

Below the Surface:

CALIFORNIA'S FRESHWATER BIODIVERSITY



Water is the driving force of all nature. —LEONARDO DA VINCI

CALIFORNIANS FACE PROFOUND DECISIONS regarding the management of their state’s increasingly limited water supply. Critical for decision-making is information about the plants and animals that also rely on California’s freshwater resources to survive.

To provide that information, The Nature Conservancy created the **California Freshwater Species Database** — the first comprehensive spatial database of California’s freshwater species. In this document, we describe the database and present an atlas of the freshwater biodiversity patterns it reveals.

The database is now available to help improve conservation efforts across the Golden State. For more information, please visit www.scienceforconservation.org/projects/freshwater.

Contents

1	California’s Freshwater Biodiversity	1
2	Why Freshwater Biodiversity Matters	9
3	Our Impact on Freshwater Systems	13
4	Keep Freshwater Biodiversity Thriving	19

How to cite this report: Howard, Jeanette, Kirk Klausmeyer, and Kurt Fesenmyer. 2013. *Below the Surface: California’s Freshwater Biodiversity*. The Nature Conservancy of California. San Francisco, CA. 20 pp.

1 California's Freshwater Biodiversity

CALIFORNIA IS HOME to exceptional and diverse freshwater resources.

Fundamental to keeping these freshwater systems healthy is the biodiversity that is so often hidden beneath the water's surface.

California's freshwater plants and animals purify the water we drink and use to grow crops, and protect us from storm surges and floods. Despite their importance, freshwater species are in crisis. Nearly 60% of California's native fishes are imperiled. A crucial first step to preserving and protecting California's freshwater species is knowing what and where they are.

The California Freshwater Species Database is the first of its kind in California. The comprehensive database identifies the freshwater vertebrates, invertebrates, and plant species in the state, and provides spatial data for those most in need of conservation action.



Freshwater Biodiversity

WHAT IS IT?—All life requires water, but for some species, freshwater habitats are critically important for one or more life stages. Based on this definition, 1,728 (16%) of the over 11,000 native species in the state are freshwater species. Sixty percent of these freshwater species are invertebrates, including insects, mussels, clams, and snails. The best known group is vertebrates, which includes fish, amphibians and even some mammals like the river otter; this group makes up 12% of freshwater species in the state. The chart to the right shows the breakdown of native freshwater species in the state by taxonomic group.

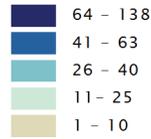
WHERE IS IT?—The diversity of freshwater life is not equally distributed in California. Not surprisingly, species rich regions are those with the most rivers, lakes and wetlands. The map on the following page shows the number of freshwater species by watershed*. Hotspots include the Sierra Nevada Mountains, Sacramento River, the Sacramento/ San Joaquin River Delta, and San Francisco Bay. The Klamath River and the other rivers of the North Coast also host tremendous diversity.



*Watersheds are geographic areas that drain to a particular location. Our study area is composed of 4,800 watersheds that average 25,000 acres (about 1/5th the size of Lake Tahoe).

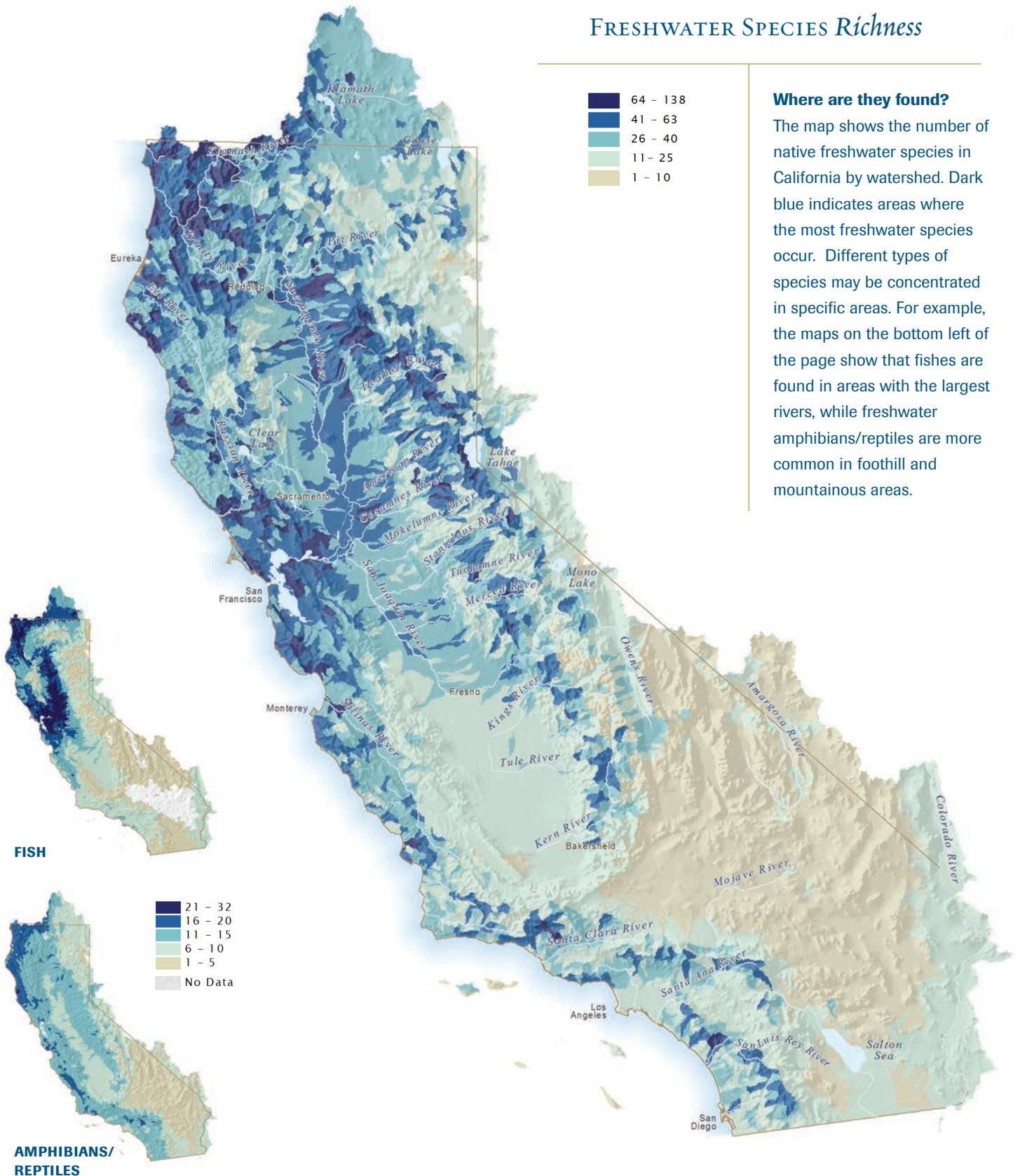


FRESHWATER SPECIES *Richness*



Where are they found?

The map shows the number of native freshwater species in California by watershed. Dark blue indicates areas where the most freshwater species occur. Different types of species may be concentrated in specific areas. For example, the maps on the bottom left of the page show that fishes are found in areas with the largest rivers, while freshwater amphibians/reptiles are more common in foothill and mountainous areas.



FISH



AMPHIBIANS/ REPTILES

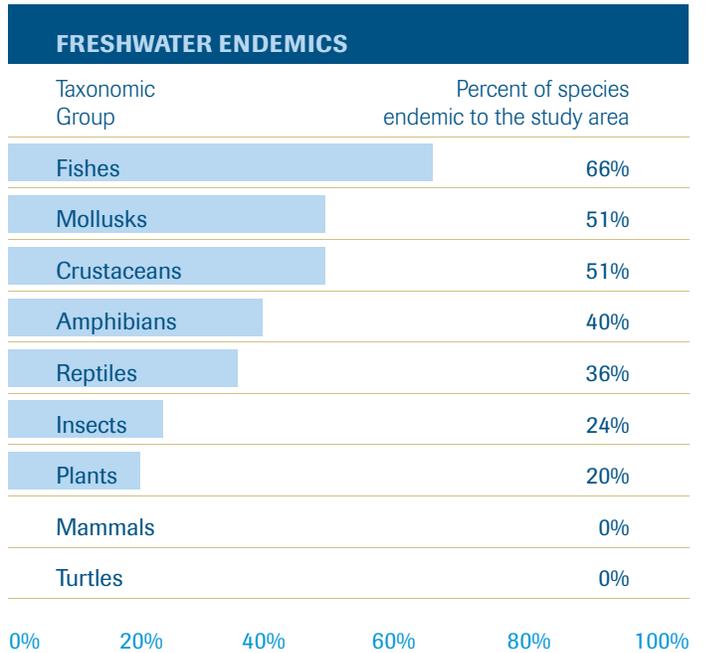
Only in California

Of the 1,728 native freshwater plants and animal species found in California, 523 (30%) are native only to California and adjacent watersheds, meaning these species are “endemic” to the study area, found nowhere else on the planet. The fate of these species is therefore largely in the hands of Californians. As noted in the chart to the right, over 60% of freshwater and anadromous* fishes are endemic to the study area. Mollusks and crustaceans are a close second with 50% endemic species.

The map on the following page shows the percent of all species in a subwatershed that are endemic. The San Joaquin River contains some of the highest concentrations of endemic freshwater species, as do the Sacramento, Salinas, upper Klamath, Pit, and Amargosa rivers.

While watersheds of the south do not have large numbers of freshwater species compared to the rest of the state, most of the species found there are endemic.

*Migrating from salt water to spawn in freshwater.



A GALLERY OF UNIQUE CALIFORNIA FRESHWATER SPECIES



Clear Lake Hitch
Lavinia exilicauda chi

The spawning of the Clear Lake Hitch is as spectacular as any salmon run on the Pacific coast, with hitches by the thousands ascending the many streams leading into Clear Lake.



California Golden Trout
Oncorhynchus mykiss aguabonita

The Golden Trout was designated the official fish of California in 1947. By the late 1800s they were transplanted throughout the Sierra Nevada for anglers.



Scale Lanx
Lanx klamathensis

The Scale Lanx is restricted to large, spring-fed lakes and streams in the Klamath and Tule Lake basins. It is commonly found with a variety of other rare mollusks, including the Archimedes Pyrg and the Klamath Rams-Horn.

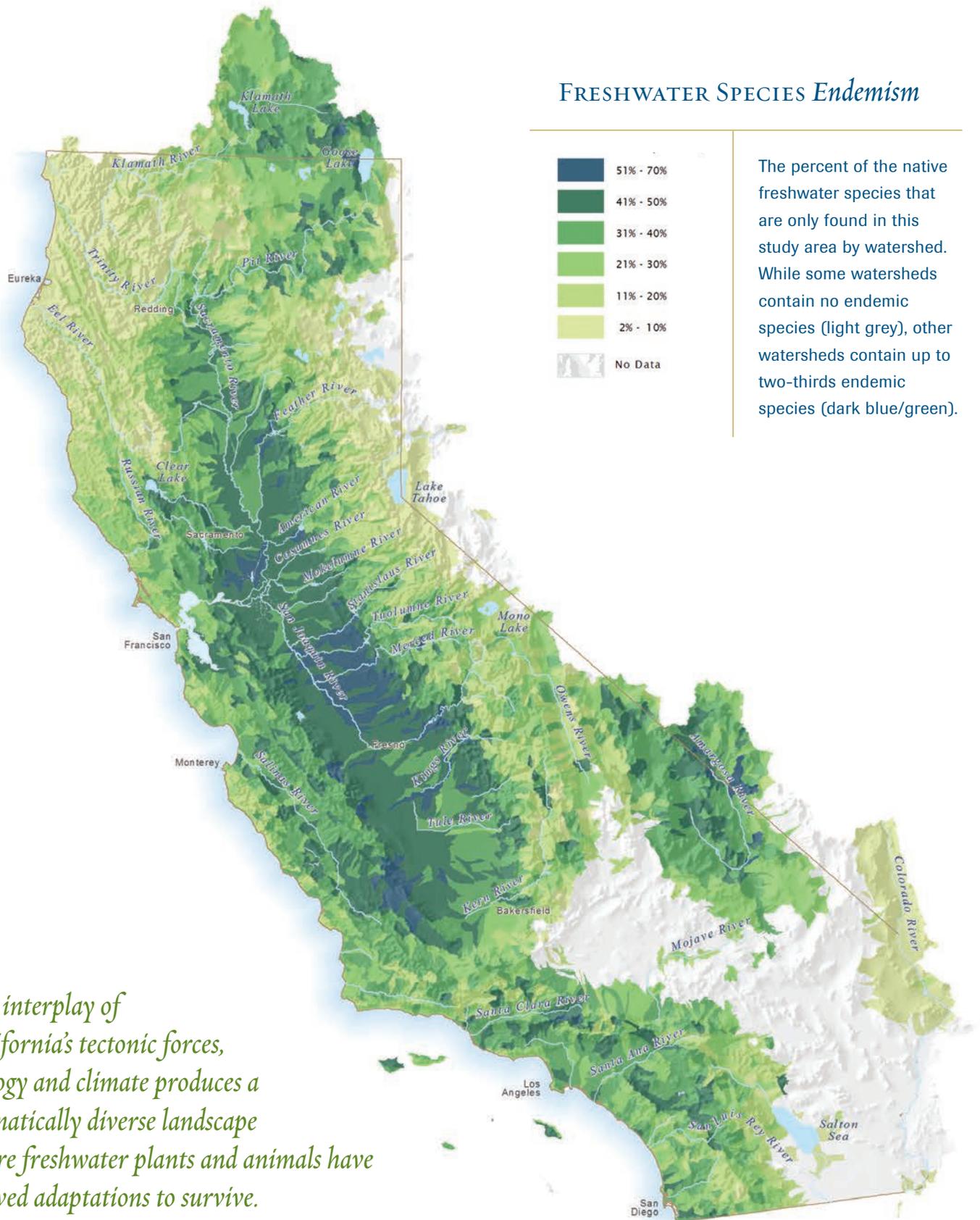


California Red-Legged Frog
Rana draytonii

Made famous in Mark Twain's story, "The Celebrated Jumping Frog of Calaveras County," this frog gets its name from the red coloring on its lower abdomen and hindquarters.



FRESHWATER SPECIES *Endemism*



The interplay of California's tectonic forces, geology and climate produces a dramatically diverse landscape where freshwater plants and animals have evolved adaptations to survive.

Where Is the Water?

California contains a diverse assemblage of watersheds providing habitat for its freshwater species. These watersheds have been categorized into 10 major hydrologic regions by the California Department of Water Resources. These regions have similar climate, geology, sediment yield and runoff characteristics, and the water within these regions flows to a similar destination.

Most of California's rain and/or snow falls in the Sierra mountains and along the coast north of San Francisco. The Sierra precipitation flows across the Central Valley and out the Golden Gate, while the north coast precipitation typically has a shorter journey to the ocean. Much of the water infrastructure in the state is designed to transport a portion of the water from the wet areas to the drier locations where most people live and grow crops.

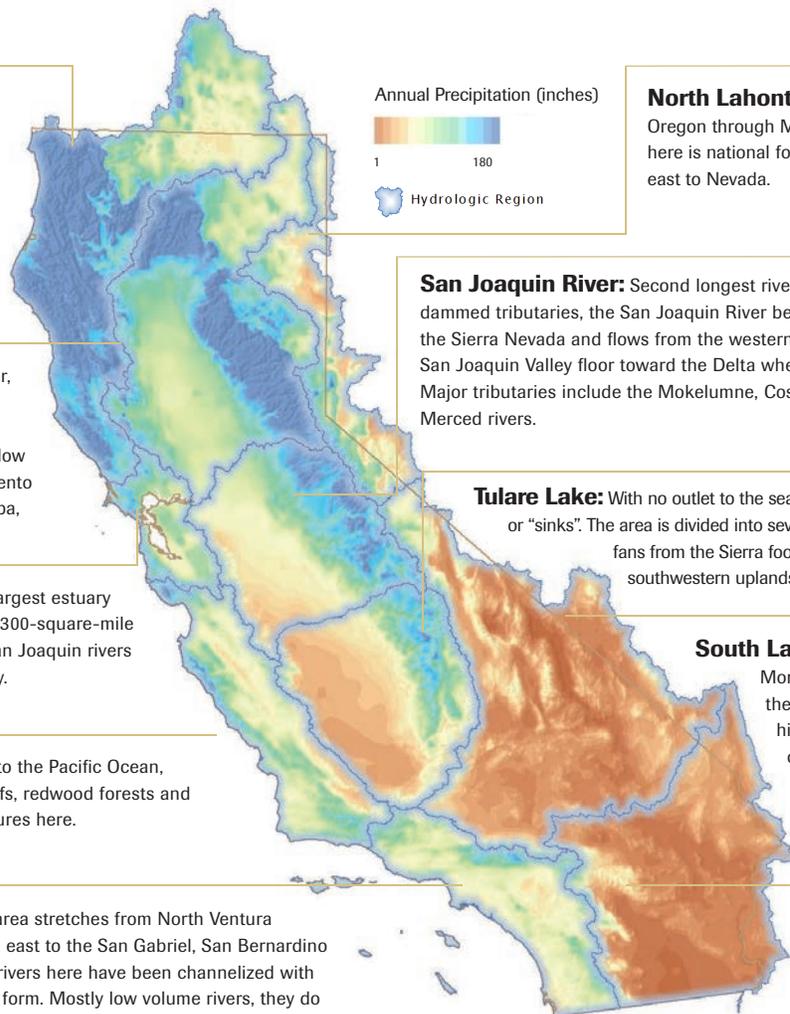
North Coast: With annual rainfall totals reaching up to 200 inches, this region is the most water abundant in California. Major topographical features include the Klamath Mountains, the Coast Range, and the high plateau area of Modoc County. Major rivers include the Klamath, Eel, Smith, Mad, and the Russian.

Sacramento: The state's longest river, the Sacramento rises in the Klamath Mountains and flows south for over 400 miles to the Bay Delta. Provides 80% of flow to the Delta. Major tributaries to Sacramento include Putah Creek, American, Bear, Yuba, Feather, and Pit rivers.

San Francisco Bay: Contains the largest estuary on the west coast of the Americas, the 1,300-square-mile Bay-Delta, where the Sacramento and San Joaquin rivers meet and flow into the San Francisco Bay.

Central Coast: All rivers here drain to the Pacific Ocean, mostly from small, steep watersheds. Cliffs, redwood forests and foggy bays are common geographic features here.

South Coast: This highly urbanized area stretches from North Ventura County south to the Mexican border, and east to the San Gabriel, San Bernardino and San Jacinto mountains. Most of the rivers here have been channelized with concrete, no longer holding their natural form. Mostly low volume rivers, they do run high at times of major rain and snow melt.



North Lahontan: A ribbon that stretches from Oregon through Mt. Lassen to Lake Tahoe, most land here is national forest. All water in the region drains east to Nevada.

San Joaquin River: Second longest river in the state (300 mi.) with many dammed tributaries, the San Joaquin River begins near the 14,000-foot crest of the Sierra Nevada and flows from the western slope turning northwest on the San Joaquin Valley floor toward the Delta where it meets the Sacramento River. Major tributaries include the Mokelumne, Cosumnes, Stanislaus, Tuolumne and Merced rivers.

Tulare Lake: With no outlet to the sea, all rivers here drain to old lakebeds, or "sinks". The area is divided into several hydrologic areas: the alluvial fans from the Sierra foothills; the Tulare Lake bed; and the southwestern uplands.

South Lahontan: Extending south from Mono Lake through the Sierra crest to the San Gabriels this region has the highest and lowest elevations in the continental U.S. (Mt. Whitney, Death Valley). Springs feed rivers in this desert area and there are few lakes.

Colorado River: In the far southeast corner of the state, this desert region is California's connection to the vital Colorado River. The Salton Sea is one of the main features here.

75 percent of California's precipitation occurs north of Sacramento, and 75 percent of its water demand lies to the south. —Hanak et al. 2011

Wild Salmon—Indicators of Watershed Health

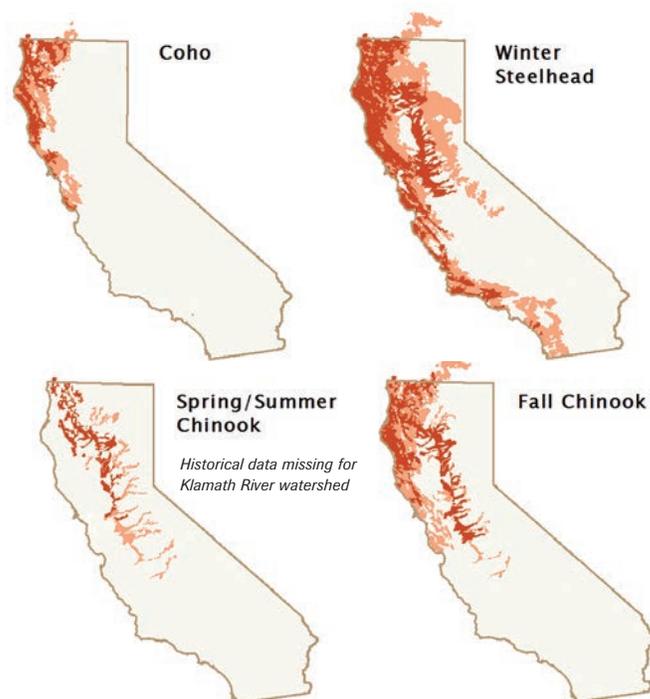
In much of California, no other species better illustrates the inter-connectedness of ecosystems than anadromous salmon and trout. Their complex lifecycle relies on the complete river system—from their hatching in headwaters to their passage through tributaries, mainstems, estuaries and finally the open ocean, and back again as spawning adults.

California marks the southern end of the range of all Pacific anadromous salmon species. Our dynamic geology, climate and productive ocean have resulted in the evolution of many distinct populations, characterized by geographic, genetic and life history patterns. Based on genetic and ecological uniqueness, 21 anadromous salmon and trout taxa and 11 nonanadromous types are recognized in the state.* Twenty-five of these taxa support—or once supported—commercial and recreational fisheries.

California’s wild salmon populations rank among the most depleted across their Pacific range. The reasons for their decline are complex and include reduced and altered flows, destruction and modification of habitat, alteration of landscapes, overfishing, and non-native predator or competitor species. Today, 13 of the anadromous taxa found in the state, are in danger of extinction.*

SALMON RANGE— Historical, Current

■ Current (Spawning and migration)
■ Historical (Spawning only)



* Moyle et al. 2008

CALIFORNIA ANADROMOUS SALMON AND TROUT SPECIES



Steelhead
Oncorhynchus mykiss

Steelhead and Rainbow Trout are the same species, but Rainbows are freshwater only, and Steelhead are anadromous, or go to sea. Unlike most salmon, Steelhead can survive spawning, and can spawn in multiple years.



Chinook
Oncorhynchus tshawytscha

Chinook, known as king salmon, are the largest of the Pacific salmon, with some individuals growing to more than 100 pounds. This species makes up the bulk of salmon commercial fisheries in the state.



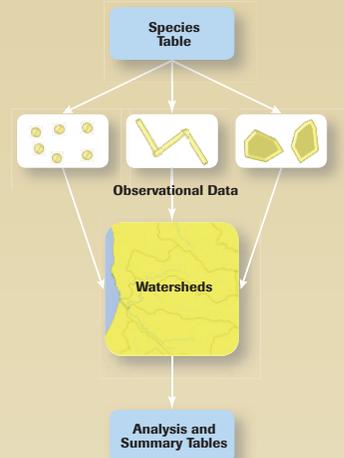
Coho
Oncorhynchus kisutch

In the 1940s, Coho populations were estimated between 200,000 to 500,000 statewide. By 2011 those numbers were down to 2,000 to 3,000. Efforts are now underway to prevent the species from going extinct.

The California Freshwater Species Database

The California Freshwater Species Database defines and lists freshwater species in the state, and provides the best available information as to where those species are located. This is the first database to compile range, historical and current distribution of freshwater species (both native and non-native) throughout California. The database will continue to evolve as knowledge of the location of freshwater species improves. Key elements of the database are:

- **Species table:** Basic information about the 1,728 freshwater species in the study area including scientific name, common name, rarity, and conservation status.
- **Observational data:** Spatially explicit information on the known locations of 878 native freshwater species. We focused our spatial data collection effort on 976 freshwater species that are in most need of conservation effort because they are considered vulnerable and/or endemic. Despite our extensive search, we were unable to find spatially explicit data for 98 vulnerable freshwater species (primarily insects and mollusks). In all, we compiled 241,500 spatial point, line, and polygon records from 141 unique data sources.
- **Observational data types:** For each record, we cataloged the available information about the data source, the specificity and nature of the observation (e.g., a general range map or a GPS coordinate of an observation), the habitat usage (e.g., spawning habitat, dispersal habitat), and the date of the observation (e.g., before or after 1980).
- **Watershed summaries:** We summarized all of the observational data by the 4,800 HUC12 watershed units in the study area to improve analysis and visualization.
- **Database format:** ArcGIS 10.1 file geodatabase

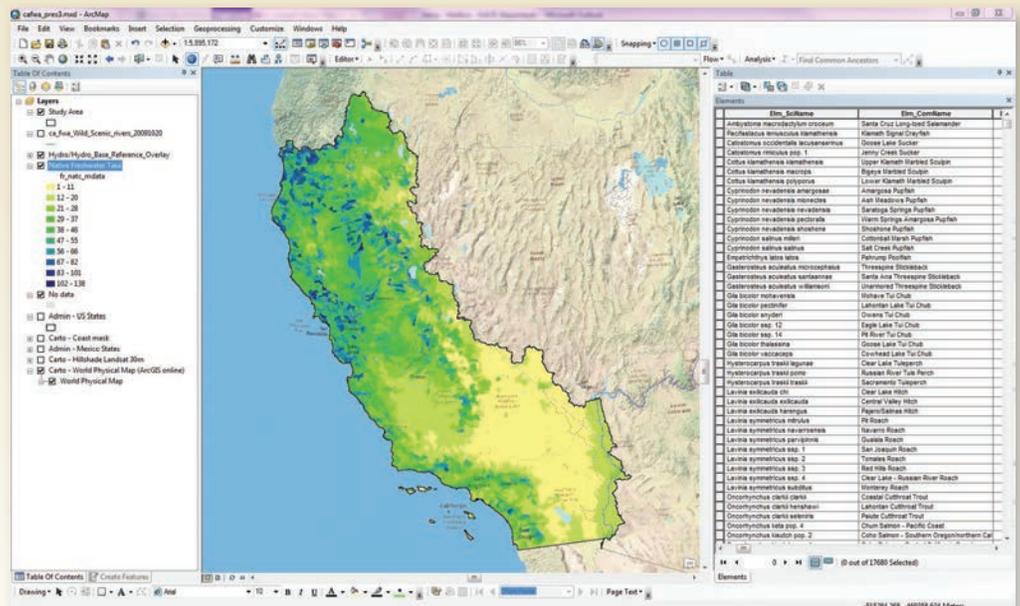


DATABASE CONCEPT

The structure of the database allows summaries and analyses by species, species locations, watersheds, hydrologic regions, and the entire study area.

A FLEXIBLE FORMAT

The California Freshwater Species Database can be seamlessly integrated with Esri ArcGIS™ software for analysis, mapping, and overlays with other spatial data. For more information on the California Freshwater Species Database, visit www.scienceforconservation.org/projects/freshwater.



2 Why Freshwater Biodiversity Matters

FRESHWATER SYSTEMS PROVIDE benefits that are essential for people.

How does biodiversity relate to these benefits?

Biodiversity contributes to more stable, reliable and resilient watersheds. For example, increasing the diversity of fish, and the food web that supports those fish, leads to greater stability of a fishery's yield. Conversely, loss of diversity causes degradation of freshwater ecosystems, which can adversely affect the quality of water for people as well.

Evidence accrued over the past two decades allows us to better understand how biodiversity affects the functioning of ecosystems, as follows:*

- Biodiversity increases the long-term stability of ecosystem functions.
- Diverse communities are more productive.
- Biodiversity loss reduces the efficiency of ecological communities to capture biologically essential resources, produce biomass, decompose and recycle needed nutrients.
- Loss of diversity across the food web impacts ecosystem functions; loss of higher consumers can cascade through a food web.

* *Cardinale et al. 2012*

Direct Benefits

Consumptive water use: drinking, domestic use, agriculture and industry

Nonconsumptive water use: generating power and transport/navigation

Food: fish for human consumption

Regulating Benefits

Maintains water quality through natural filtration and treatment

Buffers floods, controls erosion and provides flood control infrastructure

Cultural Benefits

Recreation: river rafting, kayaking, hiking and sport fishing

Aesthetic values of scenic views and parks

Indirect Benefits

Nutrient and water cycling

Soil formation and fertility

Ecosystem benefits are nature's conditions and processes that sustain and fulfill human life.

What Freshwater Biodiversity Does for Us

SUSTAINING LIFE



Surface and groundwater provide our drinking water. Maintaining biodiversity in freshwater systems helps keep water clean, and reduces the costs of purifying drinking water.

California's drinking water supply system relies on approximately 157 million acres of land spanning eight states to collect, filter, and deliver water. For more information, visit www.scienceforconservation.org/projects/freshwater.

FEEDING PEOPLE



Residing in California's freshwater for at least a portion of their life, the most iconic fish species harvested for food are the salmon and trout. In 2008 and 2009, the California commercial fishery was closed and direct financial losses were estimated at \$250 million—with the multiplying effect totaling a billion dollars a year.

White sturgeon is another harvested native freshwater species. Green sturgeon is listed as threatened under the Endangered Species Act and cannot be fished. Native California tribes value hitch, eulachon, hardhead, Sacramento pikeminnow and suckers as food sources.

PURIFYING WATER



The transitional land between terrestrial and aquatic systems, wetlands are known as nature's kidneys. They protect surface waters from nutrient overload by removing the excess nutrients and some heavy metals. Wetlands also recharge groundwater and provide shelter and food for fish and wildlife. They help maintain the carbon, nitrogen, and sulfur cycles, and play a critical role in flood control.



DRIVING THE FOOD WEB



The presence of freshwater macroinvertebrates is a robust indicator of water quality. They are very sensitive to physical and chemical changes, providing advance warning of pollution problems.

By consuming bacteria and decaying plants and animals, macroinvertebrates help maintain the health of the ecosystem. Many filter feeders such as clams and freshwater mussels supply an extremely valuable natural filtering service. In addition, macroinvertebrates are essential components of the food web, providing food for organisms further up the food chain.

PROVIDING RECREATION AND ITS ECONOMIC BENEFITS



Freshwater systems provide a variety of recreational opportunities including swimming, fishing, kayaking, canoeing and rafting. It is estimated that outdoor recreation contributes \$46 billion annually to California's economy and supports 408,000 jobs across the state. In addition, healthy freshwater systems provide aesthetic values and enhance property values.

PROTECTING PEOPLE, RECHARGING GROUNDWATER



Floodplains that remain connected to rivers support high levels of biological productivity and diversity. They improve water quality by reducing sediment, nutrients and pesticides in river water. Naturally functioning floodplains:

- serve as “relief valves” easing pressure on downstream areas during large storms.
- provide effective floodwater storage and conveyance.
- provide resiliency to potential climate change impacts.
- improve the water supply by increasing groundwater.
- provide important stopovers for millions of migrating birds.
- serve as nursery grounds for juvenile fishes.

Freshwater Benefits Under Pressure



Impacts to freshwater systems—and species—in California have been extensive.

- As a result of groundwater overdraft, parts of the Central Valley have subsided 30 feet or more. Overdrafting has also reduced flows in rivers, and in the case of coastal aquifers such as the Salinas and Santa Clara rivers, has led to saltwater intrusion of the groundwater basin.
- Accumulating contaminants (including salts and residues from fertilizers, pesticides and other chemicals) in both surface and groundwater are raising the costs of farming, drinking water and wastewater treatment. Salinity problems from agricultural drainage are greatest in the southern Central Valley and the Salton Sea, impacting drinking water supply for cities and compromising habitat for native species.
- Floodplains and the benefits we derive from them are under pressure. Of the nearly 9 million acres of floodplain in the state, over 50% have been converted to agriculture and urban areas reducing the ability of floodplains to mitigate floods.
- Knowingly or unknowingly transporting non-native plants and animals into our freshwater systems is having an expensive and pronounced effect statewide. For example, quagga and zebra mussels can quickly colonize freshwater habitats destroying fisheries, damaging boats and crippling water conveyance systems. The giant reed, *Arundo donax*, grows rapidly and alters hydrologic regimes.

3 Our Impact on Freshwater Systems

Freshwater biodiversity is directly influenced by the health of the freshwater environment, which in turn is affected by the integrity of the watershed. When disturbances occur in one part of the system, the effect can cascade throughout the rest of the watershed.

California is renowned as one of the world's most hydrologically altered landscapes. The large infrastructure projects of the mid-20th Century have allowed water use patterns to diverge from natural flow patterns—most of our water originates in the north, most of our demand is in the south. Water is scarce in California, and that has contributed to overuse and over-appropriation in many parts of the state.

We need look no further than the Sacramento-San Joaquin Delta—the hub of California's highly engineered water storage and delivery system—for proof. The negative impacts of these alterations on Delta biodiversity are well documented as native fish species and their habitats continue to deteriorate despite decades of well-intentioned efforts to improve conditions.



California has altered its natural water system by building many reservoirs, aqueducts and other facilities, the main ones of which are shown on the map.

The health of our waters is the principal measure of how we live on the land. —Luna Leopold

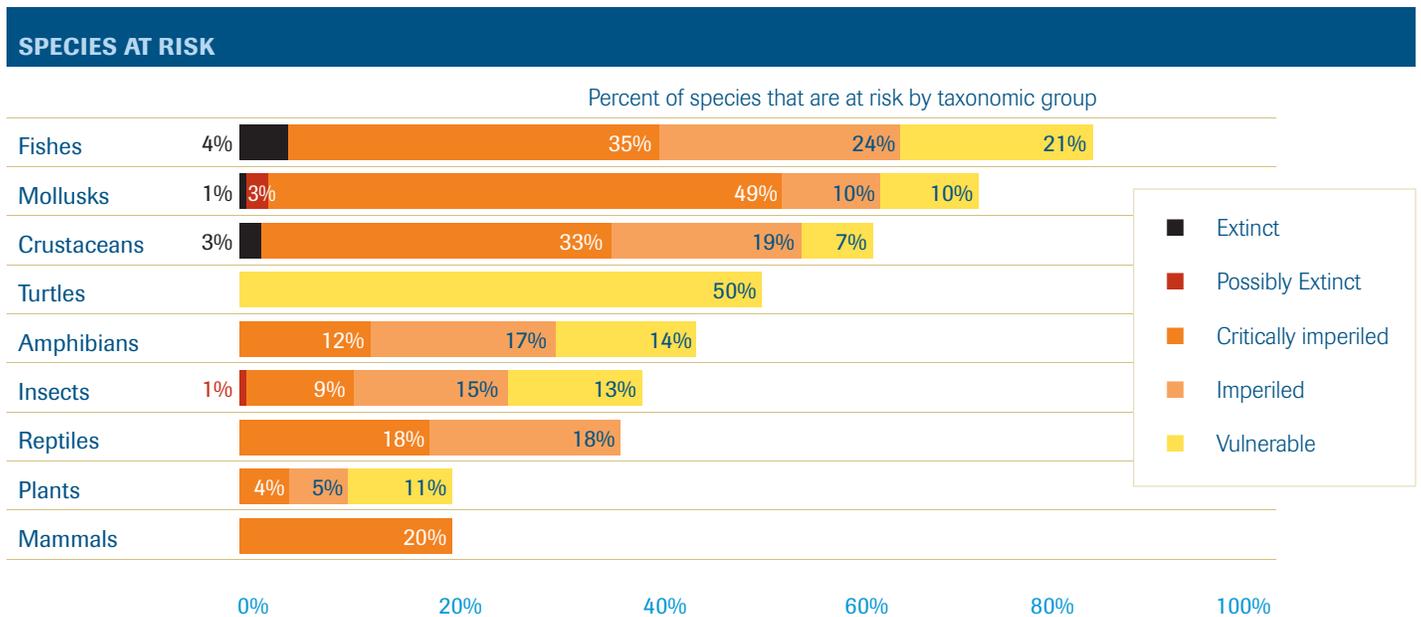
The State of Our Biodiversity

California has already experienced the extinction of 22 aquatic plant and animal species: 3 fish, 5 mollusks, 2 crustaceans, 9 insects and 3 plants. Although this is just 1% of the total number of aquatic species in the state, for every species that has gone extinct, there are 22 more that are imperiled and in danger of extinction.

Of the 1,728 native freshwater species in our study area, 482 (28%) are considered imperiled.* The chart below shows the percent of imperiled taxa by taxonomic group. Of particular concern is that 80% of California's fishes are vulnerable or imperiled.

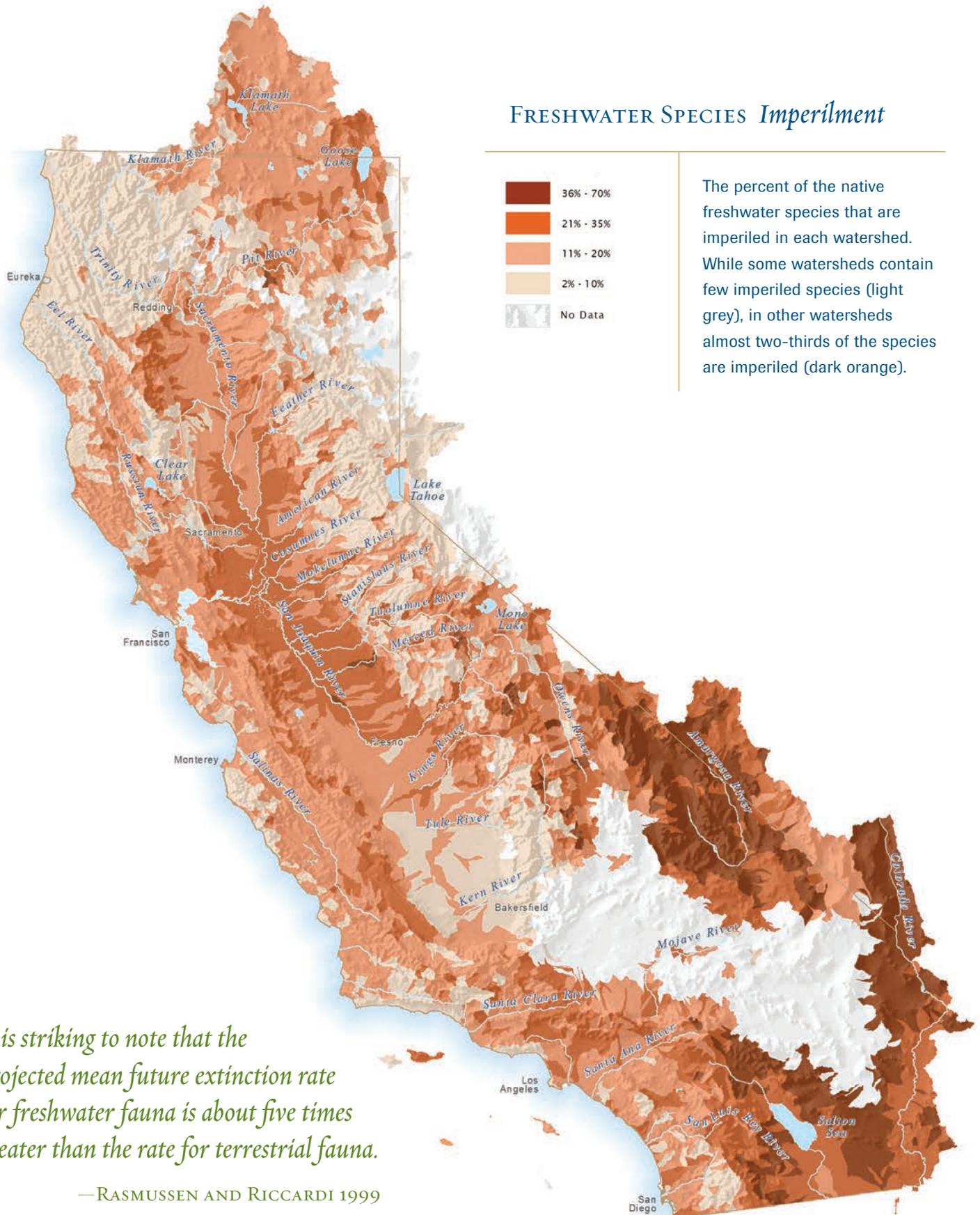
As shown in the map on the next page, most of the species found in the arid regions are imperiled. The Amargosa, Colorado, and Owens rivers, and the watersheds around the Salton Sea in the south and Goose Lake in the northeast all contain a high percentage of imperiled species.

* Imperiled species includes species identified by NatureServe (www.natureserve.org) as either critically imperiled or imperiled across their entire range. NatureServe develops its ranking by examining the abundance, recent trends, and threats for each species.





FRESHWATER SPECIES *Imperilment*



The percent of the native freshwater species that are imperiled in each watershed. While some watersheds contain few imperiled species (light grey), in other watersheds almost two-thirds of the species are imperiled (dark orange).

It is striking to note that the projected mean future extinction rate for freshwater fauna is about five times greater than the rate for terrestrial fauna.

—RASMUSSEN AND RICCARDI 1999

The State of California's Watersheds

How do our watersheds look today?

From the Lost River to the Salton Sea, California's watersheds have been affected by a wide range of human activities including land conversion, over-appropriated surface water supplies, overdrafted groundwater basins, and the introduction of invasive species.

MAP

- Agriculture
- Urban

CHARTS

Available Water

Regions that use more than available must import water or tap groundwater

20
million
acre
feet

Water Uses

- Instream / Environmental
- Agricultural
- Urban / Industrial

North Coast: Forest and rangeland make up 98% of the land area with minimal land conversion. Water quality issues include sediment, temperature and excess nutrients from logging operations, rural roads, and vineyards.

Sacramento: Supports 22% of the state's irrigated agriculture. Major water supplies in the region provided through large surface storage reservoirs and direct groundwater pumping. Water supply facilities of the State Water Project and Central Valley Project are located here and exported south. Salinity, pesticides, nitrates and mercury from legacy mining are concerns.

San Francisco Bay: More than 75% of the wetlands lost to or altered by landfill and agriculture dikes. Pollutants resulting from mining, manufacture, agricultural pesticides and industrial products include mercury, PCBs, and chlorinated pesticides. Ranks as one of the most highly non-native species invaded estuaries in the world.

Central Coast: Water supplies for this region include ground, surface, recycled and water from the State Water Project. Most of the region's urban water demands occur in the coastal zones. Groundwater overdraft is contributing to seawater intrusion along several coastal basins.

South Coast: California's most populous region with 54% of the population, water use is twice as high as locally available. All available water resources are utilized: groundwater, imported, recycled and captured surface water, water transfers, and desalination. Concerns include salinity, and contaminants from an increase in wastewater and industrial discharges, urban runoff, agricultural chemical usage, livestock operations, and seawater intrusion.

North Lahontan: Much of the region is National Forest or BLM land. Water is exported for agricultural use through an interbasin diversion from the Little Truckee River to Sierra Valley in the Sacramento River Region. Water produced here is typically high quality. Primary concern is the sediments and nutrients flowing into Lake Tahoe.

San Joaquin River: One of the most important agricultural areas in the US with roughly 2 million acres of irrigated cropland worth more than \$7.25 billion. Groundwater availability is of critical importance. Water needs met through local surface water supplies, imported surface water through the State Water Project and the Central Valley Project. Where surface water is unavailable, local groundwater is pumped. The Dept of Water Resources identifies areas here as in critical condition of groundwater overdraft.

Tulare Lake: One of the nation's leading agricultural areas. All streams in this area are diverted for irrigation (except in wettest years). The California aqueduct runs on the west side, Friant-Kern Canal on the east. Primary water supply is groundwater, but is impaired by elevated levels of nitrates and salts from irrigated agriculture, dairies, wastewater discharges, and sewage disposal.

South Lahontan: Largely desert and mountain with ranching and some agriculture, irrigated with groundwater. Quality of limited surface water considered excellent, fed by snowmelt and runoff from the eastern Sierra Nevada, San Gabriel and San Bernardino mountains.

Colorado River: Water demands met through imported surface water, local groundwater and recycled water. Salton Sea is primary focus of concern with inflow from the New and Alamo rivers and Imperial Valley agriculture, all containing pesticides, nutrients, selenium, and silt.

Source data: California Department of Water Resources — average values for 1998-2005 in millions of acre-feet. Available water data were calculated by Josh Viers in Hanak et al. 2011.

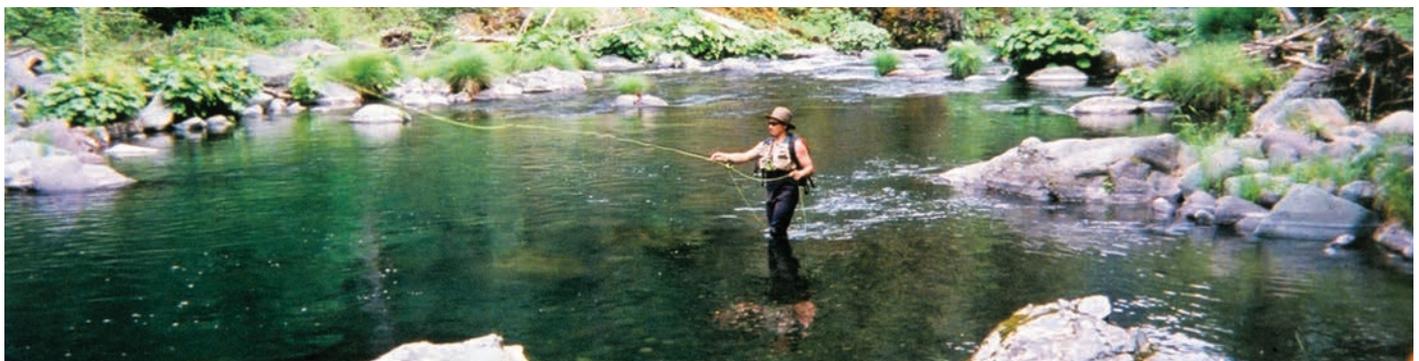
Impacts and Risks

The most urgent challenge for California’s water managers is to reconcile the needs of the environment with the evolving and growing demands of human

activities that threaten freshwater ecosystems. This table identifies threats to freshwater systems, impacts on ecosystems, and the benefits at risk.

Threat	Impact on Freshwater Ecosystems	Value/Benefits at Risk
Dams/reservoir operation	Alters timing and quantity of river flows, temperature, nutrient and sediment transport, fish migration, delta and estuary replenishment	Habitat, recreational and commercial fisheries, maintenance of estuaries
Levee construction	Severs hydrologic connection between rivers and their floodplains	Habitat, recreational and commercial fisheries, natural floodplain fertility, groundwater recharge, natural flood control
Diversions	Depletes streamflows to ecologically damaging levels	Habitat, recreational and commercial fisheries, recreation, pollution dilution
Draining of wetlands	Eliminates key component of aquatic environment	Natural flood control, natural water filtration, habitat for fisheries and waterfowl, recreation
Poor land use practices	Alters runoff patterns, inhibits natural recharge, fills water bodies with silt	Water supply (quantity and quality) fish and wildlife habitat, flood control
Pollution	Diminishes water quality	Water supply, habitat, commercial fisheries, recreation
Groundwater overdraft	Reduces surface water flows, habitat loss	Long-term reduction in water supply
Importing invasive species	Eliminates native species, alters production and nutrient cycling	Sport and commercial fisheries, waterfowl, water quality, fish and wildlife habitat, transportation
Climate change	Alters timing and quantity of flows, higher stream temperatures, movement of coastal estuaries inland (habitat loss), seawater intrusion into coastal aquifers	Water supply and quality

Table modified from Postel and Carpenter 1997.



A Troubled Outlook

The situation is urgent; the data assembled here are clear. Roughly 500 plant and animal species that rely on California's valuable freshwater are in trouble.

Compounding the situation, climate change is predicted to result in decreased precipitation, a decline in the state's snowpack (which will result in decreased runoff and earlier seasonal peak runoff), and the warming and drying of rivers. A long-term reduction of groundwater is also expected, as recharge potential decreases, and reliance on groundwater increases.

With our current growth and water use patterns, the demands on California's water supply will only increase in the future.

With this continued strain on California's water supply and biodiversity, maintaining the water flows required to sustain freshwater ecosystems and the human livelihoods they support, will only become more challenging.



Water scarcity has always been a fact in California... The magnitude or intensity of scarcity has grown over time and it continues to grow because demands have grown.

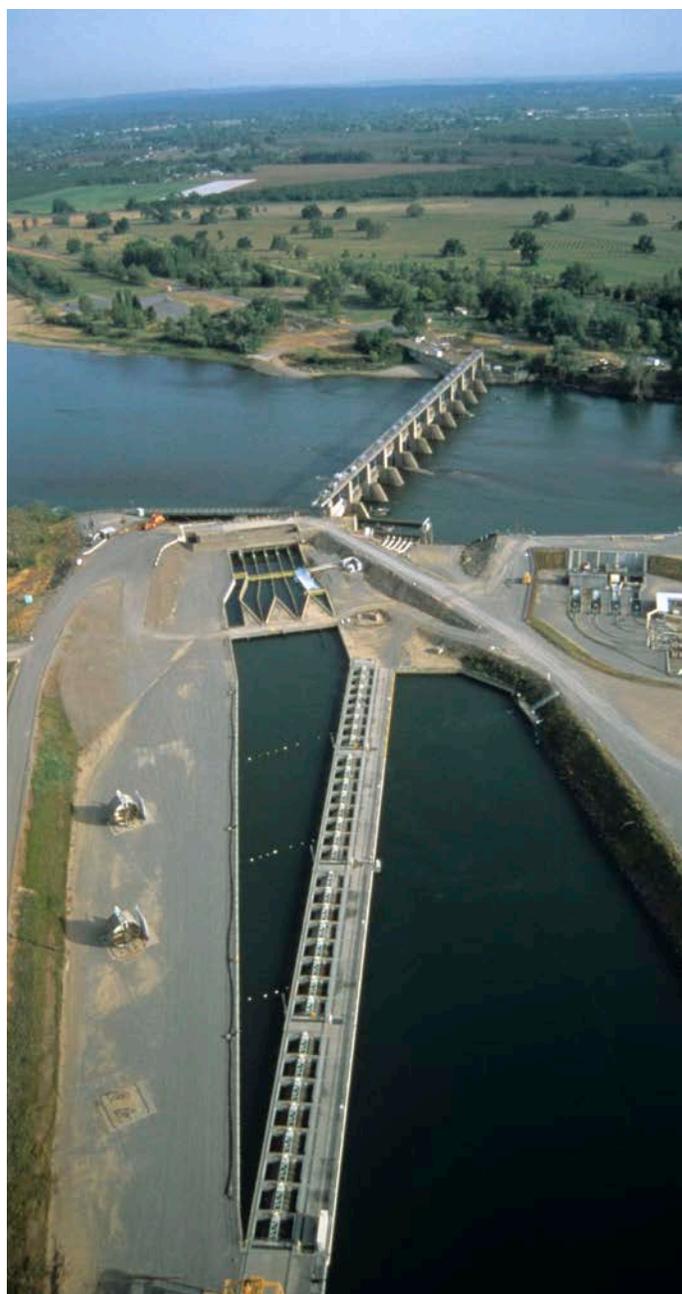
—NATIONAL RESEARCH COUNCIL 2012

4 Keep Freshwater Biodiversity Thriving

THE CHALLENGE is one of balance—meeting the needs of people *and* nature. Solutions lie in providing water for people while leaving sufficient water to support our freshwater ecosystems.

Integrated resource planning is key to providing sustainable water supplies for people and nature. California’s economic well-being is directly tied to its biodiversity, yet rarely are ecosystem needs sufficiently integrated into our water management and planning.

The California Freshwater Species Database brings needed information to the table as we address major issues affecting our economic and ecological well-being, such as how we manage groundwater, instream flows, and our interconnected water supply infrastructure.



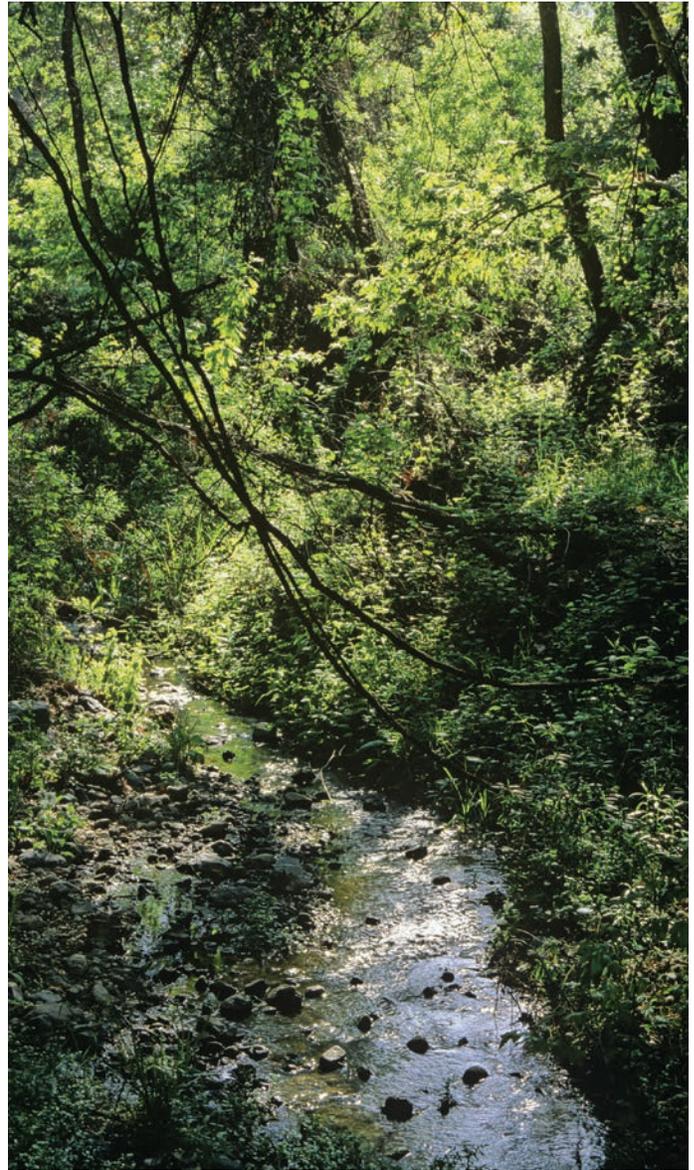
Use the California Freshwater Species Database to Protect and Restore Species and Habitats

The California Freshwater Species Database improves our ability to protect and manage freshwater biodiversity in the face of unprecedented pressures and challenges.

In an effort to improve the conservation of California's freshwater resources, this database fills a critical information gap. Policy makers and conservationists can use this resource as a foundation to:

- Enable analysis of the status and trends of biodiversity and ecosystem services.
- Integrate species into tools and models to predict responses to multiple stressors.
- Develop and integrate spatially-explicit models to quantify pressures and their impact.
- Identify biodiversity hotspots and their vulnerabilities.
- Improve monitoring systems in the state to better understand current and future status and distribution of freshwater species and ecosystems.
- Better define the water needs of ecosystems, so that ecosystem needs can be more thoroughly considered in water supply planning.
- Prioritize ecosystem water needs to help direct water and funding resources to those that are the most urgent.

California's future depends on it.



References

- California Department of Water Resources. 2009. California Water Plan Update, Bulletin 160–09. Sacramento: California Department of Water Resources.
- Cardinale, Bradley J., et al. Biodiversity loss and its impact on humanity. 2012. *Nature* 486: 59–67.
- Covich, Alan P., Margaret A. Palmer, and Todd A. Crowl. 1999. The role of benthic invertebrate species in freshwater ecosystems: zoobenthic species influence energy flows and nutrient cycling. *BioScience* 49: 119–127.
- Hanak, Ellen, et al. Managing California's water: From conflict to reconciliation. 2011. San Francisco: Public Policy Institute of California.
- Katz, Jacob, et al. 2012. Impending extinction of salmon, steelhead, and trout (Salmonidae) in California. 2012. *Environmental Biology of Fishes* 1:18.
- Mount, Jeffrey F. 1995. California rivers and streams: The conflict between fluvial process and land use. Berkeley: University of California Press.
- Moyle, Peter B. 2002. Inland fishes of California, Second Edition. Berkeley: University of California Press.
- Moyle, Peter B., and Ronald M. Yoshiyama. 1994. Protection of aquatic biodiversity in California: A five-tiered approach. *Fisheries* 19: 6–18.
- Moyle, Peter B., Joshua A. Israel, and Sabra E. Purdy. 2008. Salmon, steelhead, and trout in California: Status of an emblematic fauna. Davis, CA: Center for Watershed Sciences, University of California.
- Moyle, Peter B., et al. 2012. Where the wild things aren't: Making the Delta a better place for native species. San Francisco: Public Policy Institute of California.
- National Research Council. 2012. Sustainable water and environmental management in the California Bay-Delta. Washington, DC: The National Academies Press.
- Opperman, Jeffrey J., et al. 2009. Sustainable floodplains through large-scale reconnection to rivers. *Science* 326: 1487–8.
- Opperman, Jeffrey J., et al. 2010. Ecologically functional floodplains: Connectivity, flow regime, and scale. *Journal of the American Water Resources Association* 46: 211–226.
- Postel, Sandra, and Stephen Carpenter. 1997. "Freshwater ecosystem services," in *Nature's services: societal dependence on natural ecosystems*, 195–214, edited by Gretchen Daily. Washington, DC: Island Press.
- Ricciardi, Anthony, and Joseph B. Rasmussen. 1999. Extinction rates of North American freshwater fauna. *Conservation Biology* 13: 1220–1222.

Image credits

- Front Cover: Caddisfly larvae (*Dicosmoecus gilvipes*): © Larry Serpa/TNC; Western Pearlshell (*Margaritifera falcata*): © Jeanette Howard/TNC; Chinook salmon (*Oncorhynchus tshawytscha*): © Ian Shive
- Page 2: Mount Shasta: © Harold E. Malde
- Page 4: Clear Lake Hitch: © FISHBIO; California Golden Trout: © Joseph Tomelleri; Scale Lanx: © Femorale.com; Red Legged Frog – Roger Hall Scientific Illustration
- Page 7: Salmon illustrations: © Joseph Tomelleri
- Page 10: Sustaining life: © J. Clifton Meek; Feeding people: © Bridget Besaw; Wetlands: © Harold E. Malde
- Page 11: Cascades Stone (*Doroneuria baumanni*): © Larry Serpa/TNC; Recreation: © Karen Gregg Elliott/TNC; Floodplains: © Geoffrey Fricker
- Page 12: Don't jump from bridge: © David McNew/Getty Images
- Page 17: Fishing in river: © Avi Hesterman
- Page 18: Pacific Tree Frog (*Pseudacris regilla*): © Larry Serpa/TNC; Sierra Newt (*Taricha sierrae*): © Jackson Shedd/TNC; California Giant Salamander (*Dicamptodon ensatus*): © Larry Serpa/TNC
- Page 19: Red Bluff Diversion Dam: © Geoffrey Fricker; Pumping well: © Maurice Hall/TNC
- Page 20: Stone Creek, tributary to Santa Margarita River: © Harold E. Malde
- Back Cover: Western Pond Turtle (*Actinemys marmorata*): © Larry Serpa/TNC; Longhorn Fairy Shrimp (*Branchinecta longiantenna*): © Larry Serpa/TNC

CREDITS

Report design and maps by **GreenInfo Network**  www.greeninfo.org
Report graphic design by **Ison Design** www.isondesign.com

