CHAPTER X. OAK WOODLANDS

CHAPTER OUTLINE

EXECUTIVE SUMMARY

Oak dominated habitats, including oak woodlands, forests, and savannahs, have the greatest species richness of any vegetation type in California (Allen-Diaz et al. 2007). Characterized by dominance of one or more of the nine native tree oaks of California, these habitats harbor more biodiversity than any other, supporting over 300 species of vertebrates, 5,000 invertebrates, and 2,000 plant species (Barrett 1980, Zack et al. 2005, Verner 1980, UCANR 2019). Oak habitat in the Area of Focus (AOF) grows predominantly as woodlands, which provide specific services to human society such as rangeland forage and recreation (Davis et al. 2016), as well as research opportunities as ecosystem indicators for climate change and forest disease (McLaughlin et al. 2014, McPherson et al. 2015).

Three metrics were developed to assess the health of oak woodlands within the AOF: 1) Spatial extent of oak woodland vegetation communities in each of the sub-region within the AOF; 2) Acres of healthy oak woodland canopy in the AOF; and 3) Viability of blue oak and valley oak sapling recruitment. These metrics were selected because there was adequate support in the literature for assigning values to meaningful, specific goals, and thresholds that could be measured across space and time. Despite the absence of sufficient existing data to assess the condition and trend for all metrics, vegetation mapping efforts that are currently underway will inform future condition and trend analysis for this resource.

Metrics 1 and 2 were preliminary assessed based on existing Conservation Lands Network (CLN) (BAOSC 2021) vegetation data; however, the success of these metrics as indicators of ecosystem health is dependent on finalizing and then using a region-wide fine-scale vegetation map (completion estimated to be 2025) to inform oak woodland extent and viability. Metric 3 is highly dependent on performing a base-line sapling recruitment survey effort in the blue oak and valley oak communities across the AOF. Limitations in the accuracy and availability of existing data for all landscape units resulted in an overall condition and trend of "Unknown," with "Low" confidence.

This chapter presents the current state of oak woodland-related science, identifies recommended monitoring and mapping efforts, and provides a framework to assess condition over time in oak woodland metrics across lands in the AOF.

METRICS SUMMARY AT A GLANCE

The condition, trend, and confidence for the three oak woodland metrics are summarized in Table 1, below. Additional details and discussion are provided in the Metrics in Detail section. Future updates to this chapter may present condition, trend, and confidence for each of the landscape units individually.

Table 1. Condition, Trend, and Confidence for Oak Woodland Metrics

Metric 1: Spatial Extent of Oak Woodland Vegetation Communities – Maintain the current spatial extent (acres) of oak woodlands within each of the sub-regions, across the AOF	
Condition	Unknown
Trend	Unknown
Confidence	Low
Metric 2: Acres of Healthy Oak Woodland Canopy – Maintain or increase the current area (acres) of healthy, living oak woodland canopy in the Area of Focus	
Condition	Unknown
Trend	Unknown
Confidence	Low
Metric 3: Viability of Blue Oak and Valley Oak Sapling Recruitment – Increase recruitment of viable saplings (including stump sprouts) in blue oak woodlands and valley oak woodlands, to support regeneration of the blue oak and valley oak overstory over time	
Condition	Unknown
Trend	Unknown
Confidence	Low

CONDITION, TREND, AND CONFIDENCE SUMMARY

The overall condition, trend, and confidence assessment of oak woodlands in the AOF represented by the graphic below is based on the combined values of the individual metrics in Table 1. Each of these metrics is described in depth in the Metrics in Detail section of this chapter.

Condition: Unknown (color: gray)

Trend: Unknown (symbol: question mark)

Confidence: Low (line around circle: absent)

WHY IS THIS RESOURCE INCLUDED?

Oak dominated habitats, including oak woodlands, forests, and savannahs, have the greatest species richness of any vegetation type in California (Allen-Diaz et al. 2007). Characterized by dominance of one or more of the nine native tree oaks of California, these habitats harbor more biodiversity than any other, supporting over 300 species of vertebrates, 5,000 invertebrates, and 2,000 plant species (Barrett 1980, Verner 1980, UCANR 2019). The unique physiology of the California oak species, combined with the characteristics they hold in common (notably the production of nutrient dense acorns, development of strong resilient wood, and production of ample summer shade) support an array of ecosystem services such as high-quality proteins (McPherson 2012), erosion protection, carbon storage, and water quality protection. Oak woodlands are considered one of the most productive habitat types in California, providing a myriad of benefits and services that support wildlife, insects, plants, soil stability, water quality, and recreation. Oak trees define these communities acting as "Foundation species," defined by Ellison et al. (2005) as species that control population and community dynamics and modulate ecosystem processes. Oak habitat in the Area of Focus (AOF) grows predominantly as woodlands, which provide specific services to human society such as rangeland forage and recreation (Davis et al. 2016), as well as research opportunities as ecosystem indicators for climate change and forest disease (McLaughlin et al. 2014, McPherson et al. 2015). For these reasons, oak woodlands are included as an indicator of ecosystem health for the AOF.

Oak dominated habitat has undergone massive transformation since the Holocene period, notably a constriction in its extent, not only within the AOF but across California. Fossil pollen evidence demonstrates significant changes in oak abundance state-wide over the past 10,000 years, with the patterns of cooling and warming associated with glacial and interglacial periods (Byrne et al. 1991). Human settlement and resulting land use, particularly after the Gold Rush, introduced new transformational agents within the oak woodland landscape as oaks were cut down for firewood as well as to enhance forage production for grazing mammals, while fire suppression efforts were introduced. As such, the oak woodlands we experience now are not indicative of a past condition and further, have been highly altered in the past 200 years. Oak habitat may be in decline due to continued habitat loss, lack of sufficient recruitment to replace dead and dying trees, climate change, invasive plant pathogens, and habitat fragmentation as well as low levels of natural seedling recruitment in some of the dominant species. Major losses of oak woodland habitat between 1945 and 1973 were caused by rangeland clearing, while losses since 1973 were from land conversion to residential and other uses (intensive agriculture, firewood harvesting, and urban expansion) (Allen-Diaz et al. 2007). More recent losses in oak woodlands have been observed and linked to changes in climate and associated altered fire regimes. For instance, Dwomoh et al. identified significant spikes in the amount of both fire and non-fire induced blue oak tree cover loss and tree cover change associated

with 2012–2016 state-wide drought, which extended over multiple years and co-occurred with warmer than historically normal temperatures (2021).

In the AOF, oak woodlands are largely protected from further urban encroachment and land conversion; however, reservoir and water conveyance management is still a potential stressor on the natural community as increasing periods of drought in the AOF may necessitate the expansion of reservoirs currently fringed by oak woodlands. Warming climate and changes in fire regimes are anticipated to be persistent stressors throughout the AOF in the coming decades.

DESCRIPTION OF OAK WOODLANDS IN THE AREA OF FOCUS

Oak dominated habitat in the AOF presents primarily as woodlands where soil moisture is limiting and adjacent tree canopies touch but rarely overlap, exhibiting 10% to 60% tree canopy cover dominated by one or more arborescent oaks (Davis et. al 2016). Oak woodlands are defined as areas dominated by one or more of the arboreal oak species found in the AOF, which include coast live oak (*Q. agrifolia*), interior live oak (*Q. wislizeni*), blue oak (*Quercus douglasii*), valley oak (*Q. lobata*), black oak (*Q. kelloggii*) and canyon live oak (*Q. chrysolepis*).Other species of arborescent oaks co-occur in these woodland types or occur as a dominant in highly limited areas of the AOF. These species include canyon oak (*Q. chrysolepis*), Oregon oak (*Q. garryana*) and black oak (*Q. kelloggii*). In addition, several species of scrub oak such as Palmer's oak (*Q. palmerii*) and huckleberry oak (*Q. vacciniifolia*), are found in the AOF but are not examined in this indicator worksheet.

The relative spatial extent and position of each oak woodland type in the AOF is summarized based upon coarse mapping provided by the Conservation Lands Network (CLN) (BAOSC 2021) and the general arrangement of the woodland types are understood to occur on the landscape following moisture availability and soil nutrient composition (Figure 1). The CLN vegetation data follows Calveg[1] alliances, and these vegetation alliances cross-walk nearly identically to the *Manual of California Vegetation, second edition* (MCV2) alliances referenced in this worksheet, which include: coast live oak (*Q. agrifolia*), interior live oak (*Q. wislizeni*), blue oak (*Quercus douglasii*), valley oak (*Q. lobata*), black oak (*Q. kelloggii*), canyon live oak (*Q. chrysolepis*) (Table 1) (Sawyer et al. 2009). The CLN data for the AOF includes one additional oak-dominated community called "Interior Mixed Hardwood Alliance" which is described in the Calveg field key as a "mixture of hardwoods in which no one species occupies

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[1] "Calveg" stands for "Classification and Assessment with Landsat of Visible Ecological Groupings" and is a United States Forest Service Region 5 vegetation classification system focused on "existing vegetation". Calveg was developed for use in statewide resource planning considerations and is regularly updated by R5. (https://www.fs.usda.gov/detail/r5/landmanagement/resourcemanagement/?cid=fsbdev3_046815).

> 50% and where blue oak is usually present…" (USFS 2010). Based upon the Calveg official description and key to the type and the location of this vegetation community within the AOF, mapped areas of Interior Mixed Hardwood Alliance within the AOF were included within the blue oak alliance coverage.
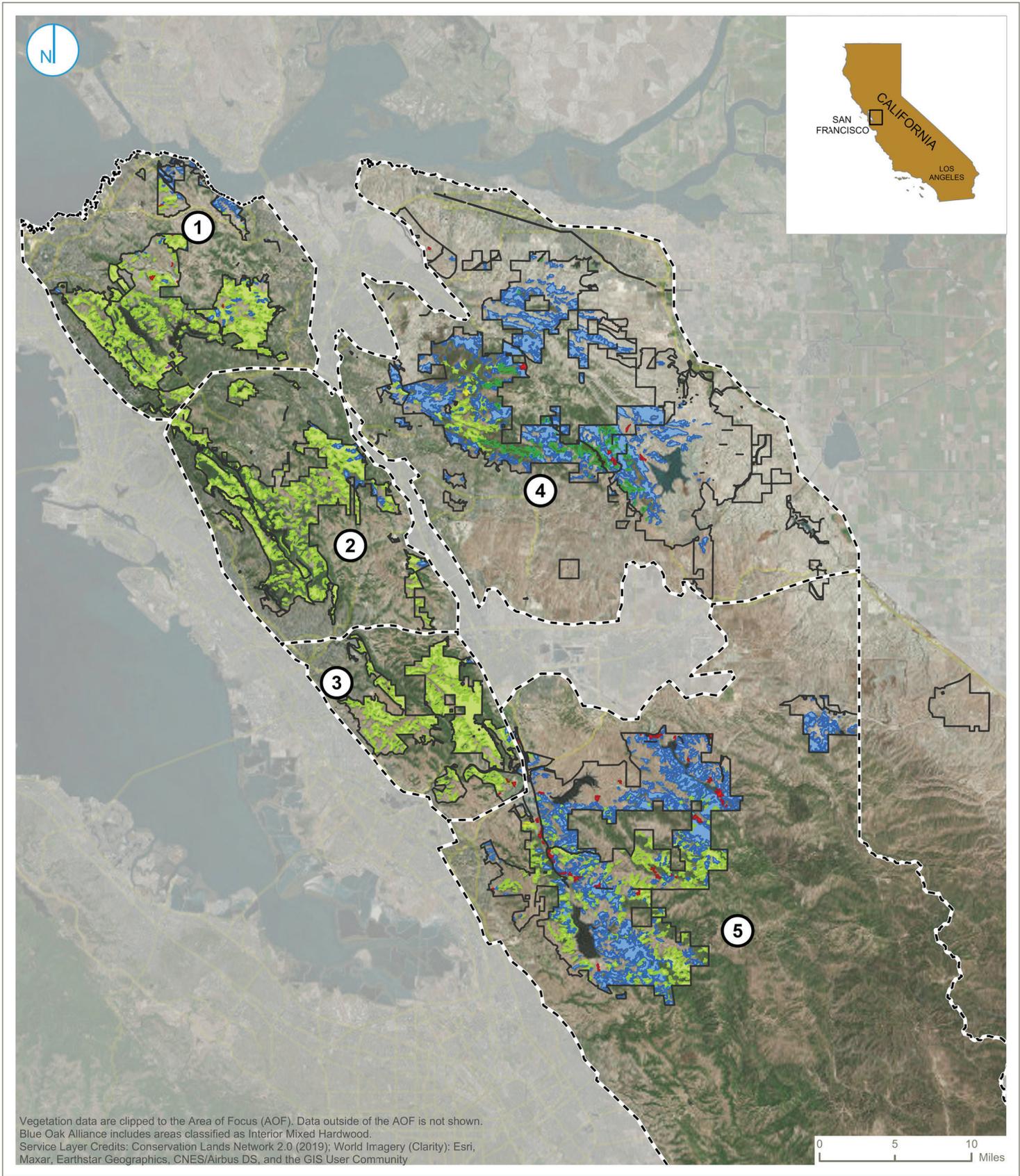
Table 1. Oak Woodlands in the Area of Focus

MCV2 Alliance	Scientific Name of Dominant	Approximate coverage in the AOF (acres)[1]	Landscape Unit where mapped[2]
Coast live oak alliance	*Quercus agrifolia*	35,325 ac	1,2,3,5 (<15% by acreage in 4)
Interior live oak alliance	*Quercus wislizeni*	2,058 ac	4
Valley Oak alliance	*Quercus lobata*	693 ac	4,5
Blue Oak alliance	*Quercus douglasii*	30,806 ac	4,5 (<15% by acreage in 1,2,3)
Black oak alliance	*Q. kellogii*	19 ac	1
Canyon live oak alliance	*Q. chrysolepis*	56 ac	4,5
Total Oak Woodlands		**68,958 ac**	(all)

[1] Acreages are based on the full CLN 2.0 GIS database (Version 2.0.1), compiled by the Conservation Lands Network as part of their 2.0 Regional Conservation Strategy (BAOSC 2021).

[2] Landscape units correspond to those shown on Figure 1. Oak Woodlands Extent in the AOF, as follows:
   (1) North East Bay Hills
   (2) Middle East Bay Hills
   (3) South East Bay Hills
   (4) Mt Diablo Range
   (5) Mt. Hamilton

Although most common in the state on the dry, hot foothills of Sierra Nevada Mountain range, blue oak woodlands occur in the AOF in more xeric microsites as well as the drier eastern portion of the AOF and within the southern portion of the AOF in the Mt. Hamilton Range. Live oak woodlands are the dominant woodland type in the AOF and occur throughout in mesic and xeric microsites, particularly in areas that exhibit well drained soils and experience some coastal fog influence (Pavlik et al. 2006). Valley oak is the most water dependent woodland type in the AOF, occurring in valley bottoms, but also in association with sites where the water table is closer to the surface. All three oak species are wind pollinated and obligate out-crossers. Hybridization of coast live oak and interior live oak is assumed but not well understood spatially (Freyer 2012), and hybridization of blue oak and valley oak is also common, especially in the southern part of the Mt. Hamilton Range.

CALIFORNIA

SAN FRANCISCO

LOS ANGELES

N

1

2

3

4

5

Vegetation data are clipped to the Area of Focus (AOF). Data outside of the AOF is not shown.
Blue Oak Alliance includes areas classified as Interior Mixed Hardwood.
Service Layer Credits: Conservation Lands Network 2.0 (2019); World Imagery (Clarity): Esri,
Maxar, Earthstar Geographics, CNES/Airbus DS, and the GIS User Community

0   5   10
|____|____|____|
                  Miles

AREA OF FOCUS

CONSERVATION LANDS
NETWORK (CLN) LANDSCAPE

CLN VEGETATION CLASSIFICATION

COAST LIVE OAK ALLIANCE
CANYON LIVE OAK ALLIANCE
BLUE OAK ALLIANCE
BLACK OAK ALLIANCE
VALLEY OAK ALLIANCE
INTERIOR LIVE OAK ALLIANCE

EAST BAY HILLS SUB-REGION

1   NORTH EAST BAY HILLS
2   MIDDLE EAST BAY HILLS
3   SOUTH EAST BAY HILLS

OTHER SUB-REGIONS

4   MT. DIABLO RANGE
5   MOUNT HAMILTON

**OAK WOODLANDS
EXTENT IN THE
AREA OF FOCUS**

FIGURE 01

NatureCheck

East Bay
Regional Park District

DESIRED CONDITION AND TREND

The desired condition and trend for oak woodlands is to maintain or increase the current spatial extent, persistence, and health of oak woodlands in the Area of Focus. Healthy oak woodlands exhibit healthy crowns (free of sudden oak death (SOD) and other pathogen stressors), recruitment success that supports the replacement of dead/dying trees, and spatial extent on the landscape that supports genetic diversity and resilience in a rapidly changing climate.

CURRENT CONDITION AND TREND

The existing current and historical data on distribution and extent of oak woodlands is insufficient to allow an evaluation of current indicator condition and trend, and so condition, trend and confidence in oak woodland health is not certain across the AOF. Limited studies in small areas throughout the AOF tend to confirm regional concern that oak woodlands are facing threats from changing climate and invasive epidemic pathogens, putting stress on the woodland communities; however, given historic changes in the composition of oak woodlands on the landscape, a wide-ranging regional approach to examining trends in oak woodland health and distribution is needed to determine the effect and severity of stressors on this indicator.

STRESSORS

The following stressors range from those that may be aptly characterized as disturbances, many of which are natural ecosystem processes, to those that promote landscape conversion from oak woodland to other land-cover types. Disturbances are defined as relatively discrete events that disrupt ecosystem, community, or population structure and change resources, substrate availability, and/or the physical environment (Davis and Moritz 2013). While discrete disturbances tend to open up resource availability and trigger ecosystem processes (Davis et al. 2016), the confluence of multiple disturbances may overwhelm landscape resilience and manifest in habitat conversion. Stressors are synergistic and interactive, and therefore, the following disturbances and land conversion processes observed to affect oak woodlands in the AOF are all considered stressors but are not ranked in terms of magnitude of importance:

Invasive species: Invasive epidemic plant pathogens such as (*Phytophthora ramorum)* that causes SOD and other pests may affect the health and viability of oak woodlands. In addition, non-native and invasive plant and wildlife species may reduce oak woodland health and viability (Sweitzer and Van Vuren 2002).

Fire Regime Change: Altered fire regimes may change the composition and extent of oak woodlands depending upon the severity, extent and intensity of the altered regime.

Direct Human Impacts: Direct human impacts include both historical and current impacts, including and natural resources use, including legacy woodcutting, legacy and current mining, dryland farming, infrastructure development and incompatible grazing practices may alter the composition and extent of oak woodlands through land use conversion (Lopez-Sanchez et al. 2014). New infrastructure such as the development of new transmission lines[2], buildings, parking lots, trails, roads may result in permanent oak woodland habitat loss.

Indirect Human Impacts: Infrastructure protection and maintenance efforts within the AOF (i.e. removal of trees around power lines and buildings) and discing and mowing for fire protection may affect tree health and seedling survival by disturbing the ground surface within oak woodlands and/or removing branches and weakening individual trees.

Climate Change: Increases in the severity and frequency of drought, flooding, extreme temperatures, rainfall, etc. may affect the composition and distribution of oak woodland communities.

CONDITION AND TRENDS ASSESSMENT

METRICS IN DETAIL

The following metrics have some available data to preliminarily assess the baseline condition of oak woodlands in the AOF. Metrics were developed to monitor the effects of one or more identified stressor on oak woodlands in the AOF. Additional metrics, such as those discussed but dismissed, should be considered in the future, as resources and baseline data become available, to further assess and monitor the condition of oak woodlands within a consistent long-term monitoring program throughout the AOF.

METRIC 1: SPATIAL EXTENT OF OAK WOODLAND VEGETATION COMMUNITIES

Based upon their important role as foundation species in California and within the AOF, the spatial extent of oak woodlands on the landscape, including the vegetation community as a whole and each of the primary oak woodland alliances found in the AOF, is an important indicator of ecosystem health and resilience, particularly as we experience rapidly changing climate conditions that test the resilience of each oak tree and the ecological communities they anchor.

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[2] Includes overhead and buried transmission lines for electricity and internet service.

Rationale: The spatial extent of oak woodlands in the Area of Focus has changed dramatically since the arrival of Europeans. Oak woodlands are a valuable component of the AOF for wildlife habitat (insect diversity, food for birds and small mammals), plant species and fungal diversity, water system regulation and carbon storage. Understanding and tracking the spatial extent of oak woodlands in the AOF is important as species are already responding to climate change through detectable changes in distribution (McLaughlin and Zavaleta 2012) and therefore the spatial extent of oak woodlands in the AOF provides indications of potential habitat fragmentation and genetic bottlenecks as well as opportunities for species survival under uncertain climate conditions. This metric was developed to monitor health/resilience of oak woodlands with particular focus on the potential effects from utilities management, reservoir and water conveyance management, legacy and current land management (including rangeland management) and altered fire regimes.

Current Baseline: Oak woodlands are currently distributed throughout the AOF, and the five partner agencies manage approximately 68,962 acres of oak woodlands, based upon CLN mapping. Live oak woodland dominated by coast live oak is the dominant woodland type in the East Bay Hills sub-region, blue oak woodland is the dominant woodland type in the Mt. Diablo Range sub-region, and coast live oak woodland and blue oak woodland are co-dominant woodland types in the Mt. Hamilton sub-region. Valley oak woodland is limited in the AOF and found most commonly in the Mt. Hamilton sub-region, with small, isolated patches in the Mt. Diablo Range sub-region. The only examples of black oak woodland in the AOF are found in drainages near San Pablo Dam Rd. in the North East Bay Hills Landscape unit. Two small areas of canyon live oak are mapped in the AOF, one of which is in the Mt. Hamilton sub-region and the other is in the Mt. Diablo Range sub-region. It is anticipated that with improvements in the resolution of future fine scale vegetation mapping in the AOF, additional areas of oak woodland may be identified, and some currently mapped areas will be attributed more precisely.

Condition Goals:
- Maintain the spatial extent (acres) of oak woodlands within each of the sub-regions, across the AOF[3]. This metric may be applied to track the spatial extent of oak woodlands overall, as well as the extent of individual oak woodland alliances within the AOF.

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[3] If desired, the data used to measure this metric could be further pulled apart to review the conditions of the oak woodland communities individually, across each of the 4 AOF sub-regions.

Condition Thresholds:

- *Good:* Maintain or increase the spatial extent of oak woodlands within the AOF, measured based upon aerial cover of all woodland types combined as well as individually by alliance, within any of the AOF sub-regions.
- *Caution:* Decrease in the spatial extent of oak woodlands (as a whole and individually by alliance) within the AOF, in each of the AOF sub-regions
- *Significant Concern:* Declining trend in the spatial extent of oak woodlands (as a whole and individually by alliance) over a period of five[4] years, within any of the sub-regions in the AOF.

Trend: Declining

Early travelers in the AOF in the 1800's, notably in the Alameda Creek Watershed (the northern portion of the Mt. Hamilton Sub-Region) observed oaks grew on the hillsides surrounding the dry, Livermore-Amador valley, but not across the valley floor. Historical ecology investigations of East Contra Costa County (the Mt. Diablo Range Sub-Region) indicate a similar pattern of oak paucity on the plains; oak savannahs in the foothills; and oak woodlands (blue oak predominantly) on the steeper montane slopes (Stanford et al. 2011). By contrast the Sunol Valley (part of the East Bay Hills Sub-Region) and other valleys closer to the coast, were observed to contain lofty white oaks that provided shade below (Stanford et al. 2013). Some accounts describe notable stands of oak in the riparian areas around larger creeks of the Mt. Hamilton sub-region (near Livermore), but the conclusion of historical ecologists is that the large interior Valley in the northern portion of the Mt. Hamilton Sub-Region was largely devoid of oak woodland vegetation. In the 1800's these few oaks on the valley floor within riparian corridors, were often removed and used as fuel wood (Stanford et al. 2013). Over the past 60 years, oak woodland area has diminished further in the AOF, including major losses on the hillsides surrounding the valleys, from rangeland clearing for enhancement of forage production (Barbour et al. 2007, Allen-Diaz et al. 2007, Stanford et al. 2011). While residential sprawl development, sprawl and water diversions and development has permanently removed oak woodland habitat from the AOF valley bottoms where sparse oak savannahs were cleared as early as the 1930's (Stanford et al. 2013), cleared rangelands adjacent to existing oak woodlands found on steeper slopes offer an opportunity to expand oak woodland extent in the AOF. The spatial extent of this opportunity for expansion has not yet been quantified.

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[4] There is a data gap related to how long of a monitoring period is required to assess a trend in oak woodland spatial extent. The monitoring period for Metric 1 would initially be set at 5 years and then reviewed and updated (if needed), based upon available monitoring resources and observed conditions on the ground.

Based upon observations across the AOI and anecdotal accounts, the current trend in the spatial extent of oak woodlands as of 2022, appears to be declining as a result of the following factors: pathogens including sudden oak death, prolonged and more severe drought conditions, and fuels management tree cutting by local utility companies.

Confidence: Low

A comprehensive baseline oak woodland coverage dataset is not available for the AOF. A formal assessment of the baseline condition needs to be established before trends in oak woodland extent can be assessed.

METRIC 2: ACRES OF HEALTHY OAK WOODLAND CANOPY

Rationale: Healthy oak woodlands require a green, living canopy to satisfy the full range of ecosystem services they offer. The leafy canopy is not only the engine of growth for the tree, but also provides shade and shelter to wildlife and contributes to higher soil nutrient levels (Dahlgren et al. 2003). Therefore, oak woodlands with healthier canopies are an indication of oak woodland areas that support a higher diversity of plant, animal, and insect species. As such, changes in canopy health are indicators of shifts in important ecological processes, including tree mortality, reduced primary productivity, loss of tree-held carbon stores, and ecosystem degradation (Dwomoh et al. 2021).

Oak woodlands in the AOF are currently threatened by a number of natural stressors, including but not limited to extensive drought-induced stress, insect pests, and disease. Non-native fungal pathogens, such as *Phytopthera* spp. which causes SOD, continue to pose a threat to live oaks. Both drought stress, insect pests, and fungal pathogens manifest a number of primary symptoms across all species, ultimately killing the host tree which results in a dead, brown canopy. Primary symptoms of canopy decline include, but are not limited to, foliar discoloration, crown thinning, and trunk and branch damage. Tracking trends in oak woodland canopy health is a good indicator of overall oak woodland resilience and health in the AOF. This metric was developed initially to measure health/resilience of live oak woodlands with particular interest in the potential effects from invasive epidemic plant pathogens. Extensive drought in the AOF has compounded the stress on all oaks, as have new introduced pathogens and pests, expanding the purpose of this metric to capture the effect of extreme climate events as well as invasive, epidemic plant pathogens on all oak woodland communities in the AOF.

Current Baseline: Current baseline is unknown. Satellite/Aerial imagery can be used to assess canopy health (canopy density and/or discoloration) across the AOF, once a fine scale vegetation map has been created and there is clear understanding of mapped oak woodland extent in the AOF. The baseline data will allow us to determine potential associations between regions or species and canopy stress indicators. Canopy condition and health could be assessed following methods adapted from the United State Geological Survey (USGS) Land Change Monitoring, Assessment, and Projection (LCMAP)

initiative, which offers various annual land-cover and land-surface change products for use in an analysis of tree cover and condition change over time (USGS 2023). Data availability and remote sensing techniques are improving rapidly around vegetation change detection; therefore, this metric would be measured using best available techniques and tools at the time of sampling. The condition goal and thresholds will be refined (if needed) once the unit of analysis is established for this metric.

Condition Goals:

- Maintain or increase the current area (acres) of healthy, living oak woodland canopy in the Area of Focus[5].

Condition Thresholds[6]:

- *Good:* Maintain or increase the extent of healthy oak woodland canopy within existing oak woodlands
- *Caution:* Decrease in extent of healthy oak woodland canopy, within existing oak woodlands
- *Significant Concern:* Decreasing trend, year over year, in the extent of healthy oak woodland canopy within existing oak woodlands.

Trend: Caution

As noted, changes in tree canopy are associated with several different stressors, some of which are species-specific. SOD, which was first identified in the San Francisco Bay Area in the summer of 2000 (Rizzo et. al 2002), has had a devastating effect upon coast live oak canopy health, across the species range. A study across the East Bay Hills found that between 6 and 17 percent of coast live oaks were symptomatic of SOD and 2 to 8 percent were dead with symptoms of SOD between 2008 to 2013 (McPherson et al. 2015). Studies have shown that SOD has dramatically changed the structure of live oak woodlands in the AOF, including the age distribution, size classes and species composition of the forests (McPherson and Wood 2017, Frangioso et al. 2019). By contrast, the Mount Hamilton region exhibits very low to no infection by SOD. Subsequent to these SOD-specific studies, the AOF has undergone a significant period of drought which has increased the stress upon all oak woodlands. Longer, hotter droughts have, in recent years, reduced blue oak canopy across the species' California

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[5] Increases would occur in appropriate locations, including where oak trees have been lost and not at the expense of other high-quality habitat, to be determined in coordination with land managers and restoration specialists.
[6] Measurement of Metric 2 would be undertaken in cooperation with remote sensing and data analysis experts, which would inform the metric's goals, conditions and thresholds based upon the availability and cost of data.

range (Dwomoh et al. 2021). These studies and others indicate the ongoing impacts of a recently introduced pathogen as well as increasingly severe patterns of drought and wetness, both of which have resulted in extensive reductions in oak woodland canopy throughout many portions of the AOF (McPherson et al. 2019).

Confidence: To be completed after analysis is done.

METRIC 3: VIABILITY OF BLUE OAK AND VALLEY OAK SAPLING RECRUITMENT

Successful oak recruitment to the overstory, understood as the graduation of individual oak trees from the sapling size class into the mature overstory, is a topic of concern for ecologists focused on the health of blue oak and valley oak woodlands in California. There is considerable concern that overstory recruitment in trees of the white oak group in the AOF (blue oak and valley oak) is insufficient to support blue and valley oak woodland survival. Most studies agree (and it is also confirmed by partner agencies) that saplings, rather than seedlings, are the bottleneck to successful recruitment of new white oak cohorts into the overstory. Studies reviewed and summarized by Tyler et al 2006 and by Allen-Diaz et al. 2007) show a shortage of blue oak and valley oak saplings in certain regions of the state including low elevation sites on south- and west-facing slopes with shallow soils and high populations of herbivores. There are conflicting opinions over whether current, observed low levels of sapling recruitment are evidence of a decline in populations of these species (Tyler et al. 2006); however, it appears successful recruitment of saplings into the overstory is critical to the ongoing health of woodlands, particularly those dominated by members of the white oak group.

Blue oak. The Swiecki study (Swiecki et al. 1997) (included plots on Mt. Diablo) estimated a net regeneration rate based on data collected through a statewide study of recruitment of blue oak saplings. In that study, they estimated that one live sapling was needed to offset every tree that had died in the last 20 years or had been cut in the last 30–42 years. Another study by Zavaleta (2007) assumed longevity for an adult oak tree was less than 1,000 years, and under this assumption, 0.001 to 0.01 saplings would be required per existing adult tree to promote adequate recruitment rates. The statewide study of blue and valley oaks (Zavaleta 2007) acknowledged that more data is needed on mortality rates in the long term to determine what the true replacement rates are for dead and dying individual oaks. McLauglin et al. found that patterns of blue oak adult mortality and recruitment in the Mt. Hamilton sub-region tracked with climate models, suggesting an emerging shift in species distribution consistent with ongoing rapid anthropogenic warming (2014).

Valley oak. Recruitment varies across time and also with land use for valley oak, as the species is water sensitive. Zavaleta (2013) suggests analyzing recruitment in both areas that are grazed and those that are ungrazed to provide for range in variability.

Rationale: Oaks are long-lived species; however, healthy white oak woodlands still require recruitment of saplings into the overstory in adequate numbers to support the replacement of dead or dying oaks. Sapling recruitment is suspected by scientists and managers to be the bottle-neck in oak replacement, particularly in the white oak group. This metric was developed to monitor health/resilience of oak woodlands with particular interest in the potential effects from land management such as incompatible grazing practices and dry land farming, as well as from non-native and invasive plant and wildlife species, and altered fire regimes.

Current Baseline: A survey of studies across the state indicates that both blue oak and valley oak show very limited graduation of seedlings into the sapling class (sapling recruitment) at present; however, studies are limited and none of them are from the AOF (Tyler et al. 2006). Although blue oak and valley oak sapling recruitment patterns are not documented for the AOF there is some concern that levels are below the desired rate of recruitment to support persistence of existing blue oak and valley oak woodland coverage in the AOF, but data is needed to determine the baseline condition.

Condition Goals:

- Increase recruitment of viable saplings (including stump sprouts) in blue oak woodlands and valley oak woodlands, to support regeneration (replacement of individuals lost from mortality) of the blue oak and valley oak overstory over time.

Condition Thresholds:

- *Good:* The abundance (number) of viable saplings is consistent or increasing in the AOF.
- *Caution:* The abundance (number) of viable saplings is decreasing in the AOF.
- *Significant Concern:* A declining trend in abundance (number) of viable saplings, year-over-year in the AOF.

Trend: Unknown.

Confidence: To be completed after analysis is done.

OTHER METRICS CONSIDERED BUT NOT INCLUDED HERE

- **Native Plant species richness in understory of oak woodlands**. Metric was eliminated due to lack of data and complexity of establishing a baseline and then performing adequate regular monitoring with limited resources.
- **Patch Size and Patch Distribution of Valley, Blue, and Coast Live Oak Woodlands**. Metric was eliminated due to lack of clear scientific consensus on ideal or desired patch size and distribution in the two species and a lack of consensus on the appropriate way to measure the metric to reach a meaningful conclusion. In the future, if more research on the topic is

published, we recommend considering the addition of a metric that looks at the size and distribution of oak woodland stands (patches) in the AOF and how change over time indicates changes in oak woodland health.

DATA, MANAGEMENT, AND SUPPORTING INFORMATION

DATA GAPS AND DATA COLLECTION/MANAGEMENT NEEDS

Metric 1: Spatial Extent of Oak Woodland Vegetation Communities

- Historic records of oak woodland distribution across the AOF are largely qualitative and descriptive, with limited spatial data that is largely restricted to hand drawn maps. These historic datasets are problematic for use in trend analysis because they are incomplete and use incompatible mapping standards.
- The data source for current vegetation mapping in the AOF, made available within CLN 2.0, is the USFS Calveg existing vegetation (EVeg) dataset with 5-meter spatial resolution and based on imagery dated between 1997 and 2001 (USFS 2023, BAOSC 2019). The mapping resolution is variable and coarse, and the acreage calculations and analyses based upon this dataset carry the limitations of relying on mid-resolution satellite imagery to derive fine-scale changes in oak woodland community boundaries.
- A systematic effort to map vegetation communities across the AOF is critical to the success and utility of this metric. Specifically, oak woodland mapping should be refined so that the minimum mapping unit (MMU) is consistent across the AOF (1 acre or less) and the classification scheme is based on the Manual of California Vegetation (MCV) or another suitable classification system. A fine-scale vegetation map for the region is currently underway and will apply an MMU for oak woodland alliances equal to 1-acre. Contrasting life forms within the oak woodland alliances will be captured at the ½-acre MMU (Dina Robertson, personal communication).

Metric 2: Acres of Healthy Oak Woodland Canopy

- Current vegetation mapping in the AOF lacks significant ground-truthing and presents data at various spatial resolutions, as described above. In addition, the spatial resolution available in the CLN dataset is not refined enough to establish existing extent of various oak woodland community types, which is a needed baseline for an analysis of changes in canopy health over time. Development of a fine-scale vegetation map for the AOF will support this metric by standardizing the baseline unit of analysis and the spatial distribution of the different oak woodland communities across the AOF.

- Once a mapping and classification effort in AOF has been finalized, collection of appropriately timed aerial imagery or remote sensed data on recurring intervals will be needed to allow detection of changes in canopy condition that reflect changes in tree health rather than seasonal variations in leaf expansion, color, and presence. The timing and return interval of data collection would need to be set individually for each oak woodland community, based upon unique leaf phenology. At a minimum each oak woodland community would need to be sampled annually to effectively identify changes in canopy health. Remote sensing techniques using aerial imagery and processes to detect changes on the landscape (i.e. the normalized difference vegetation index [NDVI] using near infrared wavelengths) are advancing our ability to detect near-term changes in landscape and vegetation community condition and in combination with the forthcoming fine-sale vegetation map for AOF this remote sensing index, as well as others in development, may allow increasingly fine scale detection of canopy conditions.

Metric 3: Viability of Blue Oak and Valley Oak Sapling Recruitment

- There are no comprehensive long-term / multi-year studies to track the long- term outlook for blue oak and valley oak sapling presence, distribution, and therefore recruitment in the AOF; however, the SFPUC performed a study in 2011 that provided a snapshot of oak recruitment within the AOF with reference to stressors and historical recruitment levels extrapolated from historic aerial imagery (URS and SFPUC 2013). Study plots suitable for Metric 3 therefore exist on SFPUC lands within the AOF but not on land outside SFPUC ownership.
- Blue oak and valley oak sapling plots would need to be established in the remaining portions of the AOF, based upon the results of fine-scale vegetation mapping effort combined with field observation in the non-SFPUC portions of the AOF.
- The plot-based oak sapling monitoring would need to occur annually, at multiple locations per species, ideally representing a range of geographic, edaphic, and land use histories, where available. The number and location of plots selected for regular monitoring may vary by agency availability and funding.

PAST AND CURRENT MANAGEMENT

Past and current oak woodland monitoring in the AOF is largely informed by long term management plans prepared by Network partners to address site-specific concerns. The type and frequency of oak woodland monitoring and management activities varies between Network partners based on a host of factors, notably management priorities and available resources. Some of the Network partners employ monitoring-based adaptive management approaches that allow for up-to-date research and monitoring results to inform management decisions based on specific goals and objectives. In some cases, monitoring

and subsequent management decisions are driven by observed changes in oak woodland health (i.e. riparian oak recruitment studies, planting, and monitoring on SFPUC property and SOD monitoring and study on EBRPD lands [McPherson et al. 2015]), and in other cases management decisions are driven by stochastic events and associated response protocols (ex. removal of fire-damaged, hazard trees on EBRPD lands after a wildfire event).

EBRPD is currently leading a fine scale vegetation classification and mapping effort covering Alameda and Contra Costa Counties, applying the most current CNPS and CDFW vegetation classification and mapping protocols. The effort is anticipated to conclude in 2025. This effort will directly inform future iterations of this worksheet, as well as management decisions and Nature Check planning.

POTENTIAL FUTURE ACTIONS

- Utilize anticipated fine-scale vegetation map to establish baseline conditions for oak woodland extent and canopy health.
- Develop change detection methodology for measuring Metrics 1 and 2, using multitemporal image classification (with the harmonized Landsat and Sentinal-2 [HLS] or a similar imagery product) to consider where changes in oak woodland extent and condition are occurring and using high resolution imagery (NAIP or similar) to characterize what kind of change is occurring (i.e., foliar change, trunk mortality, canopy expansion, etc.).
- Utilize anticipated fine-scale vegetation map to prioritize blue oak and valley oak areas that are suitable for collecting blue oak and valley oak sapling baseline data and establishing long-term recruitment monitoring plots.
- Develop a consistent set of long-term monitoring methods and protocols across Network partners.

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CHAPTER AUTHORS AND KEY CONTRIBUTORS

Primary Author

Galen Peracca. MF Forestry, Ecologist and Senior Managing Consultant, Ramboll, Inc.
gperacca@ramboll.com

Key Contributors

Dina Robertson, Wildand Vegetation Program Manager, EBRPD

Kristen Van Dam, Ecological Services Coordinator, EBRPD

Mia Ingolia, Senior Biologist, Natural Resources and Land Management Division, SFPUC

Scott Simono, Biologist, Natural Resources and Land Management Division, SFPUC

James Bartolome, Professor Emeritus, UC Berkeley

Kass Green, Principal and Owner, Kass Green & Associates

Workshop Participants

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

David Ackerly, professor and College Dean, UC Berkeley

Jeffrey Clary, Reserve Director, UC Natural Reserve System

Heath Bartosh, Ecologist, Nomad Ecology

Josh Philips, Ecological Services Coordinator, EBRPD

Ellen Natesan, Ecosystem Stewardship Coordinator, SFPUC

Michele Hammond, Botanist, EBRPD

Valerie Eviner, Professor, University of California, Davis

Roxanne Foss, Ecologist, Vollmar Natural Lands Consulting

Brice McPherson, Specialist, UC Berkeley

Susan Frankel, Plant Pathologist, US Department of Agriculture

Alison Rofe, Rangeland Management Specialist, EBRPD

Barry Hecht, Principal Geomorphologist/Hydrogeologist, Balance Hydrologics

Pamela Beitz, Integrated Pest Management Specialist, EBRPD

Ted Swiecki, Plant Pathologist, Principal/Phytosphere Research