Title
Natural History of the Central Coast Bioregion

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Central Coast oak woodland landscape. *Photo*: Bruce Lyon

Natural History of the Central Coast Bioregion

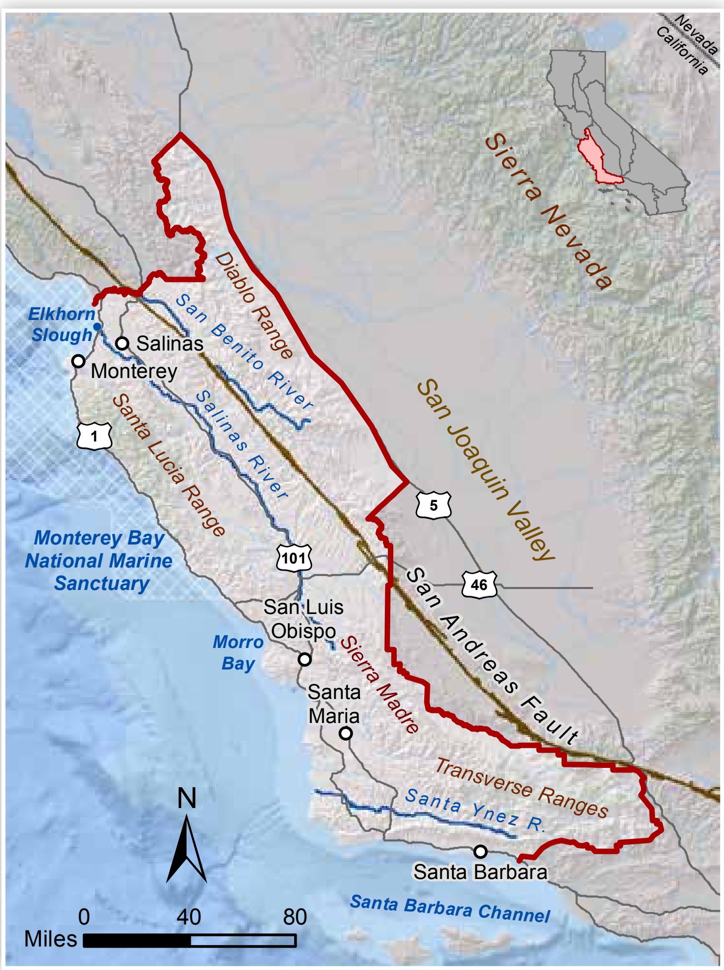
It is advisable to look from the tide pool to the stars and then back to the tide pool again.

— John Steinbeck, from The Log from the Sea of Cortez

Whether one drives the Big Sur coastline, or stands at the foot of a giant coast redwood (*Sequoia sempervirens*) or in the shade of an ancient valley oak (*Quercus lobata*), it is clear that California's Central Coast Bioregion embodies exceptional biological diversity and natural beauty. Extending from the southwest corner of San Joaquin County south to northern Ventura County, the bioregion is bounded on the west by the Pacific Ocean and on the east by the San Joaquin Valley, Carrizo Plains, and the interior Transverse Ranges. Across the bioregion's 15,000 square miles (9% of California's area), physical and biological processes, combined with time and human actions, have resulted in a broad range of ecosystems, each harboring distinct assemblages of plants and animals.

Similar to most California regions, the current human inhabitants of the Central Coast Bioregion are concentrated in urban areas. However, much of the rural environs are working landscapes dominated by livestock grazing and farming, with interspersed areas devoted to open space conservation and nature-based recreation. Examples of natural attractions include iconic oak-studded rangelands, Monterey Bay, and the rugged splendor of the Big Sur coastline. The biodiversity of these fascinating environments is threatened by exurban development, agricultural expansion, and increasingly by climate change. The conservation challenges are formidable, but creative measures are being developed and implemented to sustain both biodiversity and the livelihoods of the bioregion's residents.

Rocky shoreline at Big Sur. *Photo*: Bruce Lyon



Physical geography of the Central Coast Bioregion. *Source*: R. Johnson, UC ANR IGIS Program

PHYSICAL ATTRIBUTES

Geology

The Central Coast Bioregion lies mainly within the Southern Coast Ranges, with its southernmost extent encompassing the western portion of the Transverse Ranges. Most of the region is comprised of rolling and hilly topography with scattered areas exhibiting very steep slopes. Average elevations are generally below 3,000 feet. However, more prominent highlands are found in the Transverse Ranges, which contain over three dozen summits that surpass 6,000 feet in elevation. One of these is Mount Pinos at 8,831 feet. It is the tallest mountain in the bioregion. Impressive uplands are also encountered in the Santa Lucia, Caliente, San Rafael, and Diablo mountains. Of these, the loftiest are in the Santa Lucia Mountains, which rise abruptly from the Big Sur coast to elevations exceeding 5,000 feet.

The bioregion's surface landforms are primarily sedimentary in content with varying intermixtures of metamorphic and igneous rock materials. With the exception of the Transverse Ranges, the mountains and intervening valleys trend in a northwest-to-southeast direction. The Southern Coast Ranges are geographically divided into three linear belts that roughly align with the overall structural orientation. Each is distinguished according to surface rock content and delineating fault lines. In the northern portion of the bioregion, lying between the San Joaquin Valley and the San Andreas Fault, is the eastern belt. It is largely composed of a geological formation called the Franciscan Assemblage. Folded metamorphic (e.g., schist and serpentine) and sedimentary rocks (e.g., sandstones and shales with some limestone) are the principal components. To the west of the San Andreas Fault is the central belt, or the Salinan Block. This formation possesses a core of granitic and metamorphic materials that are overlaid by younger sediments. The Sur-Nacimiento Fault defines the belt's western edge, and between it and the coast is found the Nacimiento Block. Here Franciscan crustal materials are once again foremost; however, they contain more surface igneous (i.e., volcanic) features than the interior regions.

The western extension of the Transverse Ranges constitutes the southern reaches of the bioregion, and their structural orientation contrasts with the Southern Coast Ranges. That is, they have more of an east to west alignment than the highlands to the north. Although the Santa Ynez Fault separates the Transverse Ranges from the Southern Coast Ranges, both share some geologic properties. For example, Salinan Block and Franciscan rock materials are well represented in the western Transverse Ranges.

Soils

Soils of the bioregion are mainly residual, having formed in place through the decomposition of underlying rock material. Soil depth (measured to bedrock) varies and is a factor that strongly influences associated plant communities. With sufficient moisture, the majority of the soils in the drier interior are adequate to support grasslands, shrublands, and woodlands. An exception to this pattern is found on higher ridges, where slopes are steeper. These environs tend to have shallow soils and are more conducive to supporting grass and shrub communities. Closer to the coast where rainfall is higher, soils are typically deeper and nurture a striking mosaic of grassland, chaparral, woodland, and riparian communities.

Serpentine soils produce unique plant assemblages. Predominant plants shown here are goldfields and purple needlegrass, a perennial native bunchgrass that thrives on serpentine soils. *Photo*: Matt Ritter

In contrast to the soils on hilly land, stream floodplains and deltaic plains are largely composed of depositional or alluvial soils. These materials are usually deeper and more fertile than those found on adjacent uplands and are well represented in the floodplains and deltas of the Salinas, Santa Maria, and Santa Ynez rivers. Not surprisingly, they are used extensively for orchards, vegetable crops, vineyards, and grazing.

These comprehensive soil patterns are punctuated in places by parent materials exhibiting chemistries that produce unique soil and vegetation communities. Perhaps most renowned in this respect are serpentine soils, which are more abundant in the western areas of the bioregion. They contain large concentrations of heavy metals and a deficiency of the more common plant nutrients. Consequently, areas with serpentine soils are easily distinguished from adjacent communities by plants that have managed to adapt to these unusual soils, such as San Luis Obispo sedge (*Carex obispoensis*), serpentine manzanita (*Arctostaphylos obispoensis*), leather oak (*Quercus durata*), and Sargent cypress (*Hesperocyparis sargentii*).

Climate

The climate of the Central Coast Bioregion is quintessentially Mediterranean. It is characterized by cool, rainy winters with occasional snowfall on the higher peaks and warm to cool rainless summers. In addition to this general climatic pattern, the region experiences periodic El Niño–La Niña cycles that alternate between wetter than average and drier than average conditions.

Moisture-bearing storms originate offshore and bring precipitation that varies according to topography, latitude, and distance from the coast. Average annual precipitation for the entire bioregion hovers around 20 inches, with coastal highlands receiving significantly more. For instance, in the north near Monterey, yearly precipitation at the higher elevations in the Santa Lucia Mountains can surpass 50 inches.

Average annual precipitation also typically declines from west to east. This pattern is strongly influenced by elevational differences within the Transverse and Southern Coast ranges. In essence, the western, or windward, sides of highlands receive more precipitation than the downwind, or lee, slopes and lowlands. This topographic and moisture pattern repeats itself across the bioregion. A west-to-east transect along the boundary between Monterey and San Luis Obispo counties is a case in point. At the western end, lowland precipitation averages between 20 and 24 inches and generally declines toward the east. Within this trend, however, rainfall fluctuates according to elevation. As an example, the intervening Salinas Valley is drier (10 to 12 inches) than its bracketing highlands. Finally, at the eastern edge of the bioregion, rainfall averages only 6 to 8 inches.

Geographic variability in annual precipitation is more variable than the spatial differences in annual temperatures. For most of the bioregion's territory, average annual temperatures are between 55° and 60°F. Lower annual averages of between 50° and 55°F characterize mountainous regions on the northern coast. The coolest annual averages of between 40° and 50°F are typical at the higher elevations in the western Transverse Ranges of Santa Barbara and Ventura counties. In general, coastal environments are more moderate and display less daily and seasonal temperature variation than inland regions. As an illustration, average daily maximum temperatures in Morro Bay range from 62°F in January to 69°F in October. In comparison, Paso Robles, which is located 20 miles inland, has average daily maximums ranging from 59°F in January to 94°F in July.

Over the course of a winter, temperatures of 32°F and below occur on occasion and happen with a greater frequency inland from the coast. For the majority of the bioregion, the first day of freezing temperatures normally takes place during the last week of November or later. In turn, the last day for frost typically occurs in late February and early March. The outcome is a frost-free growing season of approximately 250 days. The exceptions are along and directly inland from the Big Sur coastline and at higher elevations in the Transverse Ranges, where the growing season is 3 to 4 weeks shorter. It has increased by over 15 days during the last 100 years due to climate change, and this trend is expected to continue.

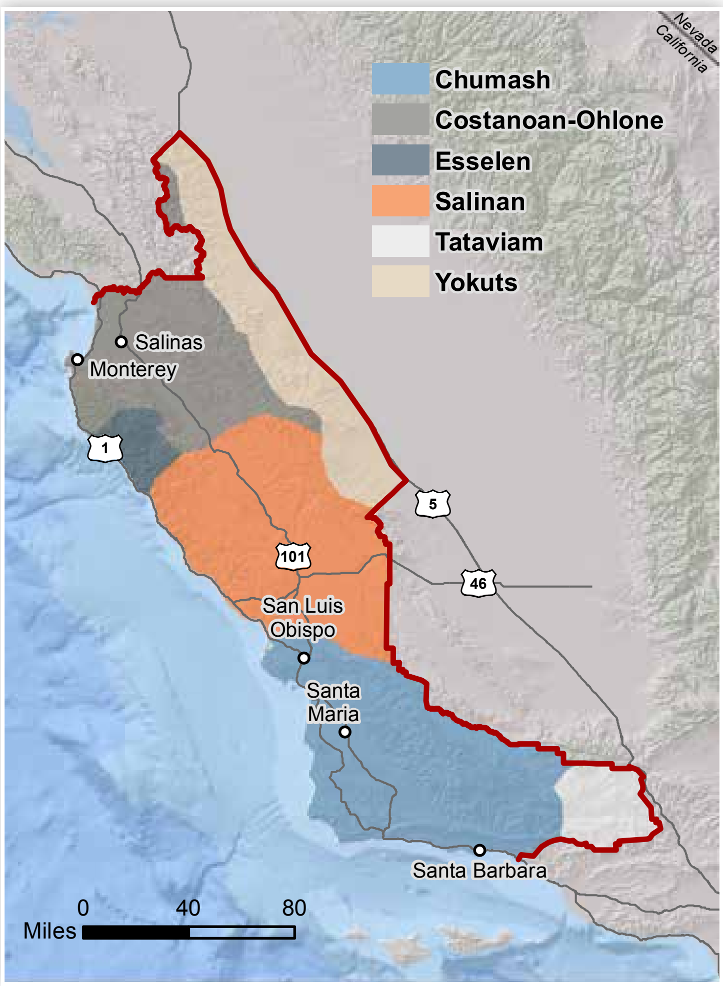
Hydrology

The location, size, and hydrology of the bioregion's major watersheds are determined mainly by precipitation and topography. Perennial and intermittent streams, along with reservoirs, comprise the surface hydrology. Perennial streams are characterized by year-round flow in all or in parts of the channel. On the other hand, intermittent streams have surface water only during the wet season and have dry beds for the remainder of the year. Perennial streams and their tributaries drain most of the highlands near the coast. Conversely, the smaller waterways located on the comparatively dry eastern side of the region are predominantly intermittent.

Larger watercourses include the Pajaro, San Benito, Salinas, Santa Ynez, and Nacimiento rivers. The Salinas River and its tributaries drain the largest watershed in the bioregion. The main channel flows northwest for roughly 170 miles before emptying its water, sediments, and nutrients into Monterey Bay. Inland standing water bodies are nearly all artificial reservoirs. The exceptions are Zaca Lake in Santa Barbara County and a number of coastal ponds, like Osos Flaco Lake in San Luis Obispo County. Some of the largest reservoirs are Lake San Antonio, Lake Nacimiento, Lake Cachuma, Lopez Lake, Pyramid Lake, and San Luis Reservoir.

Biogeography

Variation in surface topography, microclimates, hydrology, and soils largely accounts for the distribution and diversity of terrestrial biological communities. Accordingly, the more moisture-dependent mixed hardwood-conifer forests are found predominantly in the northern coastal highlands and at higher elevations in the Transverse Ranges. In comparison, grassland, shrubland, and oak woodland are foremost at lower elevations and in the interior of the region. Owing to its central location and diverse environments, the bioregion also shares species more commonly encountered in adjacent territories to the south and north. For example, due in large measure to the north-south moisture gradient, the bioregion encompasses the northern range limit of the western patch-nosed snake (*Salvadora hexalepis*) and the southern range limit of the coast redwood.



Indigenous populations who lived in the Central Coast Bioregion when Europeans arrived. *Source*: R. Johnson, UC ANR IGIS Program

HISTORY

Native Californian Period (circa 14,000 years ago to 1769)

People have been an ecological component of the Central Coast Bioregion for over 10,000 years. Although little is known about the earliest occupants, the native populations and their life ways as first encountered by Europeans are better understood. At contact, the majority of the northern area of the region was home to Costanoan-Ohlone and Esselen speakers, while in the south, Salinan- and Chumash-speaking peoples were preeminent. Yokuts and Tataviam were also present along the eastern periphery of the bioregion.

The native peoples adapted to the bioregion's varied environments through a hunting and gathering economy. However, they did not simply rely on natural processes to provide sustenance. Instead, selective habitats were expertly managed to increase and sustain plant and animal resources. Among the land-use practices implemented were transplanting, pruning, weeding, and the application of fire. Deliberate burning was an especially important tool employed in every major plant community in the bioregion. Among the benefits were the expansion and improvement of preferred floral resources, including seed plants like chia (*Salvia columbariae*) and clovers (*Trifolium* spp.). Fire was also applied to improve basket-making materials, with Santa Barbara sedge (*Carex barbarae*) being an example. Burning improved and maintained the health of oak trees and nurtured habitats for favored game animals, in particular brush rabbits (*Sylvilagus bachmani*), black-tailed deer (*Odocoileus hemionus columbianus*), and tule elk (*Cervus canadensis nannodes*).

Owing to the scale and duration of indigenous land-use practices, many landscapes of the bioregion were altered. Favored habitats spread at the expense of others, and while a selection of terrestrial and aquatic animals expanded in numbers and range, others were diminished. There is little doubt that modifications to the bioregion's plants and animals by indigenous peoples lingered long after the arrival of foreign peoples and exotic biota.

Beginning with the colonial period, exotic grasses and forbs spread throughout the Central Coast Bioregion. *Photo*: Matt Ritter

Colonial Period (1769 to 1848)

Beginning in the 1500s, European explorers periodically visited the Central Coast Bioregion. These arrivals did not occur without biological consequences. Old World plants and human diseases were likely introduced with varied outcomes for native inhabitants and biotic habitats. Beginning in 1769, colonial peoples established settlements and initiated new land-use practices that were accompanied by increased introductions of exotic diseases, plants, and animals. Accordingly, native populations and their environmental stewardship steadily diminished.

The ensuing impacts of alien species were rapid and caused substantial biological disruptions. Prominent among these introductions were Mediterranean forbs and annual grasses, including *Avena* and *Bromus* species. By the end of the colonial period (1769 to 1848), the spread of Mediterranean annuals had extensively altered the content and distribution of the native herbaceous communities. Furthermore, due to the reduction of managed fires previously set by indigenous peoples, forestland and woodland understory shrubs increased in some places, while elsewhere, owing to livestock grazing and wildfire, they decreased. Populations of certain terrestrial and aquatic animals were also significantly impacted. In particular, fur hunters markedly depleted southern sea otter (*Enhydra lutris nereis*) populations in the majority of the bioregion's coastal environs. In contrast, because of the decline of native peoples and the abundant food provided by livestock, for a short period California grizzly bears (*Ursus arctos californicus*) expanded in numbers and range (see California Grizzly sidebar on next page).

Large valley oak tree being removed to make room for the Atascadero Colony, circa 1915. *Source*: Atascadero Historical Society

American Period (1848 to present)

Following the colonial period, human impacts on the bioregion's environments intensified and became ever more varied. The American period was and is characterized by introductions of additional exotic species and a rapid increase in human occupants. Expanding cultural infrastructure, new economies and institutions, and the intensification of farming practices have substantially altered the ecology of the bioregion.

A brief review of the consequences to oak woodland provides an example of the widespread changes that occurred during the American period. The expansion of towns, agricultural activities, and infrastructure resulted in large-scale tree removal. Trees were also cut for construction materials and fuel. In fact, by the 1880s, the heart of the bioregion in northern San Luis Obispo County gained notoriety for its production of charcoal. The industry thrived for over half a century and produced charcoal for West Coast restaurants, brick-making kilns, and briquettes. For a short time, local charcoal was even used in the production of gunpowder. As a result, trees over thousands of acres of oak woodland were cut. However, most of the remaining stumps from these trees have sprouted multistemmed regrowth. Finally, government-sponsored programs contributed to the removal of oak trees. Between 1945 and 1975, for instance, ranchland owners were paid to remove oaks to improve forage for livestock.

Beginning in the mid-1970s, exurban and intensive agricultural development became increasingly prominent in removing oak woodland habitat. These undertakings are rendering large contiguous woodland habitats into smaller, isolated pieces—a process known as habitat fragmentation. Additional issues regarding the health and extent of oak woodlands include tree regeneration, sudden oak death disease, and climate change. In total, these threats to the vitality of the bioregion's oaks warrant concern and attention.

California Grizzly

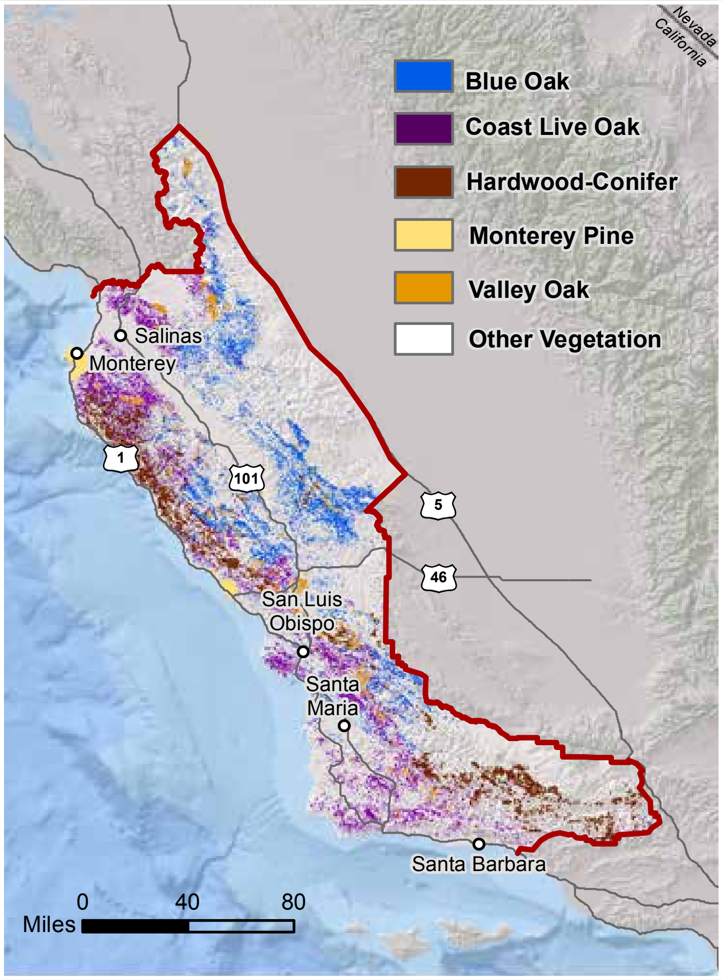
In 1602, the first known written description of a California grizzly bear was recorded by the Sebastián Vizcaíno expedition. It was not until the Portola expedition of 1769 and 1770 that additional accounts of the California grizzly appear. Several chroniclers on this trek made note of these magnificent bears, most being encountered in the Central Coast Bioregion. Of course, the native peoples were already very familiar with grizzly bears. During the preceding millennia, people and grizzly bears were the bioregion's top predators. Both the bears and people were omnivores, sought similar resources, and cohabited every terrestrial environment in the region. Native peoples were respectful of these bears, yet often hunted them. Using their knowledge, skills, dogs, and technologies, they restricted bear numbers and effectively excluded them from their settlements and favored resource settings.

Throughout the colonial period and for a short time afterward, grizzly bears were hunted for sustenance and sport. Of reknown was the exploitation of grizzlies for public entertainment. In this regard, bears were sometimes captured by vaqueros and exhibited in an arena where they fought to the death with bulls. A number of hunters in the bioregion slew dozens in one day and up to 200 over the span of a lifetime.

Vaqueros roping a California grizzly destined for combat with a bull in a public arena. This James Walker painting (1877) depicts a scene from Ranchero Santa Margarita in San Diego County. *Source:* Denver Art Museum

By the 1850s, human populations in California had increased to the point that hunting pressure and habitat loss began to overwhelm the grizzly. Bears were rapidly removed from the environs of settlements, crops, and pasturelands. It was not long before these animals were entirely eradicated from the Central Coast Bioregion; the last confirmed bear kill was in 1912 in northern Santa Barbara County. For the state in general, the last credible slaying of a grizzly occurred in 1922 in the southern Sierra Nevada Mountains. Nevertheless, unconfirmed sightings of these bears continued for a short time afterward, including one alleged sighting in 1924 in the Sierra Madre Mountains, Santa Barbara County.

Although grizzly bears are no longer a living component of the bioregion, or of California for that matter, conservation biologists have recently discussed the pros and cons of reintroducing the grizzly bear to portions of the Sierra Nevada Mountains and the Sespe Wilderness. Perhaps the story of the California grizzly bear is to be continued.



Predominant vegetation types in the Central Coast Bioregion. *Source*: R. Johnson, UC ANR IGIS Program

Valley oak woodland at Fort Hunter Liggett, Monterey County. *Photo*: Matt Ritter

TERRESTRIAL VEGETATION TYPES

Oak Woodland

Oak woodland is the most extensive vegetation community within the Central Coast Bioregion. Fifteen of the twenty-one native oak species in California are found within the region. And, of the seven oak species that are endemic to the state, six occur here. Approximately half of the oaks are tree sized. The remaining species are better described as shrubs. The shrub-sized oaks, for instance the California scrub oak (*Quercus berberidifolia*), rarely surpass 20 feet in height. In contrast, some tree-sized oaks, such as the valley oak, can attain a height of over 150 feet.

The most common tree-sized oaks in the bioregion are valley oak, blue oak, coast live oak, and canyon live oak. These and other oak trees are broadly distinguished by leaf shape; by whether they are deciduous or evergreen; by bark and wood structure; and by whether their acorns ripen in 1 or 2 years. Nonetheless, every oak species shares some characteristics. All are monoecious, that is, female and male flowers occur on the same tree. Minute female flowers are accompanied by the more prominent dangly catkins that release their pollen to the wind. Not surprisingly, the bioregion's season of oak pollination coincides with its hay fever season. Oak trees are the foundation of the largest assemblage of wildlife of any broad vegetation community in the bioregion: 145 bird, 94 mammal, 36 reptile, 22 amphibian, and thousands of invertebrate species have been catalogued in these environments.

Valley oak (*Quercus lobata*) ranks among the largest of the 91 oak species in the United States and Canada. Colloquial names are California white oak and swamp oak, the latter from the tree's preference for rich, moist alluvial soils. It is distinguished by deciduous, deeply lobed leaves, twisted branches, and deeply furrowed bark. As they mature, the exceptional size of valley oaks makes them an especially important habitat. Their extensive foliage and rutted bark harbor many invertebrate and small vertebrate species. Last but not least, the tree's acorns provide both animals and people with sustenance. Indeed, for an individual wishing to quickly fill a bucket with acorns for cookies, this tree is a good choice.

Much of the once-extensive valley oak woodland has been cleared for agricultural, urban, and infrastructure development. In the remaining woodlands, valley oaks are experiencing poor regeneration. Among the causes are naturalized annual grasses. They are more efficient than their native counterparts at extracting soil moisture, and they increase competition for water during hot, dry summers. In addition, exotic and native herbivores, typified by cattle, grasshoppers, California ground squirrels (*Otospermophilus beecheyi*), pocket gophers (*Thomomys bottae*), wild pigs (*Sus scrofa*), and black-tailed deer, feed on the roots, stems, and leaves of seedlings and young trees. Given protection and some water, however, home-grown plantings can grow fast and help sustain these iconic trees.

Blue oak woodland in south San Luis Obispo County. *Photo*: Matt Ritter

Coast live oak woodland. *Photo*: Matt Ritter

Blue oak (*Quercus douglasii*) is the most drought tolerant of the tree-sized oaks. It is especially common on hillsides overlain with shallow soils derived from sedimentary parent materials. Hence, blue oak is also informally called hill oak and rock oak. The more customary name, blue oak, relates to the bluish cast of newly flushed leaves. Similar to valley oaks, leaves are deciduous and the tree yields annual acorn crops. Unlike the bark of valley oak trees, blue oak bark is flaky and not furrowed. Dubbed "ancient oaks" by D. W. Stahle (University of Arkansas), they grow slowly and for a long duration. As a matter of fact, some blue oaks in the bioregion approach 500 years in age, having started their ascent toward the sun around the time Columbus first reached the Americas in 1492.

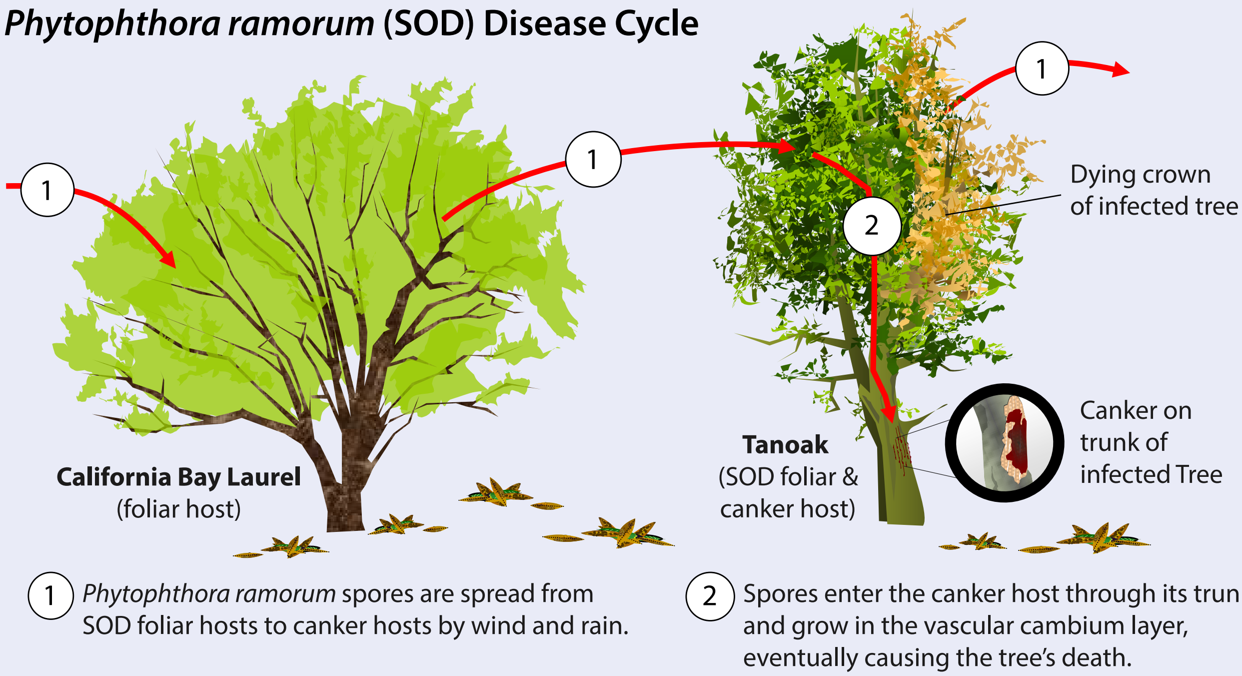
Coast live oak (*Quercus agrifolia*) thrives closer to the bioregion's coastline than either blue or valley oak; it is simply better adapted to the cooler, windier, and foggier coastal conditions than other oak trees. Retaining its foliage throughout the year counterbalances the relatively poor photosynthetic properties of the oak's thick, waxy leaves. This evergreen tree provides cover and food throughout the winter for animals that feed on leaves and the insects they shelter. Colloquial names include Encino oak, California live oak, and coastal oak. Inland from the shore, coast live oak intermingles as scattered trees among blue and valley oak. However, on moist slopes and canyon bottoms the species can form thick, homogenous stands. Depending on soil, aspect, and rainfall, mature trees can vary in age from 75 to 200 years. Once mature, the bark of the coast live oak is smooth and dark. In contrast to valley oak and blue oak, coast live oak stands may be increasing in density, especially in areas where fire is suppressed and livestock grazing is light. However, this infill may be slowing and possibly reversing in some areas because the tree is susceptible to sudden oak death, a disease that has killed thousands of

Sudden Oak Death

Phytophthora ramorum (the pathogen that causes the sudden oak death disease; SOD) is a water-loving Asian microbe that is believed to have spread to California on rhododendron (*Rhododendron* spp.) nursery stock. Sometime in the 1980s, infected nursery plants were planted adjacent to forestlands near Mount Tamalpais and Big Sur, allowing the pathogen to become established in the wild. Afterward, it spread in coast redwood, tanoak, and coast live oak woodlands across 15 California coastal counties extending from Humboldt south into Monterey. Since it became established, the SOD pathogen has destroyed millions of trees in coastal California, including coast live oak, California black oak, canyon live oak, and tanoak.

Infected trees, called canker hosts, are killed by the pathogen. The microbe also causes foliar leafspot or twig dieback on over 100 plant species. These plants are known as foliar hosts. Although the SOD pathogen seldom kills a foliar host, millions of zoospores can accumulate on its twigs and leaves and be transferred by wind and rain to adjacent canker hosts. The most significant foliar hosts in the Central Coast Bioregion are tanoak and California bay laurel (*Umbellularia californica*). In addition to being a foliar host, tanoak doubles as a canker host. In both oak and tanoak canker hosts, the SOD pathogen penetrates the bark and colonizes the underlying cambium layer. This hinders the tree's ability to transport water and frequently leads to the death of the tree.

Phytophthora ramorum (SOD) Disease Cycle



Modified with permission from Parke, J. L., and S. Lucas. 2008. Sudden oak death and ramorum blight. The Plant Health Instructor. DOI: 10.1094/PHI-I-2008-0227-01. Illustration: N. Ochiai

Since 2008, the citizen science–based SOD Blitz Program, managed by the UC Berkeley Forest Pathology and Mycology Lab, has monitored the distribution of the disease. Volunteer community members are trained in symptom identification and sampling techniques. The training takes place in the spring, followed by a weekend in the field, where bay and tanoak leaves are collected and sent to a Berkeley lab for diagnosis. In the fall, the findings are shared with the public, facilitating informed landowner and community-wide decision making as to how best to manage for the disease.

While there is no known cure for SOD, phosphonate applications can help protect high-value, high-risk trees from infection. Federal and state regulations are established to prevent the spread of the pathogen to areas that remain free from infection. For example, the movement of infected wood from contaminated to uninfected counties is regulated.

The latest SOD resources, treatment information, and management recommendations can be found at the California Oak Mortality Task Force website, www.suddenoakdeath.org.

Lace Lichen

Yellowish-green strands of lace lichen (*Ramalina menziesii*), the California State Lichen, can be observed hanging from trees in the bioregion. It is most prevalent on oak trees and where humidity is high, particularly in areas near the coast that are moistened by fog. Technically not a plant, lace lichen is an epiphyte that forms from a union between fungi and algae. The fungus is dominant in the relationship and tends the alga in a manner some describe as similar to a human farmer cultivating a crop. The fungal partner absorbs airborne gases, mineral nutrients, and moisture that nourish the alga and also protects it. In turn, photosynthesis by the green alga provides carbohydrates for the fungus. The cellular shape and vegetative structure of the lace lichen promote these symbiotic life-sustaining processes. Each lichen cell is flat, is in direct contact with the air, and with other cells forms a fine netting of filaments. These features provide an optimal surface area for the interception and absorption of atmospheric moisture, gaseous elements, mineral nutrients, and sunlight.

Due to similarities in structure and color, lace lichen in the bioregion's woodlands is commonly referred to as Spanish moss (*Tillandsia usneoides*). However, *T. usneoides* is neither a moss nor a lichen, but a flowering vascular plant that is related to the pineapple. It is native to tropical and subtropical regions, including the southeastern United States.

Lace lichen on a coast live oak tree. *Photos*: Bruce Lyon; Marlin Harms (*inset*)

Lace lichen typically occurs in the inner canopy of deciduous oak trees. In winter, the trees drop their leaves, the lace lichen absorbs water and nutrients, photosynthesizes, and grows rapidly. Indeed, lace lichen can grow more than 3 feet in length during a single growing season. When the wet season ends, the lichen dries out and is no longer capable of photosynthesis. It hangs dormant and collects dust that will provide nutrients when growth is revitalized with the return of wet conditions. Where coastal fog is common during dry months, the growing season of lace lichen is extended. Because the lichen does not extract water or nutrients from its host, it has little impact on the tree. Lace lichen simply uses the tree for residence and support.

Being dependent on photosynthesis, lace lichen may be especially prolific on trees with fewer leaves, including sick, dying, or dead oaks. Owing to this, people are often led to believe that these lichens are the cause of leaf thinning or the death of a tree, not the result. In actual fact, lace lichen benefits healthy oak trees and other woodland organisms in a variety of ways. Its filaments provide an important nesting material for a number of bird species. Prominent among these are Anna's hummingbird (*Calypte anna*) and black-chinned hummingbird (*Archilochus alexandri*); both are spring migrants that breed in the bioregion. Their nest, roughly the size of a half walnut shell, can stretch as the dry lichen filaments absorb water vapor from the growing nestlings. The accommodating nest may stretch twofold by the time the nestlings fledge. The activities of birds and other animals also serve the lichen by dispersing it to surrounding trees.

Lace lichen also provides concealment and nourishment for some woodland animals. A study in coastal northern California, for example, indicated that lace lichen is a fairly small but steady source of carbohydrates and protein for deer throughout the year. This lichen might therefore be particularly important in a deer's diet when other foods are relatively unavailable. The lichen eventually falls to the ground and its nutrients are incorporated by bacteria and fungi into the soil, benefiting both the tree and the wider ecosystem.

Lace and other species of lichens are very sensitive to sulfur dioxide and other air pollutants. Too much pollution inhibits the ability of the lichen to absorb nutrients, causing it to die, the fate of lace lichen in much of the Los Angeles Basin, where it is now scarce. This vulnerability to air pollution is studied by scientists as an indicator of air quality.

trees in the northern half of the bioregion (see the Sudden Oak Death sidebar, page 10).

California black oak (*Quercus kelloggii*) is also referred to as Kellogg oak or simply black oak. Its leaves are deeply lobed, deciduous, and display bright yellow autumn color. Acorns mature in 2 years and are large and low in tannins, making the oak a favorite among indigenous peoples. Rivaling the valley oak in size, black oak trees can grow to 9 feet in diameter and reach 125 feet tall. Thanks to its large size, numerous denning and roosting cavities, dead limbs, and relatively large acorns, black oak trees are heavily used by many species of invertebrates and small vertebrates. A typical life span is 100 to 200 years, but trees have lived for up to 475 years. Black oak trees occur throughout the Sierra Nevada and the Coast Ranges south to Marin County. However, black oak is distributed only intermittently in the Central Coast Bioregion, with most being found in the northwestern portion.

Mixed hardwood-conifer forest at Big Sur. Here, coast live oak trees are interspersed among coast redwoods. *Photo*: Bruce Lyon

Canyon live oak (*Quercus chrysolepis*) prefers the slopes and bottoms of canyons, which are widely distributed throughout the bioregion. It is renowned for its variable anatomy and can mature as a shrub or as an exceptionally large tree that rivals the valley and black oaks in size and age. Its leaf margins vary in shape from smooth to deeply sawtoothed. Due to the golden color of the canyon live oak's acorn cup and its stiff, evergreen, holly-like leaves, the tree is sometimes called gold-cup oak and laurel oak. Because the wood is unusually hard and shock resistant, settlers used it for farm tools, leading to a third nickname, maul oak.

Tanbark oak (*Notholithocarpus densiflorus*), or simply tanoak, is not technically an oak (genus *Quercus*), but it shares many features with the true oaks. Possessing flowers similar to the chestnut (*Castanea* spp.) and bearing oaklike acorns (*Quercus* spp.), taxonomists consider the tanoak a link between the two genera. The species prefers cool mountain slopes and grows in patches within the bioregion's coastal woodlands from Monterey to Santa Barbara. Though a mature tanoak is usually from 50 to 80 feet tall, under especially favorable conditions it can grow to a height of 130 feet with a trunk diameter of 75 inches. Leaves are oblong and toothed, with a hard, leathery texture. The origin of the name refers to the tree's tannin-rich bark, which was used by Euro-American settlers for treating animal skins.

Mixed Hardwood-Conifer

Mixed hardwood-conifer forests are most abundant in the northern and southernmost reaches of the bioregion. In the north, these forests favor north-facing slopes near the sea. Farther south, they are found in patches at higher altitudes in the Santa Lucia Range and extend in scattered upland locales in Santa Barbara County's Sierra Madre. At loftier elevations in the Transverse Ranges, mixed hardwood-conifer forests again become more prevalent.

There is a large diversity of both evergreen and hardwood trees within this community. Hardwoods include big leaf maple (*Acer macrophyllum*), coast live oak, Pacific madrone (*Arbutus menziesii)*, tanoak, canyon live oak, and California black oak. In a mature forest, conifer species predominate while hardwoods intermingle as an understory. The diverse assemblage of conifers includes Douglas fir (*Pseudotsuga menziesii*), Coulter pine (*Pinus coulteri*), incense cedar (*Calocedrus decurrens*), ponderosa pine (*Pinus ponderosa*), and the coast redwood. In northern California, redwood trees live as long as 1,800 years and have been measured up to 379 feet tall, making them the tallest species on the planet and one of the oldest living life forms. The redwoods in the Central Coast Bioregion are impressive, but owing to a drier climate, mature trees are smaller than those found farther north. Coast redwood forest in the bioregion occurs mainly in pockets along the northern coast. A good place to see and experience old-growth redwood trees is approximately 25 miles south of Carmel at Pfeiffer Big Sur State Park.

Due in large measure to the microhabitats inherent to the mixed hardwood-conifer community, it rivals oak woodlands in terrestrial vertebrate diversity, with 63 mammals, 131 birds, 18 reptiles, and 11 amphibians catalogued. The community is home to one of the largest and most unusual amphibians, the California giant salamander (*Dicamptodon ensatus*). Endemic to California's hardwood-conifer forests from northern Monterey County to Mendocino County, this impressive salamander reaches 1 foot in length and is one of the few salamanders that is capable of vocalization, producing a rattling, barking sound when disturbed. It prefers the clear, cool, rocky streams and springs of coastal forests where Douglas fir and coast redwood trees predominate.

Margaret Wentworth Owings

Margaret Wentworth Owings was a California environmentalist and artist. After completing graduate studies in art at Harvard University in 1935, she devoted her life to artistic aspirations and conservation. Owings was particularly passionate about the conservation of wildlife, most specifically mountain lions and sea otters. She was a founder and first president of the Friends of the Sea Otter and was instrumental in the formation of the Rachel Carson Council. Furthermore, Owings was active in conserving the beaches from Carmel to Point Lobos, Monterey County, and thereby was prominent in the protection of the environment and beauty of the Big Sur coastline. She earned numerous awards for her conservation work. Indeed, the Audubon Society ranked Owings among the 100 most influential individuals in shaping the environmental movement. During her final years, Owings strove to compile her artwork and finish writing *Voice from the Sea: And Other Reflections on Wildlife & Wilderness* (1998). She died at 86 years of age, in 1999.

Monterey Pine Forest

Although Monterey pines (*Pinus radiata*) have been extensively planted around the world, the species faces an uncertain future across its native range. Two native stands occur within the bioregion, one on the Monterey Peninsula and the other in the vicinity of Cambria, San Luis Obispo County. These stands are threatened by pitch canker, a disease caused by *Cronartium ribicola*, a rust fungus.

The combined coastal influences of high humidity, low temperature, and summer fog, along with sandy loam soils derived from marine sediment, govern the natural distribution and composition of Monterey pine forests. Associated plants may include Douglas fir, coast redwood, coast live oak, and a variety of understory shrubs. Each spring the Monterey pine produces seeds that are released from the cones after the temperature reaches 80°F. Seedlings grow rapidly, and overtopped saplings can persist as understory for 30 years or more. Nonetheless, the pine is relatively short lived and rarely reaches 150 years of age. Scrub jay (*Aphelocoma californica*), steller's jay (*Cyanocitta stelleri*), and a number of small mammal species feed on the tree's seeds.

Shrubland

Chaparral is distinguished by evergreen shrubs and is widespread in the Central Coast Bioregion. Its regional occurrence is broadly determined by climate, topography, soil nutrients, and periodic fires. These, combined with local conditions, result in distinct associations of chaparral that are named after locally significant physical factors such as soil heterogeneity (serpentine and dune chaparral),

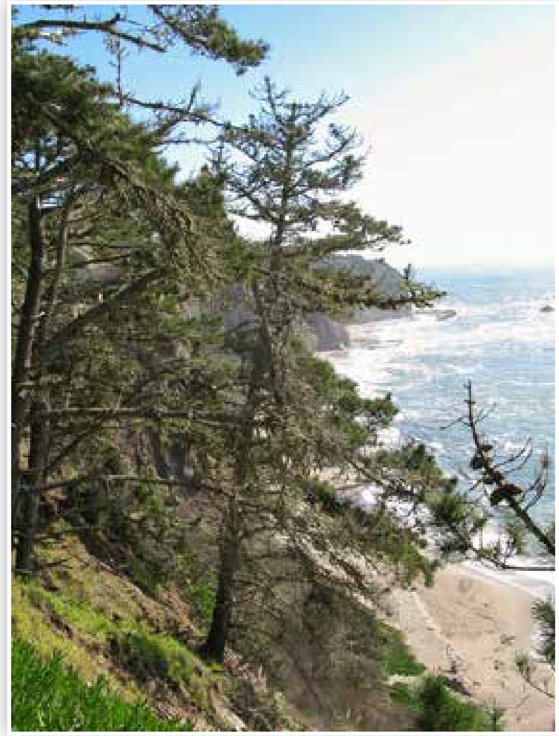
The habitat of the California giant salamander includes mixed hardwood-conifer woodland in the northern reaches of the Central Coast Bioregion. It is one of the few salamanders that can vocalize. *Photo*: John Hafernik

climate variation (maritime chaparral), and topographic differences (montane chaparral).

For most of the bioregion, chaparral stands customarily form mosaics with woodland and grasslands. Where chaparral encounters these plant communities, the landscape expression can be distinctive. The edges, or ecotones, are often sharp and form abrupt transitions with adjacent wooded or grassy environments. The reasons for this phenomenon are complex. However, small animal herbivory, seed dormancy, resource competition, and variations in soil fertility are among the contributing factors.

Although a great variety of plants are found in chaparral, a few shrub species dominate and structure the community. Chamise (*Adenostoma fasciculatum*) is common to most stands as are, to a lesser extent, ceanothus (*Ceanothus* spp.), manzanita (*Arctostaphylos* spp.), red-shanks (*Adenostoma sparsifolium*),

Maritime chaparral near San Simeon. *Photo*: Matt Ritter



Monterey pine forest. *Photo*: Matt Ritter

and especially California scrub oak. The species composition in a mature chaparral stand is variable, and is determined by variations in climate, topography, and soil. In the northern areas of the bioregion, where more abundant precipitation and fog occur, species of manzanita become the principal shrubs. In the drier southern reaches of the bioregion, the presence of manzanita diminishes as red-shanks (*Adenostoma sparsifolium*) joins chamise as codominants.

A large variety of annuals and perennials are also constituents of chaparral ecosystems. This community, like others in the bioregion, is adapted to fire. Following fires, a varied assemblage of flowering annuals and herbaceous perennials characterizes chaparral stands (see the Fire Ecology and Highway 41 Wildfire sidebar on page 16). However, their presence and overall species diversity generally decline as communities mature.

Chaparral habitats contain an impressive complement of animals. Among the common vertebrates are large mammals exemplified by coyote (*Canis latrans*), black-tailed deer, and small mammals like deer mice (*Peromyscus maniculatus*) and woodrats (*Neotoma fuscipes* and *N. macrotis* spp.). Reptiles include the western fence lizard (*Sceloporus occidentalis*) and Pacific gopher snake (*Pituophis catenifer*). A number of avian species, such as the California thrasher (*Toxostoma redivivum*) and gray gnatcatcher (*Polioptila caerulea*), are shrub obligates; that is, they require the cover and insects that only chaparral communities provide. In their entirety, vertebrates are important to ecosystem processes and functioning. They modify and extend the food web and influence the relative occurrence and dominance of certain plants.

Periodic fires and variations in microclimates, topography, soils, and herbivory by small mammals contribute to the formation of chaparral, grassland, and woodland mosaics. *Photo*: Bill Tietje

Though often ignored and imperfectly understood, an incredible variety of soil microbiota (e.g., fungi and bacteria) and invertebrate species, including insects, spiders, and scorpions are crucial to ecosystem functions. Illustrating this are the important roles microbiota play in nitrogen and mineral cycling and decomposition of organic matter. Similarly, invertebrates cycle energy and minerals throughout chaparral food webs and serve as pollinators for a variety of chaparral plants.

Coastal sage scrub is drought tolerant, but unlike chaparral, it is dominated by deciduous shrubs rather than evergreen species. Even though coastal sage scrub grows best under the influence of a shoreline marine climate where fog is particularly common, it is also found inland. In comparison to chaparral, the community generally flourishes at lower elevations and prefers more fertile, often alluvial, soils. On slopes where soils are poorer in nutrients, coastal sage scrub regularly gives way to chaparral. As is the case with chaparral, the coastal sage scrub community is fire adapted.

Chaparral 5 years after a wildfire, Santa Ynez Mountains, Santa Barbara County. Eastwood's manzanita (*Arctostaphylos glandulosa*) is sprouting from its burned skeletons. *Photo*: Drake Schultheis

Coastal sage scrub near Los Osos. Plants include fuchsia flowered gooseberry (*Ribes speciosum*) and coyote bush (*Baccharis pilularis*). *Photo*: Matt Ritter

Coastal sage scrub is known for its heady fragrances and, when blooming, its showy flowers. The community is ordinarily characterized by shrubs in the genera *Artemisia* and *Salvia*. California sage (*Artemisia californica*) is a common indicator species. Being deciduous, leaves are shed late in the year, and during the rainy season the bluish-gray foliage returns. Other representative species are California brittlebush (*Encelia californica*), black sage (*Salvia mellifera*), and white sage (*S. apiana*). Many of these shrubs bend easily and have soft, flexible leaves. Hence, the community is sometimes referred to as soft chaparral. The coastal sage understory and open areas between shrubs include an incredible variety (over 200 species) of annual and perennial forbs. These are frequently accompanied by native and exotic grasses and several species of cacti. The most widespread cactus is the coastal prickly pear (*Opuntia littoralis*). The content of the plant community varies according to successional stage following

Fire Ecology and Highway 41 Wildfire

Burning is crucial to sustaining the health and diversity of the region's woodlands, shrublands, and grasslands. The native biota of these ecosystems coevolved with fire, and numerous species have developed protective and reproductive traits to survive and even flourish under natural fire regimes.

The benefits of periodic low-intensity wildland fires are expressed at every scale: organisms, communities, and landscapes. For a variety of plant species, burning assists plant germination through litter removal, the release of seeds from serotinous cones, and by inducing sprouting. Fire can also contribute to healthier and more sustainable biota by diminishing pathogens in the soil and on tree trunks. Postfire communities provide enhanced food resources and other habitat requirements for a broad spectrum of animal species. Furthermore, periodic burns create and maintain a mosaic of vegetation types across the landscape. Taken together, fire-influenced habitats feature a variety of successional environments that promote optimal species diversity.

Each biotic community is sensitive to the length of time between fires and their severity: temperature, speed, and size. Significant departures from these parameters, such as too many, too few, or unusually severe fires, will alter species composition and hinder full ecological recovery. Chaparral communities, for example, are adapted to fires occurring at intervals of approximately 30 years or longer, the period of time it will take for the community's flora and fauna to return to their predisturbance composition. On the other hand, more frequent and intense fires are likely to destroy soil organic matter, dormant seeds, and beneficial microorganisms. Soil structure can also be negatively impacted and, along with a general reduction of soil fertility, may impede the regeneration of some chaparral plants. The attendant post-fire barrens become highly susceptible to storm-induced soil erosion, landslides, and flooding, which also hamper ecosystem recovery. Over time, healthy shrubland may be converted into a less diverse ecosystem that is distinguished by altered plant species.

A combination of factors influences how a wildfire starts and how it behaves. They include ignition source, weather (temperature, humidity, and wind), fuel load and its moisture content, seasonal timing, and topography. Historically, fire behavior has fluctuated broadly; however, in recent decades wildfires have become more frequent and more destructive. Expanding human populations and their movement into wildlands have significantly increased the number of fires and their destructive effects on ecosystems and people. Climate change is compounding these trends and their negative consequences. Warmer temperatures are lengthening fire seasons and contributing to drier fuel conditions. Moreover, the changing climate may be responsible for longer dry spells and more severe droughts.

A case in point was the 1994 Highway 41 Fire in San Luis Obispo County. Considered an extreme and exceptional wildfire for the time, it became a harbinger of future wildfires. Following over 80 years of fuel buildup and an extended drought, the fire was one of the largest and most destructive in the bioregion. At times it burned up to 7,000 acres per hour, and it ultimately consumed 48,500 acres of grassland, chaparral, and woodland between Morro Bay and San Luis Obispo. Fortunately, no human fatality occurred, but 51 residences were destroyed along with numerous outbuildings and other property.

Continued next page

Fire Ecology and Highway 41 Wildfire (continued)

The bioregion's wildlife has been resilient to natural fire regimes; the direct mortality of animals during low-intensity fire is usually low. After the swift-moving and intense Highway 41 Fire, however, U.S. Forest Service (USFS) personnel observed a large number of carcasses, including species that are highly mobile. In the course of one day, a USFS biologist counted 40 deer and a mountain lion that perished in the fire. Rabbits, woodrats, and other small mammals that had succumbed to the flames were too numerous to count.

Morro Creek choked with sediment from storm runoff during the winter following the Highway 41 Fire, San Luis Obispo County. High sediment loads can be destructive to plants and animals along waterways and downstream in estuaries and nearshore marine habitats. *Photo*: Steve Schubert

A strong El Niño winter (1995-96) followed on the heels of the Highway 41 Fire. Over two days, one especially heavy storm dropped up to 11 inches of precipitation over the burned areas. Concurrent runoff washed thousands of tons of sediment into Morro and Toro creeks and into the Morro Bay Estuary. The deposited materials covered sensitive plants and removed red-legged frog and rainbow trout habitats. USFS restoration efforts in riparian corridors focused on stream channel clearing, bank stabilization, and the planting of willows and sycamores.

In the years following the Highway 41 Fire, even larger blazes have frequented the Central Coast Bioregion. Examples were the Zaca (2007) and Thomas (2017–18) fires, which burned over 240,000 and 280,000 acres, respectively. These and other fires have been interpreted as indicators of trends that do not bode well for a variety of animals and their habitats—to say nothing of human life and property.

fires, with peak diversity occurring during the first 2 years after a burn.

The animal composition of coastal sage scrub also shifts following fire. After a blaze opens the community, lazuli bunting (*Passerina amoena*), horned lark (*Eremophila alpestris*), western fence lizard, and California vole (*Microtus californicus*) become more common. Familiar to closed canopy stands are bushtit (*Psaltriparus minimus*), wrentit (*Chamaea fasciata*), California mouse (*Peromyscus californicus*), and pacific tree frog (*Pseudacris regilla*).

Grasslands

Owing to scant evidence, the species composition and spatial distribution of the bioregion's grasslands prior to 1500 is not certain. However, it is known for certain that they were substantially altered commencing with the arrival of exotic peoples, plants, and animals. In effect, native grasses and forbs have been almost entirely replaced by nonnative species, particularly by Mediterranean annual grasses and forbs. The processes responsible for this conversion are still being investigated and debated. Nevertheless, there is considerable agreement that the competitive superiority of exotic species was pivotal in this transformation. The general advantages of many nonnative species include exceptional drought tolerance, early-spring growth and maturation, and prodigious seed production. Because many exotic grasses and forbs tolerate and adapt to stresses better than native species, severe droughts during the colonial period concurrent with unmanaged livestock grazing may also have contributed to the rapid conversion of grasslands. Livestock grazing has continued unabated throughout the American Period and remains the major disturbance to grassland communities. Indeed, over 2 centuries of sustained grazing have resulted in substantial changes to the bioregion's grassland hydrology, soils, and biota.

The contemporary distribution of grasslands within the Central Coast Bioregion is primarily controlled by the north-to-south and west-to-east rainfall gradients. However, topography, variable soil fertility, fire regimes, and human land uses are important locational determinants as well. Broadly speaking, two grassland subtypes—coastal grassland and interior grassland—are found in the bioregion and are largely differentiated according to moisture variability. As would be expected, coastal grasslands receive more annual precipitation and have longer growing seasons than do interior grasslands. Additionally, coastal grasslands receive moisture during the season from fog drip.

In fall, with the beginning of the wet season, the germination of annual grass species requires as little as half an inch of rain spread over the span of a week. As a result, the golden brown hues of summer grasslands begin their transformation to a panorama of bright green. Thereafter, the timing of rainfall events, rather than the total amount of precipitation, is more influential in determining annual biomass production and the proportional presence of grasses and forbs. Grasses tend to be more prevalent when rain events are relatively evenly spaced. On the other hand, if an early germinating rain is followed by a month or two of dry conditions, forbs increase their presence in grasslands, and ranchers call it a "forb year."

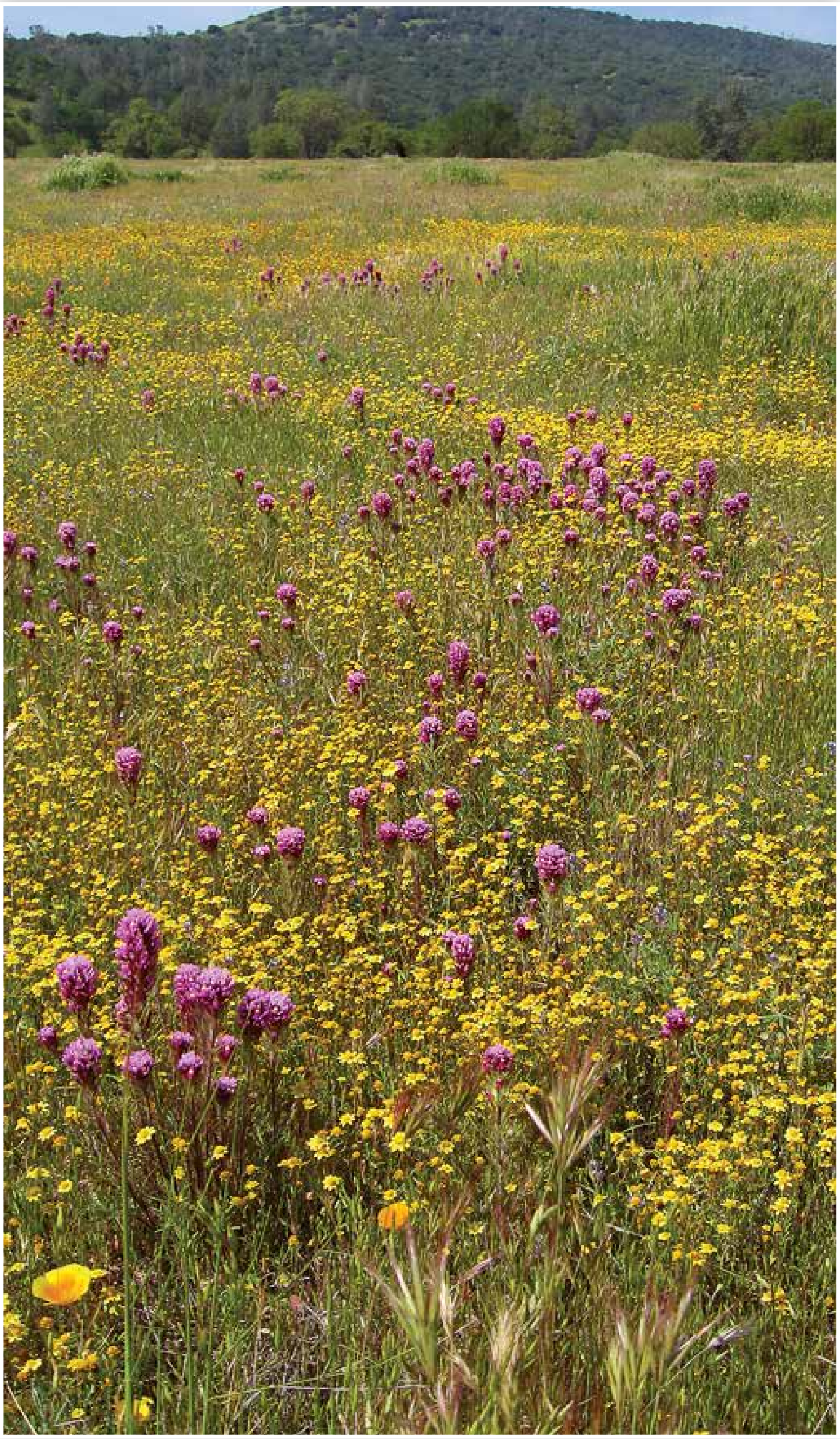
A springtime grassland near San Luis Obispo. *Photo*: Matt Ritter

Coastal and interior grasslands are comprised of many of the same grass and forb species. They also feature species commonly found in open woodland. In both grassland subtypes, nonnative species dominate and are epitomized by foxtail brome (*Bromus madritensis rubens*), wild oats (*Avena occidentalis*), and red-stemmed filaree (*Erodium cicutarium*). Although native species persist in both grassland types, they favor the moister conditions associated with coastal grasslands. Examples of indigenous species are purple needle grass (*Stipa pulchra*), blue wild rye (*Elymus glaucus glaucus*), California brome grass (*Bromus carinatus*), soft chess (*Bromus hordeaceus*), and broadleaf filaree (*Erodium botrys).*

In addition to sharing species, coastal and interior grasslands exhibit structural and aesthetic similarities. To illustrate, in both subtypes annual species are more common than perennials and the seasonal changes in visual hues are comparable. As noted before, commencing with fall and winter rains, grasslands generally appear green and lush. Later in spring, numerous grasses and forbs flower and, depending on environmental conditions and location, generate a colorful wildflower palette. Senescence follows, and wet season colors transition to the golden brown tones distinctive of the dry season. No other community in the bioregion undergoes seasonal color transitions to this extent, and the visual aesthetics are greatly appreciated by both residents and visitors.

A large assemblage of animals populates the bioregion's grasslands. Small mammals include pocket gophers, ground squirrels, mice (*Peromyscus* spp.), California voles (*Microtus californicus*), broad-footed moles (*Scapanus latimanus*), brush rabbits, black-tailed hares (*Lepus californicus*), and in some areas, kangaroo rats (*Dipodomys heermanni*). For reasons that include parasite and disease outbreaks, predator numbers, and weather conditions, rodent populations are highly variable from year to year. A good illustration is the California vole. When conditions are favorable, voles mature rapidly, bear multiple

In spring, grasslands can display a palette of colors. Owl's clover (*Castilleja* spp., lavender color) and goldfields predominate here. Tidy tips (*Layia platyglossa*) and California poppies (*Eschscholzia californica*) are also in the photo. *Photo*: Matt Ritter



litters yearly, and can reach hundreds of individuals per acre. Herds of pronghorn antelope (*Antilocapra americana*) and tule elk, California's endemic subspecies of the American elk (*Cervus elaphus*), once shared the interior grasslands with black-tailed deer. Beginning with colonial settlement, the historic populations of elk and antelope were eliminated by hunting and habitat alteration. Today, the California Department of Fish and Wildlife has reintroduced tule elk and pronghorn antelope on portions of the bioregion's interior grasslands.

Birds are also a prominent component of grasslands. Commonly encountered songbird species are grasshopper sparrow (*Ammodramus savannarum*), savanna sparrow (*Passerculus sandwichensis*), horned lark (*Eremophila alpestris*), and western meadowlark (*Sturnella neglecta*). Many of these species benefit grassland plants by their effects on seed dispersal and insect pests. Predatory birds, such as the ferruginous (*Buteo regalis*) and red-tailed (*B. jamaicensis*) hawks and the considerably larger golden eagle (*Aquila chrysaetos*), have important impacts on the behavior and population dynamics of small mammals. The turkey vulture (*Cathartes aura*), a carrion feeder, approaches the eagle in size and can be observed soaring across the grasslands. The vulture's thinner profile and V-shaped wings can help distinguish it from an eagle or another carrion feeder, the California condor (*Gymnogyps californianus*).

A wide variety of invertebrates are crucial to sustaining grassland ecology. Ants contribute by distributing bacteria, fungi, organic matter, and nutrients. Snails, slugs, and earthworms decompose organic matter, making nutrients available for plant growth. Microbes are vital in soil and plant processes as well. In this regard, bacteria, fungi, protozoa, and nematodes have mutualistic interactions with most grassland plants and influence their growth, drought-stress tolerance, and seed production.

TERRESTRIAL ANIMALS

Birds

Because oak woodland is the dominant vegetative community in the Central Coast Bioregion, the following account highlights a selection of habitat interrelationships among the approximately 145 resident and migratory bird species that share the woodland. Although acorn woodpeckers (*Melanerpes formicivorus*) are familiar birds in most of the bioregion, their distribution is limited to areas containing at least two species of acorn-producing trees. Because the timing and quantity of production

Pair of acorn woodpeckers at their nest cavity in a large blue oak tree. They live in groups comprised of a breeding pair and nonbreeding helpers that assist in caring for the nestlings. *Photo*: Bruce Lyon

A quintessential oak woodland species, the oak titmouse is a secondary cavity nester, meaning it nests in a natural tree cavity or one constructed by another bird, such as the acorn woodpecker. *Photo*: Michael Peters

The hermit thrush and Townsend's warbler (*Dendroica townsendi*) are winter visitors on the Central Coast. The hermit thrush forages on the ground and in shrubs for insects and fruits, here in a non-native hawthorn (*Crataegus* spp.). The Townsend's warbler typically forages in treetops but will feed wherever its favorite food, the sugary excretions of scale insects, is found. *Photos*: Bruce Lyon (*thrush*); Michael Peters (*warbler*)

are highly variable, the local presence of multiple oak species helps ensure that acorns will be available every year. During the nesting season, the larvae and adult insects that occur on deciduous oaks are particularly important for several species of foliage-gleaning birds, for example the orange crowned warbler (*Vermivora celata*) and several bark foragers, including the Nuttall's woodpecker (*Picoides nuttallii*). Alternately, many wintering birds rely on evergreen oaks for cover and invertebrate prey, again demonstrating the value of multispecies stands. Joseph Grinnell, a UC Berkeley naturalist whose research spanned the first half of the twentieth century, dubbed the scrub jay the "uphill planter." Each fall, a single jay may bury up to 5,000 acorns over its roughly 6-acre home range, thereby providing uphill acorn dispersal. Unrecovered acorns have higher rates of germination and survival than those that remain on the surface of the ground, where they will lose viability in a short time or be eaten by animals. Hence, the oaks feed the jays and the jays serve as oak planters—a give-and-take, or mutualistic, relationship.

Woodland bird species utilize specific habitat layers in which to search for and capture food. In this way, the species reduce competition for essential food resources. To illustrate, ash-throated flycatcher (*Myiarchus cinerascens*), violet-green swallow (*Tachycineta thalassina*), and western bluebird (*Sialia mexicana*) feed on flying insects (aerial feeding); oak titmouse (*Baeolophus inornatus*) captures insects and other arthropods from tree foliage (leaf gleaning); whereas the white-breasted nuthatch (*Sitta carolinensis*) extracts its prey from the cracks and crevices of tree bark (bark foraging). Other species, represented by scrub jay and ruby-crowned kinglet (*Regulus calendula*), rely on food and cover provided by understory shrubs, such as coffeeberry (*Rhamnus californica*), redberry (*R. crocea*), ceanothus, and toyon (*Heteromeles arbutifolia*)—sometimes called Christmas berry. Hermit thrush (*Catharus guttatus*) also feeds in the shrub layer, but this species ordinarily forages on the woodland floor amid forbs, downed logs, and litter.

Year-round residents of the bioregion: bobcat in a blue oak tree and a bugling tule elk in blue oak woodland. *Photos*: Royce E. Larsen (*bobcat*); Michael Peters (*tule elk*)

The Santa Lucia Mountains slender salamander (*Batrachoseps luciae*) is endemic to the coastal forests and woodlands of Monterey and San Luis Obispo counties. *Photo*: Robert W. Hansen

Mammals

Over 100 mammal species occupy the woodland, shrubland, and grassland communities of the Central Coast Bioregion. The mountain lion, or puma (*Felis concolor*), and its smaller cousin, the bobcat (*Lynx rufus*) share the land with grazing and browsing species. Prominent among these are black-tailed deer, tule elk, pronghorn antelope, domestic cows, and horses. Gray wolves (*Canis lupus*) no longer dwell in the bioregion, but their relatives, the coyote and the gray fox (*Urocyon cinereoargenteus*), are abundant and important predators of rodents, rabbits, and California ground squirrels.

A dozen species of insectivorous bats reside in the bioregion, and their appetite is impressive. Each night these bats can consume up to their body weight in flying insects. Their day roosts are usually in tree cavities, caves, and the eaves or attics of older wooden buildings. Examples of common species found in the bioregion are Brazilian free-tailed bat (*Tadarida brasiliensis*), little brown bat (*Myotis lucifugus*), California myotis (*Myotis californicus*), and western pipistrelle (*Parastrellus hesperus*). Some of the bat species migrate to warmer areas outside the region over the winter. Others spend the winter locally in rock and tree hollows and in structures where the temperature and humidity are favorable.

Amphibians

The Central Coast Bioregion provides habitat for 23 amphibian species, including salamanders, newts, and frogs. The California slender salamander (*Batrachoseps attenuatus*) is the most widely distributed of the several *Batrachoseps* species that occur in the bioregion. This salamander prefers moist woodlands and forestlands and can be found under logs, among rocks and debris, and in burrows. The Santa Cruz long-toed salamander (*Ambystoma macrodactylum croceum*) breeds in vernal pools in Santa Cruz and northern Monterey counties; during the summer, it dwells in burrows in adjacent woodlands.

Newts differ from other salamanders in being semiaquatic as adults and in having conspicuous red and yellow skin that secretes

Red-legged frog in Las Flores Canyon, Santa Barbara County. The American bullfrog (*Lithobates catesbeianus*), a California invasive, preys on red-legged frog populations and threatens their survival in the bioregion. *Photo:* Robert W. Hansen

Ringneck snakes live under rocks, bark, and leaf debris, where they hunt invertebrates and small vertebrate animals. *Photo*: Marlin Harms

The coast garter snake (*Thamnophis elegans terrestris*) is endemic to the California Central Coast. This one is from the southern edge of its range in Santa Barbara County. It has a mild venom that helps it subdue its prey. *Photo:* Robert W. Hansen

toxins as a defense mechanism. The California newt (*Taricha torosa*), the only species of newt in the bioregion, occurs throughout coastal canyons and riparian habitats. The region is also home to the foothill yellow-legged frog (*Rana boylii*), which lives along slow-moving streams, where it lays clusters of eggs in shallow water. The egg masses are attached to underwater gravel, rocks, and other debris. Its relative, the California red-legged frog, has declined in the southern part of the Central Coast Bioregion but is protected and making a slow recovery.

Reptiles

The bioregion provides habitat for approximately 40 species of snakes, lizards, skinks, and turtles. Representatives are the Pacific rattlesnake (*Crotalus oreganus*), southern alligator lizard (*Elgaria multicarinata*), Gilbert's skink (*Plestiodon gilberti*), and western skink (*P. skiltonianus*). Mature specimens of the latter are easy to distinguish by their sleek, shiny skin and juveniles by their bright blue or red tails. Similarly, the rattlesnake and the foot-long ringneck snake (*Diadophis punctatus*) are effortlessly identified. The ringneck has a conspicuous reddish ring around its neck and, when threatened, coils its tail like a corkscrew, revealing a bright red-orange underside, which functions to warn off predators. The western pond turtle (*Actinemys marmorata*) is distributed throughout the bioregion but is imperiled by the widespread increase in mesocarnivores (medium-sized carnivores), in the form of raccoons, coyotes, and domestic cats. The turtle is also diminishing due to the loss of habitat corridors to nearby upland nesting sites and by animal collectors.

Insects

An account of the bioregion's insects affords an opportunity to explore some of the interesting ways they interact with the region's oak and eucalyptus (*Eucalyptus* spp.) trees. The endemic and rare Santa Monica Mountains hairstreak butterfly (*Satyrium auretorum fumosum*), the more common nut-brown hairstreak (*S. a. spadix*), and the California sister (*Adelpha bredowii californica*) lay their eggs on mature oak leaves, and the following spring their larvae feed on the newly flushed leaves. Eucalyptus groves provide critical overwintering habitat for declining populations of western monarch butterflies (*Danaus plexippus*). Two of these groves are located within the bioregion—one at Pacific Grove, Monterey County, and the other at Pismo Beach, San Luis Obispo County.

Some of the most fascinating insect parasites in the bioregion are the approximately 130 species of gall-forming cynipid wasps. Adult insects lay their eggs (oviposit) on oak stems or leaves, and the larvae of each species produce a unique growth-regulating chemical which stimulates the plant to create a gall that is distinctive in size, shape, and color. The gall provides shelter and food for developing larvae—which, due to temporary anatomical features, do not soil their shelter and larder. Galls are similar to benign tumors in that they do not harm their host tree.

A California sister butterfly alights on a coast live oak leaf. Eggs are laid on the margins of oak leaves, the preferred food of newly emerged larvae. *Photo*: Jay Cossey

Female cuckoo bee exiting the underground nest of its host, the Pacific digger bee (*Anthrophora pacifica*). The cuckoo bee has laid its eggs in the underground nest. Its eggs will hatch before those of its host, and the cuckoo larvae will eat the host's larvae and food. *Photo*: Rollin Coville

Destructive parasitic insects are numerous, and one group, oak pit scales (*Asterodiapsis* spp.), inject poisonous saliva into a tree's bark. Another is the California oak worm (*Phryganidia californica*). Although oak worms can completely defoliate their host, with rare exceptions the tree will refoliate. Finally, the filbert weevil (*Curculio occidentis*), and to a lesser extent the filbertworm (*Cydia latiferreana*), can infest the endosperm of up to two-thirds of a tree's acorns, threatening their viability.

Notably beneficial to the bioregion's natural and agricultural landscapes are its approximately 400 native bee species. They range in length from 1/8 inch to over 1 inch and come in numerous shapes and colors. Names of the various groups of bees reveal the diversity of their lifestyles: digger bees (*Anthophorini* spp.) live underground, carpenter bees (*Xylocopa* spp.) live in woody stems, and California bumblebees (*Bombus californicus*) and nonnative European honey bees (*Apis mellifera*), being social bees, congregate in large natural cavities or in hives. Most of the natives are generalists and can garner nectar and pollen from a variety of indigenous and exotic flowering plants. A particularly interesting group of bees is cuckoo bees (*Nomada* spp.)—which, reminiscent of the breeding behavior of the common cuckoo bird (*Cuculus canorus*), do not build nests but lay their eggs in the nests of other species of bees. Once hatched, the larvae of the cuckoo bee live on the food stores and larvae of their host, a behavior termed brood parasitism.

The occurrence and beauty of native bees also extend to backyard garden plantings. Plants especially attractive to bees in urban and rural environs are Oregon gumplant (*Grindelia* *stricta*), Great Valley gumplant (*G. camporum*), scorpionweeds (*Phacelia* spp.), common sunflower (*Helianthus annuus*), beardtongues (*Penstemon* spp.), wild buckwheats (*Eriogonum* spp.), and bush sunflower (*Encelia californica*).

FRESH WATERS

Streams

A stream ecosystem includes the physical and biological content of the watercourse and its associated riparian community. Taken together, they comprise the stream corridor. Most of the perennial waterways within the bioregion pass through oak woodlands, and we use this community to illustrate the importance of stream corridors to local and regional biodiversity.

Local physical and spatial variations in geology, topography, hydrology, and soils are influential in shaping the biological composition of stream ecosystems. Proximity to the channel and soil moisture are particularly important. Directly adjacent to the water, only plants that require or can tolerate saturated soil will be found. Two of the most common of these are arroyo willow (*Salix lasiolepis*) and red alder (*Alnus rubra*). Farther up the bank, a wider zone is characterized by larger willow trees, bigleaf maple (*Acer macrophyllum*), Fremont cottonwood (*Populus fremontii*), and western sycamore (*Platanus racemosa*). Abundant soil moisture and a relatively humid microclimate may also nurture a well-developed understory composed of native shrubs, including California blackberry (*Rubus ursinus*), poison oak (*Toxicodendron diversilobum*), blue elderberry (*Sambucus nigra caerulea*), and coffeeberry. These species may overlie a ground cover of mugwort (*Artemisia douglasiana*), hedge nettle (*Stachys bullata*), and several species of ferns and mosses. On the outer edge of the riparian corridor where moist alluvial soils are available, sycamore trees may be joined by sizable coast live oak and valley oak trees.

Upper reaches of the Salinas River in San Luis Obispo County. Foreground trees are western sycamore (left) and black cottonwood (*Populus trichocarpa*, right). Other trees in the photo are red willow (*Salix laevigata*), arroyo willow, and foothill pine (*Pinus sabiniana*). Stream corridors are especially rich in plants and animals. *Photo*: Matt Ritter

Due to the density and structural complexity of riparian vegetation, the community is exceptionally biodiverse. To be sure, it supports a greater diversity of animals than any other terrestrial community in the bioregion. Bird diversity is especially high. According to the California Wildlife Habitat Relationships System, riparian corridors within the coastal counties of Monterey, San Luis Obispo, and Santa Barbara host nearly a fifth (20%) more bird species than do upland oak woodlands.

A notable component of the breeding birds that exploit the bioregion's stream corridors is visiting species from the American tropics. These visitors are known as Neotropical migrants. Abundant riparian food and cover resources allow them to complete their nesting cycle relatively quickly before returning to their wintering quarters in the tropics. Among these, the violet-green swallow feeds its nestlings with insects it chases with swift, acrobatic maneuvers while flying low over the stream channel. Upslope from the water's edge, shrub-nesting or ground-nesting neotropical migrants include blue grosbeak (*Passerina caerulea*), Wilson's warbler (*Cardellina pusilla*), and spotted towhee (*Pipilo maculatus*).

In the transition zone between riparian and upland habitats, a suite of neotropical migrant and resident birds nests in cavities in large sycamore and oak trees. The cavity-nesting birds include ash-throated flycatcher

Examples of aquatic macroinvertebrates: (a) little humpless caddisfly (*Amiocentrus aspilus*) emerging from its protective case, (b) great spreadwing damselfly (*Archilestes grandis*) larva showing the three caudal gills and its emerging thoracic wings, (c) the larva of the western stonefly (*Baumanella alameda*), and (d) the terrestrial adult form of a golden stonefly (*Calineuria californica*). *Photos*: Larry Serpa, TNC

One of several subspecies of the Sacramento sucker, the Pajaro sucker is the most common sucker in the bioregion. This one was photographed in the upper reaches of the Salinas River near Pozo, San Luis Obispo County. *Photo:* Royce E. Larsen

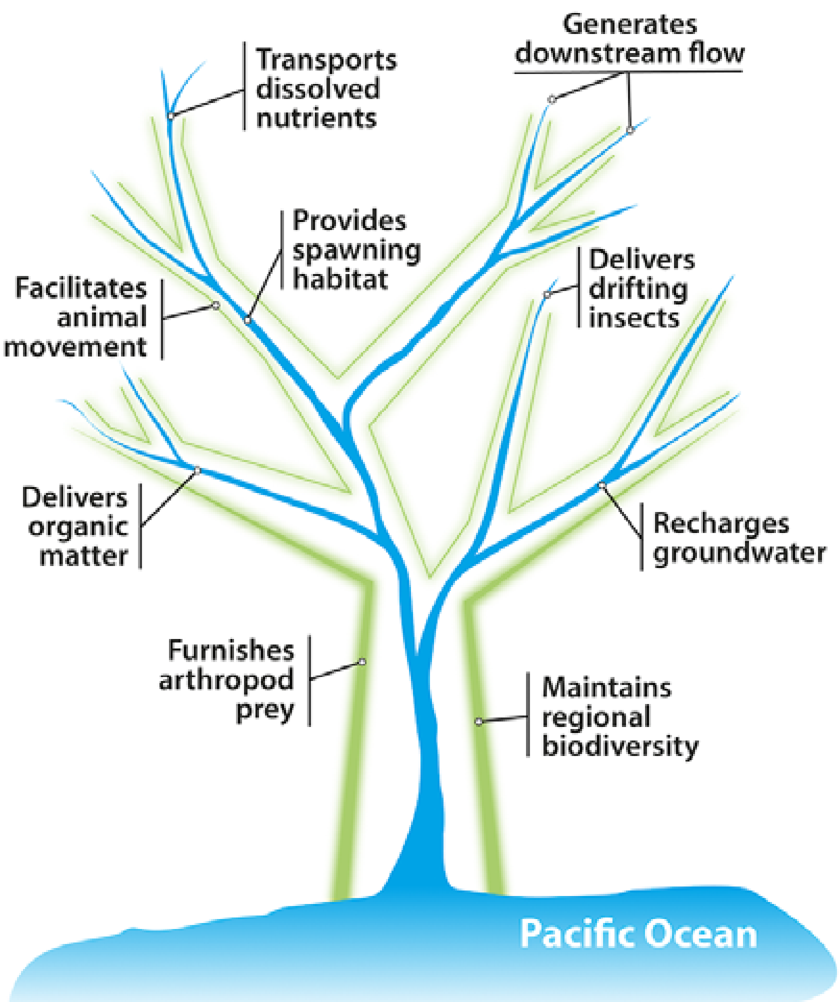
A 25-inch south-central coast steelhead trout in Maria Ygnacio Creek, Santa Barbara County. *Photo*: Mark Capelli, NOAA, West Coast Region

(*Myiarchus cinerascens*), oak titmouse, and several species of woodpeckers and owls. North America's only aquatic songbird, the American dipper (*Cinclus mexicanus*), can be found along several of the rapidly flowing and cool coastal streams in Monterey and Santa Barbara counties. Also known as the water ouzel, the American dipper builds its nest under an overhanging bankside ledge. A protective transparent eyelid (nictitating membrane), nasal flaps, and oily plumage are unique physical adaptations that equip the ouzel to hunt for aquatic invertebrates on the stream bottom.

Aquatic invertebrates are an essential food for most fish and are crucial to a productive and diverse stream ecosystem. Insects such as mayflies, dragonflies, damselflies, stoneflies, horseflies, deer flies, and the pesky midges known as no-see-ums lay their eggs in lakes or streams. The immature forms, called larvae or nymphs, live in the water for months or even years before emerging from the water as flying adults. They survive only long enough to complete their life cycle through mating and the depositing of eggs in the water or on the underside of overhanging leaves. The adults are food for invertebrates, amphibians, songbirds, and bats. The aquatic larvae of many species are sensitive to stream conditions, and their presence or absence is used by biologists to assess the overall condition of the aquatic ecosystem.

Unlike the introduced game fish that predominate in the bioregion's lakes, most stream fish are California native minnows, suckers, and salmonids. Sacramento pikeminnows (*Ptychocheilus grandis*) are widespread in the bioregion where slow-moving sections of streams are shaded and cooled by overhanging vegetation. In contrast, the California roach (*Lavinia symmetricus*) requires only a relatively warm, persistent pool to survive the summer. The speckled dace (*Rhinichthys osculus*) thrives where the water is fast moving and turbulent. The Sacramento sucker (*Catostomus occidentalis*), the most widespread sucker found in California, occurs as four isolated subspecies. The Pajaro sucker (*C. o. mniotiltus*) is the most prevalent form within the bioregion. Similar to all suckers, it feeds on benthic invertebrates, algae, and fine detritus. On the other hand, trout feed on drifting invertebrates or on adult insects and other arthropods, such as spiders, that fall into the water. The resident coastal rainbow trout (*Oncorhynchus mykiss irideus*) is the most common trout in the bioregion. Its anadromous form (meaning that it returns from the ocean to its natal stream to spawn), the south-central coast steelhead, is much diminished today due to the modification and loss of natural habitat from mining, forestry, agriculture, and urbanization. Small populations still occur in streams from Monterey Bay to Point Conception, Santa Barbara County.

Conservation efforts are helping to sustain populations of the arroyo toad, an amphibian adapted to conditions in intermittent stream channels. It occurs from Santa Barbara County south into Baja California. *Photo*: Jeff Alvarez



Diagrammatic representation of the functions of the upper and lower reaches of a stream and its associated riparian corridor. Adapted from Cummins and Wilzbach 2005, p. 487

A number of amphibian species have interesting ways to cope with stream channels that dry up for part of the year. During the dry season, the western spadefoot (*Spea hammondii*) burrows into stream sediments using keratinized spadelike projections on its hind feet. It then enters a state of inactivity, called *torpor*, until awakened by the soft vibrations of winter rainfall. Another amphibian, the arroyo toad (*Anaxyrus californicus*), adapts to dry channels by taking refuge in loose sandy or sandy loam soils. To prevent desiccation, the toad surrounds itself with many layers of its dried skin. Red-legged and yellow-legged frogs may cope with dry conditions by moving a mile or more in search of persistent pools. Despite these unique adaptations, some riparian-dependent amphibians are declining. Habitat alterations are the primary cause, and climate change is compounding the risks to these species.

Similar to a road system, stream channels and their associated corridors provide biological pathways through the broader landscape. The upper reaches of watercourses contribute nutrients, detritus, plant seeds, and drifting aquatic invertebrates downstream and eventually to estuaries and coastal marine waters. The corridors provide dispersal and migration routes for aquatic and terrestrial animals, helping to maintain the genetic and species diversity of the entire watershed.

Streams often traverse landscapes that have been altered by human activities and rendered vulnerable to habitat loss. A good example is the lower reaches of the Salinas River, where the channel is surrounded by a broad alluvial plain used for intensive agriculture. In 2006, an outbreak of food poisoning caused by *Escherichia coli* bacteria was linked to leafy green vegetables (e.g., lettuce and spinach) grown adjacent to riparian vegetation. Some of the animals associated with the riparian habitat excrete *E. coli* pathogens in their feces. As a mitigation effort, approximately 10% of the remaining riparian vegetation in this portion of the valley was removed.

It was revealed afterward that the fields bordering the riparian vegetation were of no greater risk of *E. coli* contamination than those farther away. The riparian removals have impaired the critical role of the Salinas Valley corridor in preserving the biological continuity and health of the greater ecosystem. This consists of the surrounding highlands, estuary, and marine environments—to say nothing of the river itself. Although there are other examples of riparian degradation in the bioregion, significant efforts are being made to maintain and preserve riparian habitat.

Reservoirs

The biological consequences of artificial reservoirs (hereafter, "lakes") in the Central Coast Bioregion are profound. Preexisting habitats have been eliminated and ecological linkages to surrounding environments disturbed. Nonetheless, these water bodies have created novel freshwater ecosystems occupied by both native and exotic species. Although

Carmel River Restoration

In 1602, Spanish maritime explorer Sebástian Vizcaíno, in honor of his voyage's patron saint and protector, Our Lady of Mount Carmel, named the river El Rio de Carmelo. His expedition's account described the Carmel River as "small and lacking in depth, but with very good water." The river stretches for only 36 miles from its source in the Santa Lucia Mountains through the Carmel Valley to its mouth south of present-day Carmel-by-the-Sea. However, the current river is significantly different from the one described by the Vizcaíno expedition.

Three dams were eventually constructed on the river: Old Carmel River Dam (1882), San Clemente Dam (1921), and the Los Padres Dam (1949). The San Clemente Dam once provided water for domestic consumption, agriculture, and industry for much of the Monterey Peninsula. In 1992, with sediment clogging the reservoir behind it, the dam was declared unsafe, with the potential to fail in either a major earthquake or flood. Moreover, the environmental community was deeply troubled by the adverse effects the dam was having on the aquatic ecosystem.

Demolition of the 106-foot-high San Clemente Dam on the Carmel River. *Photo*: California American Water

These concerns led to the $84 million Carmel River Reroute & San Clemente Dam Removal (CRRDR) Project. The 106-foot-high San Clemente Dam was taken down in 2015. During the removal, the Carmel River was rerouted to minimize impacts on fish and other wildlife. Removal of the dam allayed public safety concerns and restored riparian habitat for a number of species, including the red-legged frog. The action also provided unimpaired access to 25 miles of critical spawning and rearing habitat for the south-central coast steelhead. Elimination of the San Clemente Dam was followed in 2016 by the removal of the Old Carmel River Dam. At present there is no plan to take down the Los Padres Dam; however, a multiyear study is under way to evaluate various options, including its possible demolition.

Environmental restoration and monitoring continue on the river today. The CRRDR Project is the largest dam removal undertaking in California and among the most prominent on the West Coast. It is the beginning of a long-term endeavor to return the river to conditions similar to those observed by the Sebástian Vizcaíno expedition in 1602. The Carmel River's story of development, exploitation, and degradation is chronicled in Roy March's book *River in Ruin: The Story of the Carmel River* (2012).

lake waters and shorelines provide living space for a broad spectrum of flora and fauna, the following discussion emphasizes the fish and birds that have adapted to aquatic habitats and, in the case of birds, to adjacent lands.

In the stretch of a watershed flooded by a lake, some of the stream-adapted fish have been either lost or augmented by exotic species. A representative case is Lake Cachuma in Santa Barbara County. Prior to the existence of the lake, the Santa Ynez River hosted mainly native species, such as coastal rainbow trout (resident and anadromous), threespine stickleback (*Gasterosteus aculeatus*), and prickly sculpin (*Cottus asper*). The overlying lake is now dominated by stocked and accidental introductions of at least 10 species of mainly exotic fish. They include black crappie (*Pomoxis nigromaculatus*), rainbow trout (nonanadromous), small mouth bass (*Micropterus dolomieui*), redear sunfish (*Lepomis microlophus*), channel catfish (*Ictalurus punctatus*), and black bullhead (*Ameiurus melas*). The species alterations may vary considerably from one lake to another. For instance, striped bass (*Morone saxatilis*), threadfin shad (*Dorosoma petenense atchafalayae*), and the occasional Chinook salmon (*Oncorhynchus tshawytscha*) dwell in San Luis Reservoir (Merced County). However, these fish are rare or nonexistent in the region's other lakes. Because larger and deeper lakes are likely to have a more extensive variety of aquatic habitats, they tend to contain a greater diversity of fish species than smaller water bodies.

Harvey's Cove on Lake Cachuma, Santa Barbara County. *Photo*: Chick Hebert

Eared grebes (*Podiceps nigricollis*) winter on lake and estuarine habitats, where they dive for small fish, mollusks, and aquatic invertebrates. Except for small populations that are year-round residents in Santa Barbara and northern Ventura counties, most eared grebes breed outside of the bioregion. *Photo*: Michael Peters

Bird numbers and diversity are especially high in freshwater lake environments and include a mixture of inland, aquatic, and visiting species. Indeed, where the shorelines are heavily vegetated, they somewhat mimic the renowned biotic diversity of riparian habitats. Shore and shallow-water areas are the most productive and are favored by the majority of water-dependent birds, such as snowy egrets (*Egretta thula*), great blue herons (*Ardea herodias*), and American coots (*Fulica americana*). Shorelines with emergent vegetation and mudflats are fertile habitats for Virginia rails (*Rallus limicola*), red-winged blackbirds (*Agelaius phoeniceus*), and marsh wrens (*Cistothorus palustris*). Even some shorebird transients from the coast may be found searching for invertebrates on lakeshore mudflats and in shallow water. In the less productive deeper waters, the western grebe (*Aechmophorus occidentalis*) and its white-faced cousin, the Clark's grebe (*A. clarkii*), hunt for fish and aquatic invertebrates. Owing to the enhanced avian diversity, including species not commonly found elsewhere in the bioregion, several of the bioregion's lakes have gained widespread recognition. Lake Lopez and its watershed, for instance, are designated an Important Bird Area by the National Audubon Society.

Sedimentation is diminishing the capacity and water quality of a number of the bioregion's lakes. Largely because of sedimentation and changes in stream habitat, two dams have been removed on the Carmel River. At the south end of the bioregion, Matilija Lake is nearly filled with sediment and its dam is being considered for removal. Drought, invasive species, shoreline development, aging infrastructure, and chemical pollution (e.g., mercury) are additional threats to the environmental health and longevity of the bioregion's lakes.

Vernal Pools

Vernal pools are rather rare and extraordinary ecosystems found in the bioregion's grasslands. They develop where soils laden with silt and clay form a semi-impervious hardpan that inhibits drainage. The pools fill with water during the rainy season and gradually dry during spring and summer.

Vernal pools teem with plants and animals. Common plants are clovers, California golden violet (*Viola pedunculata*), and vernal pool monkey flower (*Mimulus tricolor*). In northern areas of the bioregion, the endemic wildflower Contra Costa goldfields (*Lasthenia conjugens*) may be nurtured by vernal pools. Some animal species flourish as well. Vernal pool fairy shrimp (*Branchinecta lynchi*) lay their eggs in spring and are able to withstand summer drying through a process called *anhydrobiosis*, meaning "life without water." The eggs spring back to life when water returns. Being without fish, vernal pools also provide a safe haven for aquatic insects that are unable to survive in the presence of predatory fish.

Vernal pools are important in the annual lifecycle of the rare California tiger salamander (*Ambystoma californiense*). Its larvae mature in the pools, and after metamorphosis, juveniles move to surrounding uplands, where they spend most of the year in mammal burrows. During this time, the salamanders remain active, often emerging from burrows at night to feed on worms and insects. The following winter, the salamanders return to the vernal pools to breed. Vernal pools are delicately balanced biological systems, and their continued existence in the bioregion is threatened by encroaching development and extended droughts.

Vernal pools, such as this one in San Luis Obispo County, have three distinct phases: wet (pictured), flowering, and dry. Extended droughts and the loss of these pools due to development pose the greatest threat to the tiger salamander, which requires vernal pools for breeding. *Photos*: Matt Ritter (*vernal pool*); USFWS (*salamander*)

ESTUARIES

An estuary occurs where freshwater from rivers encounters and mixes with saltwater from the ocean. Put simply, an estuary is a zone of transition between land and sea. Because estuaries are a unique assemblage of terrestrial and marine habitats, they are among the most productive and biodiverse ecosystems in the world. They are also extraordinarily sensitive and vulnerable to human-induced disturbance. In the following sections, two estuarine treasures in the Central Coast Bioregion are examined within this context.

Elkhorn Slough

Elkhorn Slough is an estuary and tidal slough that stretches 7 miles inland from Monterey Bay. In terms of size, its tidal marsh is surpassed in California only by those along the shores of San Francisco Bay. The slough system, which includes the adjacent Bennett Slough, is fed primarily by freshwater from Carneros Creek. The slough includes extensive mudflats and networks of tidal creeks that meander through pickleweed (*Salicornia pacifica*) marshes. Saltwater, brackish, and freshwater wetlands add to the mix. Patches of oak woodland are present as well. Although these habitats are interconnected by tidal water, each possesses significant environmental differences that nurture distinct biological communities.

Elkhorn Slough provides habitat for over 700 plant and animal species. Common components of the vegetative community are pickleweed, common eelgrass (*Zontera marina*), sea lettuce, Santa Cruz tarplant (*Holocarpha macradenia*), Harding grass (*Phalaris aquatica*), and many species of lichen. Animal life abounds and includes California's greatest concentration of southern sea otters and sanctuary for the Santa Cruz long-toed salamander and California red-legged frog (*Rana draytonii*). Less conspicuous is a rich variety of subsurface aquatic species. Among these are bottom-dwelling oysters, Pacific gaper clams (*Tresus nuttallii*), and longjaw mudsuckers (*Gillichthys mirabilis*). The water column teems with at least 102 fish species, 82 of which are marine species that share the estuary. Typical freshwater species include the threespine stickleback, western mosquitofish (*Gambusia affinis*), and prickly sculpin (*Cottus asper*). Examples of seasonal animals are rays, sharks, and migratory birds.

A visitor to Elkhorn Slough will be impressed by the incredible number and diversity of birds. Indeed, the estuary provides habitat for more than 340 resident and nonresident species, including about 130 that are aquatic. Owing to evolutionary adaptation, birds are capable of taking advantage of every estuarine habitat niche, ranging from bottom sediments to the tops of emergent vegetation. Northern pintails (*Anas acuta*) feed primarily on organic materials in the sediments. Alternately, brown pelicans (*Pelecanus occidentalis*) exploit the water column. Similarly, approximately 40 species of shorebirds have adapted to a variety of habitats in close proximity to one another. Among these is the least sandpiper (*Calidris minutilla*), which favors the open or shallow mudflats, and the long-billed curlew (*Numenius americanus*), which seeks food in somewhat deeper waters.

Part of the bird diversity present in Elkhorn Slough is explained by its location under the Pacific Flyway, a major north-south migration route. Species of shorebirds, waterfowl, and seabirds that migrate along this flyway do

Tidal wetlands in Elkhorn Slough with the ocean in the distant background. American avocets (*Recurvirostra americana*) capture aquatic invertebrates by scything their curved bills from side to side through shallow water. The long-billed curlew captures a crab in a tidal pool. *Photos*: Gabi Estill, Elkhorn Slough Foundation; Michael Peters (*avocets and curlew*) stopovers at the slough and other coastal estuaries. This function makes Elkhorn Slough an important international link in sustaining and ensuring the survival of migratory species. In recognition of the slough's ecological value, it has been incorporated into the federally protected Monterey Bay National Marine Sanctuary and serves as a National Estuarine Research Reserve. A number of state and private organizations also contribute to the slough's preservation. The largest private landowner is the Elkhorn Slough Foundation, which is devoted to restoring and conserving the 3,600 acres of the estuary under its ownership. In total, approximately 8,000 acres, or 17% of the estuary, are protected.

A breeding brown pelican with a golden wash on its head and with a deep red throat patch. Brown pelicans typically capture fish in their throat pouches by plunging head-first into a school of fish. *Photo*: Michael Peters

Kathleen Goddard Jones

Kathleen Goddard Jones was an avid environmentalist dubbed by her friends the "defender of the dunes." She led collaborations with the Nature Conservancy, Wilderness Society, National Audubon Society, and California Native Plant Society to preserve the Guadalupe-Nipomo Dunes. Located in southern San Luis Obispo County, they are the largest undisturbed dune complex in the United States. In the early 1970s, Goddard Jones learned that the California Pacific Gas and Electric Company (PG&E) proposed to build a nuclear power plant on the dunes. Her challenges to the proposal were instrumental in defeating the company's plans and resulted in government protection of the Guadalupe-Nipomo Dunes as a National Natural Landmark. This effort is documented in Virginia Cornell's 2001 book, *Defender of the Dunes: The Kathleen Goddard Jones Story*. The Dunes Center in Guadalupe was built in her honor. The center promotes research, education, conservation, and the restoration of the Guadalupe-Nipomo Dunes ecosystem. Goddard Jones died in 2001, at age 89.

Morro Bay Estuary

The Morro Bay Estuary in San Luis Obispo County receives freshwater from four principal waterways: Chorro, Los Osos, San Bernardo, and Warden. The estuary's shallow water, mudflats, tidal creeks, and channel environments make it one of the largest and most important wetland systems in the bioregion. Similar to Elkhorn Slough, its habitats support a highly productive ecosystem. For example, dense meadows of common eelgrass provide a nursery ground for an inordinate number of aquatic invertebrate and vertebrate species. In addition, over 200 bird species reside in or migrate through the Morro Bay Estuary. Representative species include the brown pelican, double-crested cormorant (*Phalacrocorax auritus*), peregrine falcon (*Falco peregrinus*), and black brant (*Branta bernicla nigricans*).

Elements of Morro Bay Estuary's biodiversity are facing difficulties due to development, contaminants, and climate change. In recent years, sediment buildup has caused a marked decline in eelgrass. Measures are being taken to mitigate this and other threats to the estuary. Fundamental to these endeavors was the designation in 1995 of Morro Bay as one of 28 National Estuary Programs in the United States, each working to protect and restore estuarine communities. Over 4,000 acres of the Morro Bay Estuary have been protected, and more than 400 acres have been restored. The Morro Bay Marine Recreational Management Area and the Morro Bay State Marine Reserve also help safeguard the estuary.

NEARSHORE MARINE ENVIRONS

Extending along the bioregion's western edge, the nearshore marine community consists of four zones defined by water depth and vegetation: shore, intertidal, subtidal, and pelagic. Collectively known as the contiguous zone, they stretch seaward for approximately 12 nautical miles.

Shore Zone

The shore zone begins where terrestrial vegetation covers less than 10% of the ground and extends downslope to the water's edge

Beachscape at the Guadalupe-Nipomo Dunes. *Inset*: Dune buckwheat (*Eriogonum parvifolium*) occurs on sea cliffs and coastal sand dunes. It provides subsistence for a diversity of moth and butterfly species. *Photo*: Guadalupe-Nipomo Dunes Center

Monterey Bay National Marine Sanctuary

The 6,100-square-mile Monterey Bay National Marine Sanctuary exemplifies the inherent diversity of the bioregion's marine environments. The large sanctuary extends from 7 miles north of the Golden Gate Bridge to halfway down the bioregion's coast to Cambria and out to 53 miles offshore. Among the sanctuary's unique features are its cavernous underwater canyons; deep-sea mountains, including the 8,000-foot Davidson Seamount off the Big Sur coast; kelp forests; and Elkhorn Slough.

Pigeon guillemots (*Cepphus columba*) breed on the bioregion's rocky coastal shorelines. *Photo*: Bruce Lyon

Owing to the incredible biotic diversity contained within it, the National Marine Sanctuary is known as the Serengeti of the Sea. The sanctuary shelters at least 450 species of marine algae and 525 species of fish. These encompass fully 2% of the world's estimated 22,000 marine fish species. It also contains 31 of the Earth's 36 animal phyla. The 34 marine mammal species include the blue whale (*Balaenoptera musculus*), the largest animal ever to have lived on Earth, and roughly 180 species of shorebirds and seabirds. The marine sanctuary provides habitat for 26 threatened and endangered species, including the south-central coast steelhead, leatherback sea turtle (*Dermochelys coriacea*), western snowy plover, southern sea otter, and blue whale.

The management plan for the Monterey Bay National Marine Sanctuary emphasizes an ecosystem-based approach that underscores the complexity of ecological interrelationships. It stresses cooperation with local stakeholders, including commercial fishermen, tour operators, and recreational fishermen and boating enthusiasts.

A willet skitters away from incoming surf on a beach at Monterey. *Photos*: Michael Peters

at high tide. Owing to tidal action and topography, the width of the shore zone varies from a few feet to 1,000 feet or more. While beaches may appear lifeless, seaweed debris known as wrack attracts insects, sand crabs, and other invertebrates, which in turn lure larger animals. Uniquely adapted to this environment are shorebirds, epitomized by the western snowy plover (*Charadrius alexandrinus nivosus*), California least tern (*Sternula antillarum browni*), and willet (*Tringa semipalmata*). Animals that use the shore zone but are less reliant on it include California gull (*Larus californicus*), osprey (*Pandion haliaetus*), bald eagle (*Haliaeetus leucocephalus*), raccoon (*Procyon lotor*), coyote, and ground squirrel. Several species of seals and sea lions haul out onto the zone's rocky and sandy beaches to breed and rest. As a matter of fact, the largest

Northern Elephant Seal

Large breeding colonies of the northern elephant seal are found on several beaches within the bioregion. During the eighteenth and nineteenth centuries, northern elephant seals were intensely hunted for the oil contained in their bountiful blubber. Indeed, the blubber of one large animal harvested on Santa Barbara Island in the 1800s reportedly produced over 200 gallons of the highly sought-after oil. By the late 1800s, the seal population was limited to one breeding colony of 20 to 100 individuals around Guadalupe Island, off Mexico's Baja California coast.

The elephant seal's recovery began during the early twentieth century when Mexico and the United States officially protected the species. Today, the seals are fully protected under the Marine Mammal Protection Act of 1972. Over 150,000 animals, all descended from the Guadalupe Island colony, are distributed among several rookeries. The largest is in the Central Coast Bioregion, in the vicinity of the Piedras Blancas Lighthouse and San Simeon.

Among pinnipeds (seal, sea lion, and walrus), the northern elephant seal possesses impressive diving abilities and anatomy. It dives to depths of over 1 mile to forage on squid and fish and can stay submerged for up to 2 hours. A mature male may grow to 13 feet long and can weigh 4,500 pounds. In addition to its size, the most conspicuous feature of the male elephant seal is its big nose, or proboscis. This feature allows it to produce either soft or booming vocalizations that advertise its status to other males in the colony and assist in establishing the breeding hierarchy. Like the males, females are acoustically talented and use their high-pitched rhythmic calls to control and protect their pups.

Large breeding colonies of elephant seals winter on several of the bioregion's beaches. Fights for breeding rights between adult males can be costly for the winner and the loser. However, the combat ultimately helps ensure the health of the colony. *Photos*: Michael Peters (*seal colony*); Ari Friedlander, NMFS Permit #19108 (*fighting males*)

Ed "Doc" Ricketts

Ed "Doc" Ricketts, a native of San Francisco, was an eminent marine biologist with a specialty in intertidal invertebrate diversity and ecology. His 1939 book, *Between Pacific Tides,* is a classic in marine ecology and was one of the first to examine intertidal organisms in an ecological and holistic context. In the 1930s, Doc advocated for the viewpoint that all organisms have an intrinsic value beyond their economic utility. In the 1970s, this perspective would be labeled *deep ecology*. Although it was not widely known during the 1930s and 40s, Ricketts was good friends with John Steinbeck and influenced many of the environmental themes in Steinbeck's writings. In fact, in his 1945 novel, *Cannery Row*, Steinbeck fictionalized the Pacific Biological Laboratory that Ricketts established in Monterey. Moreover, in *Beyond the Outer Shores: The Untold Story of Ed Ricketts* (2004), author Eric Tamm asserted that Steinbeck's books *Cannery Row* and *The Grapes of Wrath* could be interpreted as an early warning of anthropogenic environmental degradation. Ricketts died in 1948, at age 50.

Ochre sea stars (*Pisaster ochraceus*) in Morro Bay. *Photo*: Marlin Harms

A tiger shark (*Galeocerdo cuvier*) moves slowly through a kelp forest. *Photo*: Monterey Bay Aquarium

West Coast rookery of the northern elephant seal (*Mirounga angustirostris*) is found within the bioregion, near San Simeon.

Intertidal Zone

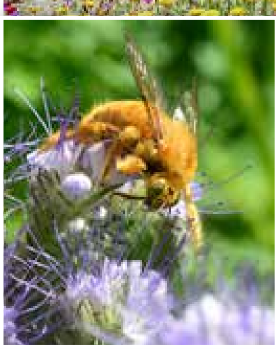
The intertidal, or littoral, zone is the area below the shore zone that is covered by water at high tide and uncovered at low tide. The rhythmic ebb and flow of the tides refreshes this habitat with abundant nutrients, which support an intricate web of life. A large number of biological *phyla* (the taxonomic group between kingdom and class) are represented in the intertidal zone, including Porifera (sponges), Annelida (segmented worms), Mollusca (e.g., clams, octopuses, squid, scallops, oysters, chitons), Arthropoda (e.g., shrimp, crabs, barnacles, sea spiders), and Echinodermata (e.g., sand dollars, sea stars, sea urchins). Within these phyla, the casual beachgoer commonly encounters crabs, barnacles, clams, sea snails, mussels, and sea stars.

Subtidal Zone

The subtidal zone extends from the low tide line to a water depth of roughly 250 feet. The zone supports phytoplankton, algae, seagrass, and kelp. On suitable substrate, these plants form a kelp forest that may rise 200 feet or more through the water column. Kelp forests are among the most productive aquatic ecosystems, and they provide habitat for an exceptional variety of invertebrates, fish, marine mammals, and birds. Central to the health of the kelp forest and the larger marine system is the interrelationship between two

Southern sea otter near Moss Landing, Monterey County, feeding on a cancrid crab. Otter populations were nearly decimated during the colonial period. *Photo*: Bruce Lyon forest inhabitants, sea otters and their prey, sea urchins (*Strongylocentrotus* spp.). Without sea otters, sea urchins can multiply and decimate kelp forests and the life they support, leaving urchin barrens in their wake. Thus, sea otters help to keep sea urchins in check and allow kelp forests and their associated species to flourish.

Harlequin ducks (*Histrionicus histrionicus*) winter along the bioregion's coastal waters as far south as Morro Bay. *Photo*: Michael Peters



Bee garden featuring sweet pea (*Lathyrus odoratus*, foreground), rosemary (*Rosmarinus officinalis*, green shrub midscene), and purple smoke tree (*Cotinus coggygria*, background). These are great choices for attracting bees. A male valley carpenter bee (*Xylocopa varipuncta*) foraging on lacy phacelia (*Phacelia tanacetifolia*). *Photos*: Ray Kindlig, San Luis Obispo Botanical Garden (*bee garden*); Kathy Keatley Garvey (*carpenter bee*)

Pelagic Zone

The pelagic zone is the final and deepest nearshore marine community. It stretches from depths greater than those where kelp will grow to the outer limit of the 12-mile contiguous zone. Vegetation in the pelagic zone is limited to floating phytoplankton, which are restricted to the depth where photosynthesis can occur (photic zone). Phytoplankton are the source of energy for zooplankton; together they form the base of the marine food chain. Plankton are particularly abundant where there is coastal upwelling. This occurs when surface water is pushed away from the coast by wind and is replaced by colder, nutrient-rich water from beneath. Upwelling fosters some of the world's most productive ocean fishing grounds, including the once-thriving sardine fishery near Monterey.

ECOSYSTEM-HUMAN SERVICES

The critically important pollination service provided by the European honey bee and native bees is an excellent example of an ecosystem-human service. Bees pollinate the blossoms of some of the bioregion's most economically important crops: strawberries, avocados, broccoli, and cut flowers. In fact, many native bee species can be more effective pollinators of some agricultural crops than the European honey bee. Decline of bee populations due to habitat loss, herbicide and pesticide use, parasites, and diseases has been a major concern for farmers whose crops rely on insect pollination.

Most of the bioregion is owned and managed by private landowners as working landscapes. Private lands deliver a wide range of values and goods that benefit everyone—free of charge. Vegetation in these lands intercepts rainfall and enhances water infiltration. Strong plant roots stabilize the soil and reduce the risks of flooding and landslides, which is particularly important on steep slopes. Water that falls on private lands is essential for keeping reservoirs full, replenishing near-surface water that supports stream flow, and recharging aquifers that provide critical water for agriculture, industry, and domestic consumption. Eventually, much of this water flows to the bioregion's estuaries and nearshore marine habitats, where it contributes nutrients and sustains salinity levels.

The production of free-ranging livestock and related agribusinesses rank among the top economic enterprises in the bioregion. Increasingly, ranches are supplementing their income with ecotourism activities such as hunting, bird watching, and trail rides. For example, after a Monterey County ranching couple viewed *City Slickers,* a 1991 movie in which urban dwellers experience a cattle drive, the couple said "we can do that"—and they did! The ecologically sustainable tourism on their ranch is sought after by residents and visitors alike. In this manner, the couple enhanced public services and benefited the economic sustainability of their ranch.

Landowners are also working with public agencies to manage their properties for private and public benefit. In just three counties within the Central Coast Bioregion (Monterey, San Benito, and San Luis Obispo), 21 properties enroll over 175,000 acres in the California Department of Fish and Wildlife's Private Lands Management (PLM) Program. They account for 20% of the properties and 14% of the acreage in the entire statewide program. The PLM Program offers landowners incentives to maintain and improve habitats for hunting and fishing, which increases ranch revenue and benefits watersheds and biological diversity.

The natural amenities provided by oak woodland are highly sought after for large-lot residences. *Photo*: Bill Tietje

Privately held lands are critically important to the environmental and economic well-being of the Central Coast Bioregion. In addition to providing profitable commodities and ecological services, their natural and cultural attributes contribute to a robust tourism. In 2017, for example, the three coastal counties in the region (Monterey, San Luis Obispo, and Santa Barbara) collectively recorded $6.4 billion in travel-related spending, generating over 63,000 jobs and providing over $572 million in tax revenue. The economic support, ecological services, historical and cultural values, and beautiful landscapes provided by private lands are fundamental to the environmental and cultural well-being of the bioregion.

ENVIRONMENTAL ISSUES

Suburban and Exurban Development

Having an average density of one home per 20 acres, nearly 90% of the bioregion is classified as rural. Increasingly, however, suburban and exurban developments, including ranchettes, golf courses, and infrastructure are accelerating habitat fragmentation. Within these developments, indigenous plants are often replaced with exotics, resulting in a reduction of native wildlife. To illustrate, the typical backyard supports some native bird species, but not all. It is unlikely that the urban resident will see or hear native habitat specialists such as the orange-crowned warbler or ruby-crowned kinglet. On the other hand, the northern mockingbird (*Mimus polyglottos*) and the exotic English sparrow (*Passer domesticus*) are frequently heard and seen. These species are *synanthropes*, meaning they have adapted to artificial urban landscapes. Exotic animals can also reduce populations of native birds. Domestic cats are a good example. When allowed to prowl outside, they are likely to prey on birds and other small vertebrates. Even well-fed cats exercise their natural predatory behavior. The best solution is to keep them permanently indoors.

As with bees and butterflies, some kinds of birds can be coaxed to live near people by planting or retaining native vegetation. Where there is a patch of willows (*Salix* spp.) or other native shrubs, urbanites may chance upon the

Bats and Large Vineyard Trees

By providing essential habitat for many invertebrates and vertebrates, large trees make an outsized contribution to animal diversity. Compared with smaller trees, large trees have more foliage, bark crevices, and nesting sites. In nonforested environments in particular, sizable isolated trees provide critical plant structure that lessens the biological effects of habitat fragmentation.

Insectivorous bats use large trees for foraging, protection from predators, roosting, and reproduction. Grape growers who retained large, isolated oak trees within their vineyards recently participated in research designed to assess the influence of these trees on bat foraging activity and species diversity. This study revealed the existence of 11 species of insectivorous bats in the interior of the vineyards. In addition, the isolated oak trees provided foraging areas for some species of woodland bats, increasing their presence within central coast vineyards.

Large valley oak trees in a San Luis Obispo County vineyard. A foraging Yuma myotis (*Myotis yumanensis*) has captured a moth. *Photos*: Marlin Harms (*vineyard*); Marlin Tuttle's Bat Conservation International (*bat*)

Bats are valued as natural predators of agricultural pests and are credited with saving the agricultural industry billions of dollars nationwide by helping to keep insects in check, reducing the need for pesticide application. Unfortunately, many species of bats are threatened by habitat loss and disease, and some are declining alarmingly. This is another reason why grape growers should maintain the majestic oaks within their vineyards and appreciate the trees' full worth. In addition to attracting insectivorous bats to their vineyards, trees provide habitats for diverse wildlife, stepping stones for passage across agricultural landscapes, and added beauty to the vineyard and to the broader rural countryside. The aesthetic enhancement strengthens tourism in the bioregion and the overall economy. Truly, the maintenance and restoration of large majestic oak trees in vineyards can be a win for the environment, the grower, and the public.

Bewick's wren (*Thryomanes bewickii*) and hear the incessant chirping of American bushtits (*Psaltriparus minimus*). A park, an urban greenway, or even a single large urban tree can provide many of the ecological functions of a rural habitat. These features also support biodiversity by serving as urban stepping stones for dispersing or migrating animals.

Intensive Agriculture

Rapid vineyard expansion has played a major role in the alteration of the bioregion's landscapes. Since the 1990s, the region's vineyard acreage has dramatically increased and now covers over 120,000 acres. The bioregion hosts over 400 wineries and produces nearly 15% of the state's wine grapes, valued at over $2 billion a year. Vineyard expansion results in the homogenization of vegetation and diminishes native animal diversity. Alternately, because of their adaptations to human-modified habitats, raccoons, opossums (*Didelphis virginiana*), domestic cats, dogs, and several species of birds, for example, the European starling (*Sturnus vulgaris*), may increase.

There are measures that growers can take to attract desirable and beneficial native animals. The preservation and restoration of patches of trees surrounding the vineyard and of individual large trees within it are particularly helpful. The placing of nest boxes along vineyard roads attracts barn owls (*Tyto alba*), violet-green swallows, ash-throated flycatchers, and western bluebirds, which can provide pest control benefits to the grower. Unfortunately, if the vineyard is both large and treeless, the addition of nest boxes may not complete the habitat requirements of some species of birds. As an illustration, oak mistletoe (*Phoradendron villosum*) seeds in the diet of juvenile bluebirds help them survive a harsh winter. Mistletoe, of course, requires local trees, which is another incentive for vineyard operators to preserve and incorporate native oak trees.

Invasive Animals

It is important to distinguish the difference between exotic and invasive species. Invasive species are nonnative plants and animals that are present in a given region and are known to cause harm to native ecosystems, human health, or infrastructure. Only a small portion of exotic species are actually considered invasive. Of the bioregion's roughly 460 terrestrial vertebrates (birds, mammals, amphibians, reptiles), 16 have been introduced, and some of these have proven detrimental to local biota and agricultural economies. Selected examples are wild pigs, quagga mussels (*Dreissena rostriformis bugensis*) and zebra mussels (*D. polymorpha*), and the Eurasian collared dove (*Streptopelia decaocto*).

Wild pigs in the bioregion include escaped domestic pigs and the descendants of Eurasian wild boars that were released in the 1920s in the vicinity of the Carmel Valley in Monterey County. They are now abundant throughout the rural lands of the bioregion. Pigs root for soil invertebrates (including earthworms), bulbs, roots, and acorns and other seeds, and even consume small mammals. As a consequence, successful oak regeneration may be hindered due to damaged tree seedlings, and riparian habitats can be severely degraded. Rooting is especially destructive when large numbers of pigs populate a relatively small habitat.

Feral pigs are widespread across the bioregion's rural lands. Their rooting can be destructive to native plant and animal habitats, especially in riparian corridors. *Photo*: Michael Peters

Among the most serious problems facing the bioregion's inland water bodies are exotic quagga and zebra mussels. These mollusks are native to Eastern Europe and are believed to have been inadvertently introduced to the United States in the 1980s in transoceanic ship ballast. After the turn of the century, quagga and zebra mussels were identified in California and more recently within the bioregion itself. The infected water bodies are San Justo Reservoir in San Benito County and Piru and Pyramid lakes near the southern margin of the region. Where they are present, the mussels reduce water nutrients, clog water infrastructure, and replace native mussel species. Efforts are ongoing to keep the mollusks from becoming more widespread in the bioregion's freshwater environments.

So far, the early fears that the introduced Eurasian collared dove would have adverse impacts on native species have not come to light. That said, the collared dove provides an example of how quickly an alien species can spread. The dove was found breeding in Florida in 1982. From there, it rapidly dispersed across North America and today is common in many urban environments within the Central Coast Bioregion. Long-term monitoring of the collared dove may be warranted.

A collared dove preyed upon by a peregrine falcon. *Photo*: Bruce Lyon

Species in Peril

Invasive species, various forms of development, and climate change have contributed to declines in the populations and distributions of many species. A small selection of these includes the Morro Bay kangaroo rat (*Dipodomys heermanni morroensis*), kit fox (*Vulpes macrotis*), California tiger salamander, yellow-legged and red-legged frogs, western pond turtle, northern elephant seal, southern sea otter, and the California condor.

The Central Coast Bioregion has played a pivotal and an emblematic role in the recovery and restoration of the California condor, one of the rarest birds in the world. Crucial to the condors' survival was the concern and dedication of the McMillan brothers. Eben and Ian McMillan owned a 640-acre ranch on the east side of the Central Coast Bioregion near the Carrizo Plain. Throughout their lives, the brothers observed and studied the environmental complexity of their local ecosystem. From the 1930s through the 1950s, their sightings of the California condor became fewer and fewer. By the middle of the twentieth century, the condor's slow reproductive rate, combined with egg collecting, shooting, environmental contaminants (DDT), and habitat loss, resulted in its near extinction. Eben and Ian's concern brought attention to the plight of the condor and to the broader issues that precipitated the decline of the species. In 1963, the National Audubon Society commissioned the self-taught naturalists and conservationists to monitor and count the condors. They determined that only 40 condors remained.

California condor nest in the Los Padres National Forest, Ventura County. The nestling is being brooded by its father. *Photo*: Joseph Brandt, USFWS

The McMillan brothers' cautions and forewarnings were finally heeded in the late 1970s, when approximately 30 condors remained. In 1979, the California Condor Recovery Program was established by a collaboration between government agencies and concerned citizens. In 1983, the partnership implemented a captive breeding program as a means to save the species. The last of the remaining condors were removed from the wild in 1987 and taken to the Los Angeles and San Diego zoos for breeding. The endeavor proved successful, and in 1992 the first condors were released back into the wild in the southern reaches (Ventura County) of the bioregion. More birds were let loose in Santa Barbara County in 1993, San Luis Obispo County in 1996, and Monterey County in 1997.

In conjunction with the captive breeding program, a number of areas in the bioregion were designated as condor sanctuaries. These habitats are managed to ensure the survival of the species and provide settings for additional research. The largest (53,000 acres) is the Sespe Condor Sanctuary in northern Ventura County. Others include the Sisquoc Condor Sanctuary in the San Rafael Wilderness and the Big Sur Coast Sanctuary in the Ventana Wilderness. As of 2018, 160 condors were flying again in California, the majority in the Central Coast Bioregion. The best chance for visitors and residents to see California condors is along the Big Sur coast, in the vicinity of Pinnacles National Park, and near the condor sanctuaries in Santa Barbara and Ventura counties.

Climate Change

During the last few thousand years, the plants and animals of the Central Coast Bioregion have adapted to climate conditions that varied over the short term but remained relatively consistent over the long term. Now, both short-term and long-term climate regimes are clearly changing. Climate-change indicators and forecasts for the bioregion portend longer periods of warmer and drier conditions punctuated by shorter interludes of greater and more intense rainfall. The consequences for the bioregion are expected to be comprehensive and challenging. For example, by 2100, portions of the bioregion's signature blue oak and valley oak woodland will likely be replaced by vegetation types that are adapted to drier conditions, such as shrubland and grassland. The ability of these oak species to adapt to a changing climate by dispersing to new areas may be hindered by competition with other plants, limits of pollen dispersal, habitat fragmentation, and wildfire events. In contrast, owing to their ability to endure moderate temperature increases and precipitation decreases, coast live oak and canyon live oak may experience little change.

Climate change will also diminish the region's higher-elevation mixed hardwood-conifer forests and decrease the chaparral vegetation in the eastern part of the bioregion. Reduced water flows and increased temperatures will detrimentally impact amphibians, invertebrates, and freshwater fish, especially cold-water species. Warmer temperatures, higher acidity, rising sea levels, and modified food webs will alter the nature of the nearshore marine ecosystem. Put simply, climate change will create a broad spectrum of challenges to healthy ecosystem functioning and human well-being.

CONCLUSION

Biotic interactions with the region's singular geology, climate, hydrology, and soils over millennia have yielded fascinating, and in many cases, unique mosaics of land and life. Humans initially became a component of the bioregion's biotic communities more than 10,000 years ago. Over time, native peoples adapted their lifeways to the local environment and learned to support themselves in a relatively sustainable fashion. Although they modified portions of the region's biota and landscapes, their stewardship rarely threatened the bioregion's overall natural biodiversity.

The arrival of European explorers beginning in the 1540s and settlers in the 1700s triggered the rapid demise of indigenous populations, profoundly changing the extent and character of their land-use practices. Foreign economies were swiftly imposed with attendant increases in human populations, settlement infrastructure, and exotic species. As a consequence, land uses became progressively more intensive, more extensive, and often damaging to the region's inherent biodiversity.

By the latter half of the twentieth century, the economic and societal benefits of conserving native terrestrial and aquatic habitats were being recognized and good stewardship encouraged. A major and chronic challenge to these continuing endeavors is the discord between development and biodiversity conservation. Therefore, the primary stewards of the land, private landowners, have an opportunity to maintain and ensure the ecological, economic, and cultural viability of the bioregion. Governments, nongovernment organizations (NGOs), community groups, and universities are working with private landholders to address sustainability issues, and progress has been achieved. These undertakings are ongoing, and the growing recognition that societal well-being is inextricably intertwined with environmental health is reassuring. Nonetheless, human encroachment on wild organisms and their habitats continues.

The long-term implications of our interaction with the natural world are fraught with uncertainty and difficult to forecast. There is still much to learn about the bioregion's natural history and ecology. It is crucial for people to develop lifeways that are more harmonious with the bioregion's natural environment.

Explore the Bioregion

The Central Coast Bioregion offers residents and visitors countless opportunities to explore and enjoy its natural and cultural diversity. The following is a sampling of transportation arteries and places that distinguish the bioregion.

Explore the Central Coast Bioregion. *Source* R. Johnson, ANR IGIS.

The much-photographed Bixby Creek Bridge on U.S. Highway 1 south of Carmel, Monterey County. *Photo*: California Department of Transportation

Highways. The bioregion is transected by a number of east-west and north-south highways that afford the visitor opportunities to observe many of the physical and biological features discussed in the text. For example, while crossing the bioregion on Highway 46, the traveler will note how differences in moisture, topography, aspect, and soils influence vegetation patterns. In addition, a number of geologic structures, most prominently the San Andreas Fault, are traversed by the thruway. Similarly, the north-to-south highways provide informative and striking views of the bioregion's remarkable natural and cultural landscapes. California Highway 1 is particularly noteworthy because it closely follows one of the most scenic and rugged coastlines in North America. In the north, the route offers spectacular views of craggy coastal features and mixed biological communities ranging from patches of coast redwoods to colonies of elephant seals. Farther south, it skirts sandy beaches and meanders through oak woodlands, grasslands, and chaparral-covered hills. The highway also links the bioregion's major coastal cities and associated cultural attractions, including missions and museums. These and other motorways connect numerous features that are particularly expressive of the region. Selected special locales are listed below, from north to south.

Central California Missions. San Juan Batista is the most northerly of the nine missions located within the bioregion. As a group, they are among the 21 missions established in California from 1769 to 1833 by Catholic priests of the Franciscan order. The missions primarily express the region's Hispanic heritage and offer opportunities for reflection on the ways in which Spanish colonization forever changed the ecosystems and native cultures of the region. Prominent among these are the missions at Carmel, San Luis Obispo, and Santa Barbara. A few, like La Purisima, have active, well-interpreted gardens where visitors can observe indigenous and introduced plants that were important to both native and colonial peoples.

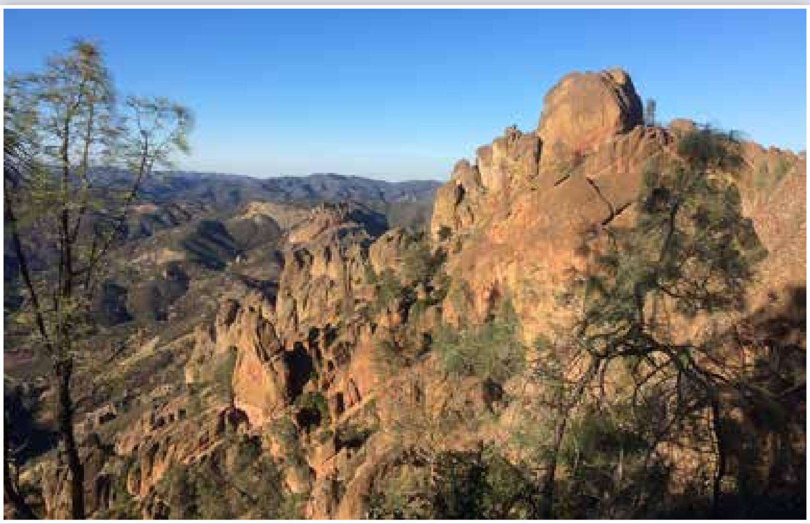
Henry W. Coe State Park. The northeastern corner of the bioregion incorporates a component of Henry W. Coe State Park. Located in the Diablo Range, it is comprised of lofty ridges, steep canyons, and a variety of biotic environments. Camping, birding, and nature photography are especially popular, as are backpacking and bike riding on the many trails. Spring is often ushered in with fabulous wildflower displays. A quarter of the park's 89,000 acres (22,000 acres) are designated Henry W. Coe State Wilderness.

Monterey Bay Aquarium. The aquarium is located at the site of the former sardine cannery that inspired John Steinbeck's book *Cannery Row* (1945). In this huge aquarium, visitors experience the amazing diversity of marine life, including giant kelp, sea otters, jellyfish, and numerous other native marine plants and animals. In addition to its varied displays, the aquarium brings attention to many of the human-induced environmental challenges to healthy marine ecosystems. The Aquarium is building the Bechtel Family Center for Ocean Education and Leadership to advance and expand its Education and Teacher Professional Development programs. The intent is to provide today's young people with the necessary knowledge, skills, and motivation to create solutions for the complex environmental challenges facing the region and planet.

Students in a Discovery Lab during a field trip to the Monterey Bay Aquarium. The students are studying the purple sea urchin (*Strongylocentrotus purpuratus*). During the past few years, purple sea urchin populations have grown rapidly along some northern California coastlines, devastating kelp forests that provide cover and food for many marine animals. *Photo*: Monterey Bay Aquarium

Pacific Grove Natural History Museum. The museum opened its doors in 1883 as one of the first natural history museums in the country. The facility shares with the bioregion's residents and visitors the natural history of local terrestrial and marine ecosystems. The museum is a hub for community science efforts—including LiMPETS (Long-term Monitoring Program and Experiential Training for Students), a citizen science program that provides youth with hands-on experience in the scientific process. In addition, the museum offers California Naturalist classes.

Pfeiffer Big Sur State Park. The park is found just off California Highway 1 in the heart of Big Sur near the Bixby Creek Bridge. Pfeiffer Big Sur offers spectacular views of California's most iconic coastline and is composed of over 1,000 acres of redwood, oak, chaparral, and grassland environments. Julia Pfeiffer Burns State Park is located 8 miles farther south along Highway 1, where a famous attraction is the scenic McWay Falls, which drops 80 feet into the Pacific Ocean. The offshore waters of both parks are located within the California Sea Otter Game Refuge and provide one of the best opportunities to observe otters and other marine wildlife.



Along the High Peaks trail, Pinnacles National Park. *Photo*: Beth Hudick, National Park Service

Pinnacles National Park. First created as a national monument in 1908 by President Theodore Roosevelt and later designated a national park, the Pinnacles straddle the San Andreas Fault. Over millions of years, the fault has transported exotic rock formations to this region that sharply contrast with the surrounding physical landscape. Visitors can explore extensive talus caves and hike among towering rock spires. Peregrine falcons, golden eagles, and California condors may be noticed by sightseers. The 26,000-acre park is east of Highway 101 and mostly within San Benito County. Nearby towns are Salinas, Soledad, and King City.

Maritime chaparral in Montaña de Oro State Park. *Photo*: Matt Ritter

Piedras Blancas and Elephant Seal Rookery. Constructed in 1875, the Piedras Blancas Light Station offers an excellent location for viewing a broad range of coastal habitat. A mile south is the largest elephant seal rookery on the West Coast. Annually, up to 17,000 seals visit the secluded 6-mile stretch of sandy beaches. The seals are best viewed from designated observation areas during December, January, and February.

Montaña de Oro State Park. Located near Morro Bay, San Luis Obispo County, the park offers a variety of physical environments, including rugged cliffs, coastal terraces, canyons, mountains, and secluded sandy beaches. In spring, the visitor may catch the blooming of golden wildflowers after which Montaña de Oro ("Mountain of Gold") State Park is named. A visit to the park also provides opportunities to explore the biodiverse intertidal zone and nearby Morro Bay Estuary.

A kaleidoscope of monarch butterflies wintering near Pismo Beach, California. *Photo*: Bruce Lyon

Monarch Butterfly Grove at Pismo Beach. Adjacent to Highway 1, this eucalyptus grove hosts thousands of monarch butterflies that gather on the trees from late October to February. One of the largest monarch colonies in the United States, the Pismo Beach grove winters up to 25,000 butterflies.

Santa Barbara Botanic Garden. The 65-acre garden located in Santa Barbara's Mission Canyon features approximately 1,000 species of indigenous and rare plants. Workshops and outdoor instruction, including a California Naturalist class, are offered on ecology, landscape design, and gardening. The emphasis is on native plants that attract bees and birds, save water, and are compatible with the Mediterranean climate of the bioregion.

Santa Barbara Museum of Natural History. This moderate-sized natural history museum is located in an idyllic oak woodland setting. The facility accommodates a variety of interpretive exhibits that emphasize the region's flora and fauna. Offering many hands-on activities for visitors, the museum is a great place for a school field trip. It also encompasses a backyard for both kids and adults to explore and learn about the natural history of the Central Coast Bioregion.

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—William D. Tietje

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