16 vegetation types for the Marin Coast Range landscape unit. Table 26.1 shows a table of climate "winners and losers" using a four-square visual representation of variability based on higher or lower rainfall scenarios. This approach does not aim to estimate where or what kind of novel vegetation communities may occur.

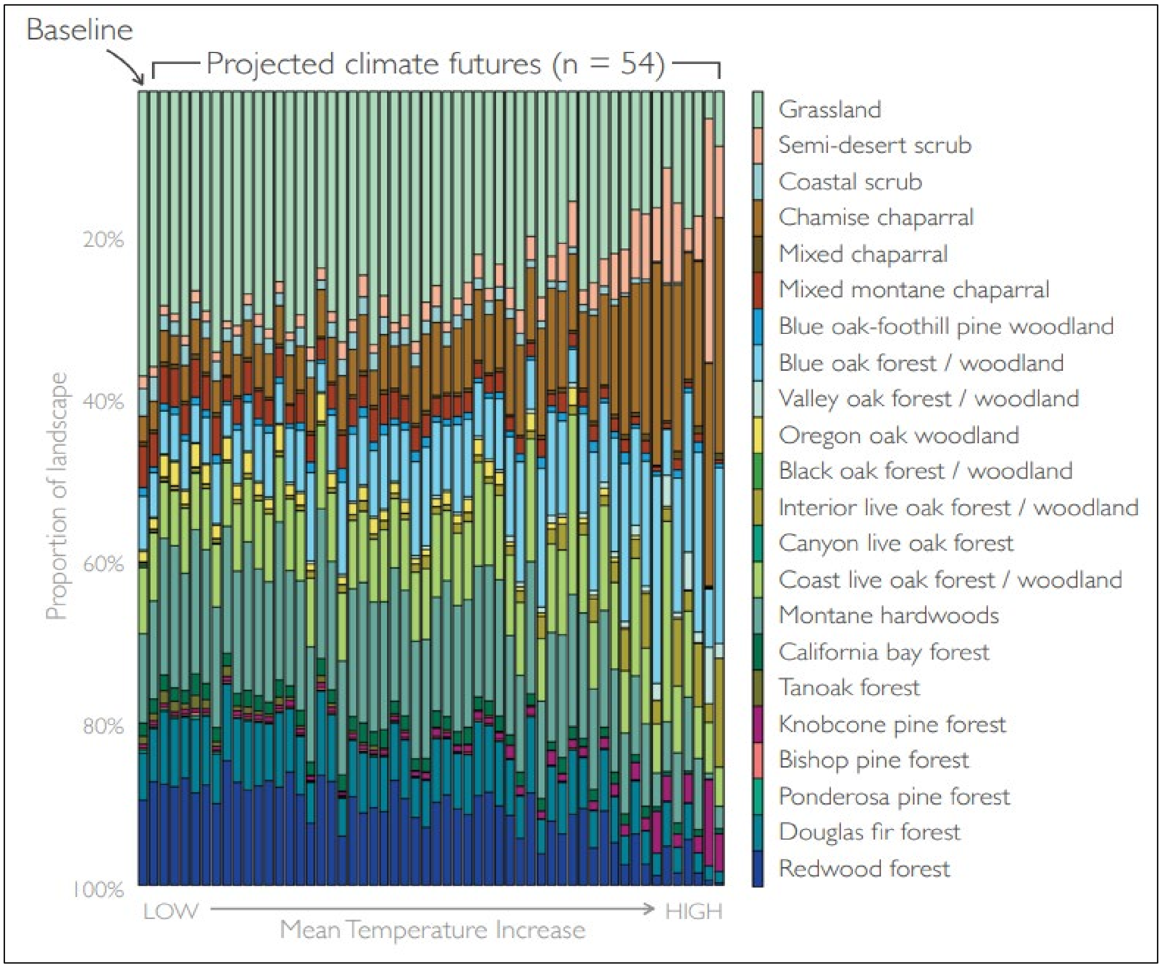
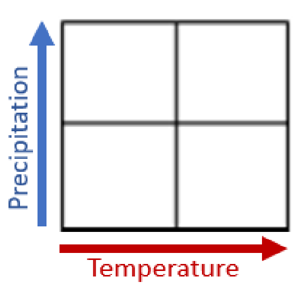


FIGURE 26.10 PROJECTED SPATIAL EXTENTS OF 16 VEGETATION TYPES FOR THE MARIN COAST RANGE LANDSCAPE UNIT (ACKERLY ET AL., 2015)

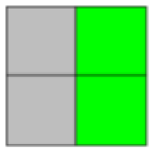
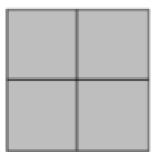
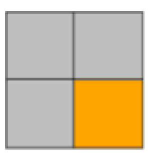
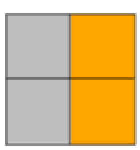
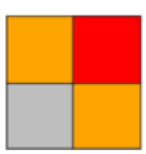
Note: The horizontal axis represents incremental increases in future temperature for 54 selected climate futures with variable precipitation. Colored bars spanning the vertical axis indicate whether vegetation types shrink or expand in spatial extent relative to the 2010 baseline (Ackerly et al., 2015).

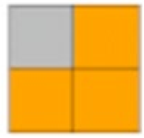


Squares in the climate change vulnerability diagrams in Table 26.1 represent increasing precipitation on the vertical axis and increasing temperature on the horizontal. The colors indicate how a particular plant community will fare under these different precipitation and temperature combinations: green = good, gray = stable, orange = concern, red = significant concern.

The finding indicated in the Trend column is based on the vegetation type's projected extent compared to its current status: climate "winners" increase 125%, stable communities occupy 75% to 125%, and "losers" occupy less than 75% (Ackerly et. al 2015).

TABLE 26.1 SUMMARY OF PROJECTED VEGETATION TRENDS FOR THE MARIN COAST LANDSCAPE UNIT (ACKERLY ET AL., 2015)

Vegetation Type	Trend	Climate Change Vulnerability	Description
Chamise chaparral	Winner		Chamise is a climate-change winner. It does better as the conditions get warmer and drier and is projected to increase across the Bay Area. Although it is capable of forming dense stands on southern slopes and hot microsites, its dispersal may be limited, and its persistence depends on fire. Succession to oak woodland can happen over many decades.
Coast live oak	Stable		Coast live oak is sensitive to increased rainfall and warmer summers, but it is not expected to decline and may even increase. It shows potential for expansion into the Bay Area's northern coastal range as the climate warms and dries.
Douglas-fir	Stable		Douglas-fir is sensitive to CWD increases but responds positively to increased winter temperatures, except when it gets too hot (increases >3° to 4° C). It will do best where CWD values are low, and winters are warm.
Canyon oak	Loser		Canyon oak is sensitive to warming, especially in the winter. This widespread species is found in most woodland vegetation types but is not abundant.
Grassland	Loser		Grassland abundance is driven by management as much as climate. Vulnerable to shrub invasion, it can be maintained by fire, grazing, or mowing. It is also very sensitive to nitrogen deposition.

Redwood	Loser		Redwoods are sensitive to both moisture and temperature. They are likely to persist on cool northern slopes, in riparian and moist valleys, and in areas of persistent fog. They grow best where CWD values are low. These areas should be prioritized for protection and stewardship.

DISCUSSION AND NEXT STEPS

Although the methods for the three approaches described previously vary, there was enough agreement to confidently establish a climate vulnerability framework for vegetation communities. Taken together, this research can be summarized to hypothesize how vegetation may respond to climate change. For example, all three approaches agree that redwood forests are likely one of the region's most vulnerable vegetation communities. In fact, vegetation that occupies cooler, moister landscapes is projected to be most vulnerable, even though these niches may be described as potential climate refugia. Those projected to substantially shrink include redwood forest and coastal scrub, while other communities (e.g., black oak forest/woodland, canyon live oak forest, and tanoak forest) may disappear entirely. On the other hand, vegetation types adapted to hotter and more arid conditions are expected to expand toward a warming coast and lower elevations.

There are also some differences in results between the three approaches that underscore the need for empirical data to inform and improve our understanding. For example, Ackerly et al. (2015) projected that the extent of chamise chaparral will increase across the Bay Area, while Thorne et al. (2016) ranked chamise chaparral zones as moderately vulnerable. However, Thorne et al (2016) also suggest that chamise may be relatively less vulnerable than other local vegetation types, which could permit it to expand its range as other more vulnerable types decline, contingent on the timing of those declines. Another example: While the Ackerly et al. (2015) analysis suggests that Douglas-fir may be stable under future climates, the Thorne et al. (2016) analysis indicates it may be moderately vulnerable.

Grasslands are currently the most extensive vegetation type in the Marin Coast Range landscape unit projected to decline, though the impacts appear highly dependent upon future rainfall and thus are subject to significant uncertainty. The Bay Area Open Space Council (2019) suggests that what the Conservation Lands Network classifies as cooler grasslands are currently on the edge of their climatic tolerance, while the warmer grasslands are still within theirs. Thorne et al. (2016) rank grasslands (one unit) as having mid-to-high vulnerability and project that, should we experience warmer and wetter futures, much of Marin County will be unsuitable for this vegetation type. Ackerly et al. (2015) project major declines in grassland extent, especially at much higher temperatures. The fate of grasslands in particular may be influenced by management actions that prevent their conversion to other vegetation types. As grasslands can be highly responsive to stewardship, there may be significant opportunities to pursue and monitor adaptive management strategies.

These types of models do not predict when or exactly how the changes will occur. Mechanisms for change may be episodic over the long term, punctuated by extreme events such as drought and fire. Potential adaptation will depend upon each species' capacity for dispersal and migration, as well as any barriers to these processes.

Identified uncertainties underscore why field-based observations are needed to better understand what the mechanisms of change will be, what the rate of change might look like, and when or where vegetation communities may reach a tipping point beyond which rapid declines or transitions may occur. This will require a field-based effort (augmented by remote sensing data) to observe when, where, and how plants decline or shift due to climate-stress-driven mortality and limits on or opportunities for dispersal. An excellent approach would be to build on recent fine-scale vegetation mapping efforts and to repeat these surveys over time to detect net shifts in species composition and distribution. When change happens, it will be critical to monitor the relationship of native species survival relative to invasive species distribution. Also, since these models rely on existing units of vegetation communities to project future distributions, monitoring may reveal that these communities are dissolving or reorganizing in novel and difficult-to-predict ways.

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APPENDICES

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APPENDIX 1. ALL ECOLOGICAL HEALTH INDICATORS CONSIDERED

Following is a list of all the indicators for the health of Mt. Tam that were originally proposed in 2016, why they were proposed, if they were included in either the 2016 report or this 2022 update, and the rationale for that decision.

Indicator	Why Is This Considered an Indicator of Mt. Tam's Health?	Included in the 2016 Report or This Update?	Are There Adequate Existing Data?
Vegetation			
Grasslands	Declining quality and extent due to increasing non-native, invasive species and colonization by woody plants. Mammals and grassland-nesting birds—many of which are also declining—rely on large grassland patches for reproduction and forage.	Yes	The 2018 Marin Countywide Fine Scale Vegetation Map includes grassland mapping with high spatial resolution but low floristic detail. Field-based mapping and inventories of priority grasslands carried out by individual agencies, including Marin County Parks and Marin Water, provide greater insight into grassland-species composition.
Open-canopy oak woodland	Plant community of concern. Oak woodlands on Mt. Tam have been heavily impacted by Sudden Oak Death.	Yes	The 2018 Marin Countywide Fine Scale Vegetation Map includes detailed mapping of the alliances and associations that comprise open-canopy oak woodlands. The Marin Regional Forest Health Strategy includes detailed analysis of this vegetation community at the countywide scale, including assessment of 2018/2019 conditions, threats, and healthy attributes.
Redwood forest	An indicator of biological integrity/biodiversity, natural-disturbance regime, and habitat quality. The Northern Spotted Owl nests and the Townsend's big-eared bat roosts in large trees within redwood forests.	Yes	Years of agency and Save the Redwoods League studies of these forests provide data needed to assess current condition and trends. Data from the 2014 National Park Service and National Geographic

Indicator	Why Is This Considered an Indicator of Mt. Tam's Health?	Included in the 2016 Report or This Update?	Are There Adequate Existing Data?
	By storing carbon, this forest type also provides an essential ecosystem service. Today, old-growth redwood forests occupy a tiny fraction of their historical extent and are further threatened by climate change and disease.		BioBlitz at Muir Woods provided additional supporting information for age structure and health. Additionally, the 2018 Marin Countywide Fine Scale Vegetation Map provides consistent, mountain-wide spatial information on the distribution of redwood forests. The Marin Regional Forest Health Strategy includes a detailed analysis of this forest type at the countywide scale, including assessment of 2018/2019 conditions, threats, and healthy attributes.
Sargent cypress forests	An indicator of biological integrity and diversity, natural-disturbance regimes, and habitat quality. Relatively limited in distribution and globally rare, Sargent cypress forests provide habitat for California ground-cone (*Kopsiopsis strobilacea*) and pleated gentian (*Gentiana affinis* var. *ovata*), which are also locally rare.	Yes	The 2018 Marin Countywide Fine Scale Vegetation Map provides consistent, mountain-wide spatial information on the distribution of Sargent cypress forests. The Marin Regional Forest Health Strategy includes detailed analyses of this forest type at the countywide scale, including assessment of 2018/2019 conditions, threats, and healthy attributes.
Seeps, springs, and wet meadows	Indicators of biological integrity and diversity, natural processes, climate-change vulnerability, natural-disturbance regime, and habitat quality. These plant communities have limited distribution and provide favorable conditions for several rare plants. Butterflies and band-tailed pigeons rely on seeps for essential minerals. Native amphibians breed in wet	Needs Statement	Appropriate metrics and data need further work. More baseline data across a broader geography are also needed. Due to the limitations of remotely sensed data analysis, the 2018 Marin Countywide Fine Scale Vegetation Map provides limited information on the distribution of these vegetation communities.

Indicator	Why Is This Considered an Indicator of Mt. Tam's Health?	Included in the 2016 Report or This Update?	Are There Adequate Existing Data?
	meadow habitats to avoid American bullfrogs (*Lithobates catesbeianus*) found in perennial waters. Other wildlife use these features for drinking water.		
Shrublands (coastal scrub and chaparral)	Important habitats for numerous wildlife species potentially threatened by heat and drought stress as a result of climate change. Chaparral is largely resilient to non-native plant invasion. Coastal scrub is more susceptible, but large core areas, which are actively managed by the National Park Service and California State Parks, remain free of target weed species.	Yes	Agency data on this plant community are sufficient to make some assessment of its condition and trend. Additionally, the 2018 Marin Countywide Fine Scale Vegetation Map provides consistent, mountain-wide spatial information on its distribution.
Rocky outcrops	Important to birds and easily damaged. It often contains plant species adapted to survive extremely low soil moisture, which may add value when compared with other communities.	No	Represents a small portion of the area of focus; some overlap with birds, serpentine barrens, and lichen indicators/metrics.
Mixed hardwoods	Constitute approximately 17% of the open space in the area of focus. This forest community is susceptible to the impacts of plant pathogens and changed fire regimes.	Needs Statement	The 2018 Marin Countywide Fine Scale Vegetation Map provides consistent, mountain-wide spatial information on the distribution of hardwood forests and woodlands. While the Marin Regional Forest Health Strategy did not include detailed analysis of this forest type, it does provide foundational data that can be used to conduct future assessments of its condition and trend.

Indicator	Why Is This Considered an Indicator of Mt. Tam's Health?	Included in the 2016 Report or This Update?	Are There Adequate Existing Data?
Serpentine barrens	Constitute approximately 0.2% of the open space in the area of focus. It is largely resistant to invasion, but barbed goatgrass (*Aegilops triuncialis*) and purple false brome (*Brachypodium distachyon*) are encroaching, and lack of fire may allow native shrubs to overtake open areas.	Yes	Agency data on this plant community are sufficient to make some assessment of its condition and trend. Additionally, the 2018 Countywide Fine Scale Vegetation Map includes the California Cliff, Scree, and Rock Vegetation Group.
Maritime chaparral	Plant community of concern in California. Its community endemics can be used as indicators of biological integrity or diversity, natural-disturbance regime, and habitat quality.	Yes	Current Marin Water and National Park Service rare-plant monitoring data facilitated an assessment of status and trends for this plant community. Additionally, the 2018 Marin Countywide Fine Scale Vegetation Map provides consistent, mountain-wide spatial information on its distribution.
	Hydrological Systems		
Hydrological systems (overall)	An overarching indicator. The state of water quality (temperature, dissolved oxygen, nitrogen deposition, etc.), stream flow, depth to groundwater, wetland extent, and hydro-fluvial geomorphic character are widely relevant across the One Tam area of focus.	Needs Statement	In partnership with the U.S. Geological Survey NHD/WBD stewards, hydrological system mapping was completed for Marin County using 2019 lidar scanning, which included updating mapping of both the hydrological system as well as of watershed and subwatershed boundaries. Future analysis can utilize this mapping to improve our understanding of the health of hydrological systems.
Lagunitas Creek below dams	An important measure of floodplain connectivity.	No	Same as above.
Watershed function: Redwood Creek, Easkoot	Indicators of the system's hydrological conditions. These include flow that approximates	No	Need to develop metrics and also assess baseline data requirements. Some connectivity

Indicator	Why Is This Considered an Indicator of Mt. Tam's Health?	Included in the 2016 Report or This Update?	Are There Adequate Existing Data?
Creek, Corte Madera Creek	maximum naturalistic hydrograph (acknowledging current constraints), winter flows, summer flows, diversion, temperatures, and floodplain connectivity.		data gaps will be or are likely resolved by the new lidar-derived hydrological system mapping.
Wetlands (overall): lakes/reservoirs, seeps/springs, isolated ponds	Aquatic resources that provide essential habitats and drinking water for numerous species across multiple taxonomic groups.	No	Need to develop metrics and assess baseline data needs.
Invertebrates			
California freshwater shrimp (*Syncaris pacifica*)	Very limited global distribution.	No	This group may be evaluated as part of the larger invertebrate discussion.
Other aquatic macroinvertebrates	Important in aquatic food webs; demonstrated to be good indicators of water quality.	No	Same as previous entry.
Terrestrial (land) snails and slugs	An important food source for many species.	No	Same as previous entry.
Invertebrate pollinators (intentional, i.e., bees, and incidental, e.g., other invertebrates)	Provide important ecosystem services. Many pollinators are in decline worldwide and may be sensitive to climate change/shifts in phenology.	A chapter on bees has been included in this update. There is also a Needs Statement for monarch butterflies.	Same as previous entry.
Fish			
Anadromous fish: Coho salmon (*Oncorhynchus kisutch*)	Spends part of its life in freshwater streams and part in the ocean. It is a good indicator of riparian habitat and hydrological conditions as well as of ocean health, an important food source for many species, and source of nutrients for riparian forests. This	Yes	Data collected since the 1990s through various long-term monitoring programs allow us to understand condition and trends.

Indicator	Why Is This Considered an Indicator of Mt. Tam's Health?	Included in the 2016 Report or This Update?	Are There Adequate Existing Data?
	species is federally endangered.		
Anadromous fish: Steelhead trout (*Oncorhynchus mykiss*)	See aspects of anadromous fish species described above. This species is federally threatened.	Yes	Data collected since the 1990s through various long-term monitoring programs allow us to understand condition and trends.
Anadromous fish: Threespine stickleback (*Gasterosteus aculeatus*)	See aspects of anadromous fish species described above.	Yes (2016); no (2022)	Despite limited data, this species is an important indicator that is easy to recognize and conducive to citizen-science monitoring. However, because no data were collected between 2016 and 2022 and there are no plans to start collecting data in the near future, this species was removed from the Anadromous Fish chapter (Chapter 14) in this update.
Amphibians and Reptiles			
California giant salamander (*Dicamptodon ensatus*)	Excellent indicator of stream biological diversity. It is relatively long-lived and has a stable population size. It can also provide insights into riparian health, including for smaller streams that do not have fish to use as indicators. Although not federally listed, this species is a special status animal and has a state Natureserve rank of S2/S3 (imperiled/vulnerable) and an ICUN status of near threatened.	Yes (2022)	Preliminary metrics have been developed for this indicator, although currently, there are not enough data to evaluate its condition or trend.
California red-legged frog (*Rana draytonii*)	Good indicator of freshwater wetland condition. It is relatively long-lived and breeds and rears progeny in wetland and aquatic sites. It was federally listed as a threatened	Yes	The National Park Service and U.S. Geological Survey have sporadically collected data on breeding California red-legged frog populations in Olema Valley and Bolinas Lagoon. In Redwood

Indicator	Why Is This Considered an Indicator of Mt. Tam's Health?	Included in the 2016 Report or This Update?	Are There Adequate Existing Data?
	species in 1996, and the area of focus is part of the species' core recovery area.		Creek Watershed, consistent annual surveys have been made since 2002.
Foothill yellow-legged frog (*Rana boylii*)	Good indicator of perennial stream conditions. It is sensitive to changes in water temperature and vulnerable to both recreational use and invasive aquatic species. It is also considered vulnerable to climate change. It is a federal species of concern, a U.S. Forest Service sensitive species, and a California Species of Special Concern.	Yes	Sufficient data exist thanks to Marin Water, which began monitoring the species in 2004.
Western pond turtle (*Actinemys marmorata*)	Good indicator of freshwater aquatic conditions and, to some extent, terrestrial grassland conditions. In its aquatic habitat, it is vulnerable to predation and competition with invasive species. On land, breeding adults, nests, and hatchlings are vulnerable to habitat degradation as well as to predation by over-abundant ravens, crows, skunks, and raccoons. It is considered vulnerable to climate change. The western pond turtle is a California Species of Special Concern.	Yes	Marin Water has several years of turtle trapping and volunteer observational data as well as monitoring data dating back to 2004. It has also implemented restoration, reintroduction, and other protection measures for this species in the area of focus. In addition, the National Park Service has western pond turtle inventory data for the area of focus from 1996 and from 2014 to the present.
Birds			
Birds (overall)	Recognized indicators of ecological change. Birds provide a wide variety of ecosystem services.	Yes	Agencies within the area of focus have a relatively long history of bird monitoring, which enables and supports estimates of population trends

Indicator	Why Is This Considered an Indicator of Mt. Tam's Health?	Included in the 2016 Report or This Update?	Are There Adequate Existing Data?
			for multiple species in multiple vegetation communities.
Osprey (*Pandion haliaetus*)	Breeding success a good indicator of water quality and fish availability. The Osprey, which is protected by the Migratory Bird Treaty Act, is a California Species of Special Concern and a California conservation focal species.	Yes	The Kent Lake Osprey colony was founded in the mid-1960s and has been monitored continuously by Marin Water since 1985.
Northern Spotted Owl (*Strix occidentalis caurina*)	Good indicator of forest ecosystem condition. Species numbers appear to be decreasing dramatically across its range. However, the Marin County population seems to be stable. The Northern Spotted Owl was listed as a federally threatened species in 1990.	Yes	Agencies have a wealth of inventory and long-term monitoring data on this species for much of Marin County, going back to the 1980s and 1990s.
Mammals			
Native mammal richness (overall)	Facilitates a more complete picture of terrestrial ecosystem condition, trophic relationships, and different mammal guilds.	Yes	Preliminary data are available from the Marin Wildlife Watch project, and One Tam agencies plan to continue this project in the future.
American badger (*Taxidea taxus*)	An important predator in grassland/coastal scrub communities. Its relatively large home range makes it sensitive to habitat loss and a good indicator of grassland patch size and condition. The American badger is recognized as a species of concern by some agencies.	Yes (2016); no (2022)	This species is one of the few mammals on Mt. Tam that is associated with specific habitat types (grassland and coastal scrub). This indicator was folded into the overall Mammals chapter in 2022 because there have been no dedicated badger studies since 2016. Also, data on this species

Indicator	Why Is This Considered an Indicator of Mt. Tam's Health?	Included in the 2016 Report or This Update?	Are There Adequate Existing Data?
			is now included in the Marin Wildlife Watch project.
Bats (overall)	Upper-level predators that provide key ecosystem services. Sensitive to climate change, habitat loss, pesticides, disease, and disturbance at breeding colonies, bats are also highly susceptible to certain diseases such as white-nose syndrome, which is known to be spreading.	Yes (2022)	A Marin County-wide bat monitoring project began in 2017 after data on bats was identified as a priority need in 2016. The program enabled us to include a new chapter on bats in this update.
Black-tailed deer (*Odocoileus hemionus*)	Prey species for the mountain lion, coyote, and bobcat. Its grazing may negatively affect tree regeneration; it can also be a nuisance in developed areas and a hazard on roads.	No	Included in the overall mammal richness section.
Black-tailed jackrabbit (*Lepus californicus*)	An important prey species in terrestrial ecosystems.	No	Included in the overall mammal richness section.
Bobcat (*Lynx rufus*)	Important upper-level predator found in many types of habitats in the area of focus.	No	Included in the overall mammal richness section.
Brush rabbit (*Sylvilagus bachmani*)	An important prey species in terrestrial ecosystems.	No	Included in the overall mammal richness section.
Coyote (*Canis latrans*)	Important upper-level predator recovering from historical persecution; now commonly observed in Marin County.	No	Included in the overall mammal richness section.
Gray fox (*Urocyon cinereoargenteus*)	A key predator in terrestrial ecosystems; seems to be increasing after a distemper outbreak in mid-1990s.	No	Included in the overall mammal richness section.

Indicator	Why Is This Considered an Indicator of Mt. Tam's Health?	Included in the 2016 Report or This Update?	Are There Adequate Existing Data?
Mountain lion (*Puma concolor*)	Iconic species and apex predator in terrestrial systems. Higher population numbers may indicate better habitat quality.	No	Included in overall mammal diversity section.
North American river otter (*Lontra canadensis*)	An important upper-level predator in aquatic systems; may be sensitive to water quality. It has recently returned to the San Francisco Bay Area after having been extirpated for decades.	Yes	The River Otter Ecology Project maintains ongoing monitoring and seasonal observational information on likely denning and dispersal areas.
Raccoon (*Procyon lotor*)	An omnivorous native species. It is common in riparian and developed areas, where it can reach nuisance levels.	No	Included in the overall mammal richness section.
Sonoma chipmunk (*Tamias sonomae*)	An important prey species in terrestrial ecosystems.	No	Included in the overall mammal richness section.
Striped skunk (*Mephitis mephitis*)	An omnivorous native species. It is common in riparian and developed areas, where it can reach nuisance levels.	No	Included in the overall mammal richness section.
Townsend's big-eared bat (*Corynorhinus townsendii*)	A candidate species under the California Endangered Species Act and a federal species of concern.	No	Included in the new bats chapter.
Western gray squirrel (*Sciurus griseus*)	A wide-ranging omnivore and important prey species in terrestrial ecosystems.	No	Included in the overall mammal richness section.

OBSERVED SPECIES LISTS

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The following are lists of all the known species for particular taxonomic groups found in the One Tam areas of focus.

They represent current, verified information compiled by One Tam partner agencies at this time, and will likely be updated in the future through further review of additional technical reports, inventories, and validation of other data sources.

A link to species lists from the community science iNaturalist app for the One Tam area of focus have also been included as supplemental information to each list below. You can also access a full list of all iNaturalist observations for this area here. This includes taxonomic groups not included in the lists below such as insects and fungi.

APPENDIX 2. OBSERVED PLANT SPECIES

An [iNaturalist list of plant species] is also available.

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Grass		*Hordeum murinum* ssp. *leporinum*	Farmer's foxtail	**X**
Annual Grass	*Aegilops triuncialis*		Goatgrass	
Annual Grass	*Aira caryophyllea*		Silvery hairgrass	
Annual Grass	*Aira elegans*		Elegant hair grass	
Annual Grass	*Alopecurus saccatus*		Foxtail	**X**
Annual Grass	*Avena fatua*		Wildoats	
Annual Grass	*Beckmannia syzigachne*		American sloughgrass	**X**
Annual Grass	*Briza maxima*		Rattlesnake grass	
Annual Grass	*Briza minor*		Little rattlesnake grass	
Annual Grass	*Bromus diandrus*		Ripgut brome	
Annual Grass	*Bromus hordeaceus*		Soft chess	
Annual Grass	*Bromus madritensis*	*Bromus madritensis* ssp. *rubens*	Foxtail brome	
Annual Grass	*Bromus sterilis*		Sterile brome	
Annual Grass	*Bromus tectorum*		Downy chess	
Annual Grass	*Cynosurus echinatus*		Dogtail grass	
Annual Grass	*Cyperus difformis*		Variable flatsedge	
Annual Grass	*Deschampsia danthonioides*		Annual hairgrass	**X**
Annual Grass	*Echinochloa crus-galli*		Barnyard grass	
Annual Grass	*Eleocharis engelmannii*		Engelmann's spikerush	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Grass	*Elymus caput-medusae*		Medusa head	
Annual Grass	*Festuca microstachys*		Small fescue	**X**
Annual Grass	*Gastridium phleoides*		Nit grass	
Annual Grass	*Hordeum marinum*	*Hordeum marinum* ssp. *gussoneanum*	Barley	**X**
Annual Grass	*Hordeum murinum*	*Hordeum murinum* ssp. *glaucum*	Foxtail	**X**
Annual Grass	*Hordeum vulgare*		Common barley	
Annual Grass	*Isolepis cernua*		Low bulrush	**X**
Annual Grass	*Juncus capitatus*		Leafy-bracted dwarf rush	
Annual Grass	*Juncus kelloggii*		Kellogg's dwarf rush	**X**
Annual Grass	*Koeleria gerardii*		Annual june grass, bristly koeleria	
Annual Grass	*Phalaris canariensis*		Annual canary grass	
Annual Grass	*Phalaris lemmonii*		Lemmon's canarygrass	**X**
Annual Grass	*Phalaris paradoxa*		Hood canarygrass	
Annual Grass	*Poa annua*		Annual blue grass	
Annual Grass	*Poa howellii*		Howell's blue grass	**X**
Annual Grass	*Polypogon monspeliensis*		Annual beardgrass	
Annual Grass	*Scribneria bolanderi*		Scribneria	**X**
Annual Herb		*Nemophila menziesii* var. *menziesii*	Menzies' Baby blue eyes	**X**
Annual Herb		*Claytonia exigua* ssp. *glauca*	Blue-leaved spring beauty	**X**
Annual Herb		*Trifolium depauperatum* var. *depauperatum*	Dwarf bladder clover	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb		*Trifolium depauperatum* var. *truncatum*	Dwarf sack clover	X
Annual Herb		*Clarkia amoena* ssp. *huntiana*	Farewell to spring	X
Annual Herb		*Eriogonum luteolum* var. *luteolum*	Golden buckwheat	X
Annual Herb		*Collinsia sparsiflora* var. *sparsiflora*	Spinster's blue-eyed mary	X
Annual Herb		*Streptanthus glandulosus* ssp. *secundus*	One-sided jewelflower	X
Annual Herb		*Trifolium bifidum* var. *decipiens*	Notchleaf clover	X
Annual Herb	*Acmispon americanus*		Spanish Clover	X
Annual Herb	*Acmispon brachycarpus*		Short-podded lotus	X
Annual Herb	*Acmispon micranthus*		Small-flowered lotus	X
Annual Herb	*Acmispon parviflorus*		Hill lotus	X
Annual Herb	*Acmispon strigosus*		Stringose lotus	X
Annual Herb	*Acmispon wrangelianus*		Chilean trefoil	X
Annual Herb	*Agoseris heterophylla*		Mountain dandelion	X
Annual Herb	*Amaranthus californicus*		California amaranth	X
Annual Herb	*Ammannia coccinea*		Red ammannia	X
Annual Herb	*Amsinckia intermedia*		Common fiddleneck	X
Annual Herb	*Amsinckia lunaris*		Bent-flowered fiddleneck	X
Annual Herb	*Amsinckia menziesii*		Fiddleneck	X

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Amsinckia spectabilis*		Seaside fiddleneck	X
Annual Herb	*Anthemis cotula*		Dog fennel	
Annual Herb	*Antirrhinum kelloggii*		Lax snapdragon	X
Annual Herb	*Antirrhinum vexillocalyculatum*		Wiry snapdragon	X
Annual Herb	*Astragalus breweri*		Brewer's milk vetch	X
Annual Herb	*Astragalus gambelianus*		Loco weed	X
Annual Herb	*Athysanus pusillus*		Dwarf athysanus	X
Annual Herb	*Bellardia trixago*		Mediterranean lineseed	
Annual Herb	*Borago officinalis*		Borage	
Annual Herb	*Brassica nigra*		Black mustard	
Annual Herb	*Brassica rapa*		Common mustard	
Annual Herb	*Cakile maritima*		European searocket	
Annual Herb	*Calandrinia breweri*		Brewer's calandrinia	X
Annual Herb	*Calandrinia menziesii*		Red maids	X
Annual Herb	*Calendula arvensis*		Field marigold	
Annual Herb	*Callitriche heterophylla*	*Callitriche heterophylla* var. *bolanderi*	Bolander's water starwort	X
Annual Herb	*Calycadenia multiglandulosa*		Rosin weed	X
Annual Herb	*Campanula angustiflora*		Eastwood's harebell	X
Annual Herb	*Campanula griffinii*		Griffin's harebell	X
Annual Herb	*Cannabis sativa*		Herb	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Capsella bursa-pastoris*		Shepherd's purse	
Annual Herb	*Carduus pycnocephalus*		Italian thistle	
Annual Herb	*Carthamus lanatus*		Woolly distaff thistle	
Annual Herb	*Castilleja ambigua*	*Castilleja ambigua* ssp. *ambigua*	Johnny nip	**X**
Annual Herb	*Castilleja attenuata*		Narrow-leaved owl's clover	**X**
Annual Herb	*Castilleja densiflora*	*Castilleja densiflora* ssp. *densiflora*	Denseflower owl's clover	**X**
Annual Herb	*Castilleja minor*	*Castilleja minor* ssp. *spiralis*	Lesser paintbrush	**X**
Annual Herb	*Castilleja rubicundula*	*Castilleja rubicundula* ssp. *lithospermoides*	Cream sacs	**X**
Annual Herb	*Caulanthus lasiophyllus*		California mustard	**X**
Annual Herb	*Centaurea melitensis*		Tocalote	
Annual Herb	*Centaurea solstitialis*		Yellow starthistle	
Annual Herb	*Centaurium tenuiflorum*		Slender centaury	
Annual Herb	*Cerastium glomeratum*		Large mouse ears	
Annual Herb	*Chenopodium album*		Lamb’s quarters	
Annual Herb	*Chloropyron maritimum*	*Chloropyron maritimum* ssp. *palustre*	Point Reyes bird's beak	**X**
Annual Herb	*Chorizanthe membranacea*		Pink spineflower	**X**
Annual Herb	*Chorizanthe polygonoides*	*Chorizanthe polygonoides* var. *polygonoides*	Knotweed spineflower	**X**
Annual Herb	*Cicendia quadrangularis*		Common microcalis	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Clarkia amoena*	*Clarkia amoena* ssp. *amoena*	Farewell to spring	X
Annual Herb	*Clarkia concinna*	*Clarkia concinna* ssp. *concinna*	Red ribbons	X
Annual Herb	*Clarkia gracilis*	*Clarkia gracilis* ssp. *gracilis*	Graceful clarkia	X
Annual Herb	*Clarkia purpurea*	*Clarkia purpurea* ssp. *quadrivulnera*	Purple clarkia	X
Annual Herb	*Clarkia rubicunda*		Farewell to spring	X
Annual Herb	*Clarkia unguiculata*		Woodland clarkia	X
Annual Herb	*Claytonia exigua*	*Claytonia exigua* ssp. *exigua*	Viridis	X
Annual Herb	*Claytonia gypsophiloides*		Gypsum spring beauty	X
Annual Herb	*Claytonia parviflora*		Small-leaved miner's lettuce	X
Annual Herb	*Claytonia perfoliata*	*Claytonia perfoliata* ssp. *perfoliata*	Miner's lettuce	X
Annual Herb	*Collinsia heterophylla*		Chinese houses	X
Annual Herb	*Collinsia sparsiflora*	*Collinsia sparsiflora* var. *collina*	Hillside collinsia	X
Annual Herb	*Collomia heterophylla*		Varied-leaved collomia	X
Annual Herb	*Cordylanthus pilosus*	*Cordylanthus pilosus* ssp. *pilosus*	Hairy bird's beak	X
Annual Herb	*Cotula australis*		Brass buttons	
Annual Herb	*Crassula aquatica*		Aquatic pygmy weed	X
Annual Herb	*Crassula connata*		Sand pygmy weed	X
Annual Herb	*Crassula tillaea*		Mediterranean pygmy weed	
Annual Herb	*Croton setigerus*		Dove weed	X

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Cryptantha clevelandii*		Common cryptantha	**X**
Annual Herb	*Cryptantha flaccida*		Beaked cryptantha	**X**
Annual Herb	*Cypselea humifusa*		Panal	
Annual Herb	*Datura stramonium*		Jimson weed	
Annual Herb	*Daucus pusillus*		Wild carrot	**X**
Annual Herb	*Dittrichia graveolens*		Stinkwort	
Annual Herb	*Draba verna*		Whitlow grass	**X**
Annual Herb	*Epilobium brachycarpum*		Willow herb	**X**
Annual Herb	*Epilobium campestre*		Smooth boisduvalia	**X**
Annual Herb	*Epilobium densiflorum*		Willow herb	**X**
Annual Herb	*Epilobium foliosum*		California willowherb	**X**
Annual Herb	*Epilobium minutum*		Minute willowherb	**X**
Annual Herb	*Epilobium torreyi*		Narrow boisduvalia	**X**
Annual Herb	*Erigeron canadensis*		Canada horseweed	**X**
Annual Herb	*Erigeron sumatrensis*		Tropical horseweed	
Annual Herb	*Eriogonum luteolum*	*Eriogonum luteolum* var. *caninum*	Tiburon buckwheat	**X**
Annual Herb	*Erodium botrys*		Big heron bill	
Annual Herb	*Erodium brachycarpum*		White-stemmed filaree	
Annual Herb	*Erodium cicutarium*		Coastal heron's bill	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Erodium moschatum*		Whitestem filaree	
Annual Herb	*Eschscholzia caespitosa*		Tufted eschscholzia	**X**
Annual Herb	*Euphorbia maculata*		Spotted spurge	
Annual Herb	*Euphorbia peplus*		Petty spurge	
Annual Herb	*Euphorbia spathulata*		Reticulate-seeded spurge	**X**
Annual Herb	*Galium aparine*		Cleavers	**X**
Annual Herb	*Galium divaricatum*		Lamarck's bedstraw	
Annual Herb	*Galium murale*		Tiny bedstraw	
Annual Herb	*Galium parisiense*		Wall bedstraw	
Annual Herb	*Galium triflorum*		Sweet bedstraw	**X**
Annual Herb	*Geranium dissectum*		Wild geranium	
Annual Herb	*Geranium robertianum*		Robert's geranium	
Annual Herb	*Gilia achilleifolia*		California gilia	**X**
Annual Herb	*Gilia capitata*	*Gilia capitata* ssp. *capitata*	Blue field gilia	**X**
Annual Herb	*Gilia clivorum*		Purple spot gilia	**X**
Annual Herb	*Githopsis specularioides*		Venus' looking glass	**X**
Annual Herb	*Glebionis coronaria*		Crown daisy	
Annual Herb	*Gnaphalium palustre*		Lowland cudweed	**X**
Annual Herb	*Gratiola ebracteata*		Common hedge hyssop	**X**
Annual Herb	*Hedypnois cretica*		Crete weed	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Hemizonia congesta*	*Hemizonia congesta* ssp. *lutescens*	Hayfield tarweed	**X**
Annual Herb	*Hesperevax sparsiflora*	*Hesperevax sparsiflora* var. *sparsiflora*	Few-flowered evax	**X**
Annual Herb	*Hesperocnide tenella*		Western stinging nettle	**X**
Annual Herb	*Hesperolinon congestum*		Marin western flax	**X**
Annual Herb	*Hesperolinon micranthum*		Smallflower western flax	**X**
Annual Herb	*Heterocodon rariflorum*		Heterocodon	**X**
Annual Herb	*Hypochaeris glabra*		Smooth cat's ear	
Annual Herb	*Lactuca saligna*		Willow lettuce	
Annual Herb	*Lactuca serriola*		Prickly lettuce	
Annual Herb	*Lagophylla ramosissima*		Common hairleaf	**X**
Annual Herb	*Lamium purpureum*		Purple deadnettle	
Annual Herb	*Lapsana communis*		Common nipplewort	
Annual Herb	*Lasthenia californica*		Goldfields	**X**
Annual Herb	*Lasthenia gracilis*		Needle goldfields	**X**
Annual Herb	*Lathyrus sphaericus*		Grass Peavine	
Annual Herb	*Lathyrus tingitanus*		Tangier pea	
Annual Herb	*Layia gaillardioides*		Woodland layia	**X**
Annual Herb	*Layia platyglossa*		Tidy tips	**X**
Annual Herb	*Leontodon saxatilis*	*Leontodon saxatilis* ssp. *saxatilis*	Hairy Hawkbit	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Lepidium didymum*		Lesser swine cress	
Annual Herb	*Lepidium nitidum*		Shining pepper grass	**X**
Annual Herb	*Lepidium strictum*		Peppergrass	**X**
Annual Herb	*Leptosiphon acicularis*		Bristly leptosiphon	**X**
Annual Herb	*Leptosiphon androsaceus*		False babystars	**X**
Annual Herb	*Leptosiphon bicolor*		True babystars	**X**
Annual Herb	*Leptosiphon grandiflorus*		Large-flowered leptosiphon	**X**
Annual Herb	*Leptosiphon parviflorus*		Variable linanthus	**X**
Annual Herb	*Lessingia hololeuca*		Woolly headed lessingia	**X**
Annual Herb	*Lessingia micradenia*	*Lessingia micradenia* var. *micradenia*	Tamalpais lessingia	**X**
Annual Herb	*Limosella acaulis*		Stemless mudwort	**X**
Annual Herb	*Linum bienne*		Flax	
Annual Herb	*Logfia filaginoides*		California cottonrose	**X**
Annual Herb	*Logfia gallica*		Narrowleaf cottonrose	
Annual Herb	*Lupinus microcarpus*	*Lupinus microcarpus* var. *densiflorus*	Chick lupine	**X**
Annual Herb	*Lupinus nanus*		Valley sky lupine	**X**
Annual Herb	*Lupinus succulentus*		Hollow stem blue lupine	**X**
Annual Herb	*Lysimachia arvensis*		Scarlet pimpernel	
Annual Herb	*Lysimachia minima*		Chaffweed	**X**
Annual Herb	*Lythrum tribracteatum*		Three-bracted loosestrife	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Madia anomala*		Tarweed	X
Annual Herb	*Madia elegans*		Common madia	X
Annual Herb	*Madia exigua*		Small tarweed	X
Annual Herb	*Madia gracilis*		Gumweed	X
Annual Herb	*Madia sativa*		Coastal tarweed	X
Annual Herb	*Malva nicaeensis*		Bull mallow	
Annual Herb	*Matricaria discoidea*		Pineapple weed	
Annual Herb	*Mauranthemum paludosum*		Creeping Daisy	
Annual Herb	*Medicago arabica*		Spotted burclover	
Annual Herb	*Medicago polymorpha*		California burclover	
Annual Herb	*Medicago praecox*		Mediterranean medick	
Annual Herb	*Melilotus indicus*		Annual yellow sweetclover	
Annual Herb	*Micropus californicus*	*Micropus californicus* var. *californicus*	Q tips	X
Annual Herb	*Microseris bigelovii*		Coast microseris	X
Annual Herb	*Microseris douglasii*	*Microseris douglasii* ssp. *douglasii*	Douglas' microseris	X
Annual Herb	*Microsteris gracilis*		Slender phlox	X
Annual Herb	*Mimulus congdonii*		Congdon's monkeyflower	X
Annual Herb	*Mimulus douglasii*		Purple mouse ears	X
Annual Herb	*Mimulus rattanii*		Rattan's monkeyflower	X
Annual Herb	*Minuartia douglasii*		Douglas' sandwort	X
Annual Herb	*Minuartia pusilla*		Annual sandwort	X

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Mollugo verticillata*		Indian chickweed	
Annual Herb	*Montia fontana*		Water montia	**X**
Annual Herb	*Myosotis discolor*		Forget-me-not	
Annual Herb	*Najas guadalupensis*		Guadalupe water nymph	**X**
Annual Herb	*Navarretia heterodoxa*		Calistoga navarretia	**X**
Annual Herb	*Navarretia intertexta*		Interwoven navarretia	**X**
Annual Herb	*Navarretia mellita*		Honey navarretia	**X**
Annual Herb	*Navarretia rosulata*		Marin county navarretia	**X**
Annual Herb	*Navarretia squarrosa*		Skunkweed	**X**
Annual Herb	*Navarretia viscidula*		Sticky navarretia	**X**
Annual Herb	*Nemophila heterophylla*		Canyon nemophila	**X**
Annual Herb	*Nemophila menziesii*	*Nemophila menziesii* var. *atomaria*	Baby blue eyes	**X**
Annual Herb	*Nemophila parviflora*	*Nemophila parviflora* var. *parviflora*	Small flowered nemophila	**X**
Annual Herb	*Oxalis micrantha*		Dwarf woodsorrel	
Annual Herb	*Oxalis pilosa*		Hairy woodsorrel	**X**
Annual Herb	*Papaver californicum*		Fire poppy	**X**
Annual Herb	*Parentucellia latifolia*		Broadleaf parentucellia	
Annual Herb	*Persicaria maculosa*		Spotted lady's thumb	
Annual Herb	*Petrorhagia dubia*		Wilding pink	
Annual Herb	*Petrorhagia prolifera*		Pink grass	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Phacelia distans*		Common phacelia	**X**
Annual Herb	*Phacelia divaricata*		Divaricate phacelia	**X**
Annual Herb	*Phacelia malvifolia*		Stinging phacelia	**X**
Annual Herb	*Pholistoma auritum*		Blue fiestaflower	**X**
Annual Herb	*Plagiobothrys bracteatus*		Bracted allocarya	**X**
Annual Herb	*Plagiobothrys nothofulvus*		Rusty haired popcorn flower	**X**
Annual Herb	*Plagiobothrys reticulatus*		Reticulate popcorn flower	**X**
Annual Herb	*Plagiobothrys tenellus*		Slender popcorn flower	**X**
Annual Herb	*Plagiobothrys undulatus*		Coast allocarya	**X**
Annual Herb	*Plantago coronopus*		Cut leaf plantain	
Annual Herb	*Plantago erecta*		California plantain	**X**
Annual Herb	*Plantago truncata*	*Plantago truncata* ssp. *firma*	Chilean plantain	**X**
Annual Herb	*Platystemon californicus*		Cream cups	**X**
Annual Herb	*Plectritis ciliosa*	*Plectritis ciliosa* ssp. *ciliosa*	Long-spurred plectritis	**X**
Annual Herb	*Plectritis congesta*	*Plectritis congesta* ssp. *brachystemon*	Shortspur seablush	**X**
Annual Herb	*Plectritis macrocera*		White-headed plectritis	**X**
Annual Herb	*Polycarpon tetraphyllum*		Four-leaved allseed	
Annual Herb	*Portulaca oleracea*		Common purslane	
Annual Herb	*Pseudognaphalium luteoalbum*		Jersey cudweed	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Psilocarphus tenellus*		Slender woolly heads	**X**
Annual Herb	*Pterostegia drymarioides*		Fairy mist	**X**
Annual Herb	*Rafinesquia californica*		California chicory	**X**
Annual Herb	*Ranunculus hebecarpus*		Tiny buttercup	**X**
Annual Herb	*Rigiopappus leptocladus*		Wire weed	**X**
Annual Herb	*Rorippa curvipes*		Bluntleaf yellow cress	**X**
Annual Herb	*Sagina apetala*		Dwarf pearlwort	**X**
Annual Herb	*Sagina decumbens*	*Sagina decumbens* ssp. *occidentalis*	Western pearlwort	**X**
Annual Herb	*Salvia columbariae*		Chia sage	**X**
Annual Herb	*Scabiosa atropurpurea*		Pincushions	
Annual Herb	*Scleranthus annuus*		German knotgrass	
Annual Herb	*Sedum radiatum*		Coast range stonecrop	**X**
Annual Herb	*Senecio sylvaticus*		Woodland groundsel	
Annual Herb	*Senecio vulgaris*		Common groundsel	
Annual Herb	*Sherardia arvensis*		Field madder	
Annual Herb	*Sidalcea calycosa*	*Sidalcea calycosa* ssp. *calycosa*	Checker mallow	**X**
Annual Herb	*Sidalcea diploscypha*		Fringed checkerbloom	**X**
Annual Herb	*Silene antirrhina*		Sleepy catch fly	**X**
Annual Herb	*Silene coniflora*		Fire-following campion	**X**
Annual Herb	*Silene gallica*		Common catchfly	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Sisymbrium altissimum*		Tall tumble mustard	
Annual Herb	*Sisymbrium officinale*		Hedge mustard	
Annual Herb	*Soliva sessilis*		South American soliva	
Annual Herb	*Sonchus asper*		Spiny sowthistle	
Annual Herb	*Sonchus oleraceus*		Sow thistle	
Annual Herb	*Spergula arvensis*		Corn spurry	
Annual Herb	*Stebbinsoseris decipiens*		Santa Cruz microseris	**X**
Annual Herb	*Stebbinsoseris heterocarpa*		Hybrid microseris	**X**
Annual Herb	*Stellaria media*		Chickweed	
Annual Herb	*Stellaria nitens*		Shining chickweed	**X**
Annual Herb	*Stephanomeria elata*	*Stephanomeria exigua* ssp. *coronaria*	White plume wirelettuce	**X**
Annual Herb	*Stephanomeria virgata*		Twiggy wreath plant	**X**
Annual Herb	*Streptanthus batrachopus*		Tamalpais jewelflower	**X**
Annual Herb	*Streptanthus glandulosus*	*Streptanthus glandulosus* ssp. *pulchellus*	Mt. Tamalpais jewelflower	**X**
Annual Herb	*Tetragonia tetragonioides*		New Zealand spinach	
Annual Herb	*Tetrapteron graciliflorum*		Hill sun cup	**X**
Annual Herb	*Thysanocarpus curvipes*		Common fringe pod	**X**
Annual Herb	*Torilis arvensis*		Field hedge parsley	
Annual Herb	*Torilis nodosa*		Wild parsley	
Annual Herb	*Trifolium albopurpureum*		Indian clover	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Trifolium angustifolium*		Narrow-leaved clover	
Annual Herb	*Trifolium barbigerum*		Bearded clover	**X**
Annual Herb	*Trifolium bifidum*	*Trifolium bifidum* var. *bifidum*	Notchleaf clover	**X**
Annual Herb	*Trifolium campestre*		Hop clover	
Annual Herb	*Trifolium cernuum*		Nodding clover	
Annual Herb	*Trifolium ciliolatum*		Tree clover	**X**
Annual Herb	*Trifolium depauperatum*	*Trifolium depauperatum* var. *amplectens*	Pale sack clover	**X**
Annual Herb	*Trifolium dichotomum*		Branched Indian clover	**X**
Annual Herb	*Trifolium dubium*		Shamrock	
Annual Herb	*Trifolium fucatum*		Bull clover	**X**
Annual Herb	*Trifolium glomeratum*		Clustered clover	
Annual Herb	*Trifolium gracilentum*		Pinpoint clover	**X**
Annual Herb	*Trifolium hirtum*		Rose clover	
Annual Herb	*Trifolium macraei*		Macrae's clover	**X**
Annual Herb	*Trifolium microcephalum*		Small head clover	**X**
Annual Herb	*Trifolium microdon*		Valparaiso clover	**X**
Annual Herb	*Trifolium obtusiflorum*		Creek clover	**X**
Annual Herb	*Trifolium oliganthum*		Few-flowered clover	**X**
Annual Herb	*Trifolium olivaceum*		Olive clover	**X**
Annual Herb	*Trifolium striatum*		Knotted clover	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb	*Trifolium subterraneum*		Subterranean clover	
Annual Herb	*Trifolium tomentosum*		Woolly clover	
Annual Herb	*Trifolium variegatum*	*Trifolium variegatum* var. *geminiflorum*	Small-flowered variegated clover	**X**
Annual Herb	*Trifolium willdenovii*		Tomcat clover	**X**
Annual Herb	*Triodanis biflora*		Venus looking glass	**X**
Annual Herb	*Triphysaria pusilla*		Little owl's clover	**X**
Annual Herb	*Uropappus lindleyi*		Silver puffs	**X**
Annual Herb	*Urtica urens*		Annual stinging nettle	
Annual Herb	*Veronica peregrina*	*Veronica peregrina* ssp. *xalapensis*	Speedwell	**X**
Annual Herb	*Veronica persica*		Bird's eye speedwell	
Annual Herb	*Vicia tetrasperma*		Four-seeded vetch	
Annual Herb	*Xanthium strumarium*		Rough cockleburr	**X**
Annual Herb	*Yabea microcarpa*		Hedge parsley	**X**
Annual Herb	*Yabea microcarpa*		Hedge parsley	**X**
Annual Herb	*Zeltnera exaltata*		Cancha lagua	**X**
Annual Herb	*Zeltnera muehlenbergii*		Muehlenberg's centaury	**X**
Annual Herb	*Zeltnera trichantha*		Alkali centaury	**X**
Annual Herb (aquatic)	*Callitriche stagnalis*		Pond water starwort	
Annual Herb (aquatic)	*Triglochin scilloides*		Flowering quillwort	**X**
Annual Herb, Vine		*Vicia sativa* ssp. *sativa*	Common vetch	**X**
Annual Herb, Vine	*Anthriscus caucalis*		Bur chevril	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual Herb, Vine (parasitic)	*Cuscuta californica*		California dodder	X
Annual Herb, Vine (parasitic)	*Cuscuta pacifica*	*Cuscuta pacifica* var. *pacifica*	Pacific saltmarsh dodder	X
Annual Herb, Vine (parasitic)	*Cuscuta subinclusa*		Canyon dodder	X
Annual Herb, Vine	*Scandix pecten-veneris*		Shepherd's needle	
Annual Herb, Vine	*Tropaeolum majus*		Garden nasturtium	
Annual Herb, Vine	*Vicia benghalensis*		Purple vetch	
Annual Herb, Vine	*Vicia hirsuta*		Hairy vetch	
Annual Herb, Vine	*Vicia sativa*	*Vicia sativa* ssp. *nigra*	Smaller common vetch	X
Annual Herb, Vine	*Vicia villosa*	*Vicia villosa* ssp. *Varia*	Thick fruited vetch	
Annual, Biennial Herb	*Dianthus armeria*	*Dianthus armeria* ssp. *armeria*	Grass pink	X
Annual, Biennial Herb	*Geranium purpureum*		Herb robert	
Annual, Biennial Herb	*Melilotus albus*		White sweetclover	
Annual, Biennial Herb	*Raphanus sativus*		Jointed charlock	
Annual, Perennial Grass	*Anthoxanthum odoratum*		Sweet vernal grass	
Annual, Perennial Grass	*Avena barbata*		Slim oat	
Annual, Perennial Grass	*Avena sativa*		Wild oat	
Annual, Perennial Grass	*Brachypodium distachyon*		False brome	
Annual, Perennial Grass	*Bromus catharticus*	*Bromus catharticus* var. *elatus*	Chilean brome	
Annual, Perennial Grass	*Bromus laevipes*		Narrow-flowered brome	X

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual, Perennial Herb	*Aphanes occidentalis*		Ladies' mantle	X
Annual, Perennial Herb	*Arctotheca calendula*		Perennial cape weed	
Annual, Perennial Herb	*Arctotheca prostrata*		Prostrate cape weed	
Annual, Perennial Herb	*Camissoniopsis cheiranthifolia*	*Camissoniopsis cheiranthifolia* ssp. *cheiranthifolia*	Beach evening primrose	X
Annual, Perennial Herb	*Cardamine oligosperma*		Idaho bittercress	X
Annual, Perennial Herb	*Centaurea calcitrapa*		Purple star thistle	
Annual, Perennial Herb	*Centranthus ruber*		Jupiter's beard	
Annual, Perennial Herb	*Cirsium quercetorum*		Brownie thistle	X
Annual, Perennial Herb	*Echium plantagineum*		Salvation echium	
Annual, Perennial Herb	*Elatine brachysperma*		Shortseed waterwort	X
Annual, Perennial Herb	*Eschscholzia californica*		California poppy	X
Annual, Perennial Herb	*Euphorbia lathyris*		Gopher weed	
Annual, Perennial Herb	*Euphorbia serpyllifolia*	*Euphorbia serpyllifolia* ssp. *serpyllifolia*	Thymeleaf sandmat	X
Annual, Perennial Herb	*Geranium molle*		Crane's bill geranium	
Annual, Perennial Herb	*Helminthotheca echioides*		Bristly oxtongue	
Annual, Perennial Herb	*Heterotheca grandiflora*		Telegraph weed	X
Annual, Perennial Herb	*Hypericum anagalloides*		Creeping St. John's wort	X
Annual, Perennial Herb	*Leucanthemum maximum*		Shasta daisy	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Annual, Perennial Herb	*Lunaria annua*		Honesty	
Annual, Perennial Herb	*Lupinus bicolor*		Lupine	**X**
Annual, Perennial Herb	*Lythrum hyssopifolia*		Hyssop loosestrife	
Annual, Perennial Herb	*Medicago lupulina*		Black medick	
Annual, Perennial Herb (rhizomatous)	*Mimulus guttatus*		Yellow monkeyflower	**X**
Annual, Perennial Herb	*Nuttallanthus texanus*		Blue toadflax	**X**
Annual, Perennial Herb	*Polygonum aviculare*	*Polygonum aviculare* ssp. *depressum*	Prostrate knotweed	**X**
Annual, Perennial Herb	*Pseudognaphalium californicum*		Ladies' tobacco	**X**
Annual, Perennial Herb	*Ranunculus muricatus*		Buttercup	
Annual, Perennial Herb	*Senecio glomeratus*		Cutleaf burnweed	
Annual, Perennial Herb	*Senecio minimus*		Coastal burnweed	
Annual, Perennial Herb	*Silybum marianum*		Milk thistle	
Annual, Perennial Herb	*Sisymbrium orientale*		Indian hedge mustard	
Annual, Perennial Herb	*Solanum americanum*		White nightshade	**X**
Annual, Perennial Herb	*Spergularia rubra*		Purple sand spurry	
Biennial Herb	*Dipsacus sativus*		Indian teasel	
Biennial Herb	*Pseudognaphalium ramosissimum*		Pink cudweed	**X**
Fern	*Adiantum aleuticum*		Five-finger maidenhair fern	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Fern	*Adiantum jordanii*		California maidenhair fern	**X**
Fern	*Aspidotis californica*		California lace fern	**X**
Fern (rhizomatous)	*Aspidotis carlotta-halliae*		Carlotta hall's lace fern	**X**
Fern	*Aspidotis densa*		Lace fern	**X**
Fern	*Athyrium filix-femina*	*Athyrium filix-femina* var. *cyclosorum*	Western lady fern	**X**
Fern	*Azolla filiculoides*		Mosquito fern	**X**
Fern	*Cystopteris fragilis*		Brittle fern	**X**
Fern	*Dryopteris arguta*		Wood fern	**X**
Fern	*Dryopteris expansa*		Spreading wood fern	**X**
Fern	*Equisetum arvense*		Common horsetail	**X**
Fern	*Equisetum hyemale*	*Equisetum hyemale* ssp. *affine*	Giant scouring rush	**X**
Fern	*Equisetum laevigatum*		Smooth scouring rush	**X**
Fern	*Equisetum telmateia*	*Equisetum telmateia* ssp. *braunii*	Giant horsetail	**X**
Fern	*Isoetes howellii*		Quillwort	**X**
Fern	*Isoetes nuttallii*		Nuttall's quillwort	**X**
Fern	*Marsilea vestita*		Hairy waterclover	**X**
Fern	*Myriopteris gracillima*		Lace-lip fern	**X**
Fern	*Myriopteris intertexta*		Coastal lip fern	**X**
Fern	*Pellaea andromedifolia*		Coffee fern	**X**
Fern	*Pellaea mucronata*	*Pellaea mucronata* var. *mucronata*	Bird's foot fern	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Fern	*Pentagramma triangularis*	*Pentagramma triangularis* ssp. *triangularis*	Goldback fern	**X**
Fern	*Pilularia americana*		Pillwort	**X**
Fern	*Polypodium californicum*		California polypody fern	**X**
Fern	*Polypodium calirhiza*		Licorice fern	**X**
Fern	*Polypodium glycyrrhiza*		Licorice fern	**X**
Fern	*Polypodium scouleri*		Leather fern	**X**
Fern	*Polystichum californicum*		California sword fern	**X**
Fern	*Polystichum dudleyi*		Dudley's sword fern	**X**
Fern	*Polystichum imbricans*		Narrow-leaved sword fern	**X**
Fern	*Polystichum munitum*		Western sword fern	**X**
Fern	*Pteridium aquilinum*	*Pteridium aquilinum* var. *pubescens*	Western bracken fern	**X**
Fern	*Pteris cretica*		Cretan brake	
Fern (mosslike)	*Selaginella wallacei*		Wallace's spike moss	**X**
Fern	*Woodwardia fimbriata*		Western chain fern	**X**
Perennial Grass	*Elymus glaucus*	*Elymus glaucus* ssp. *virescens*	Virginia wildrye	**X**
Perennial Grass		*Hordeum brachyantherum* ssp. *californicum*	California meadow barley	**X**
Perennial Grass		*Juncus bufonius* var. *occidentalis*	Round-fruited toad rush	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Grass		*Juncus phaeocephalus* var. *phaeocephalus*	Brown-headed rush	X
Perennial Grass	*Agrostis avenacea*		Pacific bentgrass	
Perennial Grass	*Agrostis exarata*		Bentgrass	X
Perennial Grass	*Agrostis hallii*		Hall's bentgrass	X
Perennial Grass	*Agrostis pallens*		Diego bentgrass	X
Perennial Grass	*Agrostis stolonifera*		Redtop	
Perennial Grass	*Alopecurus pratensis*		Meadow foxtail	
Perennial Grass	*Andropogon glomeratus*	*Andropogon glomeratus* var. *scabriglumis*	Beardgrass	X
Perennial Grass	*Anthoxanthum occidentale*		California sweetgrass	X
Perennial Grass	*Arrhenatherum elatius*		Tall oatgrass	
Perennial Grass	*Arundo donax*		Giant reed	
Perennial Grass	*Bromus carinatus*		California bromegrass	X
Perennial Grass	*Bromus maritimus*		Maritime brome	X
Perennial Grass	*Calamagrostis koelerioides*		Fire reed grass	X
Perennial Grass	*Calamagrostis ophitidis*		Serpentine reed grass	X
Perennial Grass	*Carex amplifolia*		Ample-leaved sedge	X
Perennial Grass	*Carex barbarae*		Valley sedge	X
Perennial Grass	*Carex bolanderi*		Bolander's sedge	X
Perennial Grass	*Carex brevicaulis*		Short stem sedge	X
Perennial Grass	*Carex cusickii*		Cusick's sedge	X
Perennial Grass	*Carex densa*		Sedge	X

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Grass	*Carex exsiccata*		Western inflated sedge	X
Perennial Grass	*Carex feta*		Green-sheathed sedge	X
Perennial Grass	*Carex globosa*		Round fruit sedge	X
Perennial Grass	*Carex gracilior*		Slender sedge	X
Perennial Grass	*Carex gynodynama*		Olney's hairy sedge	X
Perennial Grass	*Carex harfordii*		Monterey sedge	X
Perennial Grass	*Carex hendersonii*		Henderson's sedge	X
Perennial Grass	*Carex leporina*		Hare or oval sedge	X
Perennial Grass	*Carex leptopoda*		Slender-footed sedge	X
Perennial Grass	*Carex luzulina*		Wood rush sedge	X
Perennial Grass	*Carex mendocinensis*		Mendocino sedge	X
Perennial Grass	*Carex nudata*		Torrent sedge	X
Perennial Grass	*Carex obnupta*		Slough sedge	X
Perennial Grass	*Carex pendula*		Hanging sedge	
Perennial Grass	*Carex praegracilis*		Field sedge	X
Perennial Grass	*Carex serratodens*		Bifid sedge	X
Perennial Grass	*Carex simulata*		Short-beaked sedge	X
Perennial Grass	*Carex subbracteata*		Small-bract sedge	X
Perennial Grass	*Carex subfusca*		Brown sedge	X
Perennial Grass	*Carex tumulicola*		Split awn sedge	X
Perennial Grass	*Carex utriculata*		Beaked sedge	X
Perennial Grass	*Cortaderia jubata*		Andean pampas grass	
Perennial Grass	*Cortaderia selloana*		Pampas grass	X
Perennial Grass	*Cynodon dactylon*		Bermuda grass	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Grass	*Cyperus eragrostis*		Tall cyperus	**X**
Perennial Grass	*Cyperus involucratus*		Umbrella plant	
Perennial Grass	*Dactylis glomerata*		Orchardgrass	
Perennial Grass	*Danthonia californica*		California oatgrass	**X**
Perennial Grass	*Deschampsia cespitosa*		Tufted-hair grass	**X**
Perennial Grass	*Deschampsia elongata*		Hairgrass	**X**
Perennial Grass	*Distichlis spicata*		Saltgrass	**X**
Perennial Grass	*Ehrharta erecta*		Upright veldtgrass	
Perennial Grass	*Eleocharis acicularis*		Needle spikerush	**X**
Perennial Grass	*Eleocharis macrostachya*		Spikerush	**X**
Perennial Grass	*Eleocharis rostellata*		Walking sedge	**X**
Perennial Grass	*Elymus californicus*		California bottlegrass	**X**
Perennial Grass	*Elymus elymoides*		Squirreltail grass	**X**
Perennial Grass	*Elymus glaucus*	*Elymus glaucus* ssp. *glaucus*	Blue wild rye	**X**
Perennial Grass	*Elymus mollis*	*Elymus mollis* ssp. *mollis*	American dunegrass	**X**
Perennial Grass	*Elymus multisetus*		Big squirreltail grass	**X**
Perennial Grass	*Elymus pacificus*		Pacific wild rye	**X**
Perennial Grass	*Elymus triticoides*		Beardless wild rye	**X**
Perennial Grass	*Festuca arundinacea*		Reed fescue	
Perennial Grass	*Festuca bromoides*		Brome fescue	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Grass	*Festuca californica*		California fescue	**X**
Perennial Grass	*Festuca elmeri*		Coast fescue	**X**
Perennial Grass	*Festuca idahoensis*		Blue fescue	**X**
Perennial Grass	*Festuca myuros*		Rattail six-weeks grass	
Perennial Grass	*Festuca occidentalis*		Western fescue	**X**
Perennial Grass	*Festuca perennis*		Italian rye grass	
Perennial Grass	*Festuca rubra*		Red fescue	**X**
Perennial Grass	*Glyceria declinata*		Waxy manna grass	
Perennial Grass	*Glyceria elata*		Tall manna grass	**X**
Perennial Grass (aquatic)	*Glyceria leptostachya*		Manna grass	**X**
Perennial Grass (aquatic)	*Glyceria xoccidentalis*		Western manna grass	
Perennial Grass	*Holcus lanatus*		Common velvetgrass	
Perennial Grass	*Hordeum brachyantherum*	*Hordeum brachyantherum* ssp. *brachyantherum*	Meadow barley	**X**
Perennial Grass	*Hordeum jubatum*		Foxtail barley	**X**
Perennial Grass	*Juncus articulatus*		Jointed rush	**X**
Perennial Grass	*Juncus balticus*	*Juncus balticus* ssp. *ater*	Baltic rush	**X**
Perennial Grass	*Juncus bolanderi*		Bolander's rush	**X**
Perennial Grass	*Juncus bufonius*	*Juncus bufonius* var. *bufonius*	Toad rush	**X**
Perennial Grass	*Juncus covillei*		Coville's rush	**X**
Perennial Grass	*Juncus effusus*	*Juncus effusus* ssp. *pacificus*	Pacific rush	**X**
Perennial Grass	*Juncus mexicanus*		Mexican rush	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Grass	*Juncus occidentalis*		Slender juncus	X
Perennial Grass	*Juncus patens*		Rush	X
Perennial Grass	*Juncus phaeocephalus*	*Juncus phaeocephalus* var. *paniculatus*	Rush	X
Perennial Grass	*Juncus xiphioides*		Iris-leaved rush	X
Perennial Grass	*Koeleria macrantha*		June grass	X
Perennial Grass	*Kyllinga brevifolia*		Shortleaf spikesedge	
Perennial Grass	*Luzula comosa*		Hairy wood rush	X
Perennial Grass	*Melica californica*		California melic	X
Perennial Grass	*Melica geyeri*		Geyer's onion grass	X
Perennial Grass	*Melica harfordii*		Harford's melic	X
Perennial Grass	*Melica imperfecta*		Coast range melic	X
Perennial Grass	*Melica subulata*		Alaska melic	X
Perennial Grass	*Melica torreyana*		Torrey's melica	X
Perennial Grass	*Panicum acuminatum*	*Panicum acuminatum* var. *fasciculatum*	Pacific panic grass	X
Perennial Grass	*Paspalum dilatatum*		Dallis grass	
Perennial Grass	*Paspalum distichum*		Knot grass	X
Perennial Grass	*Pennisetum clandestinum*		Kikuyu grass	
Perennial Grass	*Pennisetum setaceum*		Fountaingrass	
Perennial Grass	*Phalaris aquatica*		Harding grass	
Perennial Grass	*Phalaris californica*		Canarygrass	X
Perennial Grass	*Poa bulbosa*		Bulbous bluegrass	
Perennial Grass	*Poa pratensis*		Kentucky bluegrass	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Grass	*Poa secunda*	*Poa secunda* ssp. *secunda*	Pine bluegrass	X
Perennial Grass	*Polypogon interruptus*		Ditch beardgrass	
Perennial Grass	*Polypogon viridis*		Water beardgrass	
Perennial Grass	*Rytidosperma penicillatum*		Purple-awned wallaby gras	
Perennial Grass	*Scirpus microcarpus*		Mountain bog bulrush	X
Perennial Grass	*Setaria parviflora*		Marsh bristlegrass	X
Perennial Grass	*Spartina foliosa*		California cordgrass	X
Perennial Grass	*Stipa lepida*		Foothill needlegrass	X
Perennial Grass	*Stipa manicata*		Andean tussock grass	
Perennial Grass	*Stipa miliacea*	*Stipa miliacea* var. *miliacea*	Smilo grass	X
Perennial Grass	*Stipa pulchra*		Purple needlegrass	X
Perennial Grass	*Stipa purpurata*		Bristly needlegrass	
Perennial Grass	*Trisetum canescens*		Nodding trisetum	X
Perennial Grasslike Herb	*Juncus lescurii*		Saltmarsh rush	X
Perennial Grasslike Herb	*Schoenoplectus californicus*		California bulrush	X
Perennial Grasslike Herb	*Schoenoplectus pungens*	*Schoenoplectus pungens* var. *longispicatus*	Common threesquare sedge	X
Perennial Herb		*Cirsium occidentale* var. *venustum*	Coulter's thistle	X
Perennial Herb (rhizomatous)		*Calystegia collina* ssp. *oxyphylla*	Mt. Saint Helena morning glory	X
Perennial Herb		*Urtica dioica* ssp. *holosericea*	Stinging nettle	X
Perennial Herb		*Stachys rigida* var. *rigida*	Rough hedgenettle	X

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb		*Prunella vulgaris* var. *lanceolata*	Tall Self-heal	**X**
Perennial Herb		*Chlorogalum pomeridianum* var. *divaricatum*	Soap plant	**X**
Perennial Herb		*Drymocallis glandulosa* var. *wrangelliana*	Sticky cinquefoil	**X**
Perennial Herb		*Corallorhiza maculata* var. *occidentalis*	Summer coralroot	**X**
Perennial Herb		*Epilobium ciliatum* ssp. *watsonii*	Coast-fringed willow herb	**X**
Perennial Herb	*Abronia latifolia*		Yellow sand-verbena	**X**
Perennial Herb	*Abronia umbellata*	*Abronia umbellata* var. *umbellata*	Pink sand-verbena	**X**
Perennial Herb	*Acaena pinnatifida*		California acaena	**X**
Perennial Herb	*Achillea millefolium*		Yarrow	**X**
Perennial Herb	*Acmispon glaber*		Deerweed, California broom	**X**
Perennial Herb	*Acmispon grandiflorus*		Large-leaved lotus	**X**
Perennial Herb	*Acmispon junceus*	*Acmispon junceus* var. *junceus*	Rush lotus	**X**
Perennial Herb	*Actaea rubra*		Bearberry	**X**
Perennial Herb	*Adenocaulon bicolor*		Trail plant	**X**
Perennial Herb	*Ageratina adenophora*		Sticky snakeroot	
Perennial Herb	*Agoseris apargioides*	*Agoseris apargioides* var. *apargioides*	Coast dandelion	**X**
Perennial Herb	*Agoseris grandiflora*	*Agoseris grandiflora* var. *grandiflora*	Giant mountain dandelion	**X**
Perennial Herb	*Agoseris hirsuta*		Woolly goat chicory	**X**
Perennial Herb	*Agoseris retrorsa*		Spear-leaved agoseris	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Amaryllis belladonna*		Naked ladies	
Perennial Herb	*Ambrosia chamissonis*		Beach bur	**X**
Perennial Herb	*Anaphalis margaritacea*		Pearly everlasting	**X**
Perennial Herb	*Anemone grayi*		Blue windflower	**X**
Perennial Herb	*Anemone oregana*	*Anemone oregana* var. *oregana*	Oregon anemone	**X**
Perennial Herb	*Angelica californica*		California angelica	**X**
Perennial Herb	*Angelica hendersonii*		Coast angelica	**X**
Perennial Herb	*Angelica tomentosa*		Woolly angelica	**X**
Perennial Herb	*Anisocarpus madioides*		Woodland madia	**X**
Perennial Herb	*Apocynum cannabinum*		Indian hemp	**X**
Perennial Herb	*Aquilegia eximia*		Vanhoutte's columbine	**X**
Perennial Herb	*Aquilegia formosa*		Columbine	**X**
Perennial Herb	*Arabis blepharophylla*		Coast rock cress	**X**
Perennial Herb	*Aralia californica*		California spikenard	**X**
Perennial Herb	*Arnica discoidea*		Rayless arnica	**X**
Perennial Herb	*Artemisia douglasiana*		California mugwort	**X**
Perennial Herb	*Arum italicum*		Italian lords and ladies	
Perennial Herb	*Asarum caudatum*		Creeping wild ginger	**X**
Perennial Herb	*Asclepias fascicularis*		Milkweed	**X**
Perennial Herb	*Asyneuma prenanthoides*		California harebell	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Baccharis glutinosa*		Salt marsh baccharis	**X**
Perennial Herb	*Barbarea orthoceras*		Winter cress	**X**
Perennial Herb	*Barbarea verna*		Early Wintercress	
Perennial Herb	*Bellis perennis*		English lawn daisy	
Perennial Herb	*Boykinia occidentalis*		Western boykinia	**X**
Perennial Herb	*Brodiaea elegans*	*Brodiaea elegans* ssp. *elegans*	Harvest brodiaea	**X**
Perennial Herb	*Brodiaea terrestris*	*Brodiaea terrestris* ssp. *terrestris*	Dwarf brodiaea	**X**
Perennial Herb	*Calochortus amabilis*		Golden fairy lantern	**X**
Perennial Herb	*Calochortus luteus*		Yellow mariposa	**X**
Perennial Herb	*Calochortus tolmiei*		Hairy star tulip	**X**
Perennial Herb	*Calochortus uniflorus*		Large-flowered star tulip	**X**
Perennial Herb	*Calypso bulbosa*	*Calypso bulbosa* var. *occidentalis*	Fairy slipper	**X**
Perennial Herb	*Calystegia collina*	*Calystegia collina* ssp. *collina*	Hillside morning glory	**X**
Perennial Herb	*Calystegia occidentalis*	*Calystegia occidentalis* ssp. *occidentalis*	Modoc morning glory	**X**
Perennial Herb	*Calystegia purpurata*	*Calystegia purpurata* ssp. *purpurata*	Smooth western morning glory	**X**
Perennial Herb	*Calystegia subacaulis*	*Calystegia subacaulis* ssp. *subacaulis*	Cambria morning glory	**X**
Perennial Herb	*Cardamine californica*		Bitter cress	**X**
Perennial Herb	*Carpobrotus chilensis*		Sea fig	
Perennial Herb	*Carpobrotus edulis*		Hottentot fig	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Castilleja affinis*	*Castilleja affinis* ssp. *affinis*	Wight's Indian paint brush	X
Perennial Herb	*Castilleja foliolosa*		Texas paintbrush	X
Perennial Herb	*Castilleja subinclusa*	*Castilleja subinclusa* ssp. *franciscana*	Franciscan paintbrush	X
Perennial Herb	*Castilleja wightii*		Wight' Indian paint brush	X
Perennial Herb	*Cerastium viride*		Field chickweed	X
Perennial Herb	*Ceratophyllum demersum*		Hornwort	X
Perennial Herb	*Chasmanthe bicolor*		Chasmanthe	
Perennial Herb	*Chasmanthe floribunda*		African cornflag	
Perennial Herb	*Chlorogalum pomeridianum*	*Chlorogalum pomeridianum* var. *pomeridianum*	Common soaproot	X
Perennial Herb	*Cicuta douglasii*		Western water hemlock	X
Perennial Herb	*Cirsium arvense*		Canada thistle	
Perennial Herb	*Cirsium brevistylum*		Indian thistle	X
Perennial Herb	*Cirsium hydrophilum*	*Cirsium hydrophilum* var. *vaseyi*	Mt. Tamalpais thistle	X
Perennial Herb	*Cirsium occidentale*	*Cirsium occidentale* var. *occidentale*	Cobweb thistle	X
Perennial Herb	*Cirsium remotifolium*		Few-leaved thistle	X
Perennial Herb	*Cirsium vulgare*		Bullthistle	
Perennial Herb	*Claytonia sibirica*		Candy flower	X
Perennial Herb	*Clinopodium douglasii*		Yerba buena	X
Perennial Herb	*Clintonia andrewsiana*		Red clintonia	X
Perennial Herb	*Conium maculatum*		Poison hemlock	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Corallorhiza maculata*	*Corallorhiza maculata* var. *maculata*	Summer coralroot	**X**
Perennial Herb	*Corallorhiza striata*		Striped coralroot	**X**
Perennial Herb	*Cotula coronopifolia*		Brass buttons	
Perennial Herb	*Crocosmia x crocosmiiflora*		Monbretia	
Perennial Herb	*Cynoglossum grande*		Houndstongue	**X**
Perennial Herb	*Delairea odorata*		Cape ivy	
Perennial Herb	*Delphinium californicum*	*Delphinium californicum* ssp. *californicum*	California Larkspur	**X**
Perennial Herb	*Delphinium hesperium*	*Delphinium hesperium* ssp. *hesperium*	Western larkspur	**X**
Perennial Herb	*Delphinium nudicaule*		Canyon larkspur	**X**
Perennial Herb	*Delphinium patens*	*Delphinium patens* ssp. *patens*	Spreading larkspur	**X**
Perennial Herb	*Dicentra formosa*		Pacific bleedinghearts	**X**
Perennial Herb	*Dichelostemma capitatum*	*Dichelostemma capitatum* ssp. *capitatum*	Wild hyacinth	**X**
Perennial Herb	*Dichelostemma congestum*		Fork-toothed ookow	**X**
Perennial Herb	*Digitalis purpurea*		Foxglove	
Perennial Herb	*Dipsacus fullonum*		Wild teasel	
Perennial Herb	*Drosanthemum floribundum*		Rosy iceplant	
Perennial Herb	*Drymocallis glandulosa*	*Drymocallis glandulosa* var. *glandulosa*	Sticky cinquefoil	**X**
Perennial Herb	*Duchesnea indica*		Mock strawberry	
Perennial Herb	*Dudleya cymosa*	*Dudleya cymosa* ssp. *cymosa*	Canyon liveforever	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Dudleya farinosa*		Coastal bluff lettuce	**X**
Perennial Herb	*Egeria densa*		Brazilian water weed	
Perennial Herb	*Elodea canadensis*		Common water weed	**X**
Perennial Herb	*Epilobium canum*		California fuchsia, zauschneria	**X**
Perennial Herb	*Epilobium ciliatum*	*Epilobium ciliatum* ssp. *ciliatum*	Willow herb	**X**
Perennial Herb	*Epipactis gigantea*		Stream orchid	**X**
Perennial Herb	*Epipactis helleborine*		Helleborine	
Perennial Herb	*Erigeron foliosus*	*Erigeron foliosus* var. *franciscensis*	San Francisco leafy fleabane	**X**
Perennial Herb	*Erigeron glaucus*		Seaside daisy	**X**
Perennial Herb	*Erigeron karvinskianus*		Latin American fleabane	
Perennial Herb	*Erigeron petrophilus*		Cliff fleabane	**X**
Perennial Herb	*Erigeron reductus*	*Erigeron reductus* var. *angustatus*	Pine erigeron	**X**
Perennial Herb	*Eriogonum latifolium*		Coast buckwheat	**X**
Perennial Herb	*Eriophyllum lanatum*	*Eriophyllum lanatum* var. *arachnoideum*	Wooly sunflower	**X**
Perennial Herb	*Eriophyllum staechadifolium*		Lizard tail	**X**
Perennial Herb	*Eryngium aristulatum*	*Eryngium aristulatum* var. *aristulatum*	Jepson's button celery	**X**
Perennial Herb	*Eryngium armatum*		Coyote thistle	**X**
Perennial Herb	*Eryngium jepsonii*		Delta coyote thistle	**X**
Perennial Herb	*Erysimum capitatum*		Wallflower	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Erysimum franciscanum*		Franciscan wallflower	**X**
Perennial Herb	*Euphorbia oblongata*		Eggleaf spurge	
Perennial Herb	*Eurybia radulina*		Roughleaf aster	**X**
Perennial Herb	*Euthamia occidentalis*		Western goldenrod	**X**
Perennial Herb	*Foeniculum vulgare*		Fennel	
Perennial Herb	*Fragaria chiloensis*		Beach strawberry	**X**
Perennial Herb	*Fragaria vesca*		Wild strawberry	**X**
Perennial Herb	*Frankenia salina*		Alkali heath	**X**
Perennial Herb	*Fritillaria lanceolata*	*Fritillaria lanceolata* var. *tristulis*	Marin checker lily	**X**
Perennial Herb	*Fumaria capreolata*		Ramping fumitory	
Perennial Herb	*Galium californicum*	*Galium californicum* ssp. *californicum*	California bedstraw	**X**
Perennial Herb	*Galium nuttallii*		Climbing bedstraw	**X**
Perennial Herb	*Gamochaeta ustulata*		Featherweed	**X**
Perennial Herb	*Gentiana affinis*	*Gentiana affinis* var. *ovata*	Gentian	**X**
Perennial Herb	*Geranium core-core*		Pink perennial cranesbill	
Perennial Herb	*Goodyera oblongifolia*		Rattlesnake plantain	**X**
Perennial Herb	*Grindelia camporum*		Gumweed	**X**
Perennial Herb	*Grindelia hirsutula*		Gumweed	**X**
Perennial Herb	*Grindelia stricta*		Coastal Gumweed	**X**
Perennial Herb	*Helenium puberulum*		Sneezeweed	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Heracleum maximum*		Common cowparsnip	X
Perennial Herb	*Heterotheca sessiliflora*	*Heterotheca sessiliflora* ssp. *bolanderi*	Golden aster	X
Perennial Herb	*Heuchera micrantha*		Alum root	X
Perennial Herb	*Hieracium albiflorum*		White-flowered hawkweed	X
Perennial Herb	*Hirschfeldia incana*		Mustard	
Perennial Herb	*Hoita macrostachya*		California hemp	X
Perennial Herb	*Hoita orbicularis*		Creeping leather root	X
Perennial Herb	*Holozonia filipes*		Holozonia	X
Perennial Herb	*Horkelia californica*		California horkelia	X
Perennial Herb	*Horkelia tenuiloba*		Thin-lobed horkelia	X
Perennial Herb	*Hosackia crassifolia*		Broad-leaved lotus	X
Perennial Herb	*Hosackia gracilis*		Harlequin lotus	X
Perennial Herb	*Hosackia pinnata*		Pinnate lotus	X
Perennial Herb	*Hosackia rosea*		Rose-flowered lotus	X
Perennial Herb	*Hosackia stipularis*	*Hosackia stipularis* var. *stipularis*	Stipulate lotus	X
Perennial Herb	*Hydrocotyle verticillata*		Whorled marsh pennywort	X
Perennial Herb	*Hypericum concinnum*		Gold wire	X
Perennial Herb	*Hypericum perforatum*		Klamathweed	
Perennial Herb	*Hypericum scouleri*		Scouler's St. John's wort	X
Perennial Herb	*Hypochaeris radicata*		Hairy cat’s ear	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Ipheion uniflorum*		Spring star	
Perennial Herb	*Iris douglasiana*		Douglas iris	**X**
Perennial Herb	*Iris foetidissima*		Stinking iris	
Perennial Herb	*Iris germanica*		German iris	
Perennial Herb	*Iris longipetala*		Central coast iris	**X**
Perennial Herb	*Iris macrosiphon*		Ground iris	**X**
Perennial Herb	*Iris pseudacorus*		Horticultural iris	
Perennial Herb	*Jaumea carnosa*		Fleshy jaumea	**X**
Perennial Herb	*Kniphofia uvaria*		Redhot poker	
Perennial Herb	*Kopsiopsis hookeri*		Small groundcone	**X**
Perennial Herb	*Lactuca virosa*		Poison wild lettuce	
Perennial Herb	*Lamiastrum galeobdolon*		Yellow archangel	
Perennial Herb	*Lathyrus latifolius*		Sweet pea	
Perennial Herb	*Lathyrus torreyi*		Redwood pea	**X**
Perennial Herb	*Lathyrus vestitus*	*Lathyrus vestitus* var. *vestitus*	Hillside pea	**X**
Perennial Herb	*Lemna minuta*		Least duckweed	**X**
Perennial Herb	*Leucanthemum vulgare*		Oxeye daisy	
Perennial Herb	*Ligusticum apiifolium*		Celery-leaved lovage	**X**
Perennial Herb	*Lilium pardalinum*		Leopard lily	**X**
Perennial Herb	*Lilium pardalinum*	*Lilium pardalinum* ssp. *pardalinum*	Leopard lily	**X**
Perennial Herb	*Limonium californicum*		Marsh rosemary	**X**
Perennial Herb	*Lithophragma affine*		Common woodland star	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Lithophragma heterophyllum*		Woodland star	X
Perennial Herb	*Lomatium californicum*		Celery weed	X
Perennial Herb	*Lomatium dasycarpum*	*Lomatium dasycarpum* ssp. *dasycarpum*	Hog fennel	X
Perennial Herb	*Lomatium macrocarpum*		Large-fruited lomatium	X
Perennial Herb	*Lomatium utriculatum*		Hog fennel	X
Perennial Herb	*Lotus corniculatus*		Bird's foot trefoil	
Perennial Herb	*Lotus tenuis*		Narrow-leaf bird's-foot trefoil	
Perennial Herb	*Lupinus adsurgens*		Drew's sticky lupine	X
Perennial Herb	*Lupinus formosus*	*Lupinus formosus* var. *formosus*	Summer lupine	X
Perennial Herb	*Lupinus latifolius*	*Lupinus latifolius* var. *latifolius*	Broadleaf lupine	X
Perennial Herb	*Lysimachia latifolia*		Starflower	X
Perennial Herb	*Maianthemum dilatatum*		False lily of the valley	X
Perennial Herb	*Maianthemum racemosum*		Feathery false lily of the valley	X
Perennial Herb	*Maianthemum stellatum*		Starry false lily of the valley	X
Perennial Herb	*Marrubium vulgare*		White horehound	
Perennial Herb	*Medicago sativa*		Alfalfa	
Perennial Herb	*Melissa officinalis*		Lemon balm	
Perennial Herb	*Mentha aquatica*		Water mint	
Perennial Herb	*Mentha arvensis*		American wild mint	X

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Mentha pulegium*		Pennyroyal	
Perennial Herb	*Micranthes californica*		Greene's saxifrage	**X**
Perennial Herb	*Mimulus cardinalis*		Cardinal monkeyflower	**X**
Perennial Herb	*Mimulus moschatus*		Musk monkeyflower	**X**
Perennial Herb	*Modiola caroliniana*		Carolina bristle mallow	
Perennial Herb	*Moehringia macrophylla*		Large-leaved sandwort	**X**
Perennial Herb	*Monardella purpurea*		Siskiyou monardella	**X**
Perennial Herb	*Monardella villosa*	*Monardella villosa* ssp. *villosa*	Coyote mint	**X**
Perennial Herb	*Montia parvifolia*		Showy rock montia	**X**
Perennial Herb	*Myosotis latifolia*		Wide-leaved forget-me-not	
Perennial Herb	*Myriophyllum spicatum*		Water milfoil	
Perennial Herb	*Oenanthe sarmentosa*		Water parsley	**X**
Perennial Herb	*Osmorhiza berteroi*		Sweet cicely	**X**
Perennial Herb	*Oxalis articulata*	*Oxalis articulata* ssp. *rubra*	Windowbox woodsorrel	**X**
Perennial Herb	*Oxalis corniculata*		Creeping woodsorrel	
Perennial Herb	*Oxalis incarnata*		Crimson woodsorrel	
Perennial Herb	*Oxalis latifolia*		Mexican oxalis	
Perennial Herb	*Oxalis oregana*		Redwood sorrel	**X**
Perennial Herb	*Oxalis pes-caprae*		Bermuda buttercup	
Perennial Herb	*Parnassia palustris*		Marsh grass of Parnassus	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Paronychia franciscana*		California whitlow wort	
Perennial Herb	*Pedicularis densiflora*		Indian warrior	**X**
Perennial Herb	*Perideridia gairdneri*	*Perideridia gairdneri* ssp. *gairdneri*	Squaw potato	**X**
Perennial Herb	*Perideridia kelloggii*		Yampah	**X**
Perennial Herb	*Persicaria hydropiperoides*		Water pepper	**X**
Perennial Herb	*Persicaria punctata*		Dotted smartweed	**X**
Perennial Herb	*Petasites frigidus*	*Petasites frigidus* var. *palmatus*	Western coltsfoot	**X**
Perennial Herb	*Phacelia californica*		Rock phacelia	**X**
Perennial Herb	*Phacelia egena*		White-flowered perennial phacelia	**X**
Perennial Herb	*Phacelia imbricata*	*Phacelia imbricata* ssp. *imbricata*	Imbricate phacelia	**X**
Perennial Herb	*Phyla nodiflora*		Common lippia	**X**
Perennial Herb	*Piperia elegans*	*Piperia elegans* ssp. *elegans*	Elegant piperia	**X**
Perennial Herb	*Piperia elongata*		Dense-flowered rein orchid	**X**
Perennial Herb	*Piperia transversa*		Rein orchid	**X**
Perennial Herb	*Piperia unalascensis*		Alaska piperia	**X**
Perennial Herb	*Plantago lanceolata*		Ribwort	
Perennial Herb	*Plantago major*		Common plantain	
Perennial Herb	*Plantago maritima*		Maritime plantain	**X**
Perennial Herb	*Plantago subnuda*		Mexican plantain	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Platanthera dilatata*	*Platanthera dilatata* var. *leucostachys*	Sierra bog orchid	**X**
Perennial Herb	*Polygala californica*		Milkwort	**X**
Perennial Herb	*Potentilla anserina*	*Potentilla anserina* ssp. *pacifica*	Pacific cinquefoil	**X**
Perennial Herb	*Primula hendersonii*		Shooting star	**X**
Perennial Herb	*Prosartes hookeri*		Drops of gold	**X**
Perennial Herb	*Prosartes smithii*		Largeflower fairybells	**X**
Perennial Herb	*Prunella vulgaris*	*Prunella vulgaris* var. *vulgaris*	Self-heal	**X**
Perennial Herb	*Pseudognaphalium beneolens*		Cudweed	**X**
Perennial Herb	*Pyrola picta*		White-veined shinleaf	**X**
Perennial Herb	*Ranunculus californicus*	*Ranunculus californicus* var. *californicus*	Common buttercup	**X**
Perennial Herb	*Ranunculus repens*		Creeping buttercup	
Perennial Herb	*Reseda luteola*		Dyer's mignonette	
Perennial Herb	*Romanzoffia californica*		California romanzoffia	**X**
Perennial Herb	*Romulea rosea*	*Romulea rosea* var. *australis*	Rosy sand crocus	**X**
Perennial Herb	*Rumex acetosella*		Sheep sorrel	
Perennial Herb	*Rumex conglomeratus*		Green dock	
Perennial Herb	*Rumex crispus*		Curly dock	
Perennial Herb	*Rumex occidentalis*		Western dock	**X**
Perennial Herb	*Rumex pulcher*		Fiddleleaf dock	
Perennial Herb	*Rumex salicifolius*		Willow-leaved dock	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Rupertia physodes*		Common rupertia	**X**
Perennial Herb	*Salicornia pacifica*		Pickleweed	**X**
Perennial Herb	*Sanguisorba minor*		Small burnet	
Perennial Herb	*Sanicula arctopoides*		Yellow mats	**X**
Perennial Herb	*Sanicula bipinnata*		Poison sanicle	**X**
Perennial Herb	*Sanicula bipinnatifida*		Purple sanicle	**X**
Perennial Herb	*Sanicula crassicaulis*		Pacific sanicle	**X**
Perennial Herb	*Sanicula laciniata*		Coast sanicle	**X**
Perennial Herb	*Sanicula tuberosa*		Turkey pea	**X**
Perennial Herb	*Scoliopus bigelovii*		Slink pod	**X**
Perennial Herb	*Scrophularia californica*		California bee plant	**X**
Perennial Herb	*Scutellaria californica*		California skullcap	**X**
Perennial Herb	*Scutellaria tuberosa*		Dannie's scullcap	**X**
Perennial Herb	*Sedum spathulifolium*		Pacific stonecrop	**X**
Perennial Herb	*Senecio aronicoides*		Butterweed	**X**
Perennial Herb	*Silene laciniata*	*Silene laciniata* ssp. *californica*	California Indian pink	**X**
Perennial Herb	*Sisyrinchium bellum*		Blue-eyed grass	**X**
Perennial Herb	*Solanum douglasii*		Douglas' nightshade	**X**
Perennial Herb	*Solidago elongata*		West coast Canada goldenrod	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Solidago velutina*	*Solidago velutina* ssp. *californica*	California goldenrod	X
Perennial Herb	*Sparaxis tricolor*		Harlequin flower	
Perennial Herb	*Spergularia macrotheca*	*Spergularia macrotheca* var. *macrotheca*	Sticky sand spurry	X
Perennial Herb	*Spergularia villosa*		Villous sand spurry	
Perennial Herb	*Spiranthes porrifolia*		Western ladies' tresses	X
Perennial Herb	*Stachys ajugoides*		Hedge nettle	X
Perennial Herb	*Stachys albens*		Cobwebby hedge nettle	X
Perennial Herb	*Stachys bullata*		California hedge nettle	X
Perennial Herb	*Stachys chamissonis*		Hedge nettle	X
Perennial Herb	*Stachys pycnantha*		Short spike hedge nettle	X
Perennial Herb	*Stachys rigida*	*Stachys rigida* var. *quercetorum*	Rough hedge nettle	X
Perennial Herb	*Symphyotrichum chilense*		Pacific aster	X
Perennial Herb	*Synthyris reniformis*		Snow queen	X
Perennial Herb	*Taraxacum officinale*		Red-seeded dandelion	
Perennial Herb	*Taraxia ovata*		Sun cup	X
Perennial Herb	*Tauschia kelloggii*		Kellogg's tauschia	X
Perennial Herb	*Tellima grandiflora*		Fringe cups	X
Perennial Herb	*Thalictrum fendleri*	*Thalictrum fendleri* var. *polycarpum*	Torrey's meadow rue	X
Perennial Herb	*Thermopsis californica*		California goldenbanner	X
Perennial Herb	*Thermopsis macrophylla*		California false lupine	X

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Toxicoscordion fontanum*		Marsh zigadenus	**X**
Perennial Herb	*Toxicoscordion fremontii*		Fremont's star lily	**X**
Perennial Herb	*Tradescantia fluminensis*		Small leaf spiderwort	
Perennial Herb	*Tragopogon porrifolius*		Salsify	
Perennial Herb	*Trifolium fragiferum*		Strawberry clover	
Perennial Herb	*Trifolium incarnatum*		Crimson clover	
Perennial Herb	*Trifolium pratense*		Red clover	
Perennial Herb	*Trifolium repens*		White clover	
Perennial Herb	*Trifolium wormskioldii*		Cow clover	**X**
Perennial Herb	*Trillium chloropetalum*		Giant wakerobin	**X**
Perennial Herb	*Trillium ovatum*	*Trillium ovatum* ssp. *ovatum*	White flowered wakerobin	**X**
Perennial Herb	*Triteleia hyacinthina*		Wild hyacinth	**X**
Perennial Herb	*Triteleia laxa*		Ithuriel's spear	**X**
Perennial Herb	*Triteleia peduncularis*		Marsh tritileia	**X**
Perennial Herb	*Turritis glabra*		Tower rockcress	**X**
Perennial Herb	*Typha domingensis*		Cattail	**X**
Perennial Herb	*Urtica dioica*	*Urtica dioica* ssp. *gracilis*	Nettle	**X**
Perennial Herb	*Vancouveria planipetala*		Inside-out flower	**X**
Perennial Herb	*Verbena lasiostachys*	*Verbena lasiostachys* var. *scabrida*	Vervain	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb	*Veronica americana*		American brooklime	**X**
Perennial Herb	*Vicia gigantea*		Giant vetch	**X**
Perennial Herb	*Vinca major*		Vinca	
Perennial Herb	*Viola adunca*		Blue violet, western dog violet	**X**
Perennial Herb	*Viola glabella*		Stream violet	**X**
Perennial Herb	*Viola ocellata*		Western heart's ease	**X**
Perennial Herb	*Viola odorata*		English violet	
Perennial Herb	*Viola purpurea*	*Viola purpurea* ssp. *quercetorum*	Goosefoot yellow violet	**X**
Perennial Herb	*Viola sempervirens*		Redwood violet	**X**
Perennial Herb	*Watsonia marginata*		Fragrant bugle lily	
Perennial Herb	*Watsonia meriana*		Bulbil bugle lily	
Perennial Herb	*Wyethia angustifolia*		Narrow-leaved mule ears	**X**
Perennial Herb	*Wyethia glabra*		Smooth mule ears	**X**
Perennial Herb	*Xerophyllum tenax*		Beargrass	**X**
Perennial Herb	*Zantedeschia aethiopica*		Calla lily	
Perennial Herb (aquatic)	*Alisma lanceolatum*		Water plantain	
Perennial Herb (aquatic)	*Alisma triviale*		Northern water plantain	**X**
Perennial Herb (aquatic)	*Myriophyllum sibiricum*		Siberian water milfoil	**X**
Perennial Herb (aquatic)	*Nasturtium officinale*		Watercress	**X**
Perennial Herb (aquatic)	*Nuphar polysepala*		Rocky Mountain pond lily	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb (aquatic)	*Potamogeton nodosus*		Long-leaved pondweed	X
Perennial Herb (aquatic)	*Potamogeton pusillus*		Small pondweed	X
Perennial Herb (aquatic)	*Ranunculus aquatilis*		Whitewater crowfoot	X
Perennial Herb (aquatic)	*Stuckenia pectinata*		Sago pondweed	X
Perennial Herb (aquatic)	*Triglochin concinna*		Utah arrow grass	X
Perennial Herb (aquatic)	*Triglochin maritima*		Seaside arrow grass	X
Perennial Herb (aquatic)	*Typha angustifolia*		Narrowleaf cattail	X
Perennial Herb (aquatic)	*Typha latifolia*		Broadleaf cattail	X
Perennial Herb (bulb)	*Allium amplectens*		Narrow-leaved onion	X
Perennial Herb (bulb)	*Allium falcifolium*		Sickle leaf onion	X
Perennial Herb (bulb)	*Allium triquetrum*		White-flowered onion	
Perennial Herb (bulb)	*Allium unifolium*		One-leaf onion	X
Perennial Herb (bulb)	*Calochortus umbellatus*		Oakland mariposa lily	X
Perennial Herb (bulb)	*Fritillaria affinis*		Checker lily	X
Perennial Herb (bulb)	*Fritillaria liliacea*		Fragrant fritillary	X
Perennial Herb (bulb)	*Narcissus papyraceus*		Paperwhite narcissus	
Perennial Herb (bulb)	*Narcissus pseudonarcissus*		Daffodil	
Perennial Herb (bulb)	*Narcissus tazetta*		Cream narcissus	
Perennial Herb (mycoparasitic)	*Hemitomes congestum*		Gnome plant	X
Perennial Herb (parasitic)	*Arceuthobium campylopodum*		Pine dwarf mistletoe	X

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Perennial Herb (parasitic)	*Kopsiopsis strobilacea*		California ground-cone	X
Perennial Herb (parasitic)	*Orobanche bulbosa*		Chaparral broomrape	X
Perennial Herb (parasitic)	*Orobanche fasciculata*		Pinyon broomrape	X
Perennial Herb (parasitic)	*Orobanche uniflora*		Naked broomrape	X
Perennial Herb (rhizomatous)		*Sidalcea malviflora* ssp. *malviflora*	Checker mallow	X
Perennial Herb (rhizomatous)	*Sidalcea malviflora*	*Sidalcea malviflora* ssp. *laciniata*	Pink checkerbloom	X
Perennial Herb, Shrub	*Agave americana*		American century plant	
Perennial Herb, Shrub	*Solanum furcatum*		Forked nightshade	
Perennial Herb, Shrub	*Solanum xanti*		Nightshade	X
Perennial Herb, Vine	*Clematis lasiantha*		Pipestem	X
Perennial Herb, Vine	*Clematis ligusticifolia*		Creek clematis	X
Perennial Herb, Vine	*Convolvulus arvensis*		Field bindweed	
Perennial Herb, Vine	*Dichondra donelliana*		Dichondra	X
Perennial Herb, Vine	*Marah fabacea*		California man-root	X
Perennial Herb, Vine	*Marah oregana*		Coast man-root	X
Perennial Herb, Vine	*Vicia americana*	*Vicia americana* ssp. *americana*	American vetch	X
Shrub		*Ceanothus cuneatus* var. *ramulosus*	Buck brush	X
Shrub		*Baccharis pilularis* ssp. *pilularis*	Coyote brush	X

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Shrub		*Arctostaphylos glandulosa* ssp. *glandulosa*	Eastwood's hispid manzanita	**X**
Shrub		*Lupinus albifrons* var. *collinus*	Silver bush lupine	**X**
Shrub		*Lupinus albifrons* var. *douglasii*	Douglas' silver bush lupine	**X**
Shrub		*Cornus sericea ssp. sericea*	Smooth American dogwood	**X**
Shrub	*Amelanchier utahensis*		Pale-leaved serviceberry	**X**
Shrub	*Amorpha californica*	*Amorpha californica* var. *napensis*	Indigo bush	**X**
Shrub	*Arctostaphylos canescens*	*Arctostaphylos canescens* ssp. *canescens*	Hoary manzanita	**X**
Shrub	*Arctostaphylos glandulosa*	*Arctostaphylos glandulosa* ssp. *cushingiana*	Non-glandular Eastwood's manzanita	**X**
Shrub	*Arctostaphylos manzanita*	*Arctostaphylos manzanita* ssp. *manzanita*	Common manzanita	**X**
Shrub	*Arctostaphylos montana*	*Arctostaphylos montana* ssp. *montana*	Mt. Tamalpais manzanita	**X**
Shrub	*Arctostaphylos sensitiva*		Glossyleaf manzanita	**X**
Shrub	*Arctostaphylos virgata*		Marin manzanita	**X**
Shrub	*Artemisia californica*		Coastal sage brush	**X**
Shrub	*Baccharis pilularis*	*Baccharis pilularis* ssp. *consanguinea*	Coyote brush	**X**
Shrub	*Berberis nervosa*		Oregon grape	**X**
Shrub	*Berberis pinnata*	*Berberis pinnata* ssp. *pinnata*	California barberry	**X**
Shrub	*Ceanothus cuneatus*	*Ceanothus cuneatus* var. *cuneatus*	Buck brush	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Shrub	*Ceanothus foliosus*	*Ceanothus foliosus* var. *foliosus*	Wavy-leaved ceanothus	**X**
Shrub	*Ceanothus gloriosus*	*Ceanothus gloriosus* var. *exaltatus*	Glory brush	**X**
Shrub	*Ceanothus jepsonii*		Musk brush	**X**
Shrub	*Ceanothus masonii*		Bolinas ceanothus	**X**
Shrub	*Ceanothus oliganthus*	*Ceanothus oliganthus* var. *sorediatus*	Jim brush	**X**
Shrub	*Cistus incanus*		Hairy rockrose	
Shrub	*Cornus sericea*	*Cornus sericea* ssp. *occidentalis*	Western dogwood	**X**
Shrub	*Corylus cornuta*	*Corylus cornuta* ssp. *californica*	Beaked hazelnut	**X**
Shrub	*Cotoneaster franchetii*		Cotoneaster	
Shrub	*Cotoneaster lacteus*		Milkflower cotoneaster	
Shrub	*Cotoneaster pannosus*		Woolly cotoneaster	
Shrub	*Crataegus monogyna*		Hawthorn	
Shrub	*Cytisus scoparius*		Scotch broom	
Shrub	*Cytisus striatus*		Portuguese broom	
Shrub	*Dendromecon rigida*		Bush poppy	**X**
Shrub	*Dirca occidentalis*		Western leatherwood	**X**
Shrub	*Echium candicans*		Pride of Madeira	
Shrub	*Erica canaliculata*		Hairy grey heather	
Shrub	*Ericameria arborescens*		Golden fleece	**X**
Shrub	*Ericameria ericoides*		Mock heather	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Shrub	*Eriodictyon californicum*		Yerba santa	**X**
Shrub	*Eriogonum fasciculatum*	*Eriogonum fasciculatum* var. *foliolosum*	California buckwheat	**X**
Shrub	*Eriogonum nudum*	*Eriogonum nudum* var. *nudum*	Naked-stemmed buckwheat	**X**
Shrub	*Eriophyllum confertiflorum*	*Eriophyllum confertiflorum* var. *confertiflorum*	Golden Yarrow	**X**
Shrub	*Frangula californica*	*Frangula californica* ssp. *californica*	California coffeeberry	**X**
Shrub	*Fremontodendron californicum*		California fremontia	**X**
Shrub	*Garrya fremontii*		Fremont's silk tassel	**X**
Shrub	*Gaultheria shallon*		Salal	**X**
Shrub	*Genista monspessulana*		French broom	
Shrub	*Helianthemum scoparium*		Broom rose	**X**
Shrub	*Heteromeles arbutifolia*		Toyon	**X**
Shrub	*Holodiscus discolor*		Oceanspray	**X**
Shrub	*Keckiella corymbosa*		Red beardtongue	**X**
Shrub	*Lavandula stoechas*		French lavender	
Shrub	*Lepechinia calycina*		Pitcher sage	**X**
Shrub	*Lonicera involucrata*	*Lonicera involucrata* var. *ledebourii*	Coast twinberry	**X**
Shrub	*Lupinus albifrons*	*Lupinus albifrons* var. *albifrons*	Silver bush lupine	**X**
Shrub	*Lupinus arboreus*		Coastal bush lupine	**X**
Shrub	*Melianthus major*		Honey flower	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Shrub	*Mimulus aurantiacus*		Sticky monkeyflower	**X**
Shrub	*Morella californica*		California wax myrtle	**X**
Shrub	*Oemleria cerasiformis*		Oso berry	**X**
Shrub	*Philadelphus lewisii*		Lewis' mock orange	**X**
Shrub	*Physocarpus capitatus*		Ninebark	**X**
Shrub	*Pickeringia montana*	*Pickeringia montana* var. *montana*	Chaparral pea	**X**
Shrub	*Plecostachys serpyllifolia*		Petite licorice	
Shrub	*Pyracantha angustifolia*		Firethorn	
Shrub	*Quercus durata*	*Quercus durata* var. *durata*	Leather oak	**X**
Shrub	*Rhamnus crocea*		Redberry	**X**
Shrub	*Rhododendron macrophyllum*		California rose bay	**X**
Shrub	*Ribes californicum*		California gooseberry	**X**
Shrub	*Ribes divaricatum*	*Ribes divaricatum* var. *pubiflorum*	Spreading gooseberry	**X**
Shrub	*Ribes menziesii*		Gooseberry	**X**
Shrub	*Ribes sanguineum*	*Ribes sanguineum* var. *glutinosum*	Flowering currant	**X**
Shrub	*Ribes victoris*		Victor's gooseberry	**X**
Shrub	*Rosa californica*		California wild rose	**X**
Shrub	*Rosa gymnocarpa*		Wood rose	**X**
Shrub	*Rosa rubiginosa*		Sweet brier	
Shrub	*Rosa spithamea*		Sonoma rose	**X**

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Shrub	*Rubus armeniacus*		Himalayan blackberry	
Shrub	*Rubus spectabilis*		Salmon berry	**X**
Shrub	*Sambucus nigra*	*Sambucus nigra* ssp. *caerulea*	Blue elderberry	**X**
Shrub	*Sambucus racemosa*	*Sambucus racemosa* var. *racemosa*	Pacific red elderberry	**X**
Shrub	*Solanum aviculare*		New Zealand nightshade	
Shrub	*Spartium junceum*		Spanish broom	
Shrub	*Symphoricarpos albus*	*Symphoricarpos albus* var. *laevigatus*	Snowberry	**X**
Shrub	*Symphoricarpos mollis*		Creeping Snowberry	**X**
Shrub	*Ulex europaeus*		Gorse	
Shrub	*Vaccinium ovatum*		Evergreen huckleberry	**X**
Shrub (parasitic)	*Phoradendron bolleanum*		Bollean mistletoe	
Shrub (parasitic)	*Phoradendron leucarpum*	*Phoradendron leucarpum* ssp. *tomentosum*	Mistletoe	**X**
Shrub (stem succulent)	*Cistus salviifolius*		Sageleaf rockrose	
Shrub (stem succulent)	*Opuntia ficus-indica*		Prickly pear cactus	
Shrub, Tree	*Quercus x chasei*		Chase Oak	**X**
Shrub, Tree	*Quercus x subconvexa*		Quercus x subconvexa	**X**
Shrub, Vine	*Helichrysum petiolare*		Licorice plant	
Tree	*Acacia decurrens*		Green wattle	
Tree	*Acacia longifolia*		Golden wattle	
Tree	*Acacia melanoxylon*		Blackwood acacia	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Tree	*Acer macrophyllum*		Bigleaf maple	**X**
Tree	*Acer negundo*		Boxelder	**X**
Tree	*Aesculus californica*		Buckeye	**X**
Tree	*Alnus rhombifolia*		White alder	**X**
Tree	*Arbutus menziesii*		Madrone	**X**
Tree	*Chamaecyparis lawsoniana*		Port Orford cedar	**X**
Tree	*Cordyline australis*		Cabbage tree	
Tree	*Cryptomeria japonica*		Japanese cedar	
Tree	*Eucalyptus globulus*		Blue gum	
Tree	*Ficus carica*		Common fig	
Tree	*Fraxinus latifolia*		Oregon ash	**X**
Tree	*Hesperocyparis macrocarpa*		Monterey cypress	**X**
Tree	*Maytenus boaria*		Mayten	
Tree	*Nerium oleander*		Oleander	
Tree	*Phoenix canariensis*		Canary Island date palm	
Tree	*Pinus attenuata*		Scrub pine	**X**
Tree	*Pinus coulteri*		Coulter pine	**X**
Tree	*Pinus muricata*		Bishop pine	**X**
Tree	*Pinus radiata*		Monterey pine	**X**
Tree	*Pittosporum tenuifolium*		Tawhiwhi	
Tree	*Prunus avium*		Sweet cherry	
Tree	*Prunus cerasifera*		Cherry plum	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Tree	*Pseudotsuga menziesii*	*Pseudotsuga menziesii* var. *menziesii*	Douglas-fir	X
Tree	*Pyrus communis*		Common pear	
Tree	*Quercus agrifolia*	*Quercus agrifolia* var. *agrifolia*	Coast live oak	X
Tree	*Quercus berberidifolia*		Inland scrub oak	X
Tree	*Quercus chrysolepis*		Gold cup live oak	X
Tree	*Quercus douglasii*		Blue oak	X
Tree	*Quercus garryana*	*Quercus garryana* var. *garryana*	Oregon oak	X
Tree	*Quercus kelloggii*		California black oak	X
Tree	*Quercus lobata*		Valley oak	X
Tree	*Quercus parvula*	*Quercus parvula* var. *shrevei*	Shreve's oak	X
Tree	*Quercus Xmorehus*		Oracle oak	X
Tree	*Robinia pseudoacacia*		Black locust	
Tree	*Salix laevigata*		Polished willow	X
Tree	*Salix lasiandra*		Pacific willow	X
Tree	*Sequoia sempervirens*		Coast redwood	X
Tree	*Thuja plicata*		Western red cedar	X
Tree	*Torreya californica*		California nutmeg	X
Tree	*Umbellularia californica*		California bay	X
Tree, Shrub		*Quercus parvula* var. *tamalpaisensis*	Tamalpais oak	X
Tree, Shrub		*Chrysolepis chrysophylla* var. *minor*	Bush chinquapin	X

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Tree, Shrub		*Quercus wislizeni* var. *wislizeni*	Interior live oak	**X**
Tree, Shrub	*Acacia dealbata*		Silver wattle	
Tree, Shrub	*Acacia retinodes*		Water wattle	
Tree, Shrub	*Acacia verticillata*		Star acacia	
Tree, Shrub	*Adenostoma fasciculatum*		Chamise	**X**
Tree, Shrub	*Alnus rubra*		Red alder	**X**
Tree, Shrub	*Buddleja davidii*		Butterfly bush	
Tree, Shrub	*Ceanothus thyrsiflorus*		Blueblossom	**X**
Tree, Shrub	*Ceanothus velutinus*		Tobacco brush, snowbrush	**X**
Tree, Shrub	*Cercocarpus betuloides*	*Cercocarpus betuloides* var. *betuloides*	Birchleaf mountain mahogany	**X**
Tree, Shrub	*Chrysolepis chrysophylla*	*Chrysolepis chrysophylla* var. *chrysophylla*	Golden chinquapin	**X**
Tree, Shrub	*Euonymus occidentalis*		Western burning bush	**X**
Tree, Shrub	*Garrya elliptica*		Coast silk tassel	**X**
Tree, Shrub	*Hesperocyparis sargentii*		Sargent cypress	**X**
Tree, Shrub	*Ilex aquifolium*		Holly	
Tree, Shrub	*Ligustrum lucidum*		Glossy privet	
Tree, Shrub	*Ligustrum ovalifolium*		California privet	
Tree, Shrub	*Myoporum laetum*		Lollypop tree	
Tree, Shrub	*Notholithocarpus densiflorus*	*Notholithocarpus densiflorus* var. *densiflorus*	Tanoak	**X**
Tree, Shrub	*Olea europaea*		Olive	

Life Form	Species Name	Subspecies or Variety Found on Mt. Tam	Common Name	Native
Tree, Shrub	*Pittosporum undulatum*		Victorian box	
Tree, Shrub	*Quercus wislizeni*	*Quercus wislizeni* var. *frutescens*	Live oak	**X**
Tree, Shrub	*Rhododendron occidentale*		Western azalea	**X**
Tree, Shrub	*Salix lasiolepis*		Arroyo willow	**X**
Tree, Shrub	*Salix scouleriana*		Scouler willow	**X**
Tree, Shrub	*Salix sitchensis*		Coulter Willow	**X**
Vine	*Asparagus asparagoides*		African asparagus fern	
Vine	*Clematis vitalba*		Old man's beard	
Vine	*Hedera canariensis*		Canary ivy	
Vine	*Lathyrus angulatus*		Angled pea vine	
Vine	*Vicia hassei*		Hasse's vetch	**X**
Vine, Shrub	*Aristolochia californica*		California pipevine	**X**
Vine, Shrub	*Galium porrigens*		Climbing bedstraw	**X**
Vine, Shrub	*Galium porrigens*	*Galium porrigens* var. *porrigens*	Graceful bedstraw	**X**
Vine, Shrub	*Hedera helix*		English ivy	
Vine, Shrub	*Lonicera hispidula*		Pink honeysuckle	**X**
Vine, Shrub	*Rubus parviflorus*		Thimbleberry	**X**
Vine, Shrub	*Rubus ursinus*		California blackberry	**X**
Vine, Shrub	*Toxicodendron diversilobum*		Poison oak	**X**
Vine, Shrub	*Whipplea modesta*		Modesty	**X**

APPENDIX 3. OBSERVED RARE, THREATENED, AND ENDANGERED PLANT SPECIES

Rank Code	Rank Description
1A	Plants Presumed Extirpated in California and Either Rare or Extinct Elsewhere
1B.1	Plants Rare, Threatened, or Endangered in California and Elsewhere- Seriously threatened in California
1B.2	Plants Rare, Threatened, or Endangered in California and Elsewhere- Moderately threatened in California
1B.3	Plants Rare, Threatened, or Endangered in California and Elsewhere- Not very threatened in California
2A	Plants Presumed Extirpated in California, But Common Elsewhere
2B.1	Plants Rare, Threatened, or Endangered in California, But More Common Elsewhere- Seriously threatened in California
2B.2	Plants Rare, Threatened, or Endangered in California, But More Common Elsewhere- Moderately threatened in California
2B.3	Plants Rare, Threatened, or Endangered in California, But More Common Elsewhere- Not very threatened in California
3**	**Plants About Which More Information is Needed - A Review List**
4.1	Plants of Limited Distribution - A Watch List- Seriously threatened in California
4.2	Plants of Limited Distribution - A Watch List- Moderately threatened in California
4.3	Plants of Limited Distribution - A Watch List- Not very threatened in California
	Information taken from *CNPS.org*
	**Rank 3 is excluded from this list

Scientific Name	Rank Code
Amorpha californica var. *napensis*	1B.2
Amsinckia lunaris	1B.2
Arabis blepharophylla	4.3
Arctostaphylos montana ssp. *montana*	1B.3
Arctostaphylos virgata	1B.2
Aspidotis carlotta-halliae	4.2

Scientific Name	Rank Code
Astragalus breweri	4.2
Calamagrostis ophitidis	4.3
Calandrinia breweri	4.2
Calochortus umbellatus	4.2
Calochortus uniflorus	4.2
Calystegia collina ssp. *oxyphylla*	4.2
Castilleja ambigua ssp. *ambigua*	4.2
Ceanothus gloriosus var. *exaltatus*	4.3
Ceanothus masonii	1B.2
Chloropyron maritimum ssp. *palustre*	1B.2
Cirsium hydrophilum var. *vaseyi*	1B.2
Dirca occidentalis	1B.2
Elymus californicus	4.3
Eriogonum luteolum var. *caninum*	1B.2
Erysimum franciscanum	4.2
Fritillaria lanceolata var. *tristulis*	1B.1
Fritillaria liliacea	1B.2
Hesperocyparis macrocarpa	1B.2
Hesperolinon congestum	1B.1
Horkelia tenuiloba	1B.2
Hosackia gracilis	4.2
Iris longipetala	4.2
Kopsiopsis hookeri	2B.3
Leptosiphon acicularis	4.2
Leptosiphon grandiflorus	4.2
Lessingia micradenia var. *micradenia*	1B.2
Navarretia rosulata	1B.2
Perideridia gairdneri ssp. *gairdneri*	4.2
Pinus radiata	1B.1

Scientific Name	Rank Code
Pleuropogon hooverianus	1B.1
Pleuropogon refractus	4.2
Quercus parvula var. *tamalpaisensis*	1B.3
Stebbinsoseris decipiens	1B.2
Streptanthus batrachopus	1B.3
Streptanthus glandulosus ssp. *pulchellus*	1B.2
Toxicoscordion fontanum	4.2

APPENDIX 4. LIKELY EXTIRPATED PLANT SPECIES

The following is a list of plant believed to be extirpated from the One Tam area of focus.

Scientific Name	Common Name
Achyrachaena mollis	Blow wives
Agrostis microphylla	Littleleaf bentgrass
Apiastrum angustifolium	Wild celery
Arabis eschscholtziana	Eschscholtz's hairy rockcress
Asclepias speciosa	Showy milkweed
Astragalus pycnostachyus	Marsh milk vetch
Blechnum spicant	Deer fern
Callitriche fassettii	Fassett's water starwort
Callitriche marginata	Winged water starwort
Callitriche palustris	Vernal water starwort
Callitriche trochlearis	Water starwort
Carex cusickii	Cusick's sedge
Circaea alpina ssp. *pacifica*	Pacific enchanter's nightshade
Cirsium andrewsii	Franciscan thistle
Clarkia purpurea ssp. *viminea*	Large godetia
Collomia grandiflora	Large-flowered collomia
Cornus nuttallii	Mountain dogwood
Cryptantha micromeres	Small-flowered cryptantha
Cryptantha muricata	Prickly cryptantha
Cryptantha torreyana	Torrey's cryptantha
Cypripedium californicum	California lady's slipper
Datisca glomerata	Durango root
Deinandra corymbosa	Coastal tarweed
Epilobium hallianum	Hall's willowherb
Equisetum laevigatum	Smooth scouring rush
Eryngium aristulatum var. *aristulatum*	Jepson's button celery

Scientific Name	Common Name
Eschscholzia caespitosa	Tufted eschscholzia
Euphorbia crenulata	Chinesecaps
Festuca octoflora	Six-weeks grass
Galium trifidum	Three-petaled bedstraw
Geranium bicknellii	Bicknell's geranium
Geranium carolinianum	Carolina geranium
Pseudognaphalium stramineum	Cottonbatting plant
Helenium bigelovii	Bigelow's sneezeweed
Heliotropium curassavicum var. *oculatum*	Seaside heliotrope
Holocarpha macradenia	Santa Cruz tarplant
Lathyrus jepsonii var. *californicus*	California tule pea
Lewisia rediviva	Bitter root
Limnanthes douglasii	Common meadow foam
Lythrum californicum	Common loosestrife
Micropus amphibolus	Mt. Diablo cottonweed
Microseris paludosa	Marsh scorzonella
Paxistima myrsinites	Oregon boxwood
Penstemon heterophyllus ssp. *purdyi*	Purdy's foothill penstemon
Pentachaeta alsinoides	Tiny pygmy daisy
Pentachaeta bellidiflora	White rayed pentachaeta
Phacelia suaveolens	Sweet-scented phacelia
Pityopus californicus	Pinefoot
Plagiobothrys glaber	Hairless popcorn flower
Pleuropogon refractus	Nodding semaphore grass
Potentilla rivalis var. *millegrana*	Brook cinquefoil
Prunus subcordata	Sierra plum
Prunus virginiana var. *demissa*	Western choke cherry
Quercus dumosa	Scrub oak
Ranunculus flammula var. *ovalis*	Greater creeping spearwort

Scientific Name	Common Name
Ranunculus lobbii	Lobb's aquatic buttercup
Ranunculus orthorhynchus var. *bloomeri*	Bloomer's buttercup
Ribes malvaceum	Chaparral currant
Ribes victoris	Victor's gooseberry
Sceptridium multifidum	Leather grape-fern
Sidalcea hickmanii ssp. *viridis*	Marin checkerbloom
Sisyrinchium californicum	California golden-eyed grass
Torreyochloa pallida var. *pauciflora*	Manna grass
Trifolium amoenum	Showy Indian clover
Viola pedunculata	California golden violet

APPENDIX 5. HISTORICAL AND CURRENT BEE SPECIES IN MARIN COUNTY

Family	Historically Recorded Species	Species Detected 2017–2018
Andrenidae	*Andrena angustella*	
	Andrena angustitarsata	
	Andrena anisochlora	
	Andrena astragali	*Andrena astragali*
	Andrena auricoma	
	Andrena barbilabris	
	Andrena buckelli	
	Andrena caerulea	*Andrena caerulea*
	Andrena caliginosa	
	Andrena candida	
	Andrena candidiformis	
	Andrena cerasifolii	
	Andrena chalybaea	*Andrena chalybaea*
	Andrena chlorogaster	
	Andrena chlorosoma	*Andrena chlorosoma*
	Andrena chlorura	
	Andrena cressonii infasciata	*Andrena cressonii*
		Andrena crudeni
	Andrena cuneilabris	*Andrena cuneilabris*
	Andrena fragilis†	
	Andrena frigida	
	Andrena fuscicauda chlorosoma	
	Andrena hemileuca	
	Andrena knuthiana	
	Andrena labergei chlorura	
	Andrena latifrons cuneilabris	
	Andrena lomatii fuscicauda	
	Andrena medionitens	
	Andrena microchlora	

Family	Historically Recorded Species	Species Detected 2017–2018
	Andrena miserabilis	
	Andrena nigrae†	
	Andrena nigrihirta	*Andrena nigrihirta*
	Andrena nigrocaerulea	*Andrena nigrocaerulea*
	Andrena nigroclypeata	
	Andrena obscuripostica	
	Andrena oenotherae hemileuca	
	Andrena orthocarpi	
	Andrena pallidifovea	
	Andrena perimelas	*Andrena perimelas*
	Andrena pertristis carliniformis	
	Andrena piperi	
	Andrena principalis	
	Andrena prolixa	
	Andrena prunorum	
	Andrena pulverea	
	Andrena saccata	
	Andrena salicifloris	
	Andrena suavis	
		Andrena subchalybea
	Andrena submoesta	
	Andrena torulosa	
	Andrena transnigra	
	Andrena trevoris	
	Andrena vandykei	
	Andrena vicinoides	
	Andrena washingtoni	
	Andrena w-scripta	
	Andrena w-scripta pascoensis	
	Calliopsis fracta	
	Panurginus atriceps	

Family	Historically Recorded Species	Species Detected 2017–2018
	Panurginus gracilis	
	Panurginus melanocephalus	
		Panurginus nigrelloides
	Panurginus nigrellus	
	Panurginus nigrihirtus	*Panurginus nigrihirtus*
	Panurginus occidentalis	
		Panurginus quadratus
	Perdita viridicollis	
	Perdita vittata	
Apidae	*Anthophora bomboides gaudialis*	
	Anthophora bomboides standfordiana	
	Anthophora californica	*Anthophora californica*
	Anthophora cockerelli	
	Anthophora coptognatha	
		Anthophora edwardsii
	Anthophora pacifica	
	Anthophora urbana	*Anthophora urbana*
	Anthophora ursina	*Anthophora ursina*
	Apis mellifera	*Apis mellifera* (exotic)
	Bombus bifarius	*Bombus bifarius*
	Bombus bifarius bifarius	
	Bombus bifarius nearcticus	
	Bombus californicus	*Bombus californicus*
	Bombus caliginosus	*Bombus caliginosus*
	Bombus campestris†	
	Bombus fervidus	
	Bombus flavidus	
	Bombus flavifrons	*Bombus flavifrons*
	Bombus melanopygus	*Bombus melanopygus*
	Bombus mixtus	*Bombus mixtus*
	Bombus occidentalis	

Family	Historically Recorded Species	Species Detected 2017–2018
	Bombus pensylvanicus	
		Bombus rufocinctus
	Bombus sitkensis	*Bombus sitkensis*
	Bombus ternarius	
	Bombus vandykei	
	Bombus vosnesenskii	*Bombus vosnesenskii*
	Ceratina acantha	*Ceratina acantha*
		Ceratina arizonensis
	Ceratina micheneri	
	Ceratina nanula	*Ceratina nanula*
		Ceratina pacifica
	Ceratina punctigena	
	Ceratina tejonensis	*Ceratina tejonensis*
		Diadasia angusticeps
	Diadasia bituberculata	*Diadasia bituberculata*
		Diadasia diminuta
	Diadasia enavata	
		Diadasia nigrifrons
		Diadasia rinconis
		Eucera actuosa
	Eucera cordleyi	
	Eucera edwardsii	*Eucera edwardsii*
	Eucera frater albopilosa	*Eucera frater*
	Eucera frater lata†	
	Eucera lunata	*Eucera lunata*
		Eucera pomona
	Habropoda cineraria	
	Habropoda depressa	*Habropoda depressa*
	Habropoda miserabilis	
		Melecta pacifica
	Melecta separata callura	*Melecta separata*

Family	Historically Recorded Species	Species Detected 2017–2018
	Melissodes ablusa	
		Melissodes agilis
		Melissodes clarkiae
	Melissodes lupina	*Melissodes lupinus*
	Melissodes lustra	
	Melissodes moorei	
	Melissodes rivalis	
		Melissodes robustior
		Melissodes stearnsi
	Melissodes tepida timberlakei	
	Nomada crotchii	*Nomada* sp.
	Nomada edwardsii	
	Nomada latifrons	
	Nomada lewisi	
	Nomada tintinnabulum	
	Peponapis pruinosa	
	Triepeolus sp.	*Triepeolus* sp.
		Triepeolus heterurus
	Xeromelecta californica	*Xeromelecta californica*
	Xylocopa tabaniformis orpifex	*Xylocopa tabaniformis*
Colletidae	*Colletes clypeonitens*†	
	Colletes consors pascoensis	
	Colletes covilleae†	
	Colletes fulgidus fulgidus	*Colletes fulgidus*
	Colletes fulgidus lontiplumosus	
	Colletes hyalinus gaudialis	
	Colletes kincaidii	
	Colletes louisae	
	Colletes phaceliae	
	Colletes slevini	*Colletes slevini*
	Hylaeus calvus	

Family	Historically Recorded Species	Species Detected 2017–2018
	Hylaeus coloradensis	
	Hylaeus episcopalis episcopalis	
	Hylaeus maritimus	
		Hylaeus mesillae
	Hylaeus modestus modestus	*Hylaeus modestus*
	Hylaeus nevadensis	
	Hylaeus polifolii	*Hylaeus polifolii*
	Hylaeus rudbeckiae	
	Hylaeus verticalis	
Halictidae	*Agapostemon femoratus*	
	Agapostemon texanus	*Agapostemon angelicus texanus*
	Augochlorella pomoniella	
		Dufourea sandhouseae
	Dufourea trochantera	
	Halictus farinosus	*Halictus farinosus*
	Halictus ligatus	
	Halictus rubicundus	*Halictus rubicundus*
	Halictus tripartitus	*Halictus tripartitus*
	Lasioglossum arcanum	
		Lasioglossum channelense
	Lasioglossum cooleyi	
	Lasioglossum incompletum	
	Lasioglossum kincaidii	
	Lasioglossum longicorne	
	Lasioglossum marinense	
	Lasioglossum mellipes	*Lasioglossum mellipes*
	Lasioglossum nevadense	
	Lasioglossum olympiae	*Lasioglossum olympiae*
	Lasioglossum pacificum	*Lasioglossum pacificum*
	Lasioglossum pavonotum	
	Lasioglossum perichlarum	

Family	Historically Recorded Species	Species Detected 2017–2018
	Lasioglossum ruidosense	
	Lasioglossum sisymbrii	
	Lasioglossum tegulariforme	
	Lasioglossum titusi	*Lasioglossum titusi*
	Lasioglossum trizonatum	
	Micralictoides ruficaudus	*Micralictoides ruficaudus*
	Sphecodes arvensiformis	*Sphecodes* sp.
Megachilidae	*Anthidium collectum*	*Anthidium collectum*
		Anthidium maculosum
		Anthidium manicatum (exotic)
	Anthidium palliventre	
	Anthidium placitum longiplumosus	*Anthidium placitum*
	Anthidium utahense	*Anthidium utahense*
	Ashmeadiella australis	*Ashmeadiella australis*
	Ashmeadiella bigeloviae	
		Ashmeadiella cactorum
	Ashmeadiella californica	*Ashmeadiella californica*
	Ashmeadiella foveata	
	Ashmeadiella prosopidis	
	Ashmeadiella timberlakei	
	Atoposmia anthodyta	
		Coelioxys gilensis
	Coelioxys serricaudata	
		Dianthidium plenum
	Heriades cressoni	
	Heriades occidentalis	
	Hoplitis albifrons maura	
	Hoplitis producta gracilis	*Hoplitis producta*
	Hoplitis sambuci	*Hoplitis sambuci*
	Megachile angelarum	*Megachile angelarum*
		Megachile apicalis (exotic)

Family	Historically Recorded Species	Species Detected 2017–2018
		Megachile brevis
	Megachile coquilletti	*Megachile coquilletti*
		Megachile fidelis
	Megachile gemula	
		Megachile gentilis
	Megachile gravita	
	Megachile montivaga	*Megachile montivaga*
		Megachile onobrychidis
	Megachile parallela	*Megachile parallela*
	Megachile pascoensis	
	Megachile perihirta	
	Megachile pseudonigra	*Megachile pseudonigra*
	Megachile rotundata	*Megachile rotundata* (exotic)
		Megachile snowi
	Megachile subnigra	
	Megachile wheeleri	
		Osmia aff. pusilla
	Osmia albolateralis visenda	*Osmia albolateralis*
	Osmia atrocyanea	*Osmia atrocyanea*
	Osmia brevis	
	Osmia bucephala	
	Osmia californica	*Osmia californica*
	Osmia cobaltina	*Osmia cobaltina*
	Osmia coloradensis	*Osmia coloradensis*
	Osmia cyanella	*Osmia cyanella*
	Osmia densa	*Osmia densa*
	Osmia dolerosa	
	Osmia exigua	*Osmia exigua*
	Osmia gabrielis	*Osmia gabrielis*
	Osmia gaudiosa	
	Osmia granulosa	*Osmia granulosa*

Family	Historically Recorded Species	Species Detected 2017–2018
		Osmia grindeliae
	Osmia integra	
	Osmia juxta	
	Osmia laeta	*Osmia laeta*
	Osmia lignaria	*Osmia lignaria*
	Osmia malina	
	Osmia melanopleura	
	Osmia montana quadriceps	
	Osmia nemoris	*Osmia nemoris*
	Osmia nigrifrons	
	Osmia obliqua	
	Osmia penstemonis	
	Osmia proxima	
	Osmia pusilla	*Osmia pusilla*
	Osmia rawlinsi	
		Osmia regulina
	Osmia ribifloris biedermannii	
	Osmia sedula	
	Osmia texana	*Osmia texana*
		Osmia trevoris
	Osmia tristella tristella	*Osmia tristella*
	Protosmia rubifloris	*Protosmia rubifloris*
	Stelis ashmeadiellae	
	Stelis calliphorina	
		Stelis coarctatus
	Stelis hurdi	
	Stelis laticincta	
	Stelis perpulchra	
	Trachusa gummifera	
Melittidae	*Hesperapis fuchsi*	

† Potential taxonomic issues, species not included in condition assessments

APPENDIX 6. OBSERVED FISH SPECIES

An iNaturalist list of fish species is also available.

Scientific Name	Common Name	Native
Acanthogobius flavimanus	Yellowfin goby	
Carassius auratus	Goldfish	
Catostomus occidentalis	Sacramento sucker	X
Cottus aleuticus	Coastrange sculpin	X
Cottus asper	Prickly sculpin	X
Cottus gulosus	Riffle sculpin	X
Cyprinus carpio	Common carp	
Entosphenus tridentatus	Pacific lamprey	X
Gambusia affinis	Western mosquitofish	
Gasterosteus aculeatus	Threespine stickleback	X
Hesperoleucus symmetricus	California/Tomales roach	X
Ictalurus punctatus	Channel catfish	
Lepomis cyanellus	Green sunfish	
Lepomis macrochirus	Bluegill	
Lepomis microlophus	Redear sunfish	
Leptocottus armatus	Pacific staghorn sculpin	X
Micropterus dolomieu	Smallmouth bass	
Micropterus punctulatus	Spotted bass	
Micropterus salmoides	Largemouth bass	
Morone saxatilis	Striped bass	
Notemigonus crysoleucas	Golden shiner	
Oncorhynchus kisutch	Coho salmon	X
Oncorhynchus mykiss	Steelhead trout	X
Platichthys stellatus	Starry flounder	X
Pomoxis annularis	White crappie	
Pomoxis nigromaculatus	Black crappie	

APPENDIX 7. OBSERVED AMPHIBIAN AND REPTILE SPECIES

iNaturalist lists of amphibian and reptile species are also available.

Scientific Name	Common Name	Native
Lithobates catesbeianus	American bullfrog	
Pseudacris sierra	Sierran treefrog (Pacific treefrog)	X
Rana boylii	Foothill yellow-legged frog	X
Rana draytonii	California red-legged frog	X
Taricha granulosa	Rough-skinned newt	X
Taricha torosa ssp. *torosa*	Coast Range newt	X
Aneides lugubris	Arboreal salamander	X
Batrachoseps attenuatus	California slender salamander	X
Dicamptodon ensatus	California giant salamander	X
Ensatina eschscholtzii	Ensatina	X
Ensatina eschscholtzii ssp. *xanthoptica*	Yellow-eyed ensatina	X
Anaxyrus boreas ssp. *halophilus*	California toad	X
Elgaria coerulea ssp. *coerulea*	San Francisco alligator lizard	X
Elgaria multicarinata ssp. *multicarinata*	California alligator lizard	X
Plestiodon skiltonianus ssp. *skiltonianus*	Skilton's skink	X
Sceloporus occidentalis ssp. *bocourtii*	Coast Range fence lizard	X
Charina bottae	Northern rubber boa	X
Coluber constrictor ssp. *mormon*	Western yellow-bellied racer	X
Crotalus oreganus ssp. *oreganus*	Northern Pacific rattlesnake	X
Diadophis punctatus ssp. *amabilis*	Pacific ring-necked snake	X
Lampropeltis getula ssp. *californiae*	California kingsnake	X
Pituophis catenifer ssp. *catenifer*	Pacific gopher snake	X
Thamnophis atratus	Aquatic garter snake	X
Thamnophis elegans ssp. *terrestris*	Coast garter snake	X
Thamnophis sirtalis ssp. *infernalis*	California red-sided garter snake	X
Actinemys marmorata	Pacific pond turtle	X
Pseudemys concinna	River cooter	
Trachemys decussata	Cuban slider	
Trachemys scripta ssp. *elegans*	Red-eared slider	

APPENDIX 8. OBSERVED BIRD SPECIES

Note: this list has not been updated since 2016. It does not include revised taxonomy or birds from locations added to the One Tam area of focus since then. Please see https://checklist.americanornithology.org/ for taxonomic changes since 2016. An iNaturalist list of bird species is also available.

Life Form	Scientific Name	Common Name	Occurrence Within One Tam Area of Focus	Native
Blackbirds and Allies	*Agelaius phoeniceus*	Red-winged Blackbird	Common	X
Blackbirds and Allies	*Euphagus cyanocephalus*	Brewer's Blackbird	Uncommon	X
Blackbirds and Allies	*Icterus bullockii*	Bullock's Oriole	Uncommon	X
Blackbirds and Allies	*Icterus cucullatus*	Hooded Oriole	Irregular/ accidental visitor	X
Blackbirds and Allies	*Molothrus ater*	Brown-headed Cowbird	Uncommon	X
Blackbirds and Allies	*Sturnella neglecta*	Western Meadowlark	Uncommon	X
Chickadees, Titmice, and Bushtits	*Baeolophus inornatus*	Oak Titmouse	Common	X
Cardinals, Grosbeaks, and Allies	*Passerina amoena*	Lazuli Bunting	Uncommon	X
Cardinals, Grosbeaks, and Allies	*Pheucticus melanocephalus*	Black-headed Grosbeak	Common	X
Cardinals, Grosbeaks, and Allies	*Piranga ludoviciana*	Western Tanager	Uncommon	X
Chickadees, Titmice, and Bushtits	*Poecile rufescens*	Chestnut-backed Chickadee	Common	X
Chickadees, Titmice, and Bushtits	*Psaltriparus minimus*	Bushtit	Common	X
Cranes and Rails	*Fulica americana*	American Coot	Common	X
Cranes and Rails	*Gallinula galeata*	Common Gallinule	Rare	X
Cranes and Rails	*Laterallus jamaicensis* ssp. *coturniculus*	California Black Rail	Rare	X
Cranes and Rails	*Porzana carolina*	Sora	Uncommon	X
Cranes and Rails	*Rallus limicola*	Virginia Rail	Uncommon	X

Life Form	Scientific Name	Common Name	Occurrence Within One Tam Area of Focus	Native
Cranes and Rails	*Rallus obsoletus* ssp. *obsoletus*	California Ridgway's Rail	Rare	X
Dippers	*Cinclus mexicanus*	American Dipper	Irregular/ accidental visitor	X
Ducks, Geese, and Swans	*Aix sponsa*	Wood Duck	Rare	X
Ducks, Geese, and Swans	*Anas acuta*	Northern Pintail	Uncommon	X
Ducks, Geese, and Swans	*Anas americana*	American Wigeon	Uncommon	X
Ducks, Geese, and Swans	*Anas clypeata*	Northern Shoveler	Uncommon	X
Ducks, Geese, and Swans	*Anas crecca*	Green-winged Teal	Uncommon	X
Ducks, Geese, and Swans	*Anas cyanoptera*	Cinnamon Teal	Uncommon	X
Ducks, Geese, and Swans	*Anas platyrhynchos*	Mallard	Common	X
Ducks, Geese, and Swans	*Anas strepera*	Gadwall	Uncommon	X
Ducks, Geese, and Swans	*Aythya affinis*	Lesser Scaup	Uncommon	X
Ducks, Geese, and Swans	*Aythya collaris*	Ring-necked Duck	Uncommon	X
Ducks, Geese, and Swans	*Aythya marila*	Greater Scaup	Uncommon	X
Ducks, Geese, and Swans	*Aythya valisineria*	Canvasback	Uncommon	X
Ducks, Geese, and Swans	*Branta canadensis*	Canada Goose	Common	X
Ducks, Geese, and Swans	*Bucephala albeola*	Bufflehead	Uncommon	X
Ducks, Geese, and Swans	*Bucephala clangula*	Common Goldeneye	Uncommon	X

Life Form	Scientific Name	Common Name	Occurrence Within One Tam Area of Focus	Native
Ducks, Geese, and Swans	*Bucephala islandica*	Barrow's Goldeneye	Irregular/ accidental visitor	X
Ducks, Geese, and Swans	*Lophodytes cucullatus*	Hooded Merganser	Uncommon	X
Ducks, Geese, and Swans	*Mergus merganser*	Common Merganser	Common	X
Ducks, Geese, and Swans	*Oxyura jamaicensis*	Ruddy Duck	Uncommon	X
Finches and Allies	*Carpodacus mexicanus*	House Finch	Common	X
Finches and Allies	*Carpodacus purpureus*	Purple Finch	Common	X
Finches and Allies	*Loxia curvirostra*	Red Crossbill	Uncommon	X
Finches and Allies	*Spinus lawrencei*	Lawrence's Goldfinch	Irregular/ accidental visitor	X
Finches and Allies	*Spinus pinus*	Pine Siskin	Uncommon	X
Finches and Allies	*Spinus psaltria*	Lesser Goldfinch	Uncommon	X
Finches and Allies	*Spinus tristis*	American Goldfinch	Uncommon	X
Goatsuckers	*Phalaenoptilus nuttallii*	Common Poorwill	Uncommon	X
Gnatcatchers	*Polioptila caerulea*	Blue-gray Gnatcatcher	Uncommon	X
Grebes	*Aechmophorus clarkii*	Clark's Grebe	Rare	X
Grebes	*Aechmophorus occidentalis*	Western Grebe	Common	X
Grebes	*Podiceps nigricollis*	Eared Grebe	Uncommon	X
Grebes	*Podilymbus podiceps*	Pied-billed Grebe	Common	X
Grouse, Quail, and Allies	*Callipepla californica*	California Quail	Common	X
Grouse, Quail, and Allies	*Meleagris gallopavo*	Wild Turkey	Common	
Gulls and Terns	*Hydroprogne caspia*	Caspian Tern	Common	X
Gulls and Terns	*Larus argentatus*	Herring Gull	Rare	X

Life Form	Scientific Name	Common Name	Occurrence Within One Tam Area of Focus	Native
Gulls and Terns	*Larus californicus*	California Gull	Rare	X
Gulls and Terns	*Larus delawarensis*	Ring-billed Gull	Common	X
Gulls and Terns	*Larus glaucescens*	Glaucous-winged Gull	Rare	X
Gulls and Terns	*Larus occidentalis*	Western Gull	Rare	X
Gulls and Terns	*Sterna forsteri*	Forster's Tern	Uncommon	X
Gulls and Terns	*Sterna hirundo*	Common Tern	Irregular/ accidental visitor	X
Herons and Allies	*Ardea alba*	Great Egret	Common	X
Herons and Allies	*Ardea herodias*	Great Blue Heron	Common	X
Herons and Allies	*Butorides virescens*	Green Heron	Uncommon	X
Herons and Allies	*Egretta thula*	Snowy Egret	Common	X
Jays, Magpies, and Crows	*Aphelocoma californica*	Western Scrub-Jay	Common	X
Jays, Magpies, and Crows	*Corvus brachyrhynchos*	American Crow	Common	X
Jays, Magpies, and Crows	*Corvus corax*	Common Raven	Common	X
Jays, Magpies, and Crows	*Cyanocitta stelleri*	Steller's Jay	Common	X
Kingfishers	*Megaceryle alcyon*	Belted Kingfisher	Common	X
Kinglets	*Regulus calendula*	Ruby-crowned Kinglet	Common	X
Kinglets	*Regulus satrapa*	Golden-crowned Kinglet	Uncommon	X
Larks	*Eremophila alpestris*	Horned Lark	Uncommon	X
Loons	*Gavia immer*	Common Loon	Irregular/ accidental visitor	X
Loons	*Gavia pacifica*	Pacific Loon	Irregular/ accidental visitor	X
Mockingbirds and Thrashers	*Mimus polyglottos*	Northern Mockingbird	Uncommon	X

Life Form	Scientific Name	Common Name	Occurrence Within One Tam Area of Focus	Native
Mockingbirds and Thrashers	*Toxostoma redivivum*	California Thrasher	Rare	X
New World Sparrows and Allies	*Aimophila ruficeps*	Rufous-crowned Sparrow	Rare	X
New World Sparrows and Allies	*Ammodramus savannarum*	Grasshopper Sparrow	Rare	X
New World Sparrows and Allies	*Artemisiospiza belli*	Bell's Sparrow	Rare	X
New World Sparrows and Allies	*Chondestes grammacus*	Lark Sparrow	Uncommon	X
New World Sparrows and Allies	*Junco hyemalis*	Dark-eyed Junco	Common	X
New World Sparrows and Allies	*Melospiza lincolnii*	Lincoln's Sparrow	Rare	X
New World Sparrows and Allies	*Melospiza melodia*	Song Sparrow	Common	X
New World Sparrows and Allies	*Melozone crissalis*	California Towhee	Common	X
New World Sparrows and Allies	*Passerculus sandwichensis*	Savannah Sparrow	Uncommon	X
New World Sparrows and Allies	*Passerella iliaca*	Fox Sparrow	Common	X
New World Sparrows and Allies	*Pipilo chlorurus*	Green-tailed Towhee	Irregular/ accidental visitor	X
New World Sparrows and Allies	*Pipilo maculatus*	Spotted Towhee	Common	X
New World Sparrows and Allies	*Spizella atrogularis*	Black-chinned sparrow	Rare	X
New World Sparrows and Allies	*Spizella passerina*	Chipping Sparrow	Uncommon	X
New World Sparrows and Allies	*Zonotrichia albicollis*	White-throated Sparrow	Rare	X
New World Sparrows and Allies	*Zonotrichia atricapilla*	Golden-crowned Sparrow	Common	X

Life Form	Scientific Name	Common Name	Occurrence Within One Tam Area of Focus	Native
New World Sparrows and Allies	*Zonotrichia leucophrys*	White-crowned Sparrow	Common	X
Nuthatches and Creepers	*Certhia americana*	Brown Creeper	Common	X
Nuthatches and Creepers	*Sitta canadensis*	Red-breasted Nuthatch	Common	X
Nuthatches and Creepers	*Sitta carolinensis*	White-breasted Nuthatch	Uncommon	X
Nuthatches and Creepers	*Sitta pygmaea*	Pygmy Nuthatch	Uncommon	X
Old World Sparrows	*Passer domesticus*	House Sparrow	Uncommon	
Owls	*Aegolius acadicus*	Northern Saw-whet Owl	Rare	X
Owls	*Asio otus*	Long-eared Owl	Uncommon	X
Owls	*Bubo virginianus*	Great Horned Owl	Common	X
Owls	*Glaucidium gnoma*	Northern Pygmy-Owl	Rare	X
Owls	*Megascops kennicottii*	Western Screech-Owl	Uncommon	X
Owls	*Strix occidentalis* ssp. *caurina*	Northern Spotted Owl	Uncommon	X
Owls	*Strix varia*	Barred Owl	Rare	X
Owls	*Tyto alba*	Barn Owl	Common	X
Pelicans and Allies	*Pelecanus erythrorhynchos*	American White Pelican	Rare	X
Pelicans and Allies	*Pelecanus occidentalis*	Brown Pelican	Irregular/ accidental visitor	X
Pelicans and Allies	*Phalacrocorax auritus*	Double-crested Cormorant	Common	X
Pelicans and Allies	*Phalacrocorax pelagicus*	Pelagic Cormorant	Irregular/ accidental visitor	X
Pelicans and Allies	*Phalacrocorax penicillatus*	Brandt's Cormorant	Irregular/ accidental visitor	X
Pigeons and Doves	*Patagioenas fasciata*	Band-tailed Pigeon	Common	X
Pigeons and Doves	*Zenaida macroura*	Mourning Dove	Common	X

Life Form	Scientific Name	Common Name	Occurrence Within One Tam Area of Focus	Native
Shorebirds	*Actitis macularius*	Spotted Sandpiper	Uncommon	X
Shorebirds	*Charadrius vociferus*	Killdeer	Common	X
Shorebirds	*Gallinago delicata*	Wilson's Snipe	Uncommon	X
Shorebirds	*Haematopus bachmani*	Black Oystercatcher	Irregular/ accidental visitor	X
Shorebirds	*Himantopus mexicanus*	Black-necked Stilt	Uncommon	X
Shorebirds	*Tringa melanoleuca*	Greater Yellowlegs	Uncommon	X
Shrikes	*Lanius ludovicianus*	Loggerhead Shrike	Rare	X
Starlings and Allies	*Sturnus vulgaris*	European Starling	Common	
Swallows	*Hirundo rustica*	Barn Swallow	Common	X
Swallows	*Petrochelidon pyrrhonota*	Cliff Swallow	Common	X
Swallows	*Progne subis*	Purple Martin	Uncommon	X
Swallows	*Riparia riparia*	Bank Swallow	Irregular/ accidental visitor	X
Swallows	*Stelgidopteryx serripennis*	Northern Rough-winged Swallow	Uncommon	X
Swallows	*Tachycineta bicolor*	Tree Swallow	Common	X
Swallows	*Tachycineta thalassina*	Violet-green Swallow	Common	X
Swifts and Hummingbirds	*Aeronautes saxatalis*	White-throated Swift	Rare	X
Swifts and Hummingbirds	*Calypte anna*	Anna's Hummingbird	Common	X
Swifts and Hummingbirds	*Chaetura vauxi*	Vaux's Swift	Uncommon	X
Swifts and Hummingbirds	*Selasphorus sasin*	Allen's Hummingbird	Common	X
Thrushes	*Catharus guttatus*	Hermit Thrush	Common	X
Thrushes	*Catharus ustulatus*	Swainson's Thrush	Common	X

Life Form	Scientific Name	Common Name	Occurrence Within One Tam Area of Focus	Native
Thrushes	*Ixoreus naevius*	Varied Thrush	Common	X
Thrushes	*Myadestes townsendi*	Townsend's Solitaire	Rare	X
Thrushes	*Sialia mexicana*	Western Bluebird	Common	X
Thrushes	*Turdus migratorius*	American Robin	Common	X
Tyrant Flycatchers	*Contopus cooperi*	Olive-sided Flycatcher	Uncommon	X
Tyrant Flycatchers	*Contopus sordidulus*	Western Wood-Pewee	Common	X
Tyrant Flycatchers	*Empidonax difficilis*	Pacific-slope Flycatcher	Common	X
Tyrant Flycatchers	*Myiarchus cinerascens*	Ash-throated Flycatcher	Uncommon	X
Tyrant Flycatchers	*Sayornis nigricans*	Black Phoebe	Common	X
Tyrant Flycatchers	*Sayornis saya*	Say's Phoebe	Uncommon	X
Tyrant Flycatchers	*Tyrannus verticalis*	Western Kingbird	Rare	X
Vireos	*Vireo cassinii*	Cassin's Vireo	Uncommon	X
Vireos	*Vireo gilvus*	Warbling Vireo	Common	X
Vireos	*Vireo huttoni*	Hutton's Vireo	Common	X
Vultures, Hawks, and Falcons	*Accipiter cooperii*	Cooper's Hawk	Uncommon	X
Vultures, Hawks, and Falcons	*Accipiter striatus*	Sharp-shinned Hawk	Common	X
Vultures, Hawks, and Falcons	*Aquila chrysaetos*	Golden Eagle	Rare	X
Vultures, Hawks, and Falcons	*Buteo jamaicensis*	Red-tailed Hawk	Common	X
Vultures, Hawks, and Falcons	*Buteo lagopus*	Rough-legged Hawk	Irregular/ accidental visitor	X
Vultures, Hawks, and Falcons	*Buteo lineatus*	Red-shouldered Hawk	Common	X
Vultures, Hawks, and Falcons	*Buteo platypterus*	Broad-winged Hawk	Rare	X

Life Form	Scientific Name	Common Name	Occurrence Within One Tam Area of Focus	Native
Vultures, Hawks, and Falcons	*Cathartes aura*	Turkey Vulture	Common	X
Vultures, Hawks, and Falcons	*Circus cyaneus*	Northern Harrier	Uncommon	X
Vultures, Hawks, and Falcons	*Elanus leucurus*	White-tailed Kite	Common	X
Vultures, Hawks, and Falcons	*Falco columbarius*	Merlin	Rare	X
Vultures, Hawks, and Falcons	*Falco mexicanus*	Prairie Falcon	Rare	X
Vultures, Hawks, and Falcons	*Falco peregrinus*	Peregrine Falcon	Rare	X
Vultures, Hawks, and Falcons	*Falco sparverius*	American Kestrel	Common	X
Vultures, Hawks, and Falcons	*Haliaeetus leucocephalus*	Bald Eagle	Uncommon	X
Vultures, Hawks, and Falcons	*Pandion haliaetus*	Osprey	Common	X
Waxwings	*Bombycilla cedrorum*	Cedar Waxwing	Common	X
Wood-warblers	*Cardellina pusilla*	Wilson's Warbler	Common	X
Wood-warblers	*Geothlypis tolmiei*	MacGillivray's Warbler	Uncommon	X
Wood-warblers	*Oreothlypis celata*	Orange-crowned Warbler	Common	X
Wood-warblers	*Setophaga coronata*	Yellow-rumped Warbler	Common	X
Wood-warblers	*Setophaga nigrescens*	Black-throated Gray Warbler	Rare	X
Wood-warblers	*Setophaga occidentalis*	Hermit Warbler	Rare	X
Wood-warblers	*Setophaga petechia*	Yellow Warbler	Common	X
Wood-warblers	*Setophaga townsendi*	Townsend's Warbler	Common	X
Woodpeckers	*Colaptes auratus*	Northern Flicker	Common	X
Woodpeckers	*Dryocopus pileatus*	Pileated Woodpecker	Uncommon	X

Life Form	Scientific Name	Common Name	Occurrence Within One Tam Area of Focus	Native
Woodpeckers	*Melanerpes formicivorus*	Acorn Woodpecker	Common	**X**
Woodpeckers	*Picoides nuttallii*	Nuttall's Woodpecker	Common	**X**
Woodpeckers	*Picoides pubescens*	Downy Woodpecker	Common	**X**
Woodpeckers	*Picoides villosus*	Hairy Woodpecker	Common	**X**
Woodpeckers	*Sphyrapicus ruber*	Red-breasted Sapsucker	Common	**X**
Wrens	*Cistothorus palustris*	Marsh Wren	Uncommon	**X**
Wrens	*Salpinctes obsoletus*	Rock Wren	Rare	**X**
Wrens	*Thryomanes bewickii*	Bewick's Wren	Common	**X**
Wrens	*Troglodytes aedon*	House Wren	Uncommon	**X**
Wrens	*Troglodytes pacificus*	Pacific Wren	Common	**X**
Wrentits	*Chamaea fasciata*	Wrentit	Common	**X**

APPENDIX 9. OBSERVED MAMMAL SPECIES

An iNaturalist list of mammals is also available.

Life Form	Scientific Name	Common Name	Native
Bats	*Antrozous pallidus*	Pallid bat	X
Bats	*Corynorhinus townsendii*	Townsend's big-eared bat	X
Bats	*Eptesicus fuscus*	Big brown bat	X
Bats	*Lasionycteris noctivagans*	Silver-haired bat	X
Bats	*Lasiurus blossevillii*	Western red bat	X
Bats	*Lasiurus cinereus*	Hoary bat	X
Bats	*Myotis californicus*	California myotis	X
Bats	*Myotis thysanodes*	Fringed myotis	X
Bats	*Myotis volans*	Long-legged myotis	X
Bats	*Myotis yumanensis*	Yuma myotis	X
Bats	*Tadarida brasiliensis*	Brazilian (Mexican) free-tailed bat	X
Carnivores	*Canis latrans*	Coyote	X
Carnivores	*Lontra canadensis*	North American river otter	X
Carnivores	*Lynx rufus*	Bobcat	X
Carnivores	*Mephitis mephitis*	Striped skunk	X
Carnivores	*Mustela frenata*	Long-tailed weasel	X
Carnivores	*Procyon lotor*	Northern raccoon	X
Carnivores	*Puma concolor*	Puma (cougar, mountain lion)	X
Carnivores	*Spilogale gracilis*	Western spotted skunk	X
Carnivores	*Taxidea taxus*	American badger	X
Carnivores	*Urocyon cinereoargenteus*	Gray fox	X
Carnivores	*Ursus americanus*	American black bear	X
Hoofed Mammals	*Bos taurus*	Cow	

Life Form	Scientific Name	Common Name	Native
Hoofed Mammals	*Odocoileus hemionus*	Black-tailed (mule) deer	X
Insectivores	*Neurotrichus gibbsii*	American shrew-mole	X
Insectivores	*Scapanus latimanus*	Broad-footed mole	X
Insectivores	*Sorex trowbridgii*	Trowbridge's shrew	X
Insectivores	*Sorex vagrans*	Vagrant shrew	X
Marsupials	*Didelphis virginiana*	Virginia opossum	
Rabbits and Rodents	*Lepus californicus*	Black-tailed jackrabbit	X
Rabbits and Rodents	*Microtus californicus*	California vole	X
Rabbits and Rodents	*Mus musculus*	House mouse	
Rabbits and Rodents	*Neotamias sonomae*	Sonoma chipmunk	X
Rabbits and Rodents	*Neotoma fuscipes*	Dusky-footed woodrat	X
Rabbits and Rodents	*Peromyscus maniculatus*	Deer mouse	X
Rabbits and Rodents	*Rattus rattus*	Black rat	
Rabbits and Rodents	*Reithrodontomys megalotis*	Western harvest mouse	X
Rabbits and Rodents	*Sciurus griseus*	Western gray squirrel	X
Rabbits and Rodents	*Sciurus niger*	Eastern fox squirrel	
Rabbits and Rodents	*Sylvilagus bachmani*	Brush rabbit	X
Rabbits and Rodents	*Thomomys bottae*	Botta's pocket gopher	X