Threats to Biodiversity

California's biodiversity faces many pressures. Most are linked to supporting the state's large and growing human population. Threats to biodiversity are mainly due to the direct loss of habitat. In addition, fragmentation of habitat by developed infrastructure obstructs the movement of fish and wildlife and restricts their access to what habitat remains. A burgeoning population also places heightened demands on water, raises pollution, and increases the introduction of invasive plants and animals. Another growing threat to biodiversity comes from the rapidly changing climate, which in California means further reductions in water availability, rising sea levels, and more frequent extreme weather and wildfire events.

Human Population and Land Use

Habitat loss and fragmentation due to human population growth present the greatest problem facing native plants and animals in California. As of January 1, 2020, the state's population was estimated at 39.8 million people (CDOF 2020). The 15 counties bordering the Pacific Ocean account for 54 percent of the population, with 42 percent residing in Los Angeles, Orange, and San Diego counties alone. The nine-county San Francisco Bay Area accounts for almost 20 percent, as shown on the inset map to the right. The state's population will likely increase by approximately 5.2 million and reach 45 million people by 2060 (CDOF 2020). Most of the additional people will concentrate in the South Coast, San Francisco Bay, Central Valley, and inland Southern California areas. However, the rate of growth by county is expected to shift inland. The counties of Merced, Yuba, Placer, Sutter, and Butte are expected to increase over 45 percent during this period.

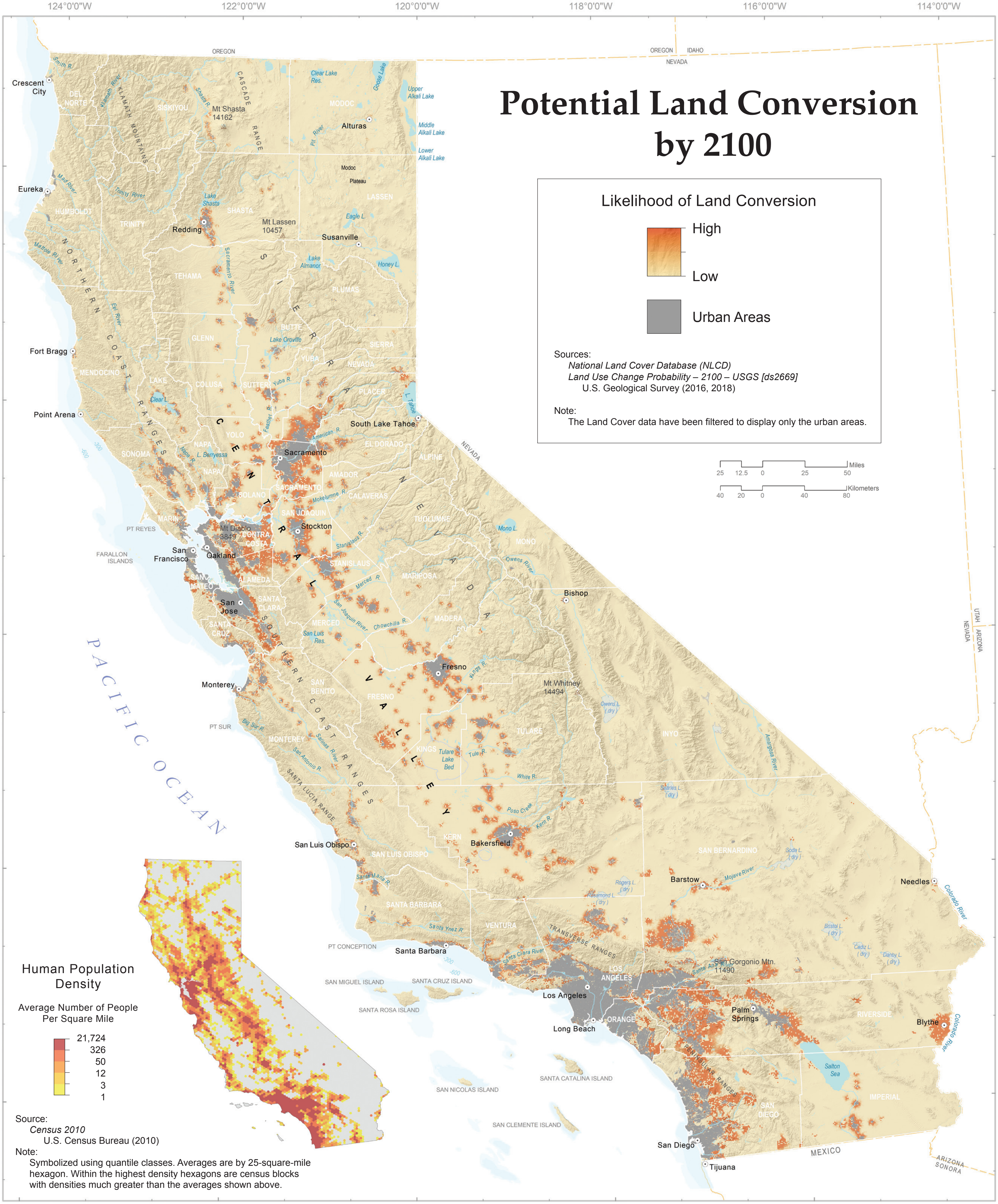
Human population growth creates new demands for housing, roads, jobs, schools, water, energy, and other infrastructure. Expansion of these services converts natural habitat and open space into highly modified landscapes, resulting in the fragmentation of habitat and the loss of native plants and animals.

Existing urban areas typically see the largest population increases in California. Such increases in existing cities generally do not result in great losses of natural habitat acreage. The increases are absorbed through infill projects or expansion along the city edges and the required large-scale infrastructure is usually already in place. However, local endemic species may be greatly affected as their remaining habitat areas are developed or subjected to an increasing human presence. The boundaries where natural areas and built landscapes meet is referred to as the wildland-urban interface. Here species and habitat are subjected to pressures such as disturbance from recreation, fire prevention, pest control, and urban runoff. Many of the state's imperiled species are found in proximity to urban areas, as illustrated in the map on page 3.

It is the rapid population growth in California's more rural areas—the Central Valley, Sierra Nevada foothills, and Southern Coast Ranges—that presents a more troubling trend for native plants and animals. These areas are likely to have housing densities much lower than in the major cities. The combination of high population growth in rural areas and expected low housing densities means that substantially more land presently in natural habitat will be converted to housing. Rural areas generally lack the infrastructure to handle the growth. Consequently, new residential and industrial development requires transportation, water, sewer, and other services to be greatly expanded or newly built, aggravating the impact on habitat. If California stays the course, natural lands are expected to decline at a rate of 54 square miles per year for the remainder of the century. Inland Southern California is projected to show the highest rate of net increase in developed area, followed by counties in coastal Southern California, the Central Valley, and the Bay Area (Sleeter et al. 2017).

The maps in the remainder of this section illustrate the effects humans and infrastructure have on the biodiversity of California.

A highly modified landscape causes fragmentation of the San Elijo Lagoon on the Southern California coast.
CDFW photo: Tim Dillingham


Potential Land Conversion by 2100
Likelihood of Land Conversion
High
Low
Urban Areas
Sources:
National Land Cover Database (NLCD)
Land Use Change Probability – 2100 – USGS [ds2669]
U.S. Geological Survey (2016, 2018)
Note:
The Land Cover data have been filtered to display only the urban areas.
Miles
Kilometers
PACIFIC OCEAN
CENTRAL VALLEY
Human Population Density
Average Number of People Per Square Mile
21,724
326
50
12
3
1
Source:
Census 2010
U.S. Census Bureau (2010)
Note:
Symbolized using quantile classes. Averages are by 25-square-mile hexagon. Within the highest density hexagons are census blocks with densities much greater than the averages shown above.

Human-Wildlife Conflict

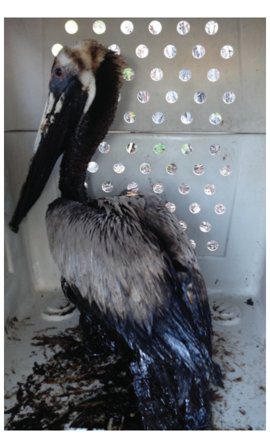
Federally endangered Peninsular bighorn sheep (*Ovis canadensis nelsoni*) graze a golf course adjacent to their natural habitat. Maintained landscapes can provide an attractive year-round food source for wildlife, which can have positive and negative effects for both humans and wildlife. CDFW photo

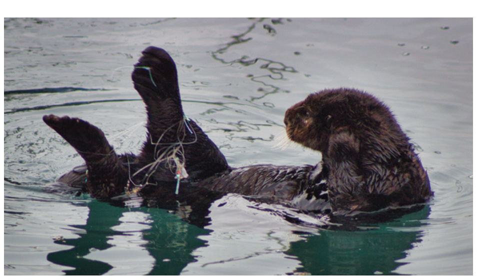
Human interactions with wildlife can occur with a diversity of native species in terrestrial, aquatic, and aerial environments throughout California. These interactions can be positive, like watching a family of bears while walking a wilderness trail during the day. They can be negative, as when the same bears attempt to break into your cabin that night. Human-wildlife conflicts occur when human actions or behaviors have an adverse effect on wildlife or when wildlife behaviors adversely affect humans. Human emotions, attitudes, and values often determine how an interaction is perceived and whether it will end in conflict or coexistence.

Coyotes (*Canis latrans*), called "song dogs" by Native Americans, are intelligent and highly adaptive. With their diverse diet, potential food sources can include unsecured trash or small pets in urban settings.

Competition for limited resources can lead to conflict. Native species are increasingly affected by loss or modification of natural habitat and loss of habitat connectivity due to increased land-use needs for agricultural, economic, and recreational activities (CDFW 2015). Humans can be affected by damage to property or crops, injury to or loss of pets and livestock, actual or perceived threats to human health or public safety, and general "nuisance wildlife" issues.

As a result of conflict, humans have driven some species to extinction, the most significant biological consequence of human interaction with wildlife. One notable example is the loss of our state animal, the California grizzly bear (*Ursus arctos californicus*).



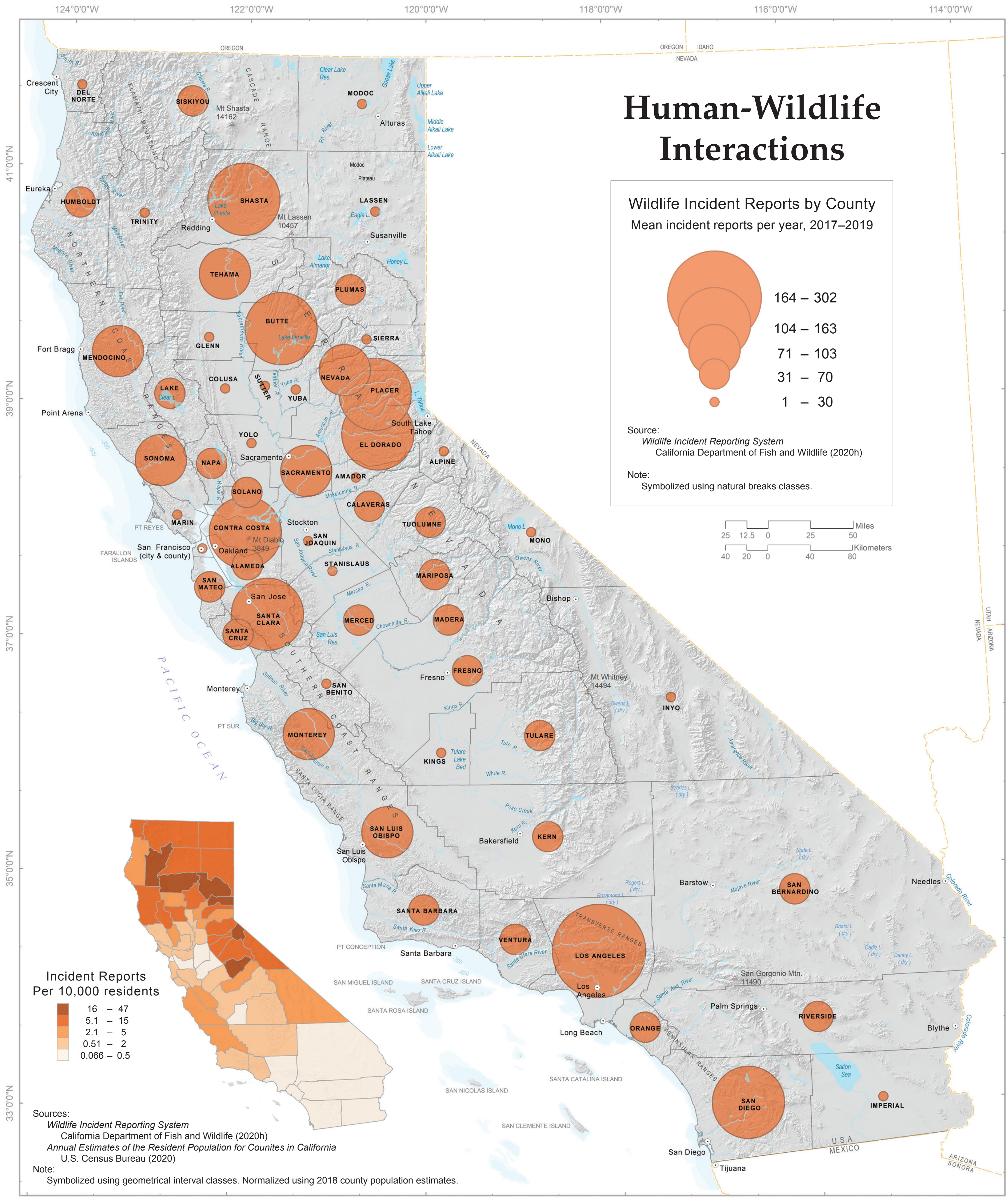


Marine and coastal wildlife, such as pelicans (*Pelicanus* spp.) and sea otters (*Enhydra lutris*), can become entangled in fishing line, imbedded with fish hooks, or exposed to oil spills and pollution. Some fish and wildlife can become too sick or injured to recover.
CDFW photos: Office of Spill Prevention and Response

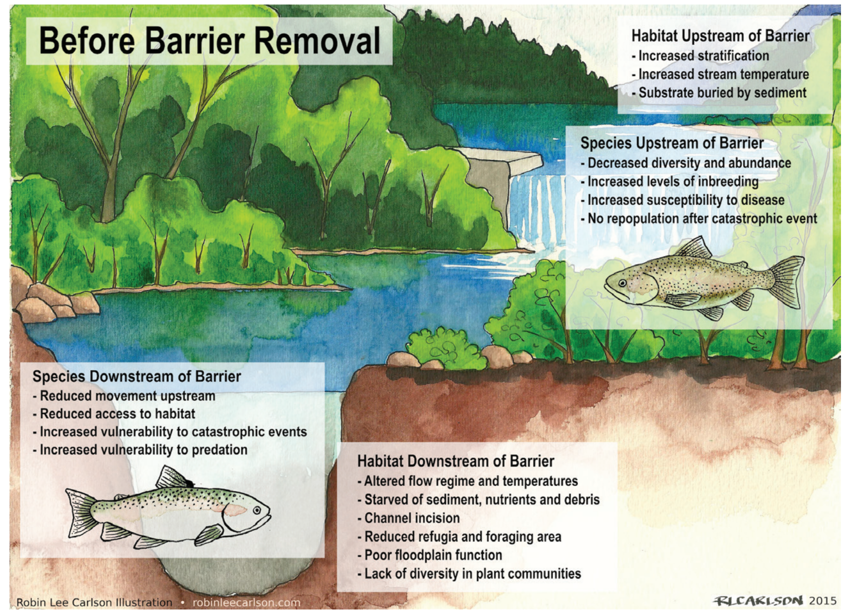
The frequency and type of reported human-wildlife interactions are highly variable across the state. Conflict hotspots often mirror the human population distribution, as shown on the map to the right. There are a high number of wildlife encounters in cities, where the sheer number of people increases the likelihood of contact with species that have acclimated to the human environment, such as coyotes and turkeys. However, the chance of any individual having a wildlife encounter is greater in rural areas (inset map), where human and domestic animal proximity to natural habitat is greater. A wider variety of animals, including mountain lions and bears, is more commonly encountered in rural areas.

There is a strong drought-associated pattern to reported conflicts with bobcats (*Lynx rufus*). The less rainfall in relation to 30-year annual averages, the greater the frequency of reported incidents.

Managing human-wildlife interactions to reduce conflict becomes more challenging as the human population in the state continues to grow. As California's trustee agency for wildlife resources, the Department takes the lead in helping to resolve reported property damage and human safety issues due to wildlife. The Department provides guidance and online resources on its "Living with Wildlife" website (CDFW 2020g). Diverse species are highlighted there, from black bears and beavers to wild turkeys, with detailed information on their behavior, ecosystem services, and ways to encourage coexistence. How people interact with, perceive, and value wildlife directly inform how conservation and management actions are prioritized to support and sustain biodiversity in California.


Human-Wildlife Interactions
Wildlife Incident Reports by County
Mean incident reports per year, 2017–2019
164 – 302
104 – 163
71 – 103
31 – 70
1 – 30
Source:
Wildlife Incident Reporting System
California Department of Fish and Wildlife (2020h)
Note:
Symbolized using natural breaks classes.
Miles
25 12.5 0 25 50
Kilometers
40 20 0 40 80
Incident Reports
Per 10,000 residents
16 – 47
5.1 – 15
2.1 – 5
0.51 – 2
0.066 – 0.5
Sources:
Wildlife Incident Reporting System
California Department of Fish and Wildlife (2020h)
Annual Estimates of the Resident Population for Counites in California
U.S. Census Bureau (2020)
Note:
Symbolized using geometrical interval classes. Normalized using 2018 county population estimates.
124°0'0"W
122°0'0"W
120°0'0"W
118°0'0"W
116°0'0"W
114°0'0"W
41°0'0"N
39°0'0"N
37°0'0"N
35°0'0"N
33°0'0"N
OREGON
IDAHO
NEVADA
UTAH
ARIZONA
U.S.A.
MEXICO
SONORA
PACIFIC OCEAN
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
BUTTE
SIERRA
GLENN
MENDOCINO
LAKE
COLUSA
SUTTER
YUBA
NEVADA
PLACER
EL DORADO
YOLO
ALPINE
SONOMA
NAPA
SACRAMENTO
AMADOR
SOLANO
CALAVERAS
MARIN
CONTRA COSTA
SAN JOAQUIN
TUOLUMNE
MONO
ALAMEDA
STANISLAUS
SAN MATEO
MARIPOSA
SANTA CLARA
SANTA CRUZ
MERCED
MADERA
FRESNO
SAN BENITO
INYO
MONTEREY
TULARE
KINGS
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
Crescent City
Mt Shasta 14162
Alturas
Eureka
Redding
Mt Lassen 10457
Susanville
Fort Bragg
Point Arena
South Lake Tahoe
Sacramento
Stockton
San Francisco (city & county)
Oakland
Mt Diablo 3849
San Jose
Bishop
Fresno
Mt Whitney 14494
Monterey
Bakersfield
San Luis Obispo
Barstow
Needles
Santa Barbara
Los Angeles
San Gorgonio Mtn. 11490
Palm Springs
Long Beach
Blythe
San Diego
Tijuana
Salton Sea
PT REYES
FARALLON ISLANDS
PT SUR
PT CONCEPTION
SAN MIGUEL ISLAND
SANTA CRUZ ISLAND
SANTA ROSA ISLAND
SANTA CATALINA ISLAND
SAN NICOLAS ISLAND
SAN CLEMENTE ISLAND
CASCADE RANGE
KLAMATH MOUNTAINS
SIERRA NEVADA
NORTHERN COAST RANGES
SOUTHERN COAST RANGES
SANTA LUCIA RANGE
TRANSVERSE RANGES
PENINSULAR RANGES

Stream Barriers

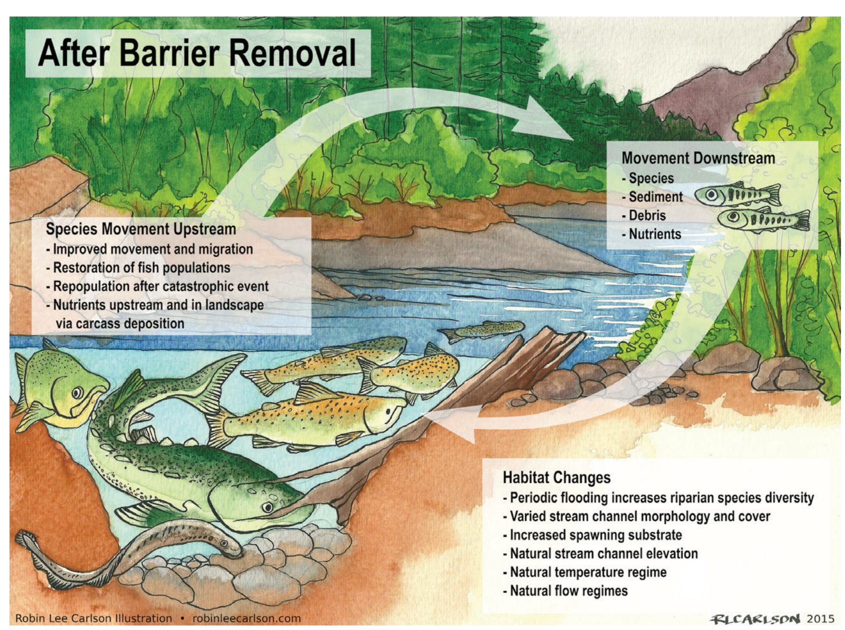


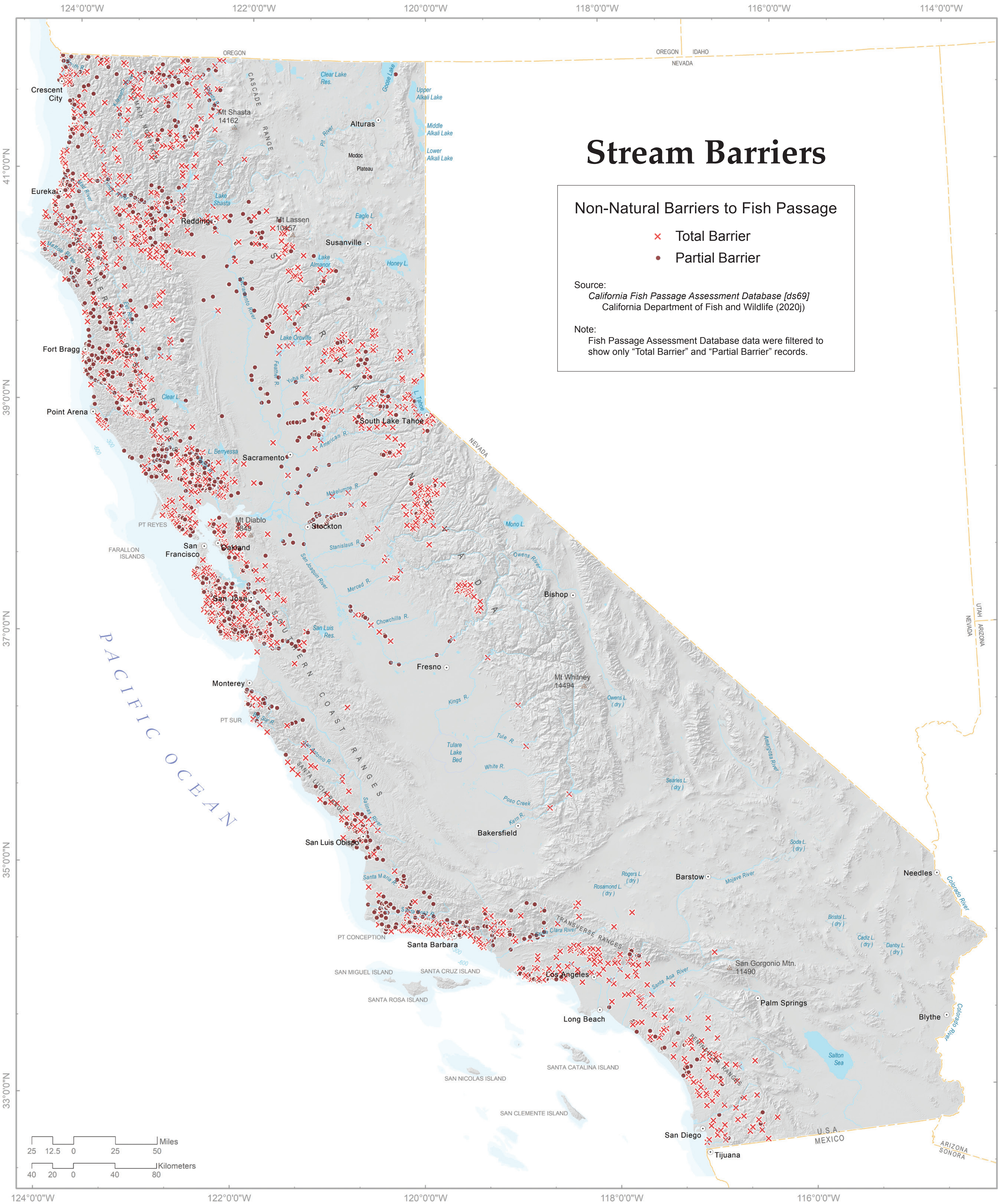
Anadromous fishes like salmon, steelhead, Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*), Pacific Lamprey (*Entosphenus tridentata*), and sturgeon hatch in freshwater rivers and streams, spending their early lives in these systems. Lampreys spend several years in fresh water and make their way to the ocean as adults; the other anadromous fishes migrate to the ocean as juveniles. They feed and grow there, returning as adults to freshwater systems to spawn before dying and completing their life cycles. They require ideal habitat conditions that vary from species to species, but which generally include low-gradient streams for spawning. These habitats were once accessible throughout California but have been partially or fully blocked by human-caused and natural disturbances for at least the last century.

Roads, bridges, and dams were built on public and private lands during the 19th and 20th centuries and water was diverted by various means, creating thousands of barriers that block the passage of anadromous fishes. Consequently, many anadromous fish populations have experienced significant declines and some of these species are now considered threatened or endangered. Man-made barriers include road-stream crossings, irrigation diversions, dams, long concrete channels in urban areas, and many other in-stream structures. Natural barriers include waterfalls, boulders, steep slopes, landslides, logs, and sediment. In some cases, previously installed fish passage structures, such as fish ladders for salmon and steelhead, act as barriers because of poor design or lack of continued maintenance. Some were built without considering the needs of all anadromous fishes and aquatic organisms. These obstacles, especially those created by humans, are one major factor in the decline of anadromous fish populations and represent a continued threat to their survival.

Stream barriers affect adult and juvenile fishes by delaying or preventing upstream migration to spawning habitat and downstream migration to the ocean. Any delays out to the ocean can mean that these fish will not enter the ocean during optimal conditions. Any upstream delays can mean that these fish will either not make it to their spawning grounds in time and will spawn in less than desirable habitat or they will not spawn at all. These barriers impact both adult and juvenile fish by preventing full use of available habitat. Our sport and commercial fisheries depend on these species as a source of income and food; Native American Tribes depend on these species for ceremony and sustenance.

Addressing connectivity has been consistently identified as a high priority, cost-effective approach to protecting and restoring anadromous fish populations. Other habitat restoration activities, like replanting native vegetation to provide shade for juvenile fish, are ineffective if the fish cannot get to the habitat. Reconnecting fragmented habitats and focusing on a multispecies approach that is climate resilient supports both aquatic and terrestrial species migration and is an essential step in species recovery.

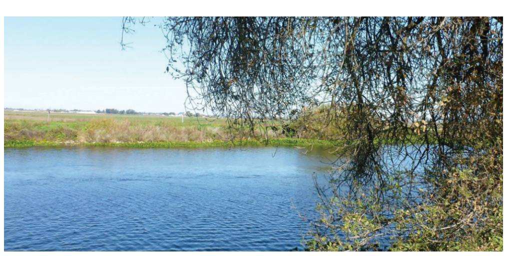



Stream Barriers
Non-Natural Barriers to Fish Passage
Total Barrier
Partial Barrier
Source:
California Fish Passage Assessment Database [ds69]
California Department of Fish and Wildlife (2020j)
Note:
Fish Passage Assessment Database data were filtered to show only "Total Barrier" and "Partial Barrier" records.
124°0'0"W
122°0'0"W
120°0'0"W
118°0'0"W
116°0'0"W
114°0'0"W
41°0'0"N
39°0'0"N
37°0'0"N
35°0'0"N
33°0'0"N
OREGON
IDAHO
NEVADA
UTAH
ARIZONA
U.S.A.
MEXICO
SONORA
PACIFIC OCEAN
Crescent City
Eureka
Redding
Fort Bragg
Point Arena
Sacramento
San Francisco
Oakland
San Jose
Stockton
Monterey
Fresno
Bishop
Alturas
Susanville
South Lake Tahoe
Mt Shasta 14162
Mt Lassen 10457
Mt Diablo 3849
Mt Whitney 14494
San Luis Obispo
Bakersfield
Santa Barbara
Los Angeles
Long Beach
Barstow
Needles
Palm Springs
Blythe
San Diego
Tijuana
San Gorgonio Mtn. 11490
Salton Sea
CASCADE RANGE
Modoc Plateau
SOUTHERN COAST RANGES
TRANSVERSE RANGES
PENINSULAR RANGES
PT REYES
FARALLON ISLANDS
PT SUR
PT CONCEPTION
SAN MIGUEL ISLAND
SANTA CRUZ ISLAND
SANTA ROSA ISLAND
SAN NICOLAS ISLAND
SANTA CATALINA ISLAND
SAN CLEMENTE ISLAND
Miles
25 12.5 0 25 50
Kilometers
40 20 0 40 80

Aquatic Invasive Species

Aquatic invasive species are non-native plants and animals that inhabit aquatic environments all or part of their lives and, when introduced to an area outside of their native range, establish in the new environment and cause harm to the environment, economy, and/or human health. Species that successfully invade new environments can typically tolerate a range of environmental conditions, lack predators in the new environment, and produce numerous offspring that readily disperse. Aquatic invasive species negatively impact California's native and game species by preying upon them; competing with them for food, shelter, and habitat; and possibly introducing and spreading disease. In addition, aquatic invasive species affect the aesthetic and recreational value of the wildlands and waterways throughout the state.

Non-native species introductions can occur naturally, such as when seeds are carried by wind or water, or intentionally or unintentionally by human activity. Until European settlement in the 1700s, California had few non-native species introductions. The earliest transcontinental introductions would have arrived attached to the hulls of ships and carried onboard among the cargo. Over the subsequent 300 years, as human travel and trade has grown and connected distant regions of the world into a global economy, non-native introductions have steadily increased. Today, non-native species are still moved unintentionally on or within commercial ships, on fishing and recreational boats and equipment, and on the vehicles that transport them. As shown on the map, the highest concentrations of invasive species occupy international marine shipping ports, the Sacramento River watershed, and inland lakes. These destinations are frequented by commercial and recreational vessels from around the state, country, and world.



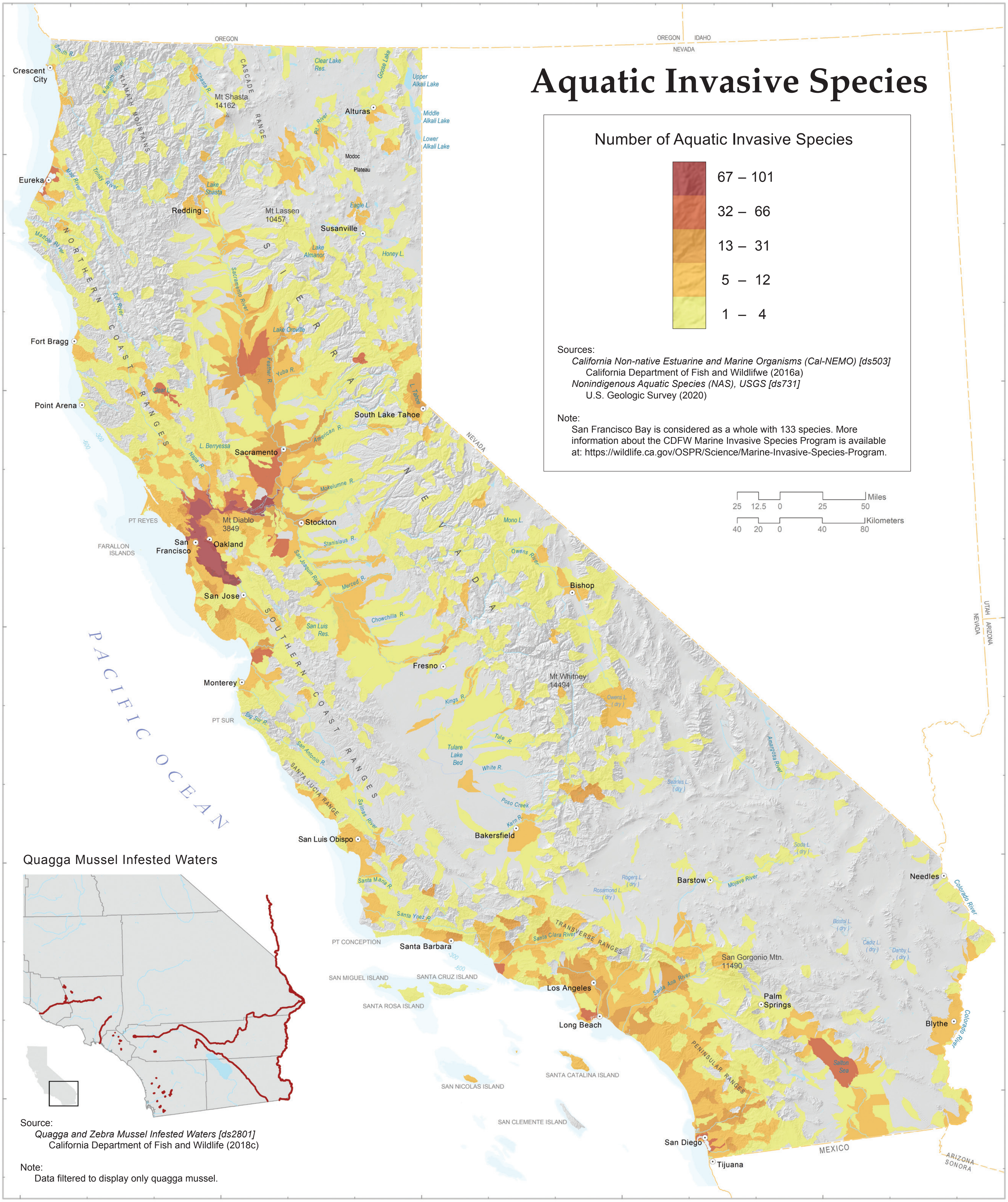
Invasive aquatic plants such as water hyacinth (*Eichhornia crassipes*) form dense blockades of vegetation that alter habitats, impede navigation, clog water intakes, and affect water quality. This waterway was completely blocked by water hyacinth and South American spongeplant (*Limnobium laevigatum*).
Photo: Division of Boating and Waterways, CA State Parks

Quagga mussels attach to the hulls and propellers of recreational watercraft, impairing their operation and potentially moving with them to other waterbodies. Photo: National Park Service

An example of an aquatic invasive species that was unintentionally introduced to California and has resulted in significant harm to the state is the quagga mussel (*Dreissena rostriformis bugensis*). Quagga mussels are freshwater bivalve mussels native to Ukraine. First detected in California waters in 2007, the quagga mussel arrived in the United States in the late 1980s by way of transoceanic shipping into the Great Lakes. Quagga mussels were likely released in the ballast water of ships. Once established, they spread throughout the vast interconnected waterways surrounding the Great Lakes.

In addition to being carried in water, quagga mussels attach to hard surfaces, such as the exterior hulls of boats, and can survive out of water for days, even weeks, by tightly closing their shells. It is likely that a small boat encrusted with quagga mussels was brought from the Great Lakes area on a trailer across the country to Lake Mead, Nevada, where it was launched, introducing quagga mussels to the West. Like the Great Lakes, Lake Mead possessed habitat suitable for the non-native quagga mussel, and it established and proliferated, producing offspring that were carried downstream in the Colorado River and into California. Their relatively small size (ranging from microscopic to the size of a fingernail) and their ability to survive out of water make quagga mussels well adapted to being inadvertently moved from one waterbody into another, furthering their spread. With a few exceptions, quagga mussels have been contained to the Southern California waterbodies that received mussel-infested water, as shown on the map inset to the right. The managers of these waters, and the boaters that use them, continue to take action to clean, drain, and dry their watercraft when leaving these infested waterbodies and have prevented further unintentional spread.

Aquatic Invasive Species



Terrestrial Invasive Species

Much of California has been invaded by yellow starthistle, a non-native plant whose biology enables it to outcompete natives and dominate landscapes.

Terrestrial invasive species are non-native plants and animals that, when introduced to an area outside of their native range, establish in the new environment and cause harm to the environment, economy, and/or human health. Plants are the most common invaders of terrestrial and riparian habitats, with well over 200 species recorded across California's wildlands. The regions of the state most impacted by invasive plants tend to be those areas with the greatest human disturbance due to urbanization, agriculture, and recreation. In addition to plants, numerous non-native insects, birds, mammals, amphibians, and reptiles have become established, negatively impacting California's native species and the habitats upon which they depend.

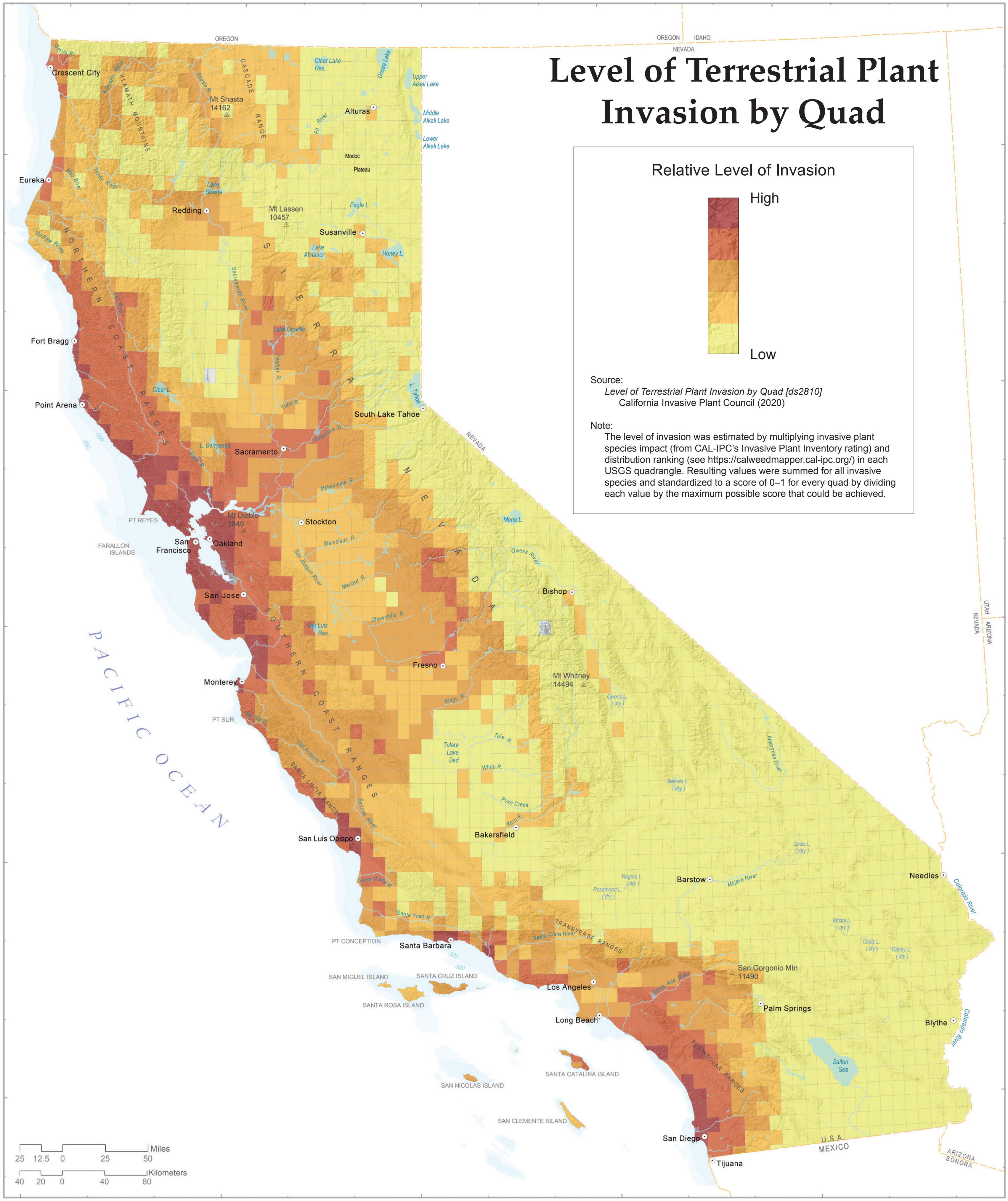
Like aquatic invasive species, there are a variety of ways terrestrial invasive species may be introduced to an environment. Plants, and particularly their seeds, are readily moved unnoticed on shoelaces, in mud embedded in the treads of tires, in harvested crops, and in an infinite number of other human activities. Because many plants are self-pollinating, it can take just one seed or plant fragment moved to a new location to result in a highly impactful invasion.

Nutria (*Myocastor coypus*) rely on both aquatic and terrestrial environments to feed and shelter. Their large populations, voracious appetite for plants, and ability to modify terrestrial landscapes threatens the state's wildlands and water conveyance systems.

Plants that are invasive in California often have some competitive advantage over our native species. These advantages may include earlier germination time, deeper roots, faster growth, higher seed production, an absence of predators, and the ability to produce chemicals that reduce the success of surrounding flora. This advantage may be very slight, but over time it can result in a significant difference in the relative reproductive success of the non-native species compared to the native species. An example of this is yellow starthistle (*Centaurea solstitialis*), a highly invasive plant estimated to have invaded 10–15 million acres across California. You have probably encountered this unpleasant invasive in open spaces and along roadsides, as well as in the state's wildlands. Its flower head bears a cluster of very sharp spines that remain well after the bright yellow flowers have withered and the plant has died.

Starthistle originates in an area with a climate that is similar to California's, so it is not surprising that it does well here. But it has a few extra advantages which have enabled it to be wildly successful. Its seeds germinate earlier than many other plant species and, rather than putting its early growth into the development of leaves, it invests in producing a long root. This root allows it to tap into moisture deep in the soil later in the summer, outcompeting shallow-rooted plants for scarce and much needed water late in the growing season. In addition, starthistle produces many seeds, at least 20 to 120 seeds per plant, but sometimes over 100,000 seeds per plant under optimal conditions. A high percentage of its seeds can successfully germinate the following season and a dense starthistle population is very quickly established. Over the span of years, when non-native species repeatedly outcompete the natives and fewer natives successfully reproduce, the native species may be extirpated, resulting in a loss of native biodiversity.

Non-native invasive plants tend to establish and thrive where plant communities and soil have been disturbed. Disturbances are temporary or long-term changes in the environment and can result from many causes including mowing, scraping or tilling the soil, livestock grazing, wildfires, landslides, and flooding. Disturbances create the opportunity for invasive species to establish in an environment, and from there they can spread. The most effective means for preventing the impacts of invasive species is to prevent their introduction and spread, and to minimize environmental disturbances that they can exploit.



Level of Terrestrial Plant Invasion by Quad
Relative Level of Invasion
High
Low
Source:
Level of Terrestrial Plant Invasion by Quad [ds2810]
California Invasive Plant Council (2020)
Note:
The level of invasion was estimated by multiplying invasive plant species impact (from CAL-IPC's Invasive Plant Inventory rating) and distribution ranking (see https://calweedmapper.cal-ipc.org/) in each USGS quadrangle. Resulting values were summed for all invasive species and standardized to a score of 0–1 for every quad by dividing each value by the maximum possible score that could be achieved.
124°0'0"W
122°0'0"W
120°0'0"W
118°0'0"W
116°0'0"W
114°0'0"W
41°0'0"N
39°0'0"N
37°0'0"N
35°0'0"N
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OREGON
IDAHO
NEVADA
UTAH
ARIZONA
U.S.A.
MEXICO
SONORA
PACIFIC OCEAN
Crescent City
Eureka
Redding
Alturas
Susanville
Fort Bragg
Point Arena
South Lake Tahoe
Sacramento
Stockton
San Francisco
Oakland
San Jose
Monterey
Fresno
Bishop
Mt Whitney 14494
Mt Shasta 14162
Mt Lassen 10457
Mt Diablo 3849
Bakersfield
San Luis Obispo
Santa Barbara
Los Angeles
Long Beach
Barstow
Needles
San Gorgonio Mtn. 11490
Palm Springs
Blythe
San Diego
Tijuana
Modoc Plateau
KLAMATH MOUNTAINS
CASCADE RANGE
NORTHERN COAST RANGES
SIERRA NEVADA
SOUTHERN COAST RANGES
SANTA LUCIA RANGE
TRANSVERSE RANGES
PENINSULAR RANGES
PT REYES
FARALLON ISLANDS
PT SUR
PT CONCEPTION
SAN MIGUEL ISLAND
SANTA CRUZ ISLAND
SANTA ROSA ISLAND
SANTA CATALINA ISLAND
SAN NICOLAS ISLAND
SAN CLEMENTE ISLAND
Salton Sea
Tulare Lake Bed
Colorado River
Mojave River
Miles
25 12.5 0 25 50
Kilometers
40 20 0 40 80

Climate Change

Trends

Climate is defined by prevailing weather conditions, typically averaged over at least 30 consecutive years. The earth's climate has changed throughout history, including long periods of warming and cooling. However, the current warming trend is occurring at an unprecedented rate and is largely due to human activity—namely, the release of large volumes of carbon dioxide and other heat-trapping gases into the atmosphere (IPCC 2014).

Over the past several decades, California's climate has been characterized by rising air temperatures and increasingly frequent heat waves, and extreme events such as droughts and heavy storms have become more common. More precipitation has fallen as rain than snow, which has reduced snowpack and dramatically decreased glacier size (CEPA 2018). This has changed the timing and volume of water runoff from upper elevations. For instance, the Sacramento River's peak runoff now occurs almost a month earlier than during the first part of the century. Recent warming has also exacerbated drought conditions, leading to drier vegetation and an increase in area burned by wildfire (Bedsworth et al. 2018).

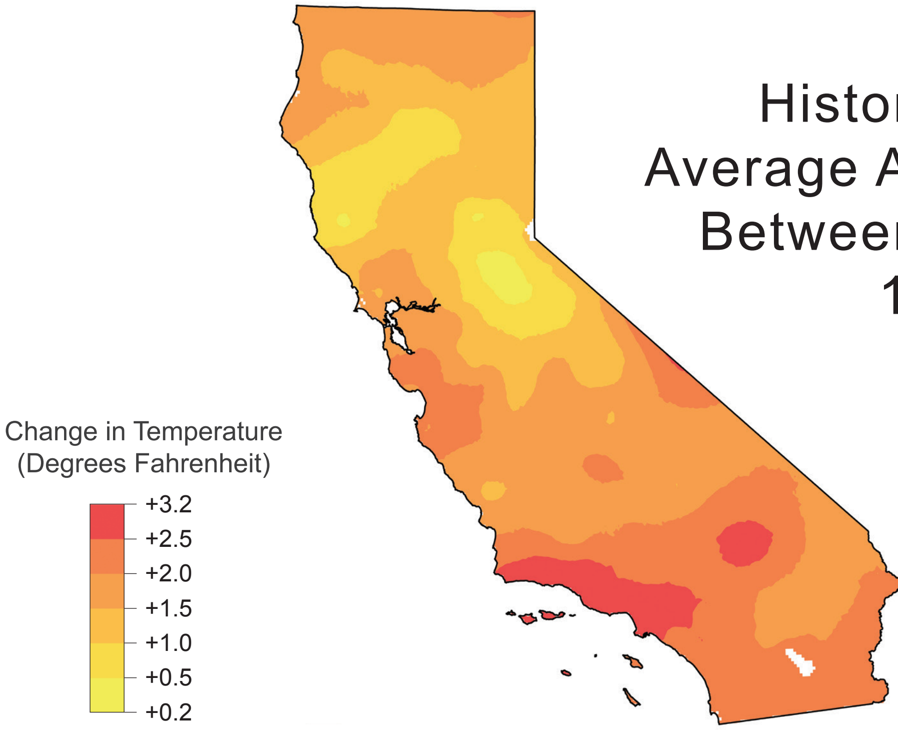
Ocean temperature off the coast of California has risen over the past century and thermal expansion in warming oceans and melting ice sheets and glaciers have contributed to local sea level rise (Sievanen et al. 2018). In addition, the frequency of strong El Niños and extreme ocean heatwaves has increased as the climate has warmed (Oliver et al. 2018). In just the past 40 years, there have been three very strong El Niños and within the past decade, the Northeast Pacific has experienced two extreme marine heatwaves: a multi-year event that extended from fall 2013 through spring 2016 (called The Blob) and a single-year event in 2019 (NOAA 2020).

Over the next several decades, California's average maximum and minimum daily temperatures will continue to increase, snowpack will continue to decline, and wildfire events are expected to increase in frequency with a trend toward more catastrophic, high-intensity fires (see the maps on the following page). Ocean temperatures are expected to rise, important ocean-atmosphere interactions (winds, currents, and coastal upwelling) will likely shift, extreme warm water events will increase, and the ocean's chemistry will change as it absorbs greater amounts of carbon dioxide from the atmosphere (Sievanen et al. 2018). Local sea levels will rise and the resulting inundation in low-lying areas such as around San Francisco Bay will be boosted by increased flooding from extreme storms (Gershunov et al. 2019).

The effects of climate change will not unfold uniformly across the landscape, but will depend on the scale in question (state, region, or locality) and will vary geographically due to differences in topography, elevation, latitude, and proximity to the ocean or other large water bodies.

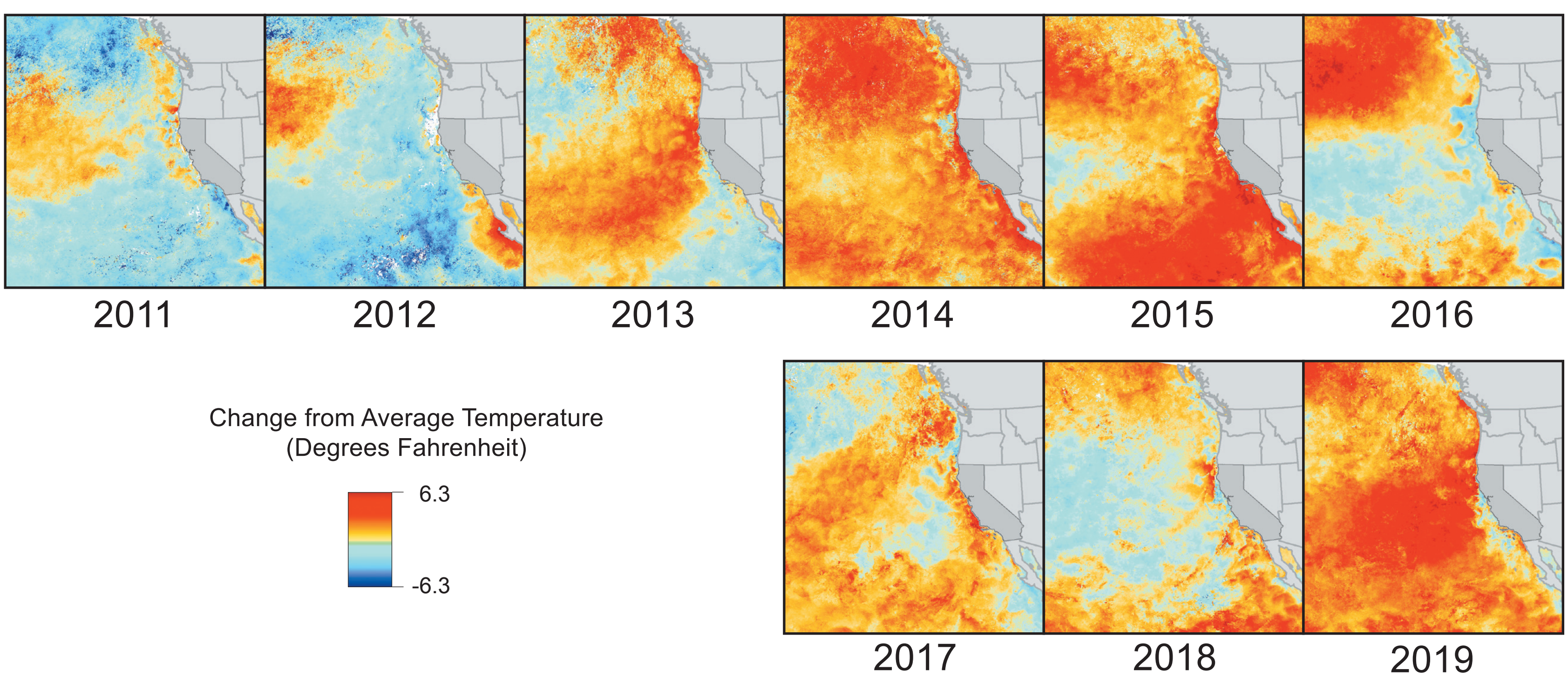
Buttonwillow Ecological Reserve. This area has been studied by the Bureau of Land Management, University of California at Santa Cruz, California Department of Fish and Wildlife, and The Nature Conservancy to document the negative effects of the 2012–2014 drought. Drought events are expected to increase in frequency as the climate changes.
Photo: Mike Westphal, BLM

Historical Change in Average Annual Temperature Between 1901–1960 and 1986–2016



Source:
Observed Changes in Annual Temperatures
Vose et al. (2017)

September Sea Surface Temperature Anomalies (2011–2019)



Source:
September Sea Surface Temperature Anomalies (2011–2019)
Ocean Ecology Laboratory (2019)

Note:
Monthly sea surface temperature (SST) anomalies were created by subtracting long-term averaged SST data from the average SST for each month shown.

Climate Change

Impacts to Biodiversity

Like humans, plant and animal species prefer certain climatic conditions and can tolerate some better than others. When exposed to climatic or environmental conditions beyond a given threshold, species can exhibit signs of physical stress. For example, extreme heat, rising water temperatures, ocean acidification, hypoxia (declining concentrations of dissolved oxygen), and changes in water salinity, can contribute directly to species loss or mortality or may prompt range shifts in the long term.

Range Shifts

Climate change is altering the environmental conditions that determine the distribution and composition of terrestrial and aquatic communities. For instance, as some locations become drier and warmer, vegetation is shifting to higher latitudes and elevations where the prevailing climate conditions are closer to what the vegetation type has experienced historically. Such vegetation changes can lead many mobile species to relocate to more suitable habitat, ultimately shifting their ranges. This movement can bring together species that were not previously in contact, resulting in new predator-prey relationships with cascading effects on food webs. Human-wildlife interactions may also increase as species move into new areas.

Atmospheric and global hydrology changes impact coastal and estuarine habitats and communities. For example, rising sea levels can change inundation periods for saltwater marsh, sandy beach, and rocky shore communities within the tidal zone. Changes in the distribution of species through the tidal zone will depend upon the rate of sea level rise as well as the availability of suitable habitat into which to expand.

Species that struggle to find suitable habitat may face extinction, extirpation, or range contraction. Range shifts have already been observed in California and across the globe.

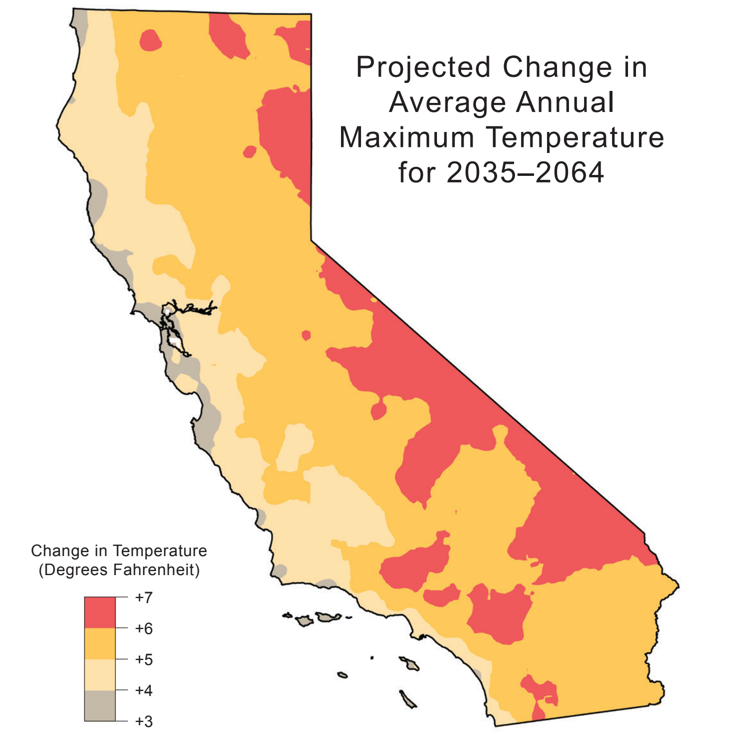
Phenological Events

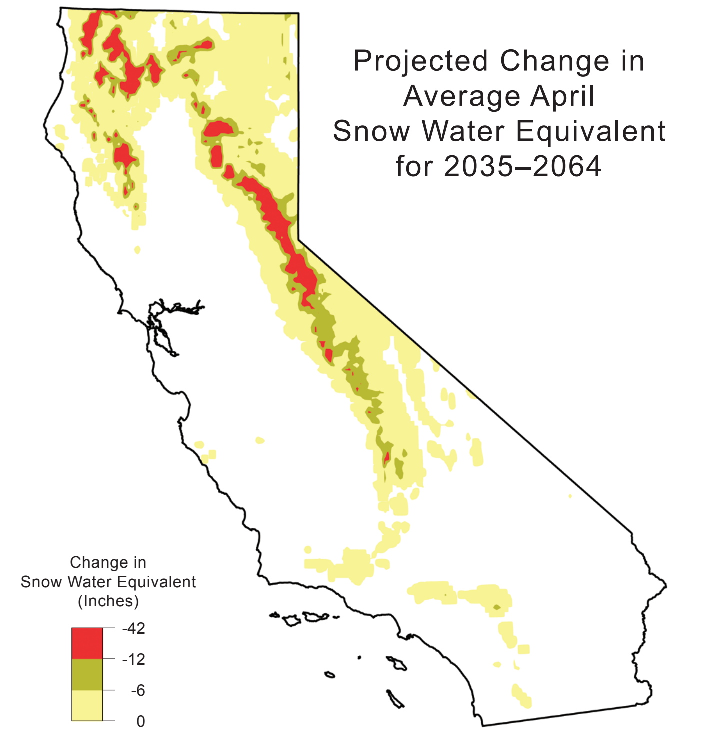
Increasing temperatures can affect the timing of seasonal life cycle events, such as migrations, breeding, pollination, or flowering. These shifts can pose grave challenges for plant and animal species. For example, migrating birds may leave their wintering habitats too early and may encounter harsh weather conditions in their breeding grounds that may negatively affect their body condition and ability to breed successfully. Plants may flower earlier in the spring than usual due to warmer temperatures, but if pollinators are not hatching at the same time, plant reproduction could decline and pollinators' food sources could disappear, damaging what had been a long-standing, mutually beneficial relationship.

In the marine environment, changes in seasonal timing, intensity, and location of upwelling can affect the availability of prey species, which can then impact the growth, spawning, breeding, and survivability of species such as salmon, seabirds, and marine mammals. These upwelling characteristics are projected to change as the climate warms, with some models indicating more upwelling in the northern region of the state and less in the southern region (Rykaczewski et al. 2015). Impacts to species will depend on how well they can respond to these changes, given their respective life histories.

(continued)

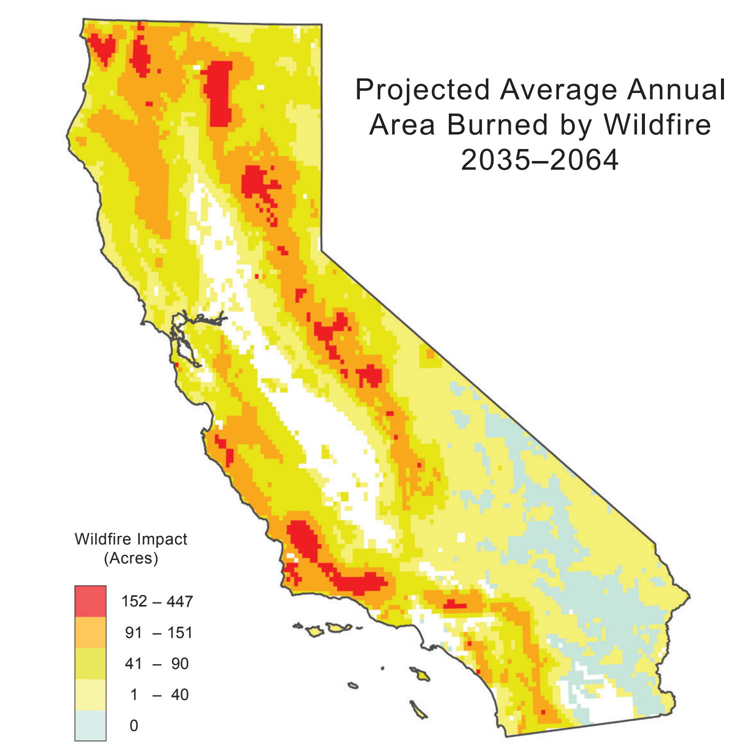
The Woolsey Fire burned 96,949 acres of Los Angeles and Ventura counties in 2018. Severe wildfire events are expected to become more frequent over the next several decades.





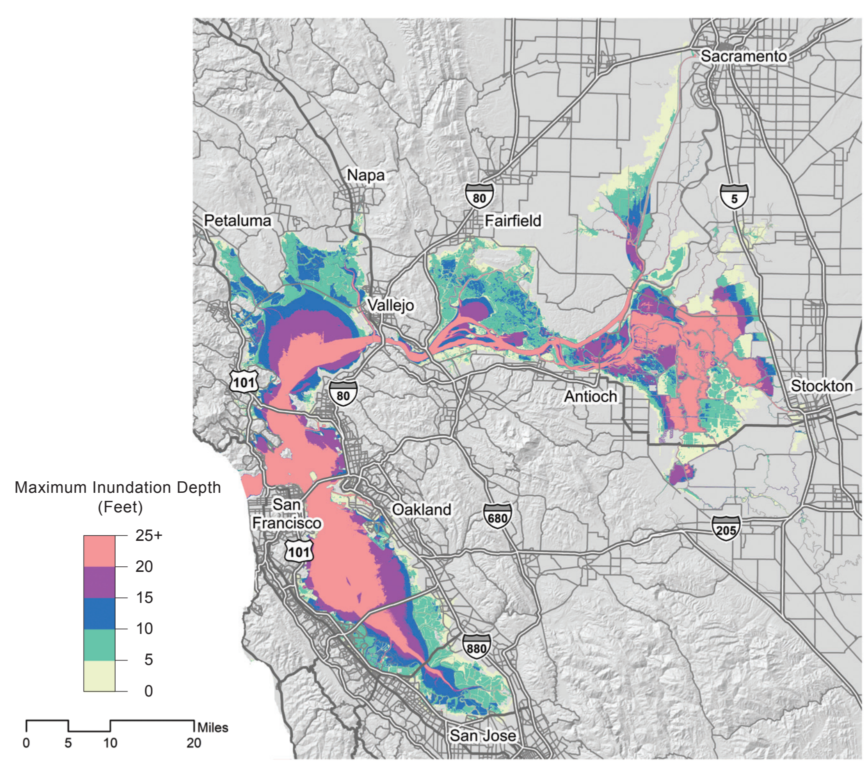
Source:
Projected long-term (30 year) Annual Average Maximum Temperature, Change from Historical Baseline, Mid-Century High Emissions (RCP 8.5), Fahrenheit
Pierce et al. (2018)

Source:
Projected Change in Average April Snow Water Equivalent for 2035–2064, RCP 8.5, 10GCMs (Inches)
Cal-Adapt (2020b)



Source:
Wildfire Simulations for California's Fourth Climate Change Assessment
Westerling (2018)

Projected San Francisco Bay and Delta Inundation



Sources:
Sea Level Rise Inundation Model – Sacramento San Joaquin Delta – UC Berkeley [ds2694]
Sea Level Rise Inundation Model – San Francisco Bay – UC Berkeley [ds2695]
Sea Level Rise Inundation Model – California Coast – UC Berkeley [ds2696]
Radke et al. (2017)

Note:
Maximum inundation depth for a projected sea level rise of 4.63 feet during a 100-year storm.

Climate Change

(continued from page 82)

Landscape and Habitat Fragmentation

As climate change alters vegetation patterns and water quality and availability, a species' habitat may become naturally disconnected, contributing to habitat loss or decline. Continued human population growth and urban sprawl further fragment the landscape by creating physical barriers that block species' movements. Climate-induced habitat fragmentation, exacerbated by physical barriers on the landscape, can lead to the decline of isolated wildlife populations, in part by increasing the potential for inbreeding that limits genetic variation and weakens populations' resilience. Barriers to movement can ultimately become barriers to species survival.

Invasive Species or Pests

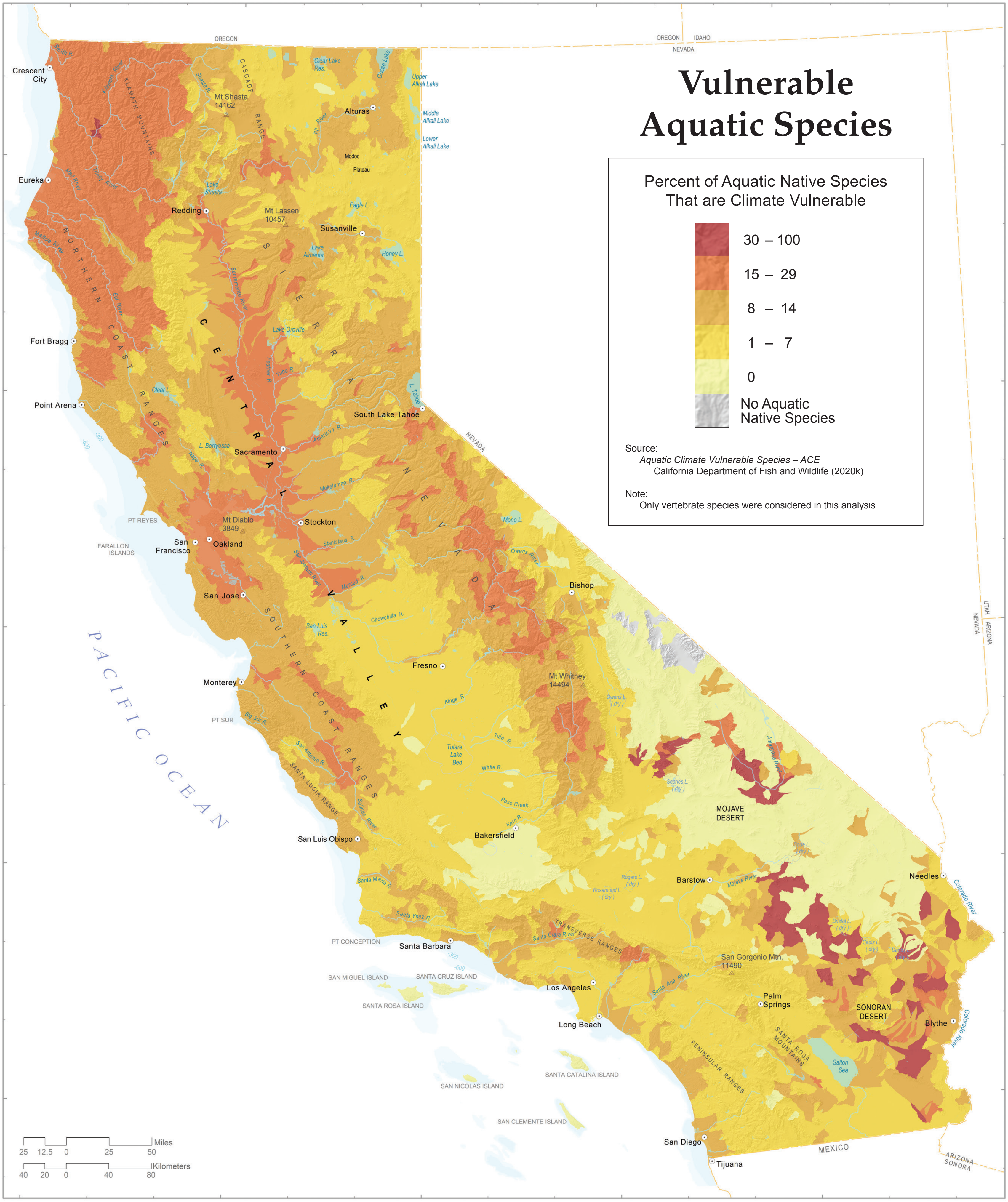
Climatic changes can favor the spread of pests, pathogens, diseases, and invasive species, which already plague many native and endemic species.

Tree mortality in the Sierra Nevada due to severe drought. Trees weakened by persisitent drought conditions are more susceptible to diseases and pests.
Photo: U.S. Forest Service Region 5

The watershed-based map to the right illustrates that vulnerable aquatic species are concentrated in several areas, including the northwest corner of the state where cool, wet conditions are anticipated to shift north and out of the state. Species are most vulnerable in the Sonoran and Mojave deserts because remnant wetlands may dry up as temperatures increase and rainfall becomes less predictable.

Climate change has already affected animals, plants, and other organisms by shifting their abundance, distribution, and migratory, flowering, or mating patterns, and by directly affecting the habitat they depend upon (CEPA 2018):

- In the Santa Rosa Mountains, small shrubs, chaparral, and large conifers have moved upslope toward a cool, wet environment.
- The American pika (*Ochotona princeps*), a species accustomed to high elevations, is experiencing significant range contraction due to reduced snowpack, with limited ability to expand upslope (Stewart et al. 2017).
- Central Valley butterflies are appearing earlier in the spring than in the past.
- Several migratory songbird species have shifted their historical departure dates from wintering grounds and arrival dates at breeding grounds.
- Warmer temperatures have enhanced the bark beetle population, which has killed a record number of coniferous trees in recent decades, increasing wildfire risk in areas such as the southern Sierra Nevada.
- The reduction in snowmelt and cold-water river and stream flows is affecting the Chinook Salmon's (*Oncorhynchus tshawytscha*) egg viability, spawning, and rearing conditions. This has led to increased variability in the annual number of adults returning from the ocean to the Sacramento River.
- A marine heatwave in 2013–2015 resulted in mass strandings of marine mammals and seabirds, documented species range shifts, and the closure of certain commercial fisheries (Cavole et al. 2016).
- Harmful algal blooms flourish in warm water conditions. These can suffocate fish, deplete oxygen in the water, and contaminate seafood and water used for drinking and recreation. Algal bloom occurrence has been increasing in California in recent years, affecting both marine and inland waterbodies.
- Ocean acidification off the coast of California has led to shell dissolution in sea snails and other physiological impacts to marine organisms including abalone, mussels, sea urchins, and crabs (CalOST 2018).
- California Mussels (*Mytilus californianus*) in the rocky intertidal along the north-central California coast died when unusually warm air temperatures occurred during mid-day low tides (Simons 2019). Such events are expected to increase as the climate warms.


Vulnerable Aquatic Species
Percent of Aquatic Native Species That are Climate Vulnerable
30 – 100
15 – 29
8 – 14
1 – 7
0
No Aquatic Native Species
Source:
Aquatic Climate Vulnerable Species – ACE
California Department of Fish and Wildlife (2020k)
Note:
Only vertebrate species were considered in this analysis.
124°0'0"W
122°0'0"W
120°0'0"W
118°0'0"W
116°0'0"W
114°0'0"W
41°0'0"N
39°0'0"N
37°0'0"N
35°0'0"N
33°0'0"N
OREGON
IDAHO
NEVADA
UTAH
ARIZONA
MEXICO
ARIZONA SONORA
PACIFIC OCEAN
Crescent City
Eureka
Fort Bragg
Point Arena
Redding
Alturas
Susanville
Sacramento
South Lake Tahoe
Stockton
San Francisco
Oakland
San Jose
Monterey
Fresno
Bishop
Bakersfield
San Luis Obispo
Santa Barbara
Los Angeles
Long Beach
San Diego
Tijuana
Barstow
Needles
Palm Springs
Blythe
Mt Shasta 14162
Mt Lassen 10457
Mt Diablo 3849
Mt Whitney 14494
San Gorgonio Mtn. 11490
KLAMATH MOUNTAINS
CASCADE RANGE
NORTHERN COAST RANGES
CENTRAL VALLEY
SIERRA NEVADA
SOUTHERN COAST RANGES
SANTA LUCIA RANGE
TRANSVERSE RANGES
PENINSULAR RANGES
SANTA ROSA MOUNTAINS
MOJAVE DESERT
SONORAN DESERT
Modoc Plateau
PT REYES
FARALLON ISLANDS
PT SUR
PT CONCEPTION
SAN MIGUEL ISLAND
SANTA CRUZ ISLAND
SANTA ROSA ISLAND
SAN NICOLAS ISLAND
SANTA CATALINA ISLAND
SAN CLEMENTE ISLAND
Salton Sea
Miles 25 12.5 0 25 50
Kilometers 40 20 0 40 80

Climate Change

Many threats to ecosystems are interrelated and the impacts may not become obvious until they are severe. Seemingly negligible effects of climate change on a species may ultimately alter an entire food chain. As the effects of these environmental changes compound, ecological tipping points may be reached, leading to rapid declines in ecosystem health and to species loss or extinction. For example, a healthy Bull Kelp (*Nereocystis luetkeana*) forest shifted to a purple urchin barren due to a catastrophic decline in kelp from a multi-year extreme warm water event and grazing from an increasing number of Purple Sea Urchins (*Strongylocentrotus purpuratus*) (Rogers-Bennett and Catton 2019). This resulted in a major decline in other species that rely on kelp, such as the Red Abalone (*Haliotis rufescens*) and the Red Sea Urchin (*Mesocentrotus franciscanus*). Just prior to this warm water event, a pivotal urchin predator, the Sunflower Sea Star (*Pycnopodia helianthoides*), experienced declines due to a sea star wasting disease. Low abundances of urchin predators and increased potential for warm water events under climate change may limit this system's ability to shift back to a kelp forest.

Recent observations have linked changes in the migratory patterns of Central Valley butterflies such as the painted lady (*Vanessa cardui*) to climate change. CDFW Photo: Annie Chang

Certain species and habitats are resilient to the effects of climate change and could potentially benefit from it, while others remain vulnerable. A species' vulnerability is determined by its exposure to projected changes, its biological sensitivities to those changes, and its ability to adapt. Species that require highly specific habitat conditions will likely have a harder time adapting to change than those that thrive under a wide variety of conditions. The map at right shows widespread vulnerability for terrestrial vertebrates, with an especially high proportion in the higher elevations where upslope movement is impossible. Species in coastal areas are also vulnerable due to sea level rise and the inability of their habitats to shift inland past existing infrastructure.

California Mussels (*Mytilus californianus*) within the rocky intertidal can be exposed to detrimental conditions such as unusually warm air temperatures during mid-day low tides. Photo © Claudia Makeyev

Prolonged climatic change will amplify the impacts discussed above and create ongoing challenges to the management and conservation of California's natural resources. Restoration, conservation, scientific research, and monitoring activities that inform adaptive management can help increase the resilience of natural lands to climate change. Restoration and protection activities can also increase the ability of natural lands to capture and store carbon, helping to mitigate climate change. A balanced portfolio of these actions will support robust, resilient ecosystems that are better equipped to adapt to the altered environmental conditions caused by climate change.

Migratory songbirds like Wilson's Warbler (*Cardellina pusilla*) are arriving at breeding and wintering grounds at different dates than historically observed.

Vulnerable Terrestrial Species