# 3.0 CLIMATE CHANGE

## 3.1 OVERVIEW

Global climate is changing as a result of human activities that emit greenhouse gases, such as carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$; IPCC 2014). Greenhouse gases trap heat in the atmosphere and are produced from the burning of fossil fuels; burning of trees, wood products, and solid waste; cement production; livestock and agricultural practices; decay of organic waste in landfills; and other industrial activities (EPA 2017). $CO_2$ makes up 81% of greenhouse gases, followed by $CH_4$ at 11%, $N_2O$ at 6%, and fluorinated gases at 3%. There is a historical record of global anthropogenic emissions for $CO_2$ emissions, but not for the other gases. $CO_2$ has increased from approximately 2 to nearly 40 gigatonnes (Gt) of $CO_2$ per year since the mid-1800s, with 50% of that increase in the last 40 years (IPCC 2014). Of these emissions, 40% stayed in the atmosphere, 30% were stored in the land in plants and soil, and 30% were absorbed into the ocean. $CO_2$ is absorbed by plants and used in photosynthesis as part of the biological carbon cycle (EPA 2017). Gases in the atmosphere are trapping heat and have led to an average increase of 0.85 degrees Centigrade (°C) in combined land and sea surface temperatures between 1880 and 2012, with the last 3 decades warmer than any preceding decade since 1850 (IPCC 2014). The ocean is storing heat and beginning to warm as energy accumulates and it is also acidifying with the increase in $CO_2$.

Climate projections for the future depend on the amount of greenhouse emissions from human activities. Recently, the Coupled Model Intercomparison Project Phase 5 (CMIP5) was completed with predictions averaged across 32–39 different global climate change models and dependent on Representative Concentration Pathways (RCPs) reflecting different emission scenarios (IPCC 2014). The models project an average global temperature increase of 1 to 4°C (1.8 to 7.2 °F) by 2100 depending on the RCP, with steep reductions in $CO_2$ emissions associated with the smallest temperature increases and increases in emission production leading to the highest temperature increases. However, some areas will be warmer than the global average temperature increase. The southwestern United States, including southern California, and northern Mexico, is considered a persistent climate change hotspot (Diffenbaugh et al. 2008). In this area, the relative changes in climate will be highest and due more to changes in the annual variability of climate variables rather than to changes in long-term means. In southern California, the changes are largely due to variability in precipitation.

CMIP5 highest emission models for the Los Angeles Basin predict that, in 2100, June through October temperatures will be more than 5°C (9°F) hotter than the warmest baseline months between 1980 to 2000 (Sun et al. 2015). There will be a predicted 60–90 more days a year with extreme heat of >35 °C (95 °F). This will shift the Los Angeles climate into a new climate state that is only 50% similar to the baseline climate, with the least amount of change from December through February. Warming is also expected to be greater in summer than winter periods (Cayan, Maurer, et al. 2008).

Global climate change models for the southwestern United States indicate that the region is making a rapid transition to a drier climate (Seager et al. 2007; Cayan et al. 2010). There is greater uncertainty about how precipitation might change in southern California, particularly from Los Angeles south to San Diego; with areas to the north having higher certainty of increased precipitation (Sun et al. 2015). However, there is a growing consensus that southern California will become drier and more vulnerable to drought (Cayan et al. 2010; Franco et al. 2011). Recent modeling indicates that southern California will be drier as it is in the transition zone of increased rain in the mid to high latitudes and decreased rainfall in the tropics (Neelin et al. 2013; Diffenbaugh et al. 2015). The amount of rainfall will be dependent on the Pacific jet stream steering storms toward the California coast. Global climate change models indicate that California will maintain a mediterranean climate, with precipitation largely in the cooler winter months and hot dry summers (Cayan, Maurer, et al. 2008; Franco et al. 2011). Temperature increases will be more extreme in inland areas greater than 50 kilometers from the coast (Messner et al. 2011). More extreme precipitation events in the form of droughts and floods are forecast for the future (Berg and Hall 2015; Diffenbaugh et al. 2015; Monier and Gao 2015).

Droughts are likely to become more frequent and intense as increases in temperature coincide with dry periods (Diffenbaugh et al. 2015). Analysis of historical climate records for California found lower rainfall was 2 times more likely to lead to drought when temperatures were warm and that the occurrence of drought was greater in the last 20 years than in the preceding 100 years (Diffenbaugh et al. 2015). The recent 2012–2014 drought was caused by the co-occurrence of warm and dry conditions (Griffin and Anchukaitis 2014; Diffenbaugh et al. 2015). While low levels of precipitation were important in the 2012–2014 drought, human-caused global warming is estimated to have contributed 8–27% of the increase in drought severity for 2012–2014 and 5–18% for 2014 (Williams et al. 2015a). An increase in global warming means there is 100% probability that increased risk of severe drought will occur in the future (Diffenbaugh et al. 2015). Warming temperatures increase evapotranspiration and the loss of soil moisture and will amplify soil moisture deficits beyond those caused by reductions in precipitation, contributing to an increase in the frequency, duration, and intensity of future droughts (Cayan et al. 2010; Diffenbaugh et al. 2015).

Based on an analysis of a portion of the drought period that extended from 2012–2016, it was found that 2012–2014 was the most extreme drought documented in southern California over the last 1,200 years based on tree ring data and precipitation reconstruction (Griffin and Anchukaitis 2014). The accumulated moisture deficit in 2014 was greater than any previous year. A reanalysis of these data, using spatially based averages to account for differences in precipitation data grid sizes, found that 2 droughts from the years 800 through 2006 were more severe than 2014, but that the 2012–2014 drought period was the most severe and represented a 10,000-year event (Robeson 2015). Extending the drought period to 2015 finds the drought was so severe there is no precedent in previous drought records and that the return interval for a similar drought is incalculably large (Robeson 2015). There is also finer-scale variation in the impact of the 2012–2015 drought within California, with coastal cities being mildly impacted, whereas, inland, more rural areas faced much more severe impacts (Swain 2015).

Based on the CMIP5 global climate models and the “business as usual” RCP, extreme precipitation events leading to flooding are likely to be 3 times more frequent in California from 2060–2100 (Berg and Hall 2015). This increased flooding is due to increased variability as well as increases in average precipitation levels for California as a whole. The CMIP5 climate models indicate there could be 2 times more extreme El Niño events globally due to a warming over the eastern equatorial Pacific that is faster than in surrounding ocean waters (Cai et al. 2014). An extreme El Niño occurred in 2015 but was not associated with higher than normal precipitation in southern California. There was an anomalous high amplitude ridge system associated with the precursor to the El Niño that diverted storm troughs to the northeast United States and away from California (Wang et al. 2014). This ridge is associated with anthropogenic warming during the 2013–2014 winter.

In addition to changes in precipitation, climate change could affect coastal low cloudiness or fog. A decrease in coastal low cloudiness was seen from 1950 to 2012 along the Pacific Coast from Alaska to southern California and was linked to increasing sea temperatures linked to the Pacific Decadal Oscillation (Schwartz et al. 2014). Since the mid-1900s, fog trends have been spatially variable at 24 airports in southern California due to differences in nighttime warming due to the amount of surrounding urban area creating a heat island effect (Williams et al. 2015b).

Coastline and estuaries in San Diego County have started to see an increase in sea level and this will be sharply intensified by 2100. A study of San Diego tidal gauges by Cayan, Bromirski, et al. (2008) found there had been an approximately 2 centimeters/decade average rise in sea level since the 1980s (Cayan, Bromirski, et al. 2008). It is anticipated that sea level will increase to 11–72 centimeters above the historic mean by 2070–2099, depending on the global climate change model and carbon emission scenario considered. The study found that, since the early 1970s, there has been a sharp increase in the number of high sea level events in San Diego. Sea level rise will increase the impacts from high tides and storms, with an upsurge in frequency and intensity of extreme events.

A changing climate may interact with multiple stressors to impact or potentially impact conserved MSP species, vegetation communities, and ecosystem processes. Information on the impacts or potential impacts of climate change on conserved resources and objectives for monitoring and managing the threat of climate change are detailed in sections of Vols. 2A, 2C, and 2D where climate change has been identified as a threat. Specific sections of Vol. 2B have information on other threats that climate change may interact with. Examples of potential impacts include the effects of climate on fire regimes; invasion dynamics of nonnative plants and animals; species responses to novel pests and pathogens; demographic responses of plants leading to changes in community composition and declines in rare plants; decreased surface water flows; rising sea level; changing food webs; phenological mismatches; disruptions of ecosystem services such as pollination; and habitat loss and fragmentation limiting the ability of species to shift their distributions in response to climate change.

## 3.2 CLIMATE CHANGE IN THE MSPA

Given the scale of climate change, the current and future climate conditions described above for southern California also apply to the MSPA. A specific assessment of future climate change impacts in 2050 for San Diego County was prepared by a team of over 40 scientists and experts as part of the San Diego Foundation's Regional Focus 2050 Study (SDF 2008a,b). If the region does not reduce the current trend in greenhouse gas emissions by 2050 then sea level will be 12–18 inches higher, the climate will be hotter and drier, and wildfires will be more frequent and intense (SDF 2008 a,b). Rising sea levels will mean the reduction and loss of beaches, disappearance of tide pools, increasing high waves, and flooding. Average temperatures will increase approximately 1 to 3°C, heat waves and drought will increase in frequency, intensity, and duration (SDF 2008a,b). The fire season will start earlier with warmer spring temperatures, drought will reduce fuel moisture and increase fire risk, Santa Ana winds may occur over longer portions of the fire season and exacerbate extreme fire conditions, and extreme weather for severe fires will increase by up to 20% (SDF 2008a,b). All of these changes will affect MSP plant and animal species, vegetation communities, and ecosystem processes. Some species may be able to migrate to more suitable conditions, others may disappear (SDF 2008a,b). A significant die-off of trees is expected, entire ecosystems will be stressed, and novel conditions could emerge.

## 3.3 RESULTS OF CLIMATE CHANGE STUDIES IN THE MSPA

The results of climate change studies in the MSPA are described in the preceding sections. These studies are summarized in the San Diego Foundation's 2015 climate impact assessment (SDF 2008a) and include modeling of future climate conditions under different emission scenarios; an examination of historical sea level rise data and modeling of future conditions; documentation of an increase in fire frequency due to changing climate conditions, including very large Santa Ana wind driven fires; modeling of suitable habitat under climate change and documented impacts to native plant and animals species, including several MSP species; and reductions in the biodiversity of San Diego's ocean habitats.

## 3.4 MANAGEMENT AND MONITORING APPROACH

The management and monitoring approach to respond to the threat of climate change currently has 5 components for the 2017–2021 and subsequent planning cycles.

The first component is information gathering and analyzing data to evaluate potential responses of conserved natural resources to climate conditions. This involves measuring climate across the MSPA using remote, automated weather stations (see Vol. 2A); monitoring species to document distribution, status, habitat and threat covariates (see Vol. 2D); monitoring vegetation communities to determine composition, structure, and ecological integrity (see Vol. 2C); monitoring ecosystem processes (see Vol. 2A and Vol. 2B); and monitoring various threat covariates that may interact with climate change (see Vol. 2B). Monitoring data will be analyzed to determine the relation between climate variables and measured aspects of MSP species, vegetation communities, ecosystem processes, and threats. An understanding of these relationships is important in developing management strategies to manage threats to promote resilience and adaptation of MSP species, vegetation communities, and ecosystem processes to climate change impacts.

A second component is to model the range in predicted responses of species and vegetation communities to potential future climate conditions, as determined by ensemble habitat models, global climate models, and various RCPs. Potential threats, such as land use change, invasive species, and altered fire regime, can be added to these models to more broadly represent the range in potential future conditions. This information will help to gauge the potential impact of changing climate and other threats on conserved natural resources and to identify potential future refugia. Related to this is an evaluation of the MSPA to determine areas that are projected to see the greatest change in climate versus those areas that remain more similar to current climate and to identify non-analog climates. This modeling can be used to inform future management strategies for MSP species, vegetation communities, and ecosystem processes.

The third component is to manage MSP species, vegetation communities, and ecosystem processes to increase resilience to short-term climate impacts by implementing management actions that reduce the level of other threats (e.g., targeted enhancement and restoration to improve habitat quality, such as controlling nonnative invasive species, enhancing food webs, and improving pollinator services).

The fourth component is to develop longer-term management strategies to facilitate adaptation of MSP species and vegetation communities to changing climate conditions. Examples of potential adaptation actions include using modeling of potential future conditions to manage for connectivity to allow for distributional shifts and potentially assisting migration of species to more suitable habitat and managing for increased genetic diversity to facilitate adaptation to changing conditions.

The fifth component is to monitor resilience and adaptation management actions to determine short-term and long-term effectiveness and improve management strategies.

### 3.4.1 General Approach Objectives

Below is a summary of the monitoring objectives for climate change in the 2017–2021 planning cycle. There are no general climate change management objectives in the current planning cycle. For the most up-to-date objectives and actions, refer to the MSP Portal Climate Change summary page: https://portal.sdmmp.com/view_threat.php?threatid=TID_20160304_1450.

The overall climate change management goal is to maintain and enhance the long-term ecological integrity, resilience, and viability of ecosystems, MSP species, and vegetation communities on Conserved Lands and to facilitate range shifts in species and vegetation communities as necessary for long-term persistence in the region.

There are 2 general approach monitoring objectives for climate change in the 2017–2021 planning cycle. The first objective is to develop habitat suitability models for plant and animal species and vegetation communities under current and future climate scenarios. This will include modeling the influence of other threats, such as altered fire regimes, projected sea level rise, and potential habitat for invasive nonnative species. The range in model predictions can be evaluated to identify where species and vegetation communities may be predicted to persist and where they may need to migrate to more suitable future conditions. The second objective is to establish a long-term monitoring network of remote, automated weather stations and soil moisture/temperature sensors on Conserved Lands across the MSPA. These should be co-located as feasible at permanent, long-term vegetation monitoring plots.

### 3.4.2 Species-Specific and Vegetation Approach Objectives

Descriptions of climate change management approaches, rationale, goals, objectives, and actions for at-risk MSP species and vegetation communities are presented in the corresponding species, threats, and vegetation sections.

Species-specific and vegetation objectives that address climate change are often combined with other threat objectives to reduce threat impacts and improve resilience of populations to enhance continued persistence. Objectives that pertain to climate change include monitoring to determine the effects of climate variables on various aspects of species and vegetation communities and management to enhance population resilience. These management actions can include controlling invasive nonnative species, restoring habitat to specifically provide more abundant food resources in drought, enhancing linkages to accommodate species range shifts, and creating habitat to escape rising sea levels. There are also climate change-specific objectives to model future conditions for MSP species. Monitoring and management objectives and actions that relate to climate change are presented in the corresponding species and vegetation sections. Links to species-specific and vegetation objectives that apply to climate change are provided in Table V2B.3-1. Use the MSP Portal for the most updated list of species and vegetation communities with Climate Change objectives.

**Table V2B.3-1. MSP plant and animal species, and vegetation communities with specific climate change management and monitoring objectives.**

| Scientific Name | Common Name | Management Category | Summary Page Link |
|---|---|---|---|
| **Plants** | | | |
| Acanthomintha ilicifolia | San Diego thorn-mint | SO | https://portal.sdmmp.com/view_species.php?taxaid=32426 |
| Acmispon prostratus | Nuttall's acmispon | SO | https://portal.sdmmp.com/view_species.php?taxaid=820047 |
| Aphanisma blitoides | Aphanisma | SL | https://portal.sdmmp.com/view_species.php?taxaid=20679 |
| Baccharis vanessae | Encinitas baccharis | SO | https://portal.sdmmp.com/view_species.php?taxaid=183764 |
| Brodiaea filifolia | Thread-leaved brodiaea | SS | https://portal.sdmmp.com/view_species.php?taxaid=42806 |
| Brodiaea orcuttii | Orcutt's brodiaea | SO | https://portal.sdmmp.com/view_species.php?taxaid=42815 |
| Chloropyron maritimum ssp. maritimum | Salt marsh bird's-beak | SL | https://portal.sdmmp.com/view_species.php?taxaid=834234 |
| Clinopodium chandleri | San Miguel savory | SL | https://portal.sdmmp.com/view_species.php?taxaid=565077 |
| Deinandra conjugens | Otay tarplant | SS | https://portal.sdmmp.com/view_species.php?taxaid=780273 |
| Dicranostegia orcuttiana | Orcutt's bird's-beak | SL | https://portal.sdmmp.com/view_species.php?taxaid=834156 |
| Eryngium aristulatum var. parishii | San Diego button-celery | VF | https://portal.sdmmp.com/view_species.php?taxaid=528066 |
| Erysimum ammophilum | Coast wallflower | SL | https://portal.sdmmp.com/view_species.php?taxaid=22928 |
| Hazardia orcuttii | Orcutt's hazardia | SL | https://portal.sdmmp.com/view_species.php?taxaid=502882 |
| Monardella viminea | Willowy monardella | SL | https://portal.sdmmp.com/view_species.php?taxaid=833060 |
| Navarretia fossalis | Spreading navarretia | VF | https://portal.sdmmp.com/view_species.php?taxaid=31328 |
| Nolina interrata | Dehesa nolina | SO | https://portal.sdmmp.com/view_species.php?taxaid=42992 |
| Orcuttia californica | California orcutt grass | SL | https://portal.sdmmp.com/view_species.php?taxaid=41970 |
| Pogogyne abramsii | San Diego mesa mint | VF | https://portal.sdmmp.com/view_species.php?taxaid=32639 |
| Pogogyne nudiuscula | Otay mesa mint | SL | https://portal.sdmmp.com/view_species.php?taxaid=32643 |
| Quercus engelmannii | Engelmann Oak | VF | https://portal.sdmmp.com/view_species.php?taxaid=19329 |
| Tetracoccus dioicus | Parry's tetracoccus | SS | https://portal.sdmmp.com/view_species.php?taxaid=28420 |

| Scientific Name | Common Name | Management Category | Summary Page Link |
|---|---|---|---|
| **Invertebrates** | | | |
| Euphydryas editha quino | Quino checkerspot butterfly | SL | https://portal.sdmmp.com/view_species.php?taxaid=779299 |
| Euphyes vestris harbisoni | Harbison's dunn skipper | SL | https://portal.sdmmp.com/view_species.php?taxaid=707282 |
| Lycaena hermes | Hermes copper | SL | https://portal.sdmmp.com/view_species.php?taxaid=777791 |
| Panoquina errans | Wandering skipper | VF | https://portal.sdmmp.com/view_species.php?taxaid=706557 |
| **Amphibians** | | | |
| Anaxyrus californicus | Arroyo toad | SO | https://portal.sdmmp.com/view_species.php?taxaid=773514 |
| Spea hammondii | Western spadefoot toad | VF | https://portal.sdmmp.com/view_species.php?taxaid=206990 |
| **Birds** | | | |
| Athene cunicularia hypugaea | Western burrowing owl | SL | https://portal.sdmmp.com/view_species.php?taxaid=687093 |
| Campylorhynchus brunneicapillus sandiegensis | Coastal cactus wren | SO | https://portal.sdmmp.com/view_species.php?taxaid=917698 |
| Charadrius nivosus nivosus | Western snowy plover | SL | https://portal.sdmmp.com/view_species.php?taxaid=824565 |
| Empidonax traillii extimus | Southwestern willow flycatcher | SL | https://portal.sdmmp.com/view_species.php?taxaid=712529 |
| Passerculus sandwichensis beldingi | Belding's savannah sparrow | VF | https://portal.sdmmp.com/view_species.php?taxaid=179325 |
| Polioptila californica californica | Coastal California gnatcatcher | VF | https://portal.sdmmp.com/view_species.php?taxaid=925072 |
| Rallus obsoletus levipes | Light-footed Ridgway's rail | SO | https://portal.sdmmp.com/view_species.php?taxaid=176211 |
| Sternula antillarum browni | California least tern | SO | https://portal.sdmmp.com/view_species.php?taxaid=825084 |
| Vireo bellii pusillus | Least Bell's vireo | SO | https://portal.sdmmp.com/view_species.php?taxaid=179007 |
| **Mammals** | | | |
| Taxidea taxus | American badger | SL | https://portal.sdmmp.com/view_species.php?taxaid=180565 |

| Scientific Name | Common Name | Management Category | Summary Page Link |
| --- | --- | --- | --- |
| **Vegetation Communities** | | | |
| Chaparral | NA | | https://portal.sdmmp.com/view_species.php?taxaid=SDMMP_vegcom_3 |
| Coastal Sage Scrub | NA | | https://portal.sdmmp.com/view_species.php?taxaid=SDMMP_vegcom_1 |
| Grassland | NA | | https://portal.sdmmp.com/view_species.php?taxaid=SDMMP_vegcom_2 |
| Oak Woodland | NA | | https://portal.sdmmp.com/view_species.php?taxaid=SDMMP_vegcom_10 |
| Riparian Forest & Scrub | NA | | https://portal.sdmmp.com/view_species.php?taxaid=SDMMP_vegcom_7 |
| Salt Marsh | NA | | https://portal.sdmmp.com/view_species.php?taxaid=SDMMP_vegcom_6 |
| Southern Interior Cypress Forest | NA | | https://portal.sdmmp.com/view_species.php?taxaid=SDMMP_vegcom_9 |
| Torrey Pine Forest | NA | | https://portal.sdmmp.com/view_species.php?taxaid=SDMMP_vegcom_8 |
| Vernal Pool/Alkali Playa | NA | | https://portal.sdmmp.com/view_species.php?taxaid=SDMMP_vegcom_4 |

## 3.5 CLIMATE CHANGE REFERENCES


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