A Definition of Biodiversity

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Biodiversity may be defined on many different levels. For a regional landscape or an entire state, it is the diversity of species, habitats, and vegetation types. For a habitat or vegetation type, it is the diversity of life forms within it. For a species, it is the genetic variation within a population or among populations.

California is truly a special place, known for its great variety of plants and animals. The state is home to some of the nation's most unique and highly threatened species (see map at right) and is one of the 35 biodiversity "hotspots" recognized worldwide (Mittermeier et al. 2004, Zachos and Habel 2010). Compared to other states, California has both the highest total number of species and the highest number of endemic species—those that occur nowhere else (Stein 2002).

This variety of life, or biodiversity, can be explained by our unique geography, climate, and geologic history. Where else can you find the highest point and the lowest point in the contiguous United States? Mount Whitney (14,494 feet) and Badwater, Death Valley (282 feet below sea level) are within 80 miles of each other, and both are only 200 miles from the Pacific Ocean, where a diverse marine landscape exists just offshore. California's high mountain ranges and deserts have kept native animals and plants relatively isolated from the rest of the continent. The warm summers and mild winters of California's rare Mediterranean climate also make the habitats different from those in other parts of the country. Then there is the sheer size of the state; California is more than 100 million acres in area and over 1,000 miles north to south. Add these factors together and you have one of the planet's richest places for plant and animal diversity. California's natural heritage embodies the very definition of biodiversity.

Because California is also a great place for human life, it is home to the largest population of people in the country. The human demands for the land, water, and natural resources that make life so abundant in California present the greatest threats to its unique plants and animals. California is second in the nation in number of rare species within a state, with over one third of its species identified as at risk. California also ranks third in the number of species that have been lost forever (Stein 2002). Our challenge is to meet the needs of society while maintaining the state's remarkable biodiversity for future generations.

For the purposes of this atlas, we are examining biodiversity on a statewide level. Updated from the 2003 edition, this atlas presents a summary of the best available information we have to date on species, habitats, and vegetation types at that level. A complete analysis of biodiversity would include many additional groups of living things for which we lack statewide data. This would include fungi, lichens, most non-vascular plants, such as mosses, and more. For animals, this would include most invertebrates, such as mollusks, insects, spiders, and crustaceans, and other marine life that reside in the waters off California's coast. Nevertheless, we can still identify places on the landscape where biodiversity appears to be unusually high.

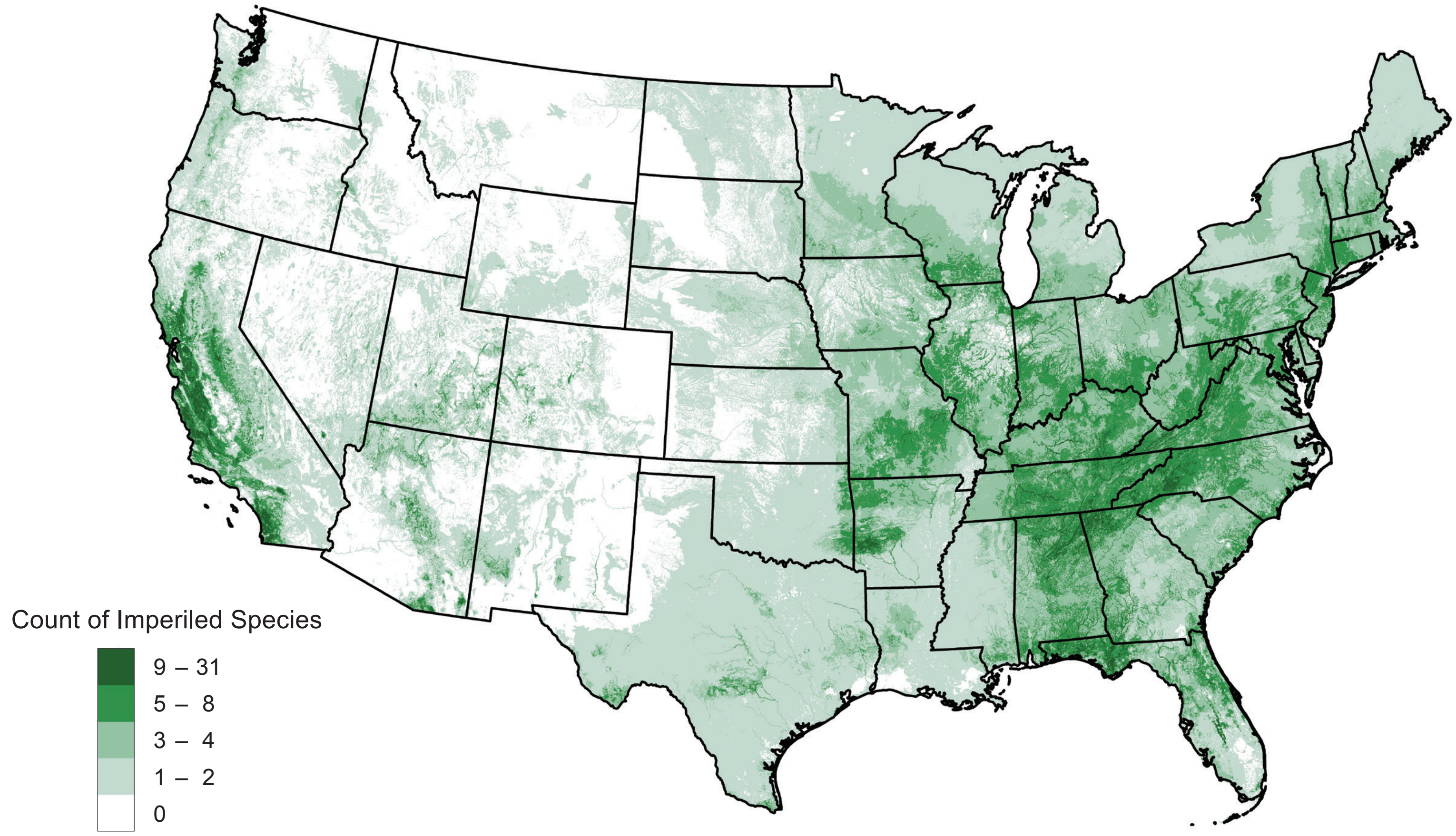
Biodiversity Analysis Main Components

Richness — a measure of diversity. The total number of plant taxa, animal species, or vegetation types in a given area. Note that this is the number of species or taxa, rather than the number of individuals. An area high in bird richness, for example, supports many different species of birds. The density of birds is not necessarily higher here than in other areas of the state.

Rarity — a measure of sensitivity. Used for those taxa that have special status due to very limited distribution, low population levels, or immediate threat, such as habitat conversion. An area high in rarity has many taxa that meet this definition.

Endemism — a measure of natural distribution. Used for those taxa that are found only in one specific area, such as one region or the state itself. A region of high endemism has many taxa restricted to it.

Note: "taxa" refers to organisms at different levels of biological classification, including species, subspecies, varieties, and evolutionarily significant units.



Richness of Imperiled Species in the United States

Numbers of species in the lower 48 United States that are protected by the Endangered Species Act and/or considered to be in danger of extinction. Adapted from NatureServe's Map of Biodiversity Importance Project (NatureServe 2019).

Biodiversity Rank	Diversity	Rarity/Risk	Endemism	Extinction
1	***California***	Hawaii	***California***	Hawaii
2	Texas	***California***	Hawaii	Alabama
3	Arizona	Nevada	Texas	***California***
4	New Mexico	Alabama	Florida	Texas
5	Alabama	Utah	Utah	Georgia

Source: Adapted from *States of the Union: Ranking America's Biodiversity* (Stein 2002).

Note: Based on analysis of over 21,000 species in the United States.

Richness in California	Number of California Native Species (Taxa)	Percent of U.S. total Species (Taxa) in California	Number of California Endemic Species (Taxa)	Number of California Special Status Taxa
Vascular Plants	5332 (6578)	32 (35) %	1315 (2309)	2351
Amphibian	68 (73)	22 (20) %	32 (36)	49
Reptile	99 (115)	29 (19) %	11 (16)	45
Bird	402 (456)	50 (44) %	2 (18)	157
Mammal	196 (313)	45 (32) %	17 (82)	143
Freshwater Fish	70 (105)	8 (10) %	19 (44)	97

Sources: NatureServe (2020a), Jepson Flora Project (2020a), Baldwin et al. (2012), California Department of Fish and Wildlife (2020a).

Note: Species and taxa counts include extinct taxa and fluctuate between authoritative sources over time due to ongoing changes in recognized taxonomy, newly described taxa, and conservation status. For this reason, numbers mentioned in later chapters may not agree with this table.

An Introduction to the Atlas

What's New in the Second Edition

The second edition of the Atlas of the Biodiversity of California has been updated with all new maps since the first edition was published in 2003. They were created using the latest mapping techniques and are based on a greatly expanded database of species locations and habitat information. The map colors have been chosen for easier interpretation by persons with color vision deficiency. The text in each chapter has been updated by experts in the field to contain the most current information available. The revised edition also includes expanded content on marine biodiversity, a new chapter on climate change, and updates on methods of conserving California's biodiversity.

The maps of taxonomic richness and rarity look slightly different than those in the first edition, reflecting improvements in available biodiversity data. The taxonomic richness maps are based on predictive habitat models that are more detailed than the species range data used previously. The vegetation maps and predictive habitat models reflect millions of additional acres of vegetation that have been mapped according to the Survey of California Vegetation fine-scale mapping standards. The rarity and endemism maps incorporate more than twice the number of CNDDB occurrences, as well as additional data gathered from BIOS and other partner datasets. The CNDDB and BIOS data systems are described below.

Organization of the Atlas

The data in the atlas are presented in five major sections. The first section, "A Remarkable Geography," showcases geographic data such as climate, geology, and vegetation that underlie California's extraordinary biodiversity. "Measures of Biodiversity" displays maps of richness, rarity, and endemism for major taxonomic groups such as plants, mammals, and invertebrates. "Examples of Biodiversity" presents iconic or unique habitats and species from across the state. "Threats to Biodiversity" outlines human-driven threats to biodiversity, including population growth and climate change. Finally, the last section, "Conserving Biodiversity," describes some of the efforts to protect California's natural heritage, such as conservation planning and habitat restoration.

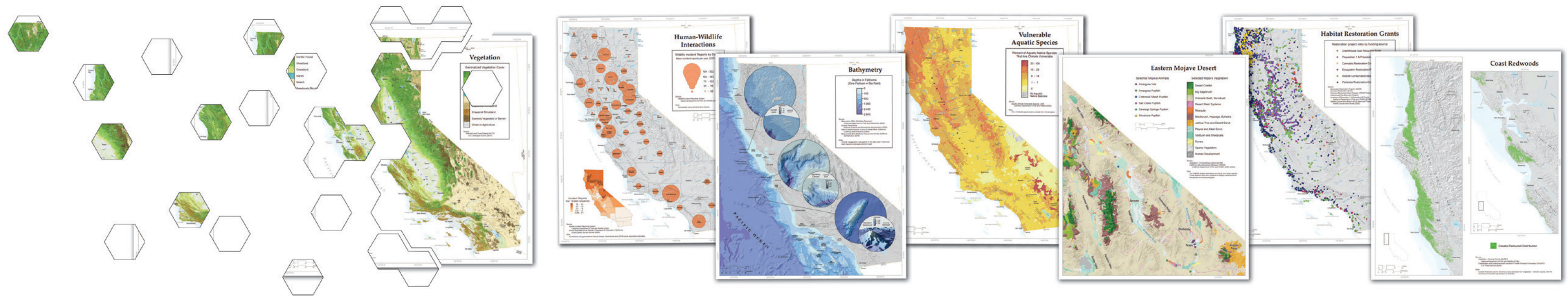
The symbols and data sources common to all of the maps in this atlas are presented on page 8. A glossary of biological, geographical, and management terms begins on page 103.

Gathering the Data

All maps in the atlas present the most comprehensive statewide or regional datasets available for the topics chosen. The data were primarily assembled from California Department of Fish and Wildlife (Department or CDFW) programs that map and track biodiversity data, as described below. The digital datasets used to create many of the maps in this book are available on the Department's BIOS website and are updated regularly to reflect the most recent information for California. Although the maps depict the entire state of California, many parts of the state have not been surveyed at this time; only the data collected in surveyed areas are represented on the maps. To some extent the topics chosen, particularly those featured in "Examples of Biodiversity," reflect what datasets are available. Unless otherwise specified, the maps in the atlas show present-day biodiversity in California and are not based on historical information.

Biogeographic Information and Observation System — a library of spatial datasets

The Biogeographic Information and Observation System (**BIOS**) is a system designed by the Department to manage and visualize biogeographic data for California. It currently includes a library of almost 2,500 spatial datasets providing information on California's flora, fauna, and natural resources, such as species ranges, distributions, and survey detection locations. BIOS houses datasets developed by Department scientists and staff, as well as data shared by partner agencies and researchers, and makes this information publicly available for online viewing and



downloading. The dataset number listed on the map sources in this book (i.e., *Vegetation - Sonoma County [ds2691]*) corresponds to the BIOS dataset number.

The Survey of California Vegetation — fine-scale vegetation maps for California

The Survey of California Vegetation (**SCV**) sets standards for vegetation surveying, classification, and mapping in California. By following these standards, vegetation maps of different parts of the state, produced by various agencies or other groups, can be combined seamlessly. To date, 52 million acres of vegetation have been mapped or are being mapped according to SCV fine-scale mapping standards. These maps can be viewed and downloaded from BIOS; the *Vegetation (MCV / NVCS) Mapping Projects – California [ds515]* dataset (CDFW 2020) lists the mapping projects that are completed or in progress at the current time. The SCV conforms to the National Vegetation Classification Standard (USNVC 2019), so that California's vegetation classification nests within the national system.

California Wildlife Habitat Relationships — a database of wildlife information

The California Wildlife Habitat Relationships (**CWHR**) system (CDFW 2014) includes several components—current range maps, habitat suitability models, and life history information—that describe all regularly occurring terrestrial vertebrates in California. The range maps represent the typical geographic extent of each species. The habitat suitability models predict the habitats (vegetation types, cover, special habitat features, etc.) that a species is likely to use for breeding, feeding, and resting. These models are combined with vegetation maps to create the CWHR predictive habitat maps, pinpointing where species are most likely to be found within their ranges. CWHR has been used for several large wildlife resource conservation efforts, including the California Wildlife Action Plan, and is used to predict wildlife response to changes in habitat condition.

California Natural Diversity Database — an inventory of California's rare species

The California Natural Diversity Database (**CNDDB**) is a statewide inventory of the locations, called occurrences, and status of the state's rarest plant and animal species. The CNDDB is California's natural heritage program and is a member of the NatureServe Network, an international network of over 100 similar programs throughout the western hemisphere. Maps representing high priority special status plants and animals, including vertebrates and invertebrates, were created using occurrence data from the CNDDB (CDFW 2020b). The CNDDB has mapped over 96,000 locations for more than 3,000 of California's rarest and most imperiled species.

Areas of Conservation Emphasis — a source for biodiversity maps

The Areas of Conservation Emphasis (**ACE**) project combines species and habitat data from BIOS, CNDDB, CWHR, and the SCV to develop maps of biodiversity for California, such as the amphibian, reptile, bird, mammal, plant, and invertebrate richness and rarity maps shown in this atlas. ACE was designed primarily to provide a set of information-rich maps to those working in the field of biodiversity and species conservation, but it is also available to any member of the public with an interest in understanding the most current data concerning California's biodiversity. In addition to maps of species diversity, ACE also develops maps of significant habitats, habitat connectivity, and climate resilience.

ACE has two principal map types: terrestrial and aquatic. Terrestrial maps summarize land-based biodiversity data using a 2.5-square-mile hexagon grid. Aquatic analyses concern fish and aquatic-obligate species such as waterfowl, many amphibians, river otters, pond turtles, and other species for which surface water is an essential habitat component. These are summarized by watershed, as described below.

Creating the Maps

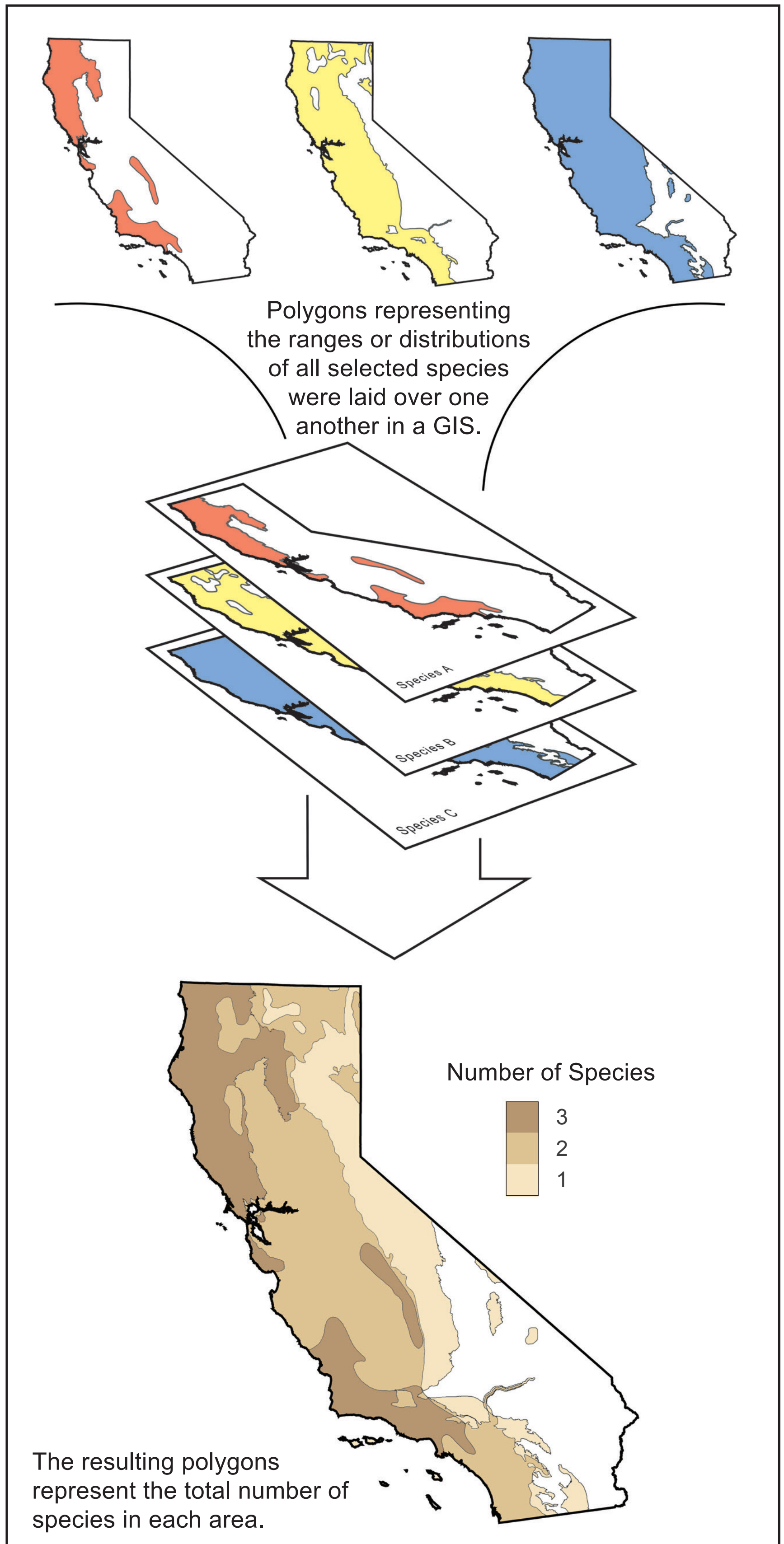
All of the maps in this atlas were created using a geographic information system (GIS). A GIS is a digital system for recording, creating, and analyzing spatial information about the world. A GIS is an excellent tool for representing the complexity of the real world because it can easily combine multiple layers of information in various ways to conduct analyses and create maps.

ACE-derived Maps

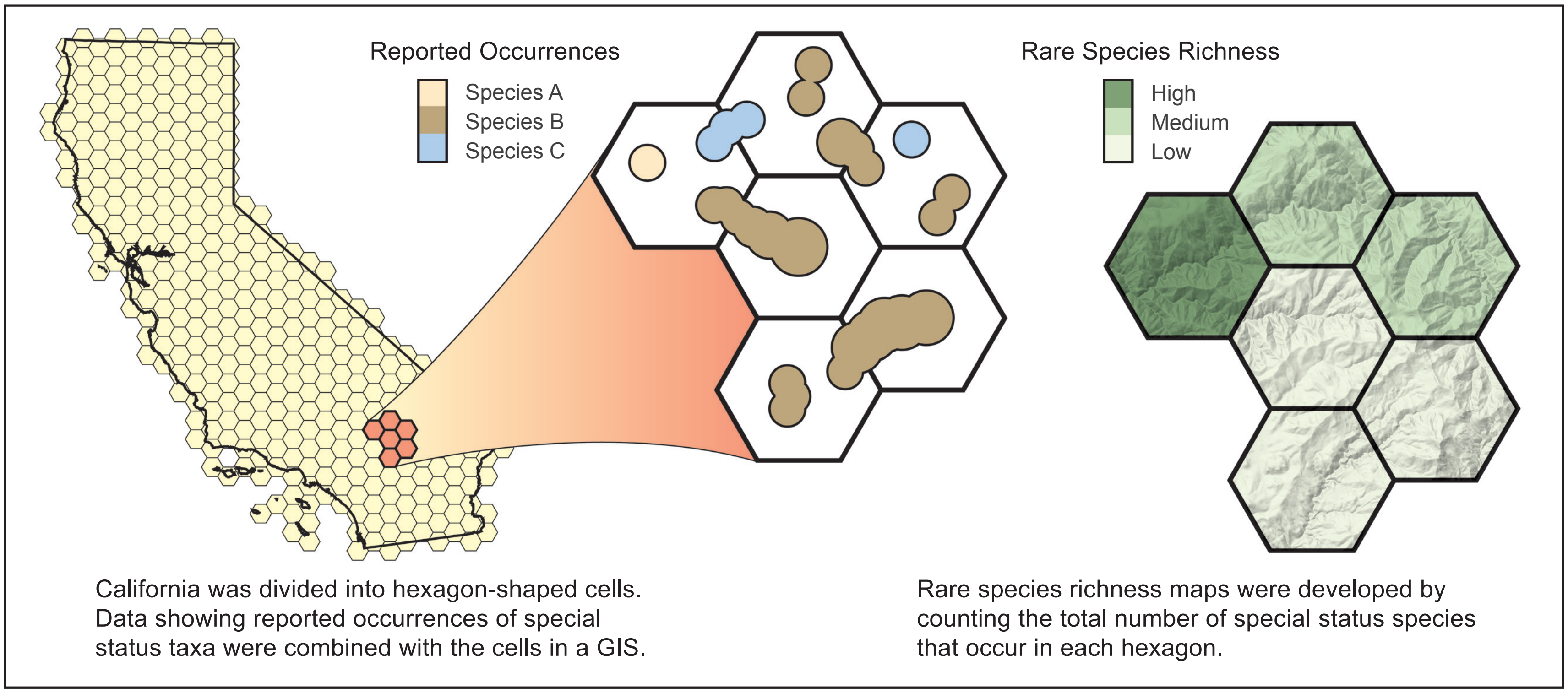
All of the ACE-derived maps represent patterns of biodiversity across the state, analyzed either by hexagon or watershed. Terrestrial ACE data are analyzed in a regular grid of 2.5-square-mile hexagons that is drawn over the entire state. Aquatic data are summarized to watersheds at the HUC12 level, rather than hexagons. Unlike the regular terrestrial hexagon grid, watersheds are defined by contours in the landscape, forming natural bowls which catch and direct water to low areas in the topography, forming ponds or streams. Because they are defined by landscape form, watersheds are variable in size and shape. The watersheds shown in these maps average 40 square miles in size but may exceed 400 square miles.

The ACE maps summarize data on species and habitats within each hexagon or watershed. For example, terrestrial ACE richness maps superimpose CWHR predictive habitat maps over the ACE hexagon grid and summarize them to reflect the total number of species that potentially occurs there (see the figure at right). Similarly, rare species occurrence information is summarized by hexagon to generate the rare species richness maps, as shown in the figure on the opposite page. Irreplaceability maps are also based on occurrence data, but they use a rarity-weighted index. Each species or subspecies is assigned a value that is inversely proportional to the number of cells in which it is found. The weighted values are then summed for each cell.

Except where noted, the legend categories were created by looking for natural breaks in the distribution of hexagon scores. On several maps, however, the data is displayed using quantiles, where each legend category contains an equal number of units. Richness and rarity maps in the "Measures of Biodiversity" section include data for native taxa only. The native richness maps for all animals are presented at the species level, except maps of climate vulnerable taxa, which include subspecies. Rarity richness maps consider taxa at both full and subspecies levels. Some maps include



How Species Richness Maps Were Created

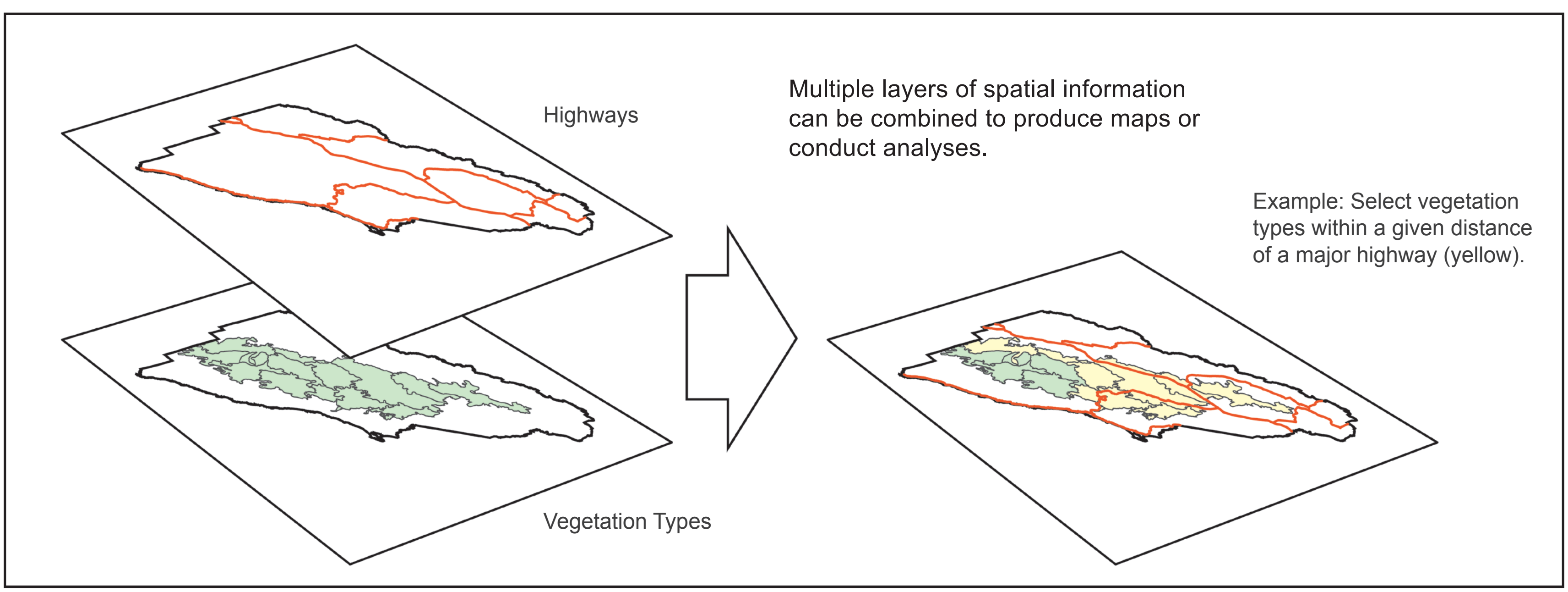


How Rare Species Richness Maps Were Created

ecoregional boundaries as defined by U.S. Department of Agriculture (USDA) sections (USFS 2010). Note that the Central Valley, which includes both the Sacramento and San Joaquin valleys, is called the Great Valley Ecoregion on these maps.

Other Maps

The remainder of the maps in the atlas were created by overlaying data from one or more sources onto a single map. The figure below shows how highways and vegetation types can be displayed on the same map. The resulting map shows where the vegetation types and highways are in relation to each other, and can be used to assess which vegetation types are within a given distance of a highway. Overlaying data layers allows the visualization of the spatial distribution and relationships among multiple sources of information.



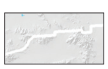
Creating Maps by Overlaying Layers

About the Maps

Map Symbols

These map symbols appear on most of the maps in this atlas. Unique symbolism is explained in the legend for each map.

State Boundary

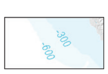

Regional Boundary

City or Town


Lake

Seasonal or Dry Lake

Historical Lakebed



Bathymetry

River or Stream

Small Islands

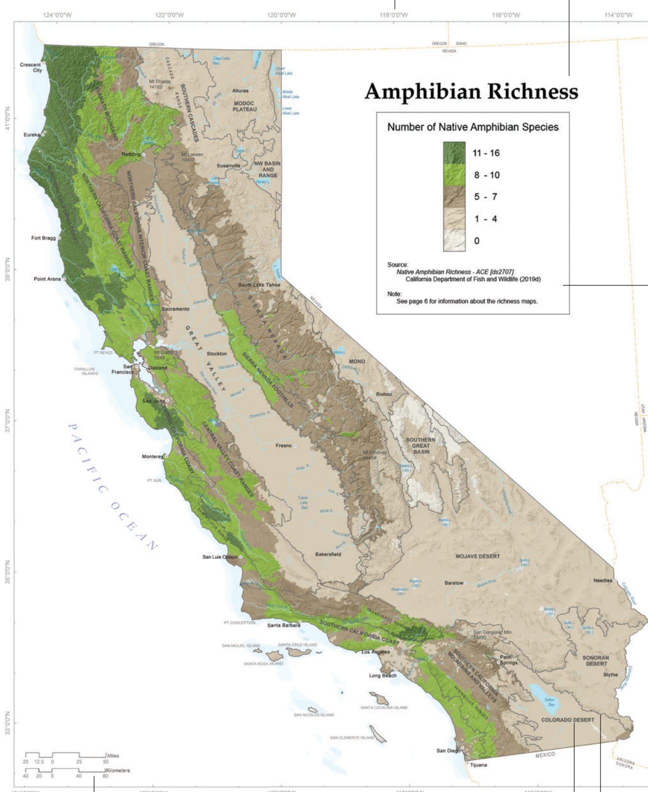
Marine Feature

Mountain Peak

Notes on reading the maps

Longitude tic marks on top and bottom neatlines count from east to west.

Legend describes the information specific to each map.



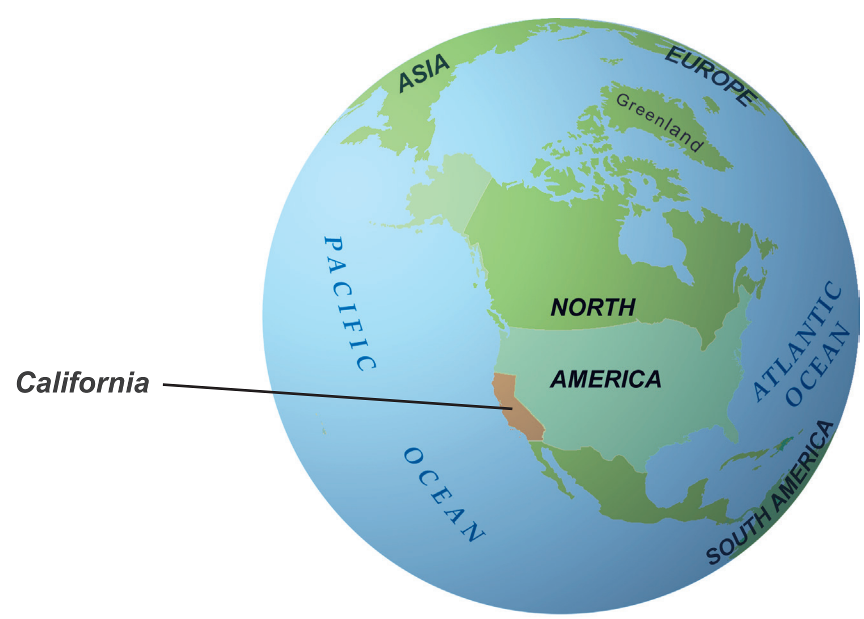
Sources listed here are unique to this map.

Latitude tic marks on left and right neatlines count from south to north.

Scale bar shows both miles and kilometers.

Regional names and boundaries help to orient the reader.

Where in the world is California?



Base Map Data Sources

Each atlas map includes "base map" reference layers that show geographic context without distracting from a map's subject matter. Here are base map data sources common to many of the maps:

<u>United States Geological Survey</u>

- State Boundaries
- Cities, Place Names
- Hydrography (lakes, rivers, coastline)
- Digital Elevation Model (hillshade, shaded relief)

<u>National Oceanic and Atmospheric Administration</u>

- Bathymetry
- Marine Place Names

<u>Esri</u>

- State and International Boundaries
- U.S. Highways (TomTom North America, Inc.)

<u>California State Lands Commission</u>

- Coastline and Islands

<u>United States Forest Service</u>

- Ecological Subregions for the State of California

Map Projection

Most of the maps use a map projection called "California Albers," which was developed in the early 1990s by the GIS staff at the Stephen P. Teale Data Center (State of California). This projection was selected because it does a relatively good job of depicting California on a flat surface. The parameters of this projection are listed below.

Projection Name: California Albers

Type: Albers Equal Area Conic

Datum: North American Datum 1983 (NAD 83)

Spheroid: Geodetic Reference System 1980 (GRS 80)

Parameters:

Units:	Meters
False Northing:	-4000000 meters
Central Meridian:	-120 00 00 (longitude)
Standard Parallels:	34 00 00 (latitude)
	40 30 00 (latitude)
Latitude of Origin:	00 00 00 (Equator)

Notes on Species Names

Names of vascular plants are from The Jepson Flora Project (Jepson 2020a). Names of amphibians and reptiles are generally those adopted by the Center for North American Herpetology and the Society for the Study of Amphibians and Reptiles Names Database (Crother 2017). Names of birds are those published by the California Bird Records Committee and the American Ornithologists' Union Committee on Classification and Nomenclature (Chessar et al. 2019). Mammal names are from the *Revised Checklist of North American Mammals North of Mexico* (Bradley et al. 2014) except where more recent taxonomic changes have been published. Names of fishes are generally those published by the American Fisheries Society's *Common and Scientific Names of Fishes from the United States, Canada, and Mexico* (Nelson et al. 2004) or *Inland Fishes of California* (Moyle 2002). For terrestrial and marine invertebrate animals, we adopted the names used by NatureServe, whose references by taxonomic group are listed at www.natureserve.org. The standard reference for marine algae used here is *Marine Algae of California* (Abbott and Hollenberg 1976). We have adopted the scientific convention for capitalization of the official common names according to the current standard for each taxon group. For example, for plants and mammals only proper names are capitalized, while all names of fish, amphibians, reptiles, and birds are capitalized.

Photographs

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