California's Freshwater Biodiversity in a Continental Context




Science *for* Conservation
Technical Brief

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Department of Conservation Science
The Nature Conservancy, California

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A Science for Conservation Technical Brief
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The Freshwater Conservation Challenge

Worldwide, freshwater species and habitats are, on average, more imperiled than their terrestrial or marine counterparts. In continental North America alone, 40% of freshwater fish are at risk of extinction or already extinct (Jelks et al. 2008). Despite concerns over the health of the world's freshwater species and systems (Millennium Ecosystem Assessment 2005), there have been few attempts to systematically describe patterns of freshwater biodiversity on Earth. This is due in part to the lack of comprehensive, synthesized data on the distributions of freshwater species (Abell 2008). Without a robust biodiversity foundation, conservationists face challenges in setting freshwater protection priorities and agendas at the global, continental and regional scales.

Freshwater Ecoregions of the World Project

To fill this void, in 2008, World Wildlife Fund-US, The Nature Conservancy, and more than 130 scientists participated in the Freshwater Ecoregions of the World (FEOW) project. FEOW identified 426 freshwater ecoregions and provided information on freshwater biogeography and biodiversity; similar analyses exist for the terrestrial and marine realms. Until this effort, global biodiversity classification and planning efforts had been characterized using land-based parameters. FEOW is the first attempt to describe the world from a freshwater perspective. With this information, scientists and conservationists can more clearly compare freshwater biota and their conservation needs across large geographies.

Biodiversity of California's Freshwater Ecoregions

This *Science for Conservation* Technical Brief builds on the FEOW assessment by examining freshwater biogeography and fish and amphibian biodiversity in California's seven freshwater ecoregions: Oregon-Northern California, Sacramento-San Joaquin, Southern California-Baja, Colorado, Lahontan, Death Valley, and Oregon Lakes. This statewide comprehensive biodiversity characterization provides a context for understanding what makes California's freshwater systems both unique among and similar to other freshwater regions of the world. As such, it enables conservationists to set priorities for freshwater systems so that they will more fully reflect the variation and uniqueness of freshwater biodiversity in the state.

Key Findings

- California's freshwater biota spans two major freshwater habitat types and seven freshwater ecoregions that are high in species endemism despite relatively low species diversity.

- A total of 66 native freshwater, estuarine or anadromous fish species are found in California and over half of the total species (35) are endemic. In addition, over half of these species are considered imperiled in North America as determined by the American Fisheries Society Endangered Species Committee (Jelks et al. 2008).

- Imperiled species occur in each of California's seven freshwater ecoregions and are primarily comprised of species and subspecies of salmon and trout, tui chubs, pupfish, suckers, dace, stickleback and lamprey.

- California holds the distinction of being at the southernmost range of five species of anadromous salmonids: chum (*Oncorhynchus keta*), pink (*Oncorhynchus gorbuscha*), chinook (*Oncorhynchus tshawytscha*), coho (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*). Including subgroups like salmonid subspecies, evolutionarily significant groups and distinct populations, a total of 31 kinds of salmonids are found within California and, importantly, 20 (62%) are endemic to the State.

- Twenty of the 31 living taxa of salmonids are in danger of extinction within the next century (Moyle et al. 2008) and one species (bull trout) has already been extirpated.

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Top left/bottom right: waterfall and Mt. Shasta, Harold E. Malde; bottom left: pupfish, California Department of Fish and Game; top right: salmon, Jeffrey Rich.

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INTRODUCTION

Freshwater habitats cover less than 1% of the world's surface (Gleick 1996) yet provide a home for 7% (~126,000 species) of the ~1.8 million described species (Balian et al. 2008) including 25% of the estimated 60,000 vertebrate species (Darwall et al. 2008). Freshwater systems not only provide habitat for species; they also enable the storage and provision of clean water for human use, facilitate transportation, generate hydropower, and provide other important goods and services ranging from food and building materials, to water filtration, to flood and erosion control.

Because of the interactions between aquatic and terrestrial environments, and the reliance of human populations on rivers and streams, aquatic environments are some of the most fragile, degraded and threatened in the world (Millennium Ecosystem Assessment 2005, Revenga et al. 2000). Freshwater species and habitats are, on average, more imperiled than their terrestrial and marine counterparts (Millennium Ecosystem Assessment 2005). And California is no exception.

Over the past 150 years, California's rivers have undergone massive alterations through urbanization, water withdrawals and diversions, dams, logging and agricultural development. California has been described as being one of the most "hydrologically altered landmasses on the planet." Indeed, California of today bears little resemblance to its former self. Today, there are reservoirs where there once was desert, desert where there once was cropland, and cropland where there once were marshes. Human modifications of California's aquatic systems have caused some rivers to dry up; others to flow through mountains into other rivers' beds; and others to even flow in reverse.

Despite the diversity of freshwater systems and human reliance on them, the biological diversity in aquatic systems is poorly documented. Relative to terrestrial ecosystems, few conservation planning efforts target freshwater systems, making systematic priority-setting to conserve California's freshwater biodiversity challenging. Species-level data at the global scale generally cover only the largest river basins, particular well-studied taxa or a few selected places. In addition, existing data syntheses have made little attempt to describe biogeographic patterns of freshwater biodiversity.

To fill this void, World Wildlife Fund-US, The Nature Conservancy, and more than 130 scientists collaborated to produce the first global biogeographic regionalization of the Earth's freshwater biodiversity, in a project called Freshwater Ecoregions of the World (FEOW) (http://www.feow.org). The FEOW project divided the world into 426 freshwater ecoregions. Until this effort, most freshwater biodiversity classification and planning efforts had been organized around terrestrial landscape units, describing the world from a terrestrial viewpoint. The FEOW project is the first attempt to look at the world from a freshwater perspective. In this analysis, we draw upon the FEOW data to characterize California's freshwater ecosystems within a broader biogeographic context.

GLOBAL REALMS

Earth's terrestrial systems can be divided into eight biogeographic realms (Olson et al. 2001): Australasia, Antarctic, Afrotropic, Indo-Malay, Nearctic, Neotropic, Oceania and Palearctic (Figure 1). These realms represent distinct biota (Udvardy 1975), within which major terrestrial habitat types and ecoregions can be delineated.

Currently, there is no broad-scale classification system similar to global realms in the freshwater world. Therefore, for purposes of global classification, we use the global realms designated for terrestrial classification in this paper. Under that classification scheme, California falls within the Nearctic realm which includes all of the United States (except Hawaii), Canada, Greenland, and Mexico. The Nearctic realm contains 102 of the 426 freshwater ecoregions of the world.

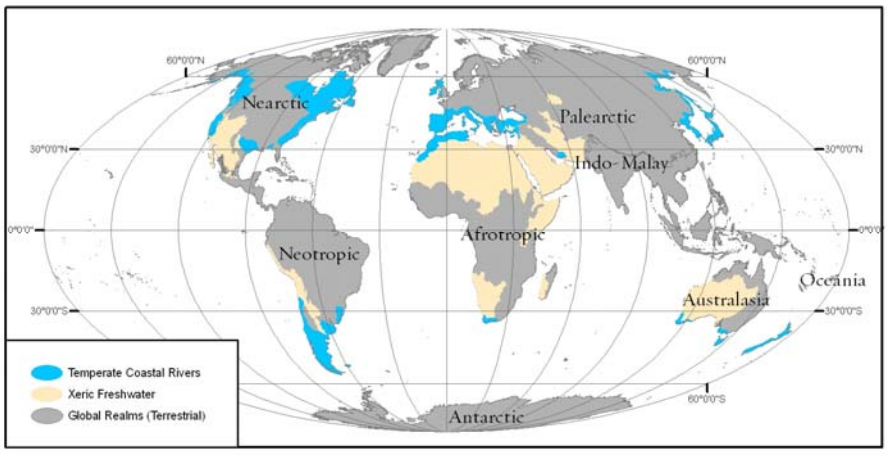


Figure 1: Biogeographic realms, and the two major habitat types that occur within California's boundaries (Olsen et al. 2001).

MAJOR HABITAT TYPES

In the same way that terrestrial systems are categorized into biomes (e.g., "deserts", "grasslands", "forest"), the FEOW project clustered the planet's freshwater systems into 12 Major Habitat Types (henceforth, MHTs) according to their dominant ecological features and morphological characteristics (Abell et al. 2008). The MHTs refer to the dynamics and habitat structure of ecological systems and provide a structured framework for examining and comparing the diversity of life in freshwater systems.

California is divided into two freshwater MHTs, the Temperate Coastal Rivers and Xeric and Endorheic (or, closed) Basins,

The **Temperate Coastal River** Major Habitat Type is dominated by several small to medium coastal basins in mid-latitudes (temperate). They are characterized by riverine ecosystems, but may also contain small lakes, coastal lagoons, and other wetlands. Migratory species that spend part of their life cycles within marine environments may inhabit this MHT. Although floodplains may occur along rivers within this MHT such as in the Sacramento-San Joaquin basin, the dominant features are numerous, small to medium-sized basins that drain to the ocean such as the Garcia, Gualala and Eel River basins along the North Coast of California.

The **Xeric Freshwater and Endorheic Basins** Major Habitat Type is dominated by endorheic (closed drainage basins that retain water and allow no outflow to other bodies of water) aquatic systems found in arid, semi-arid, or dry sub-humid environments, such as Goose Lake in the Modoc Basin. They tend to have specialized fauna adapted to ephemeral and intermittent flooding regimes or lower waters levels during certain times of the year. Death Valley is found in this MHT in California.

Descriptions of the major habitat types that comprise the freshwater ecoregions of the world are listed in Appendix 1.

FRESHWATER ECOREGIONS

Freshwater ecoregions are defined as large areas encompassing one or more freshwater systems that contain distinct assemblages of natural freshwater communities and species. The species, dynamics, and environmental conditions within the ecoregions are more similar to each other than to those of surrounding ecoregions and together form a recognizable biogeographic unit. The FEOW project divided the world into a total of 426 freshwater ecoregions. Seven (2%) of the global freshwater ecoregions fall in California (Figure 2). We analyzed

FEOW project data on fishes and amphibians in each of the seven ecoregions. The methods employed to synthesize biodiversity data are described in Appendix 2.

In addition the FEOW project conducted broad-scale threats analyses that consider land cover conversion, the presence of large cities, urban land cover, irrigation, human footprint and water stress. These analyses are based on global datasets and examine threats through the lens of freshwater systems and species. Definitions of threats and methods used to evaluate threats are included in Appendix 3.

Figure 2: Freshwater Ecoregions of California

Figure 3: Terrestrial Ecoregions of California

With the exception of Texas (which has eight), California contains the greatest number of freshwater ecoregions than any state (seven). None of California's seven freshwater ecoregions fall entirely within California and for three ecoregions (Oregon Lakes, Lahontan and Colorado), 10% of the ecoregion or less falls within California (Table 1). This has implications for setting and coordinating conservation priorities. For example, conservation of ecoregions barely within California boundaries would likely be led by efforts in neighboring states. On the other hand, 99% of the Sacramento-San Joaquin ecoregion is in California and it comprises 45% of the state. In this case, effective conservation relies upon California's engagement.

In the following pages, California's freshwater ecoregions are described as provided by the Freshwater Ecoregions of the World project (http://www.feow.org).

Table 1: Size of the freshwater ecoregions found in California

Major Habitat Type	Freshwater Ecoregion	Size of Ecoregion (km^2)	Percent of ecoregion within California	Percent of California
Temperate Coastal Rivers	Sacramento-San Joaquin	176,170	99%	45%
	Oregon-Northern California	105,520	45%	12%
Xeric Freshwaters and Endorheic Basins	Death Valley	77,000	85%	17%
	Colorado	484,110	10%	12%
	Southern California-Baja	155,850	24%	10%
	Oregon Lakes	52,760	8%	3%
	Lahontan	201,590	6%	1%

Sacramento-San Joaquin Freshwater Ecoregion

California has one of the most complex water management systems in the country with hundreds of dams and thousands of miles of canals, pipelines, and waterways used to store and convey water throughout the state. The Sacramento-San Joaquin freshwater ecoregion is at the hub of this complex water supply system.

The Sacramento-San Joaquin is the largest ecoregion in California comprising 45 percent of the state, more than twice as much as the next largest ecoregion Death Valley at 17 percent. Ninety-nine percent of this ecoregion lies within California's boundary making it the state's principal and foremost regional freshwater system (Table 1). Half of California's terrestrial ecoregions fall within this freshwater system.

Nearly half of the state's runoff from five major rivers empties into the Sacramento-San Joaquin freshwater ecoregion, which is then channeled to urban and agricultural users in the San Francisco Bay Area, the southern Central Valley, southern California, and the Sacramento Delta itself. Over two-thirds of California's population, or 25 million people, get a portion or all of their drinking water from this ecoregion. Water from this ecoregion is also used to irrigate millions of acres of prime farmland, supporting the nation's most productive agricultural area, the San Joaquin Valley. This area pumps approximately $27 billion into the state's economy and supplies approximately 45 percent of the nation's fruits and vegetables.

In many ways this freshwater ecoregion supplies the life blood of the state. Yet, the Sacramento-San Joaquin river system has recently been listed as America's most endangered river (http://www.americanrivers.org/our-work/protecting-rivers/endangered-rivers). Population growth, water demand, endangered species listings, and projected climate change impacts have brought this outmoded water and flood management system to the brink of collapse.

Over two-thirds of Californians—25 million people—get some or all of their drinking water from the Sacramento-San Joaquin freshwater ecoregion

Biologically, the ecoregion is outstanding. The confluence of the Sacramento and San Joaquin rivers form an inverted river delta that flows into San Francisco Bay, the largest estuary on the West Coast of North America. This area once supported enormous populations of migratory waterfowl in extensive freshwater marshes (Ricketts et al. 1999). Riparian woodlands were also more extensive and bordered many of the Central Valley's major rivers and tributaries. Vernal pool communities occur within the valley in seasonally flooded depressions, including those that are saline or alkaline, terrace pools, and pools on volcanic soils. Several species of aquatic invertebrates thrive in and are restricted to these habitats (Ricketts et al. 1999).

The Sacramento-San Joaquin supports nearly 40 native freshwater fish, including the southernmost populations of five anadromous fish species as well as four runs of Chinook (Abell et al. 2000) (Figure 4; Appendix 4). As shown in Figure 4, the 40 species found here are but a fraction of the nearly 200 species found in the Appalachian Piedmont freshwater ecoregion, the highest ranking region in terms of fish richness in this major habitat type. Fish groups with high representation in the Sacramento-San Joaquin include anadromous lampreys, sturgeons, smelt, and salmonids, as well as cyprinids and suckers. Additionally, there are threespine stickleback (*Gasterosteus aculeatus*), Sacramento perch (*Archoplites interruptus*), tule perch (*Hysterocarpus traski*), and tidewater goby (*Eucyclogobius newberryi*). The Sacramento perch is the only native centrarchid to occur west of the Rockies.

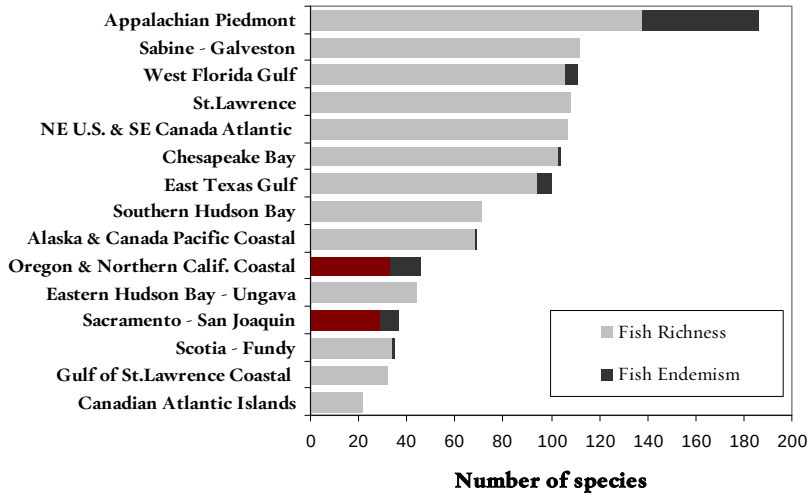


Figure 4: Fish richness and endemism in ecoregions of the *Temperate Coastal Rivers* major habitat type. California's two ecoregions are in red.

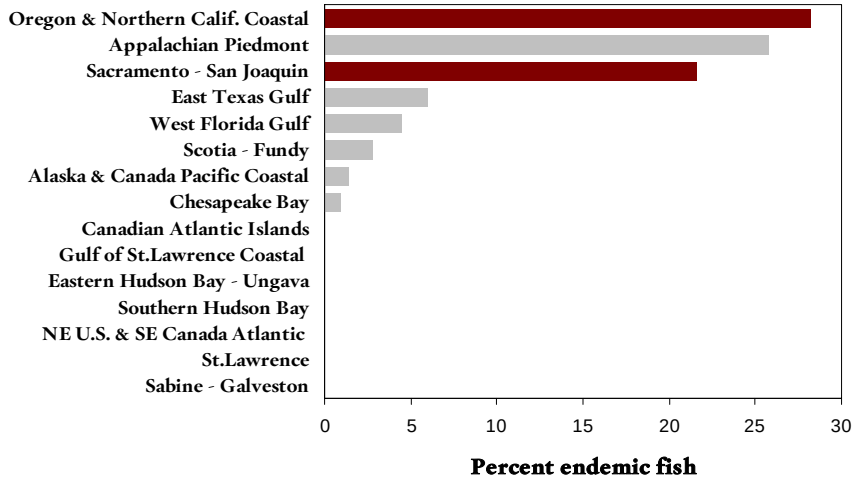


Figure 5: Percentage of fishes in the *Temperate Coastal River*s major habitat type that are endemic. California's two ecoregions are in red.

The Sacramento-San Joaquin is noted for its high taxonomic endemism of fish (Abell et al. 2000). In fact only 8 of the 15 ecoregions in this major habitat type contain endemic species–two of which are found in California (Figure 5). Although the ecoregion ranks 12th out of the 15 freshwater ecoregions within the Temperate Coastal River habitat type in terms of fish species richness, it ranks third in the percent of fish endemism. This region contains five endemic fish genera (*Archoplites, Pogonichthys, Orthodon, Lavinia, Mylopharodon*). Eight of the 37 fish species found here are found no where else on earth including the Delta smelt (*Hypomesus transpacifica*), splittail (*Pogonichthys macrolepidotus*), rough sculpin (*Cottus asperrimus*), tule perch (*Hysterocarpus traskii*), Kern brook trout (*Lampetra hubbsi*), hardhead (*Mylopharodon conocephalus*), and the Sacramento pikeminnow (*Ptychocheilus grandis*).

Seventy-five percent (30) of the fish species in this freshwater ecoregion are considered imperiled in North America as determined by the 2008 American Fisheries Society Endangered Species Committee (Jelks et al. 2008) (Figure 6). One species, the thicktail chub (*Gila crassicauda*), is considered extinct as no living individual has been documented in its natural habitat for 50 years or more (Jelks et al. 2008). The Clear Lake splittail (*Pogonichthys ciscoides*) is considered possibly extinct as it has been between 20 and 50 years since an individual was observed in nature. Five species are listed as endangered in the United States including: white sturgeon (*Acipenser transmontanus*), Modoc sucker (*Catostomus microps*), Little Kern River golden trout (*Oncorhynchus mykiss whitei*), Chinook salmon (Sacramento River winter run population) (*Oncorhynchus tshawytscha*), and the tidewater goby (*Eucyclogobius newberryi*).

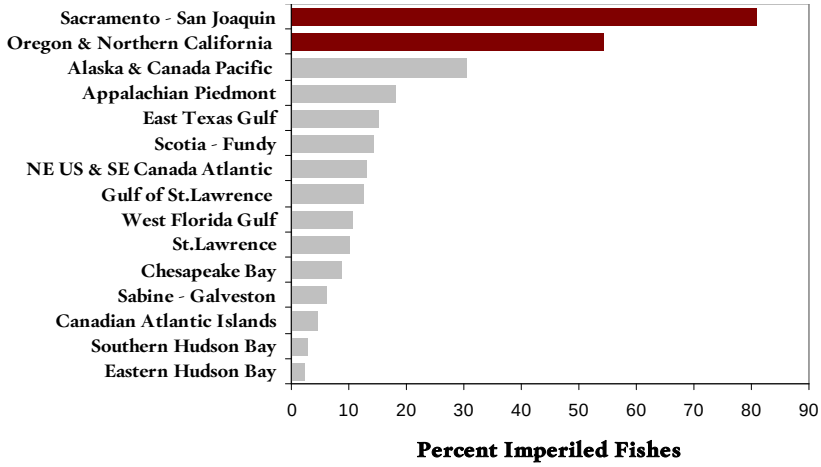


Figure 6: Percentage of fishes of the *Temperate Coastal Rivers* major habitat type that are imperiled. California's two ecoregions are in red.

As the hub of California's water supply, it is not surprising that the greatest threat in this ecoregion is surface water abstraction. Medium level threats include irrigation, urban landcover and the human footprint defined as population pressure, land use with infrastructure, and human access (Figure 7; Appendix 3). Large cities and converted lands are considered low threats at this global-scale analysis.

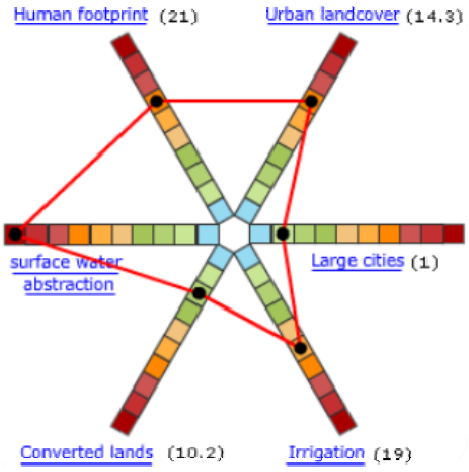


Figure 7: Diagram of threats in the Sacramento-San Joaquin ecoregion showing the relative severity of each threat. Red is highest threat and green is lowest.

Table 2: Percent of terrestrial ecoregions in the Sacramento-San Joaquin freshwater ecoregion

Terrestrial Ecoregion	Percent of terrestrial ecoregion that falls within Sacramento-San Joaquin freshwater ecoregion
Great Central Valley	100%
Sierra Nevada	90%
California Central Coast	72%
East Cascades/Modoc Plateau	53%
Klamath Mountains	38%
California North Coast	30%

Oregon-Northern California Freshwater Ecoregion

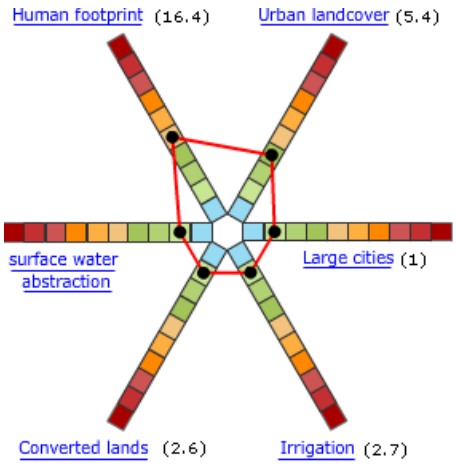
The Oregon-Northern California freshwater ecoregion extends along the Pacific Coast of Oregon and California to the northern shore of San Francisco Bay, including the western portion of the San Francisco peninsula south to Santa Cruz. In southern Oregon and Northern California, the ecoregion reaches inland, encompassing the western drainages of the Klamath and Siskiyou Mountains. Main rivers in California include the Klamath and the Eel.

Characteristic freshwater habitats of the ecoregion include coastal headlands, tidal rivers, estuaries, floodplains, wetlands, streams and rivers. The northern California coast is characterized by relatively slow streams and rivers in alluvial channels that terminate primarily in brackish estuaries (McNab & Avers 1994). Temperate coniferous forests make up a majority of the ecoregion, with dominant species including Douglas fir (*Pseudotsuga menziesii*) and redwood (*Sequoia sempervirens*) forests unique to the northern California coast.

The Oregon-Northern California freshwater ecoregion contains the highest fish richness of California's freshwater ecoregions, totaling 48 fish species (Figure 4; Appendix 5). It ranks highest in its habitat type in percentage of endemic fishes, with roughly one quarter (13) of its fish species endemic (Figure 5). These endemic fishes include the Umpqua squawfish (*Ptychocheilus umpquae*), the Klamath smallscale sucker (*Catostomus rimiculus*), the Klamath largescale sucker (*C. snyderi*), two sculpins (*Cottus princes* and *C. tenuis*), three lampreys (*Lampetra folletti*, *L. minima* and *L. similis*), two suckers (*Chasmistes brevirostris* and *Deltistes luxatus*), two chubs (*Gila coerulea* and (*Oregonichthys kalawatseti*), and Umpqua dace (*Rhinichthys evermanni*). It is also known for its higher taxonomic fish endemism including one endemic fish genus (*Oregonichthys*).

This ecoregion contains the highest number of unique species of fish of all ecoregions in California—48 fish species

More than half of fish species (25) are considered imperiled as determined by the 2008 American Fisheries Society Endangered Species Committee (Jelks et al. 2008) (Figure 6). Six species of fish in this ecoregion are considered federally endangered (in imminent danger of extinction throughout all or extirpation from a significant portion of its range). Of the six species listed as endangered, five occur in California including white sturgeon (*Acipenser transmontanus*), shortnose sucker (*Chasmistes brevirostris*), Lost River sucker (*Deltistes luxatus*), Coho salmon (central California coastal population Humboldt to Santa Cruz counties) (*Oncorhynchus kisutch*), and the tidewater goby (*Eucyclogobius newberryi*).



Five of the six threats analyzed by the FEOW are considered low level risks including: urban landcover, large cities, irrigation, converted lands, and surface water abstraction. The threat of the human footprint is the greatest threat, although it falls at the lower end of the mid-level risk bar (Figure 8). The elevated human footprint is the result of timber harvest in the ecoregion.

Figure 8: Diagram of threats in the Oregon-Northern California ecoregion showing the relative severity of each threat. Red is highest threat and green is lowest.

The Oregon-Northern California freshwater ecoregion makes up only 12% of California (Table 1) yet four of California's 12 terrestrial ecoregions are situated within it (Figures 2 and 3; Table 3).

Table 3: Percent of terrestrial ecoregions within the Oregon-Northern California freshwater ecoregion

Terrestrial Ecoregion	Percent of terrestrial ecoregion that falls within Oregon-Northern California freshwater ecoregion
California Central Coast	6%
East Cascades/Modoc Plateau	27%
Klamath Mountains	62%
California North Coast	70%

Death Valley Freshwater Ecoregion

The Death Valley freshwater ecoregion makes up the majority of the southeast corner of the state and reaches into southwestern Nevada. Included in the ecoregion are the eastern slopes of the southern Sierra Nevada Mountains and the northeastern slopes of the Transverse Range. The region is part of the Mojave high desert and is characterized by a warm temperate climate, receiving low annual precipitation ranging between 65 and 190 millimeters (Ricketts et al. 1999). This ecoregion is a closed basin into which the Owens, Amargosa, and Mojave rivers drain (Sada et al. 1995). It has few perennial rivers and streams but contains abundant springs rising along faults, which provide much of the habitat for freshwater species.

Because of the climate, this ecoregion contains some of the most extreme conditions inhabited by freshwater life and its biota has been extensively studied. Ash Meadows, covering an area of about 756 km^2, is of particular interest as its more than 30 springs and seeps create an oasis in the middle of the desert (Williams et al. 1985). Devils Hole is the highest in elevation of these springs, at 732 meters. With increasing elevation, springs have been isolated from each other for a longer time; springs only a kilometer apart may have been isolated for thousands of years (Williams et al. 1985). In this arid area groundwater recharge is so slow that the aquifers supplying springs such as Devils Hole contain fossil water (Pister 1990).

8 of the 9 species of fish found in this ecoregion are considered endangered.

Like other arid ecoregions of North America, the Death Valley fish assemblage exhibits low species diversity but extraordinarily high endemism (Figures 9 and 10; Appendix 6). Of the 18 freshwater ecoregions in the habitat type, Death Valley freshwater fish rank 17th in terms of richness, but 4th in percent endemic fishes (Figure 10). In fact, of the 60 ecoregions found within this major habitat type worldwide, Death Valley ranks 8th for the percent of endemic species. By comparison, Lake Titicaca region ranked 1st with 91% of the 37 fish found there endemic to that ecoregion. While this ecoregion has only nine species of fish, eight of those species are found nowhere else on earth. With the exception of the fish in the Owens River and Mojave River basins, all of the endemic freshwater species in this ecoregion depend on springs or spring margins. Given the small amount of freshwater available in this ecoregion, this biodiversity is as vulnerable as it is unique.

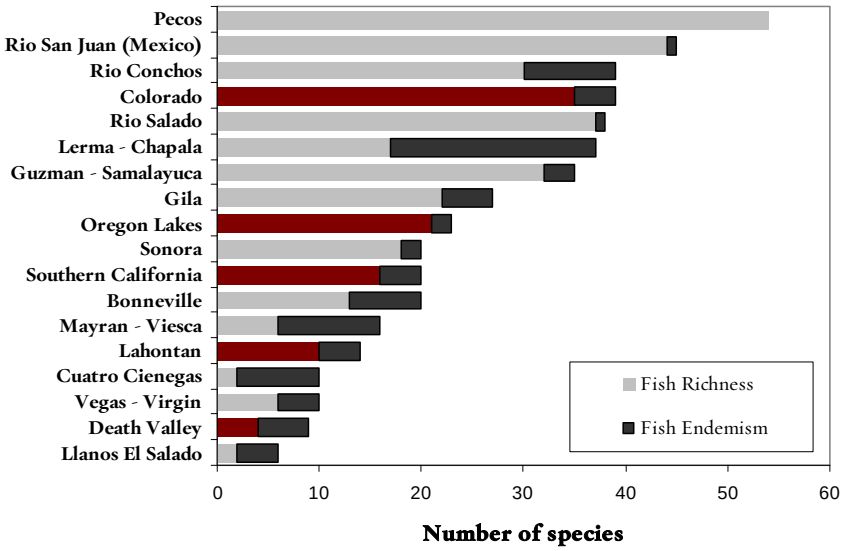


Figure 9: Fish richness and endemism in ecoregions in the *Xeric and Endorheic Basins* major habitat type. California's five ecoregions are in red.

The endemic fish come from four families, with subspecies of two minnows (*Rhinichthys osculus* and *Gila bicolor*), one sucker species (*Catostomus fumeiventris*), the extinct Ash Meadows poolfish (*Empetrichthys merriami*) (once found in the Nevada portion of this freshwater ecoregion), and four pupfish (*Cyprinodon radiosus*, *C. diabolis*, *C. nevadensis*, and *C. salinus*). Of these, five subspecies of *C. nevadensis* and two of *C. salinus* are recognized, as are three subspecies of speckled dace (*Rhinichthys. osculus*) (Sada et al. 1995). The Devil's Hole pupfish (*C. diabolis*) is distinguished by having the smallest range of any vertebrate species—23 square yards in a spring-fed, limestone cavern in Ash Meadows (Williams et al. 1985; Sada et al. 1995). The species is tiny, rarely exceeding 20 mm standard length, and populations fluctuate seasonally from between 150 and 400 individuals (Williams et al. 1985). The two forms of the Salt Creek pupfish (*C. salinus*) live between 180 and 240 feet below sea level, where temperatures can reach 130 °F (Sigler & Sigler 1994).

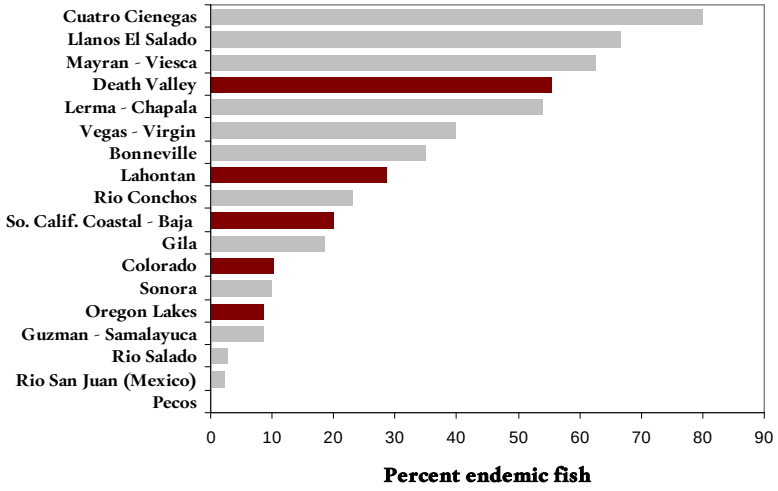


Figure 10: Percentage of fish of the *Xeric and Endorheic Basins* major habitat type that are endemic. California's five ecoregions are in red

Eight of the nine species of fish found in this region are considered endangered, and four subspecies are extinct (Figure 11). Endangered species include the following found in the California portion of this ecoregion: Mojave tui chub (*Gila bicolor mohavensis*), Owens tui chub (*Gila bicolor snyderi*), Long Valley speckled dace (*Rhinichthys osculus ssp*.), Shoshone pupfish (*Cyprinodon nevadensis Shoshone*), and the Owens pupfish (*Cyprinodon radiosus*). The subspecies Tecopa pupfish (*Cyprinodon nevadensis calidae*), once found in the California portion of the freshwater ecoregion, is extinct, as are three other subspecies once found in the Nevada portion of the ecoregion: the Raycraft Ranch poolfish (*Empetrichthys latos concavus*), the Pahrump Ranch poolfish (*Empetrichthys latos Pahrump*), and the Ash Meadows poolfish (*Empetrichthys merriami*).

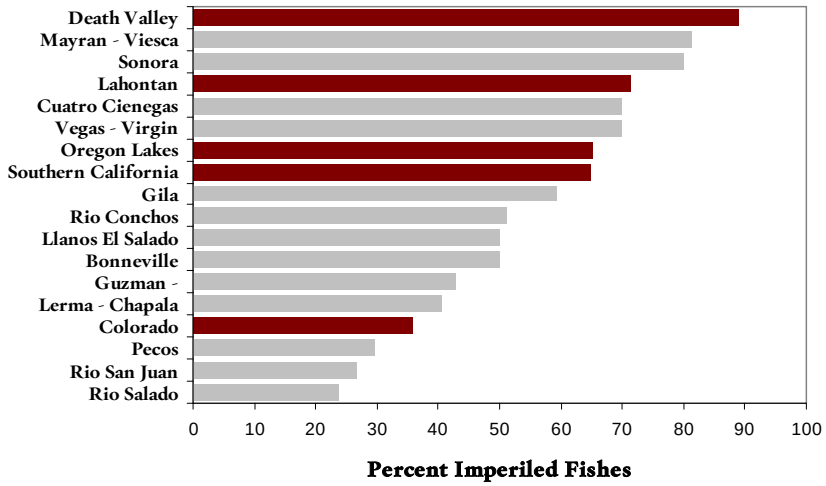


Figure 11: Percentage of fish found in the *Xeric and Endorheic Basins* major habitat type that are considered imperiled. California's five ecoregions are in red.

In this arid ecoregion, surface water abstraction is the greatest threat to biodiversity. The human footprint is a mid-level threat while all other threats considered (converted lands, urban landcover, large cities and irrigation) are ranked as low level threats (Figure 12).

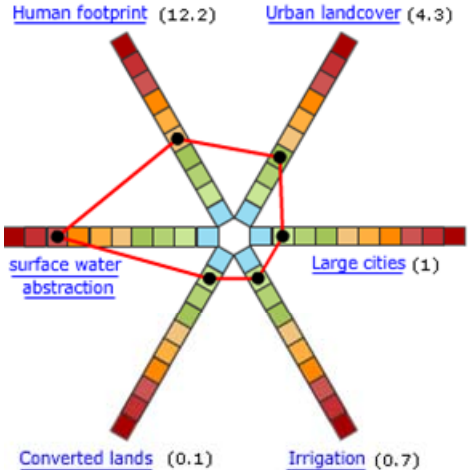


Figure 12: Diagram of threats in the Death Valley ecoregion showing the relative severity of each threat. Red is highest threat and green is lowest.

Eighty-five percent of the Death Valley freshwater region is in California (in the Great Basin and Mojave Desert terrestrial ecoregions). This ecoregion comprises 17 percent of California, the second largest freshwater ecoregion in the state (Table 1). Two of California's 12 terrestrial ecoregions are found within this freshwater ecoregion – the Great Basin and Mojave Desert (Table 4).

Table 4: Percent of terrestrial ecoregions within the Death Valley freshwater ecoregion

Terrestrial Ecoregion	Percent of terrestrial ecoregion that falls within Death Valley freshwater ecoregion
Great Basin	75%
Mojave Desert	74%

Colorado Freshwater Ecoregion

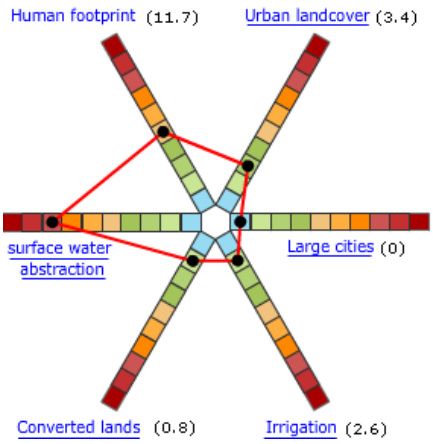
The Colorado freshwater ecoregion is comprised of the Colorado River drainage. From its headwaters in the Rocky Mountains to its terminus, the Colorado River flows 2,282 km and drops more than 2,700 meters in elevation. Its drainage is divided into an upper and lower basin. The upper basin is an area of high relief through erosive, swift-flowing rivers that have incised the landscape; the lower basin is comparatively low gradient, flowing historically through a broad alluvial valley. This large ecoregion experiences an arid climate influenced by the rain shadow of the Sierra Nevada (Minckley et al. 1986). Most of the precipitation is supplied by snowmelt in the high elevations of the upper basin. The major tributaries of the lower basin are the Little Colorado, Virgin, and Gila rivers.

Twenty-five million people in seven western states (Arizona, California, Colorado, New Mexico, Nevada, Utah, and Wyoming), two Mexican states (Sonora and Baja California), and 32 Native American tribal communities share Colorado River water. Thirty million people receive electricity from its hydroelectric power.

Thirty-nine species of fish are found in the entire Colorado freshwater ecoregion with 26 found in the lower basin (Appendix 7). The Colorado region hosts eight endemic fish species (Figure 9 and 10). The assemblage of large river fish species historically found in the mainstem of the Colorado and its main tributaries (including, in some cases, the Gila) is unique to the swift flowing waters of this region. The humpback chub (*Gila cypha*), bonytail (*G. elegans*) and razorback sucker (*Xyrauchen texanus*) all display morphological adaptations for life in turbid, fast-flowing habitats.

30 million people get their electricity from Colorado River hydroelectric power

Forty percent of the species (14 taxa) found in this ecoregion are considered imperiled as determined by the 2008 American Fisheries Society Endangered Species Committee (Figure 11). Eight of the 14 imperiled fishes are considered endangered. The endangered species that fall within California's borders include the bonytail (*Gila elegans*), Colorado pikeminnow (*Ptychocheilus lucius*), razorback sucker (*Xyrauchen texanus*), and the desert pupfish (*Cyprinodon macularius*). The Las Vegas dace (*Rhinichthys deaconi*), now extinct, was historically found in springs along Las Vegas Creek, a small tributary to the Colorado River in Nevada. Springs in this ecoregion also support endemic spring snails, including the Overton assiminea (*Fontelicella* sp.), found in separate springs in the vicinity of Lake Mead.



Like the Death Valley ecoregion, the surface water abstraction is the greatest threat in this ecoregion, followed by the human footprint as a mid-level threat. Converted lands, urban landcover, large cities and irrigation are ranked as low level threats in this ecoregion (Figure 13).

Figure 13: Diagram of threats in the Colorado ecoregion showing the relative severity of each threat. Red is highest threat and green is lowest.

The Colorado freshwater ecoregion makes up 12% of California yet only 10% of the ecoregion falls within California boundaries. Despite the small percentage within California's borders, three terrestrial ecoregions are contained within the Colorado freshwater boundaries–the Sonoran Desert, Mojave Desert and the California South Coast (Table 5).

Table 5: Percent of terrestrial ecoregions in the Colorado freshwater ecoregion

Terrestrial Ecoregion	Percent of terrestrial ecoregion that falls within Colorado freshwater ecoregion
Sonoran Desert	100%
Mojave Desert	26%
California South Coast	18%

Southern California–Baja Freshwater Ecoregion

The Southern California-Baja freshwater ecoregion begins just south of Monterey and encompasses southwestern California and the entire Baja Peninsula in Mexico. There are numerous small rivers and coastal basins within the California part of the ecoregion; however, there are almost no permanent watercourses in Baja California. Major rivers include the Santa Ynez, Santa Clara and Santa Ana rivers. These drainages flow into the Pacific Ocean and Gulf of California.

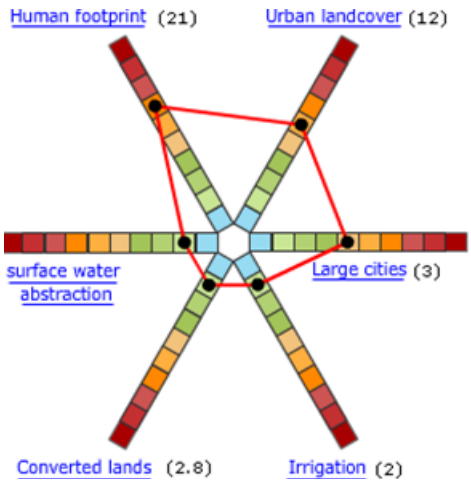
This ecoregion is characterized by extreme aridity and geological activity (Moyle 2002). The mountain chains running through the ecoregion influence the various weather patterns: the northwestern portion of the ecoregion experiences a mediterranean-type climate; valleys in central Baja experience a more humid climate; and dry, desert conditions occur along the eastern and southern portion.

Twenty species of fish are found in this ecoregion and most occur at the edge of their respective ranges (Appendix 8). Much of the fish fauna is marine-derived, and is represented by the killifish (Fundulidae), lamprey (Petromyzontidae), sculpin (Cottidae), and salmonid (Salmonidae) families. In general, the ecoregion has a relatively limited fish fauna due to aridity and geological activity but it is biologically noteworthy because it includes the southernmost range for anadromous fishes such as steelhead (*Oncorhynchus mykiss*) and the Pacific lamprey (*Lampetra tridentata*).

Ecoregion includes the southernmost range for anadromous fishes like steelhead and Pacific lamprey

The only California streams that contain endemic species are located in the Los Angeles basin (Santa Ana, San Gabriel and Los Angeles rivers). The Los Angeles Basin contains three of the six endemic species found in this freshwater ecoregion: the arroyo chub (*Gila orcuttii*), Santa Ana sucker (*Catostomus santaanae*) and speckled dace (*Rhinichthys osculus*) (Figures 9 and 10).

Sixty percent of the fish species (12 taxa) found in this ecoregion are considered imperiled as determined by the 2008 American Fisheries Society Endangered Species Committee (Figure 11). Six of the 14 imperiled fishes are considered endangered, four of which fall within California's borders: steelhead-southern California populations (*Oncorhynchus mykiss*), Santa Ana stickleback (*Gasterosteus aculeatus santaeannae*), unarmored threespine stickleback (*Gasterosteus aculeatus illiamsoni*), and the tidewater goby (*Eucyclogobius newberryi*).



As the most developed freshwater ecoregion in the state, the greatest threats to this ecoregion are the human footprint, large cities and urban landcover. Threats associated with agriculture are relatively low including irrigation, surface water abstraction and converted lands defined as cultivated and managed areas, cropland mosaics and artificial surfaces (Figure 14).

Figure 14: Diagram of threats in the Southern California-Baja ecoregion showing the relative severity of each threat. Red is highest threat and green is lowest.

Two of California's 12 terrestrial ecoregions fall within the Southern California-Baja freshwater ecoregion–the Central and South Coasts (Table 6).

Table 6: Percent of terrestrial ecoregions in the Southern California-Baja freshwater ecoregion

Terrestrial Ecoregion	Percent of terrestrial ecoregion that falls within Southern California-Baja freshwater ecoregion
California Central Coast	22%
California South Coast	82%

Oregon Lakes Freshwater Ecoregion

The Oregon Lakes freshwater ecoregion is a closed drainage system that does not flow outward into any rivers or oceans. It covers inland basins of central-southern Oregon, a small part of northeastern California, and parts of northwestern Nevada. The basins of this ecoregion represent an extension of the Basin and Range province that lies between the Cascade Mountains to the west and the Owyhee Upland to the east. The landscape is characterized by a pattern of basins and raised terraces that run in a north-south orientation (Minckley et al. 1986). This ecoregion is high desert and falls largely in the rain shadow of the Cascade Mountains.

These desert basins are largely defined by alkaline lakes such as Goose Lake, which straddles the California-Oregon border, and Lake Albert, Summer Lake, and Harney Lake in Oregon. Other freshwater habitats include wetlands, playas, isolated springs and streams, and many smaller lakes, several of which are important to the ecoregion's biological distinction.

75% of fish in this freshwater ecoregion are imperiled

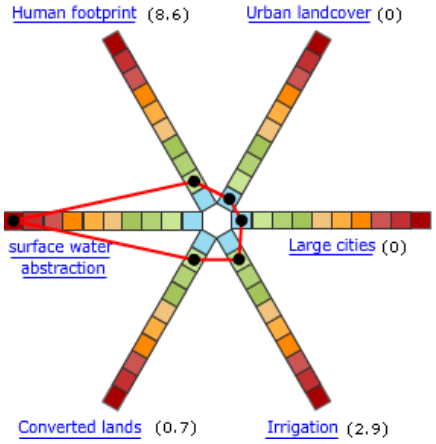


Figure 15: Diagram of threats in the Oregon Lakes ecoregion showing the relative severity of each threat. Red is highest threat and green is lowest.

The ecoregion contains 23 native fish species, 75% of which are considered imperiled (15 species) (Jelks et al. 2008), and two of which are endemic (Figures 9 and 10; Appendix 9). The endemic fish are the Borax Lake chub (*Gila boraxobius*), a dwarf species found in Borax Lake and Lower Borax Lake in Oregon, and the Warner sucker (*Catostomus warnerensis*), found in ephemeral lakes, sloughs, lower-gradient streams, and three permanent lakes in the Warner Basin in Oregon and Nevada (Sigler & Sigler 1994; Williams 1995a; Williams 1995b). Three species of fish that fall within California's boundaries in this freshwater ecoregion are listed as endangered including: white sturgeon (*Acipenser transmontanus*), Cowhead Lake tui chub (*Gila bicolor vaccaceps*), and the Modoc sucker (*Catostomus microps*).

With its low population density, the major threat to this ecoregion is surface water abstraction (Figure 15). This freshwater ecoregion makes up only 3% of California; and only 8% of this freshwater ecoregion falls within California boundaries (Table 1).

Table 7: Percent of terrestrial ecoregions within the Oregon Lakes freshwater ecoregion

Terrestrial Ecoregion	Percent of terrestrial ecoregion that falls within Oregon Lakes freshwater ecoregion
Columbia Plateau	6%
East Cascades/Modoc Plateau	8%

Lahontan Freshwater Ecoregion

Like the Oregon Lakes freshwater ecoregion, the Lahontan Basin ecoregion is a closed drainage system that does not flow outward into any rivers or oceans. The climate of this desert basin is dry and hot in the summer and cold and dry in the winter, with precipitation occurring primarily in the spring in the north and primarily in the winter in the south.

The Lahontan ecoregion includes Lake Tahoe which is distinguished by being one of the largest high-mountain lakes in the world, with a surface area of 304 km^2, a maximum depth of 501 meters, and an altitude of 1,899 meters above sea level (Moyle 1976). Within the ecoregion there are also numerous small playa lakes, as well as both warm and cold springs. The Lahontan is characterized by extreme aridity that has reduced the native freshwater fauna to a handful of species from a much greater number present in n pluvial times (times of more abundant rainfall) (Hubbs et al. 1974). One endorheic (closed) basin of note is Mono Lake, on the border with the Death Valley ecoregion, which represents a rare habitat type. It is too saline to support fish, but contains abundant populations of the alkali fly (*Ephydra hians*) and an endemic brine shrimp (*Artemia monica*), which in turn support a diverse migratory bird fauna (Moyle 1976).

Lake Tahoe and Mono Lake are endorheic basins found in this ecoregion

The Lahontan's harsh conditions and few perennial freshwater habitats (which become torrents during infrequent storms) have excluded all but the hardiest and most adaptable fish species. Those that remain have, in some cases, become extraordinarily differentiated within isolated habitats; for instance, six subspecies of tui chub (*Gila bicolor*) and five of speckled dace (*Rhinichthys osculus*) are recognized in the ecoregion (Hubbs et al. 1974; Williams et al. 1985; Sigler & Sigler 1994).

The Lahontan contains 14 species of fish, four of which are endemic (Figure 9 and 10; Appendix 10). Endemic fish include the Railroad Valley springfish (*Crenichthys nevadae*), cui-ui (*Chasmistes cujus*), desert dace (*Erimichthys acros*), and the Tahoe sucker (*Catostomus tahoensis*) (Moyle 1976; Page & Burr 1991; Sigler & Sigler 1994). The cui-ui was historically found only in Pyramid and Winnemucca lakes, but today the latter is dry (Page & Burr 1991). The desert dace, a relict species found only in thermal spring habitats of Soldier Meadow, Nevada is distinguished by its ability to inhabit much hotter water than any other minnow species. Railroad Valley supports a highly endemic fauna, with five subspecies of tui chub (*Gila bicolor ssp.*) and the Railroad Valley springfish. Each of the tui chub subspecies is restricted to single localities (Kate Spring, Butterfield Spring, Blue Eagle Spring, Bull Creek, Green Springs, and Duckwater Creek), with no apparent overlap. A sixth subspecies of tui chub is shared with two other nearby valleys (Williams et al. 1985).

Nearly 65% (n=9) of the fish species found in this ecoregion are considered imperiled (Figure 11) (Jelks et al. 2008). The High Rock Springs tui chub (*Gila bicolor ssp.*), once found within California's borders, is considered extinct as determined by the 2008 American Fisheries Society Endangered Species Committee.

Similar to the Oregon Lakes ecoregion, the major threat to the Lahontan freshwater ecoregion is surface water abstraction (Figure 16). The remaining threats—urban landcover, large cities, irrigation, converted lands, and the human footprint—are low level threats in this region.

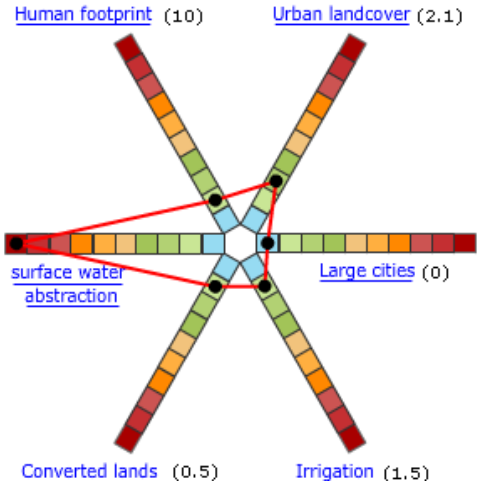


Figure 16: Diagram of threats in the Lahontan ecoregion showing the relative severity of each threat. Red is highest threat and green is lowest.

Only 1% of this freshwater ecoregion falls within California's boundary, with Lake Tahoe being a large portion of that percent. Despite the small percentage within California's borders, 4 of California's 12 ecoregions are found within the Lahontan freshwater ecoregion (Table 8).

Table 8: Percent of terrestrial ecoregions within the Lahontan freshwater ecoregion

Terrestrial Ecoregion	Percent of terrestrial ecoregion that falls within Lahontan freshwater ecoregion
Columbia Plateau	52%
Great Basin	25%
Eastern Cascades-Modoc Plateau	11%
Sierra Nevada	10%

FISH BIODIVERSITY OF CALIFORNIA'S FRESHWATER ECOREGIONS

In a continental context, California's freshwater fish biodiversity is low in terms of species richness but high in terms of species endemism. A total of 66 native freshwater, estuarine or anadromous species are found in California (Moyle 2002). Over half of these species (35) are considered endemic (FEOW data).

California is a difficult place for a freshwater fish species to persist through time; Local and regional extinctions have probably been common in the past 10,000 years as the postglacial climate became drier (Moyle 2002). Major events such as volcanic eruptions, earthquakes and movement of the earth's crust have altered entire drainage systems, creating or destroying streams, lakes and estuaries. But just as these major events may have caused local and regional extinctions, the events also isolated freshwater bodies promoting creation of subspecies and life history variants. Indeed, if we consider subspecies, marine species that enter freshwater on an irregular basis, and distinctive runs of anadromous species, the faunal count of fish species nearly doubles (Moyle 2002).

California's highly endemic fish fauna are scattered through a diversity of climates and landscapes with a dynamic and complicated geologic history (Moyle 2002). The relative isolation of California freshwater species from the rest of the continent likely precluded the spread of those species, creating a highly endemic fauna. In addition, habitats for fishes are more varied in California than those found in most states. For example, freshwater habitats in California range from cold, fast mountain streams fed most of the year by melting snow to the widely spaced desert springs and pools that are remnants of an ancient and wetter climatic period. This diversity, relative isolation and uniqueness of habitats led to evolution of California's endemic suckers, sculpins, smelts, chubs and pupfish.

Table 9: Summary of fish richness and endemism in seven freshwater ecoregions in California

Major Habitat Type	Freshwater Ecoregion	# of fish species	# of endemic fish species	% of endemic species
Temperate Coastal Rivers	Sacramento-San Joaquin	37	8	22%
	Oregon-Northern California	48	13	27%
Xeric Freshwaters and Endorheic Basins	Death Valley	9	8	89%
	Colorado	39	8	21%
	Southern California-Baja	20	6	30%
	Oregon Lakes	23	2	9%
	Lahontan	14	4	29%

ANADROMOUS FISHES: PACIFIC SALMONIDS

California holds the distinction of being at the southernmost range of salmonids (salmon, trout, steelhead). Existing on the southernmost end of their ranges, these fish are uniquely adapted to California's climatic regimes (Moyle et al. 2008). California's dynamic geology and climate has resulted in the evolution of many distinctive salmonid forms. In addition, the diversity of salmonids is also the result of California's large size, length (10 degrees of latitude), and being adjacent to the California current of the Pacific Ocean, one of the most productive ocean regions in the world (Moyle 2002). All of this has resulted in hundreds of genetically distinct populations, although there just eight recognized native species. When taking into consideration salmon, steelhead and trout species, subspecies, evolutionary significant units or distinct population segments, a total of 32 kinds of salmonids are found within California (Moyle et al. 2008). Twenty (62%) are endemic to California and one species (bull trout) has been extirpated from California (Moyle et al. 2008).

Salmonids are present in six of the seven freshwater ecoregions found in California (all but Death Valley). Five species of anadromous salmonids spawn and rear within California's boundaries: chum (*Oncorhynchus keta*), pink (*Oncorhynchus gorbuscha*), chinook (*Oncorhynchus tshawytscha*), coho (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*).

The southernmost populations of salmonids are "in deep trouble," according to a recent report by Moyle et al. (2008). Twenty of the 31 living populations of salmonids (65%) are in danger of extinctions within the next century. Of the 22 anadromous taxa found in California, 13 (59%) are in danger of extinctions, while seven (78%) of the nine living inland taxa are in danger of extinction (Moyle et al. 2008).

Despite the fact that most salmonid taxa are declining rapidly, California's salmonids still occupy most of their native ranges, although they are restricted to far fewer streams (Moyle et al. 2008) due to habitat destruction. Pacific salmon speciation dates back 6 million years (Waples et al. 2008) indicating that salmon are remarkably resilient to natural calamities, surviving an ice age, volcanic eruptions and large-scale ecosystem changes (Moyle et al. 2008). Climate change will likely pose new challenges to these species. Efforts are currently underway to identify populations most vulnerable to climate changing conditions to develop conservation strategies necessary to help wild salmon persist into the future.

AMPHIBIANS IN CALIFORNIA FRESHWATER ECOREGIONS

Amphibians in Temperate Coastal Rivers Major Habitat Type

Like California fishes, amphibians in California's freshwater ecoregions have low species richness but relatively high species endemism. Of the 15 ecoregions within the temperate coastal major habitat type on the continent, only seven contain endemic amphibians (Figures 17 and 18). Both the Sacramento-San Joaquin and Oregon-Northern California ecoregions contain endemic amphibians, ranking second and third in percent endemic amphibians (Figure 18).

The Sacramento-San Joaquin ecoregion hosts a total of 48 amphibian species, the highest of California's freshwater ecoregions. It ranks sixth in terms of the number of amphibian species but second in terms of the percent of endemic amphibian species (Figure 18). This ecoregion is noted for its high endemism of amphibians (Abell et al. 2000). Like the neighboring Sacramento-San Joaquin, the Oregon-Northern California ecoregion is noted for its relatively high taxonomic endemism in fish and amphibians. Of the 36 amphibian species found in this freshwater ecoregion, three are endemic.

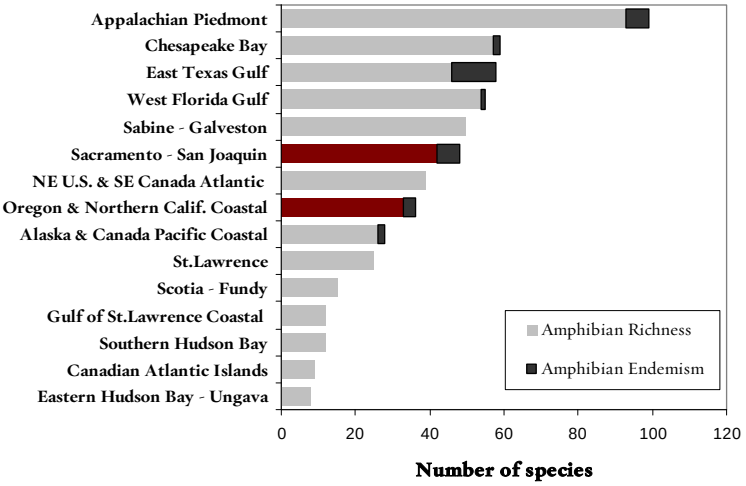


Figure 17: Amphibian species richness and endemism within each freshwater ecoregion within the *Temperate Coastal River* major habitat type. California's ecoregions are in red.

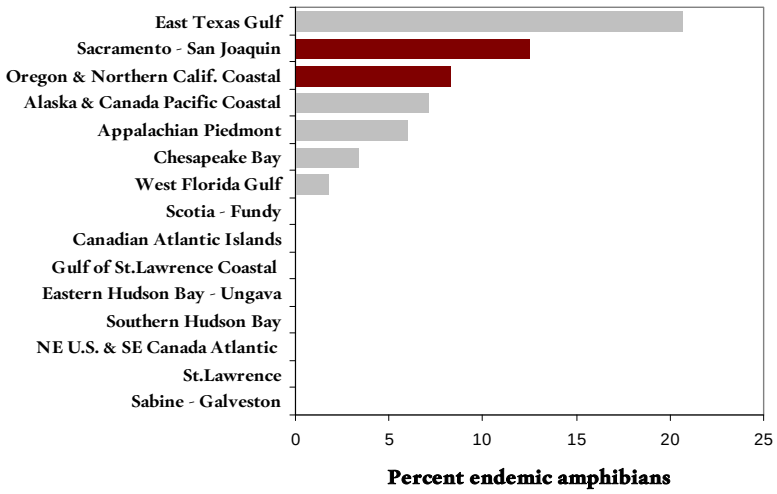


Figure 18: Percentage of amphibian species of the *Temperate Coastal Rivers* major habitat type that are endemic. California's ecoregions are in red.

Amphibians in the Xeric Freshwater and Endorheic Basin Major Habitat Type

Of the 18 ecoregions within the Xeric major habitat type found on the continent, five contain endemic amphibians (Figure 19). Three of the five xeric ecoregions in California contain endemic amphibians (Figure 20). There are 30 species of amphibians found in the Death Valley ecoregion, two of which are endemic. This region ranks first for the percent of endemic amphibians and fourth in terms of amphibian richness. The ecoregion also hosts over 20 endemic mollusks (all snails) and more than five endemic aquatic insect species. By comparison, the Colorado ecoregion has 37 amphibian species and just one is endemic. The Southern California-Baja ecoregion has 28 amphibian species with two endemics and Oregon Lakes hosts 13 species of amphibians none of which are endemic.

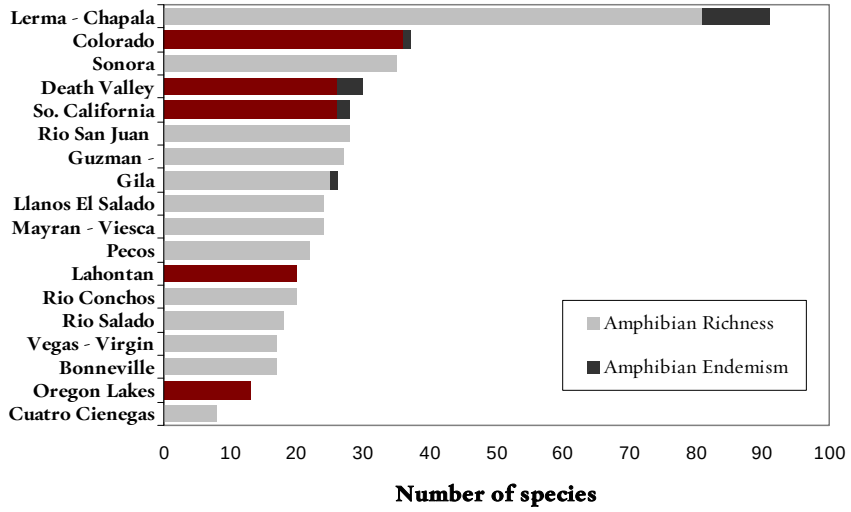


Figure 19: Amphibian species richness and endemism within each freshwater ecoregion within the *Xeric Freshwater* major habitat type. California's ecoregions are in red.

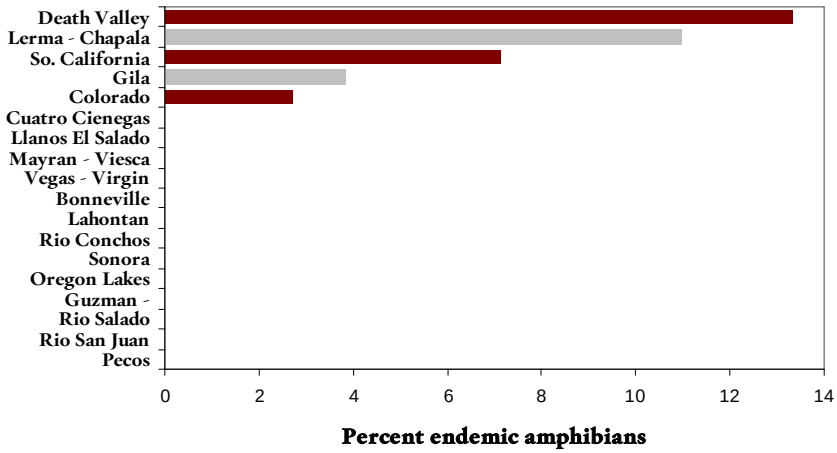


Figure 20: Percentage of amphibian species of the *Xeric Freshwater* major habitat type that are endemic.

Table 10: Summary of amphibian richness and endemism in seven freshwater ecoregions in California

Major Habitat Type	Freshwater Ecoregion	# of amphibian species	# of endemic amphibian species	% of endemic species
Temperate Coastal Rivers	Sacramento-San Joaquin	48	6	13%
	Oregon-Northern California	36	3	8%
Xeric Freshwaters and Endorheic Basins	Death Valley	30	4	13%
	Colorado	37	1	3%
	Southern California-Baja	28	2	7%
	Oregon Lakes	13	0	0%
	Lahontan	20	0	0%

CONCLUSION

For many policymakers, water resource managers, and conservation practitioners, freshwater biodiversity is often more afterthought than central consideration (Abell et al. 2008). We hope that this synthesis of freshwater ecoregional biodiversity will promote better understanding of the distribution and status of California's freshwater biodiversity. And just as terrestrial ecoregional classification and analysis spurred a decade of systematic priority-setting and more strategic conservation investment—we hope this work provides the foundation for more robust freshwater conservation planning in the future.

This assessment highlights the unique contribution California can and must play in global freshwater biodiversity protection. At the continental scale, ecoregional data distinguish California as a center of freshwater endemism—and imperilment. At the statewide scale, biodiversity and threat values can be compared across ecoregions and aid in the setting of priorities. Threats to California's seven ecoregions can be evaluated to identify those that would best be engaged at a state scale and those that might best be addressed at a more regional level. For example, in all ecoregions except Southern-California Baja and Oregon-Northern California, surface water abstraction is noted as a high-level threat—and is the only threat in the state's ecoregions that falls into the very high threat category. In a majority of California, where more water is used than gets replenished naturally, freshwater biodiversity is highly threatened. Especially given the severity of California's ongoing water crisis, solutions must be considered at the statewide scale. This analysis can help inform discussions regarding potential impacts of proposed solutions to ecoregional biodiversity.

Although this work provides an important overview of California's freshwater systems, key information gaps remain, including information on other aquatic taxa such as invertebrates, and on threats unique to the state's freshwater ecoregions such as invasive species, alteration of the state's hydrology, and groundwater withdrawal. This broad-scale assessment, however, does lay the foundation for and highlights the need for such future studies, which might include:

- Finer-scale analysis of hydrologic systems and associated biodiversity;
- Finer-scale assessment of threats (e.g., groundwater withdrawal, level of hydrologic alteration, invasive taxa, quantity, quality, and timing of surface water flows, climate change);
- Conservation management status of freshwater ecoregions and systems; and,
- Definition of conservation goals for freshwater biodiversity.

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APPENDIX 1: Freshwater Major Habitat Types

Large Lakes major habitat type is dominated and defined by large lentic systems. Examples include Lake Baikal in Siberia, Lake Malawi in Africa, or Michigan-Huron in North America.

Large River Deltas major habitat type is dominated and defined by deltaic features (e.g., tidal influences) and their associated fish faunas, which are distinctive from those occurring upstream. Examples include the Niger River Delta ecoregion and the Mekong River Delta ecoregion. Ecoregions containing deltas but not defined by specific deltaic fauna, such as the Lower Mississippi ecoregion, are not considered Large River Delta ecoregions.

Montane Freshwaters major habitat type is comprised of small streams, rivers, lakes or wetlands at higher elevations, regardless of latitude. It includes either high gradient, relatively shallow, fast-flowing streams, with rapids or complexes of high-altitude wetlands and lakes, and montane climatic conditions. Examples include Mount Nimba and Western Equatorial Crater Lakes in Africa and Orinoco Piedmont and Andes Mountains in South America.

Temperate Coastal Rivers major habitat type is dominated by several small to medium coastal basins in mid-latitudes (temperate). It is characterized by riverine ecosystems, but may also contain small lakes, coastal lagoons, and other wetlands. Migratory species that spend part of their life cycles within marine environments may inhabit this major habitat type. Although floodplains may occur along rivers such as in the Sacramento-San Joaquin basin, the dominant features are numerous, small to medium-sized basins that drain to the ocean such as the Garcia, Gualala and Eel River basins along the North Coast of California.

Temperate Floodplain Rivers and Wetland Complexes major habitat type is dominated by a single mid-latitude large river system, including the main stem river drainage and associated sub-basins, which are either currently or were historically characterized by a cyclically flooded, fringing floodplain. Examples include the Mississippi and Middle Missouri Rivers.

Temperate Upland Rivers major habitat type is dominated and defined by mid-latitude non-floodplain rivers, including headwater drainages and tributaries of large river systems. Examples include the Ozark Highlands and Ouachita Highlands in North America.

Tropical and Subtropical Coastal Rivers major habitat type is dominated by several small to medium coastal basins in the Tropics (low-latitudes). Examples include Kenyan Coastal Rivers and Mata Atlantica.

Tropical and Subtropical Upland Rivers major habitat type is dominated and defined by non-floodplain rivers, including headwater drainages and tributaries of large river systems in the Tropics. Examples include the Zambezian Headwaters, Upper Niger, and the Brazilian Shield.

Tropical and Subtropical Floodplain Rivers and Wetland Complexes major habitat type is dominated by a single low-latitude large river system. Examples include the Lower Congo, Cuvette Central, Lower Niger-Benue, Amazonas Lowland, and Orinoco-Llanos.

Polar Freshwaters major habitat type is comprised of entire drainages; from the headwaters to mouth, and found in high latitudes. Examples include the Lena River in Siberia and the Yukon in Alaska.

Oceanic Islands major habitat type is comprised of one or more islands completely surrounded by water, above high tide, and isolated from other significant landmasses. This major habitat type is characterized by freshwater biota derived from marine ancestors. Examples include Fiji and the Hawaiian Islands.

Xeric Freshwater and Endorheic Basins major habitat type is dominated by endorheic (closed drainage basins that retain water and allow no outflow to other bodies of water) aquatic systems found in arid, semi-arid, or dry sub-humid environments, such as Goose Lake in the Modoc Basin. They tend to have specialized fauna adapted to ephemeral and intermittent flooding regimes or lower waters levels during certain times of the year. Death Valley is found in this major habitat type in California.

APPENDIX 2: Methods used for assessing the freshwater biodiversity of the world's freshwater ecoregions

The FEOW project synthesized biodiversity data for each ecoregion from the best available regional information (Abell et al. 2008). The entire data set includes richness and endemism numbers for freshwater fish, amphibians, turtles and crocodiles (which of course do not occur in California). Here we examine only the information gathered for California's ecoregions for fishes and amphibians.

The available data for describing fish biogeography across the Earth vary widely. In the United States, it is possible to map presence/absence data for all freshwater fish species to subbasins averaging about 2025 km^2 (NatureServe 2006). Information sources were typically taxonomic works, some of which included biogeographical analyses. Leading ichthyologists delineated ecoregions primarily by examining the distributions of endemic species, genera, and families against the backdrop of an area's dominant habitat features and the presence of ecological (e.g., large concentrations of long-distance migratory species) and evolutionary (e.g., species flocks) phenomena. More than 130 ichthyologists and freshwater biogeographers contributed to the global map by either delineating or reviewing ecoregions.

Information for amphibian species was generated from data contained in the Global Amphibian Assessment (GAA) (IUCN, Conservation International, and NatureServe, 2006). The GAA assessed all 5,918 described amphibian species and provided distribution maps for 5,640 of those species. The FEOW final dataset included only 4,035 of those 5,918 species – restricting the list to those species that depend on fresh water during some stage of their life cycle.

Distribution maps from the GAA represent the "extent of occurrence" for each species—that is, the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred, or projected sites of known occurrence. If there is obvious discontinuity in suitable habitat, more than one polygon was developed to represent the species distribution. The species distribution maps were used to determine the number of amphibians per ecoregion. If a species range overlapped several ecoregions, species were counted as present in all of those ecoregions. A species was considered to be endemic if at least 90% of its range occurred in only one ecoregion.

APPENDIX 3: Methods and definitions used for assessing threats of the world's freshwater ecoregions

Converted Lands: Freshwater systems are linked to the catchments that they drain. Changes to land cover in those catchments can affect a freshwater system's characteristics, often to the detriment of native species and communities. To assess the relative degree of impact from land cover change, the FEOW assessed the accumulation and proportion of human-converted lands by ecoregion. The Global Land Cover 2000 database (GLC 2000) is based on remotely sensed data and describes both natural and converted land cover with global consistency. GLC 2000 classes used to determine "converted" lands are: cultivated and managed areas, cropland mosaics, and artificial surfaces and associated areas. This analysis does not quantify impact but describes the spatial extent of land cover conversion within ecoregions.

Large Cities and Megacities: Large cities form a hub of infrastructure, water use, and pollution, and put an expanded ecological footprint on their surroundings to support their populations. Freshwater biodiversity in ecoregions with these population centers is considered to be increasingly under threat. Large cities are defined as those cities with a human population over 1 million, and in 2007, there were 342 of them. Of these, 19 cities had over 10 million inhabitants and are classified as megacities. This analysis uses data from ESRI (http://www.esri.com), Columbia University's Centre for International Earth Science Information Network's Global Rural Urban Mapping Project (GRUMP) database (http://sedac.ciesin.columbia.edu/gpw/index.jsp), and the Citymayors (http://www.citymayors.com) database.

Urban Land Cover: The number of large cities and megacities identifies centers with high human population but it does not provide the spatial extent of urban areas. Lands converted to urban use generally contain large expanses of hardened surfaces as well as extensive water infrastructure, both of which affect natural runoff patterns. Urban runoff also often contains pollutants, which find their way to freshwater ecosystems. Columbia University's Centre for International Earth Science Information Network's Global Rural Urban Mapping Project (GRUMP) estimates that 3% of the earth's non-marine surface is occupied by urban areas, and these areas are more agglomerated than is normally evident when settlements are represented merely as points on a map. The GRUMP dataset identifies the extent of human settlements with a population over 5,000 globally and classifies these as urban areas. The GRUMP dataset incorporates multiple other datasets ranging from national statistics to remotely sensed data.

Area Equipped for Irrigation: Irrigation has a number of potential adverse impacts on freshwater systems. Irrigation can abstract water from natural systems and prevent or delay its return through diversions and storage; allow the conversion of natural lands into agricultural crops and infrastructure; disturb natural drainage systems through the construction of canals and drains, and pollute freshwater systems with agricultural wastewater. An analysis of the total area equipped for irrigation within each ecoregion gives an indication of the relative degree of threat posed by irrigation to freshwater systems. Data come from the FAO and University of Frankfurt's Global Map of Irrigation Areas (http://www.fao.org/nr/water/aquastat/irrigationmap/index10.stm).

Human Footprint: The Wildlife Conservation Society (WCS) and the Center for International Earth Science Information Network (CIESIN) have quantified human impacts on the natural environment through their Human Footprint dataset (http://www.ciesin.columbia.edu/wild_areas/). Human Footprint incorporates three themes: population pressure, land use with infrastructure, and human access. The FEOW project averaged human footprint values over each ecoregion, and acknowledged some limitations of using this dataset to assess threats to freshwater systems. For example, in the Human Footprint calculation navigable rivers are identified as allowing access to otherwise remote regions and are therefore highlighted as areas of higher impact. While greater human activity in a region will likely lead to greater impacts on freshwaters, those impacts may differ markedly depending on the type of human activity and the type of river use. Nonetheless, the FEOW project presents Human Footprint by ecoregion as a coarse indicator of the extent of human activity that may affect freshwaters.

Surface Water Abstraction: Water stress is defined as the ratio of water use (i.e., surface water withdrawn for domestic, agriculture and livestock use) to water availability (measured as discharge by subbasin, which were delineated at 25,000 km^2, globally). Water stress, therefore, measures the relative use of water to what is replenished naturally by precipitation and snow melt. Ecosystems and species that are adapted to particular flow patterns in rivers, lakes and wetlands are seriously affected when excessive water is removed from ecosystems. In general, ecoregions where more water is used than gets replenished naturally are considered to be under high water stress, while those with ample supplies are considered to be at low stress. Not surprisingly, arid or populous regions suffer more from water stress, as most of the water resources in those areas have already been heavily tapped. The data used to calculate the water stress indicator is from WaterGAP (http://atlas.gwsp.org), a global hydrologic model developed by the University of Kassel in Germany. WaterGAP provides both water use and discharges on a global scale. For this analysis, all non-marine areas were divided into consistently-sized subbasins using HydroSHEDS tools (http://www.worldwildlife.org/freshwater/hydrosheds.cfm). The water stress ration was then calculated for each subbasin and the results upscaled to the ecoregion level. Corrections were made for both very small ecoregions with a high proportion of their area under water stress, and for very large ecoregions with large absolute areas under water stress. Due to data limitations the analysis incorporates only annual values. An analysis of seasonal water stress would likely result in increased stress levels; agricultural water demands, for example, are generally highest in dry seasons.

APPENDIX 4: List of fishes found in Sacramento-San Joaquin freshwater ecoregion. Only fishes considered imperiled include information on status, criteria, ecoregional, state and province distribution. Species lists were obtained from the FEOW project; status, criteria, and distribution data was obtained from Jelks et al. 2008.

Family	Genus	Species	Common Name	Status [1]	Criteria [2]	Ecoregions [3]	States and Provinces	Habitat
Acipenseridae	Acipenser	medirostris	Green sturgeon	V	1,2	1,4,5,6,7,9,10,11	AK,CA,OR,WA,BC	FW, Brackish, Marine
Acipenseridae	Acipenser	transmontanus	White sturgeon	E	1,2	4,6,7,8,9,10,12	AK,CA,ID,MT,OR,WA,BC	FW, Brackish, Marine
Catostomidae	Catostomus	microps	Modoc sucker	E	1,4	10,12	CA	FW
Catostomidae	Catostomus	occidentalis	Sacramento sucker					FW
Centrarchidae	Archoplites	interruptus	Sacramento perch	T	1,4	10	CA	FW
Cottidae	Cottus	aleuticus	Coast range sculpin					FW, Brackish, Marine
Cottidae	Cottus	armatus	Staghorn sculpin					FW, Brackish, Marine
Cottidae	Cottus	asper	Prickly sculpin					FW, Brackish, Marine
Cottidae	Cottus	asperrimus*	Rough sculpin	V	1,4,5	10	CA	FW
Cottidae	Cottus	gulosus	Riffle sculpin					FW
Cottidae	Cottus	klamathensis	Bigeye marbled sculpin	V	1,4,5	10	CA	FW
Cottidae	Cottus	pitensis	Pit sculpin					FW
Cyprinidae	Gila	Bicolor	Tui chub					FW
Cyprinidae	Hesperoleucus	symmetricus	Pit roach	V	1,4,5	10	CA	FW
Cyprinidae	Lavinia	exilicauda	Clear Lake hitch	V	1,2,4,5	10	CA	FW
Cyprinidae	Mylopharodon	conocephalus*	Hardhead					FW
Cyprinidae	Orthodon	microlepidotus*	Sacramento blackfish					FW, Brackish
Cyprinidae	Pogonichthys	macrolepidotus*	Splittail	V	1,2,4	10	CA	FW, Brackish
Cyprinidae	Ptychocheilus	grandis*	Sacramento pikeminnow					FW
Cyprinidae	Rhinichthys	osculus	Speckled dace					FW
Cyprinidae	Gila	crassicauda	Thicktail chub	X	1,2,5	10	CA	
Embiotocidae	Cymatogaster	aggregata	Shiner perch					FW, Brackish, Marine
Embiotocidae	Hysterocarpus	traskii*	Tule perch	V	1,4	10	CA	FW
Gasterosteidae	Gasterosteus	aculeatus	Threespine stickleback					FW
Gobiidae	Eucyclogobius	newberryi	Tidewater goby	E	1	9,10,11	CA	FW, Brackish, Marine
Osmeridae	Hypomesus	transpacificus*	Delta smelt	T	1,4,5	10	CA	FW, Brackish
Osmeridae	Spirinchus	thaleichthys	Longfin smelt					FW, Brackish, Marine
Petromyzontidae	Lampetra	ayresii	River lamprey	V	1,4	4,5,7,9,10	AK,CA,OR,WA,BC	FW, Brackish, Marine

Petromyzontidae	Lampetra	hubbsi*	Kern brook lamprey	T	1,2,4,5	10	CA	FW
Petromyzontidae	Lampetra	lethophaga	Pit-Klamath brook lamprey	V	1,5	9,10,12	CA,OR	FW
Petromyzontidae	Lampetra	richardsoni	Western brook lamprey					FW
Petromyzontidae	Lampetra	tridentata	Pacific lamprey	V	1,2	1,4,5,6,7,8,9, 10,11	AK,CA,ID, OR,WA,B C,BCN	FW, Brackish, Marine
Salmonidae	Oncorhynchus	gorbuscha	Pink salmon					FW, Brackish, Marine
Salmonidae	Oncorhynchus	keta	Chum salmon					FW, Brackish, Marine
Salmonidae	Oncorhynchus	kisutch	Coho salmon					FW, Brackish, Marine
Salmonidae	Oncorhynchus	nerka	Sockeye salmon					FW, Brackish, Marine
Salmonidae	Oncorhynchus	tshawytscha	Chinook salmon	E	1,2,3,4, 5	10	CA	FW, Brackish, Marine
Salmonidae	Oncorhynchus	mykiss	Steelhead (south-central California coastal populations)	T	1,2,3,4, 5	10	CA	FW, Brackish, Marine
Salmonidae	Oncorhynchus	mykiss	steelhead (central California coastal populations)	T	1,2,3,4, 5	9,10	CA	FW, Brackish, Marine
Salmonidae	Oncorhynchus	mykiss	steelhead (California Central Valley populations)	T	1,2,3,4, 5	10	CA	FW, Brackish, Marine
Salmonidae	Oncorhynchus	mykiss	South Fork Kern River golden trout	T	1,2,3,4, 5	10	CA	FW, Brackish, Marine
Salmonidae	Oncorhynchus	mykiss	Kern River rainbow trout	T	1,2,3,4, 5	10	CA	FW, Brackish, Marine
Salmonidae	Oncorhynchus	mykiss	McCloud River redband trout	V	1,2,3,4, 5	10	CA	FW, Brackish, Marine
Salmonidae	Oncorhynchus	mykiss	Little Kern River golden trout	E	1,2,3,4, 5	10	CA	FW, Brackish, Marine
Salmonidae	Oncorhynchus	Tshawytscha	Chinook salmon (Sacramento River winter run population)	E	1,2,3,4, 5	10	CA	FW, Brackish, Marine
Salmonidae	Oncorhynchus	tshawytscha	Chinook salmon (California coastal populations)	T	1,2,3,4, 5	9,10	CA	FW, Brackish, Marine
Salmonidae	Oncorhynchus	tshawytscha	Chinook salmon (California Central Valley spring run populations)	T	1,2,3,4, 5	10	CA	FW, Brackish, Marine
Salmonidae	Oncorhynchus	tshawytscha	Chinook salmon (California Central Valley fall and late fall run populations)	V	1,2,3,4, 5	10	CA	FW, Brackish, Marine

[1] Status abbreviations found in Appendix 11. [2] Criteria information found in Appendix 11. [3] Codes for ecoregions found in Appendix 12. * Species is endemic to this freshwater ecoregion

APPENDIX 5: List of fishes found in Oregon-Northern California freshwater ecoregion. Only fishes considered imperiled include information on status, criteria, ecoregional, state and province distribution. Species lists were obtained from the FEOW project; status, criteria, and distribution data was obtained from Jelks et al. 2008.

Family	Genus	Species	Common Name	Status [1]	Criteria [2]	Ecoregions [3]	States and Provinces	Habitat
Acipenseridae	Acipenser	medirostris	green sturgeon	V	1,2	1,4,5,6,7,9,10,11	AK,CA,OR,WA,BC	FW, BRACKISH, MARINE
Acipenseridae	Acipenser	transmontanus	white sturgeon	E	1,2	4,6,7,8,9,10,12	AK,CA,ID,MT,OR,WA,BC	FW, BRACKISH, MARINE
Catostomidae	Catostomus	occidentalis	Sacramento sucker	None				FW
Catostomidae	Catostomus	rimiculus*	Jenny Creek sucker	V	1,4,5	9	CA,OR	FW
Catostomidae	Catostomus	snyderi*	Klamath largescale sucker	T	1,4,5	9	CA	FW
Catostomidae	Chasmistes	brevirostris*	shortnose sucker	E	1,2,4,5	9	CA,OR	FW
Catostomidae	Deltistes	luxatus*	Lost River sucker	E	1,2,4,5	9	CA,OR	FW
Cottidae	Cottus	aleuticus	coast range sculpin	None				FW, BRACKISH, MARINE
Cottidae	Cottus	armatus	staghorn sculpin	None				FW, BRACKISH, MARINE
Cottidae	Cottus	asper	prickly sculpin	None				FW, BRACKISH, MARINE
Cottidae	Cottus	gulosus	riffle sculpin	None				FW
Cottidae	Cottus	klamathensis	bigeye marbled sculpin	None				FW
Cottidae	Cottus	perplexus	reticulate sculpin	None				FW
Cottidae	Cottus	princeps*	Klamath lake sculpin	None				FW
Cottidae	Cottus	rhotheus	torrent sculpin	None				FW
Cottidae	Cottus	tenuis*	slender sculpin	V	1,4,5	9	OR	FW
Cyprinidae	Gila	bicolor	tui chub	None				FW
Cyprinidae	Gila	coerulea*	blue chub	None				FW
Cyprinidae	Hesperoleucus	symmetricus	pit roach	None				FW
Cyprinidae	Lavinia	exilicauda	Clear Lake hitch	None				FW
Cyprinidae	Mylocheilus	caurinus	Peamouth	None				FW, BRACKISH
Cyprinidae	Oregonichthys	kalawatseti*	Umpqua chub	V	4,5	9	OR	FW
Cyprinidae	Ptychocheilus	oregonensis	Northern pikeminnow	None				FW
Cyprinidae	Ptychocheilus	umpquae*	Umpqua pikeminnow	None				FW
Cyprinidae	Rhinichthys	cataractae	Millicoma longnose dace	V	1,5	9	OR	FW
Cyprinidae	Rhinichthys	evermanni*	Umpqua dace	V	1,5	9	OR	FW
Cyprinidae	Rhinichthys	osculus	speckled dace	None				FW
Cyprinidae	Richardsonius	balteatus	redside shiner	None				FW
Embiotocidae	Cymatogaster	aggregata	shiner perch	None				FW, BRACKISH, MARINE
Gasterosteidae	Gasterosteus	aculeatus	Threespine stickleback	None				FW
Gobiidae	Eucyclogobius	newberryi	tidewater goby	E	1	9,10,11	CA	FW, BRACKISH, MARINE
Osmeridae	Spirinchus	thaleichthys	longfin smelt	None				FW, BRACKISH,

								MARINE
Osmeridae	Thaleichthys	pacificus	Euchalon	None				FW, BRACKISH, MARINE
Percopsidae	Percopsis	transmontana	sand roller	None				FW
Petromyzontidae	Lampetra	ayresii	river lamprey	V	1,4	4,5,7,9,10	AK,CA,OR,WA,BC	FW, BRACKISH, MARINE
Petromyzontidae	Lampetra	folletti*	Modoc brook lamprey	None				FW
Petromyzontidae	Lampetra	lethophaga	Pit-Klamath brook lamprey	V	1,5	9,10,12	CA,OR	FW
Petromyzontidae	Lampetra	minima*	Miller Lake lamprey	E	1,2,5	9	OR	FW
Petromyzontidae	Lampetra	richardsoni	Western brook lamprey	None				FW
Petromyzontidae	Lampetra	similis*	Klamath lamprey	T	1,5	9,12	CA,OR	FW
Petromyzontidae	Lampetra	tridentata	Pacific lamprey	V	1,2	1,4,5,6,7,8,9,10,11	AK,CA,ID,OR,WA,BC,BCN	FW, BRACKISH, MARINE
Salmonidae	Oncorhynchus	clarkii	coastal cutthroat trout	V	1,3,4	4,5,7,9	AK,CA,OR,WA,BC	FW
Salmonidae	Oncorhynchus	gorbuscha	pink salmon	None				FW, BRACKISH, MARINE
Salmonidae	Oncorhynchus	keta	chum salmon	None				FW, BRACKISH, MARINE
Salmonidae	Oncorhynchus	kisutch	coho salmon (central California coastal population, Humboldt to Santa Cruz counties)	E	1,2,3,4	9	CA	FW, BRACKISH, MARINE
Salmonidae	Oncorhynchus	kisutch	coho salmon (Oregon coastal populations)	T	1,2,3,4	9	OR	FW, BRACKISH, MARINE
Salmonidae	Oncorhynchus	kisutch	coho salmon (southern OR/northern CA coastal populations)	T	1,2,3,4	9	CA,OR	FW, BRACKISH, MARINE
Salmonidae	Oncorhynchus	mykiss	steelhead (northern California coastal populations)	T	1,2,3,4,5	9	CA	FW, BRACKISH, MARINE
Salmonidae	Oncorhynchus	mykiss	steelhead (central California coastal populations)	T	1,2,3,4,5	9,10	CA	FW, BRACKISH, MARINE
Salmonidae	Oncorhynchus	mykiss	steelhead (Oregon coastal populations)	V	1,2,3,4,5	9	OR	FW, BRACKISH, MARINE
Salmonidae	Oncorhynchus	tshawytscha	chinook salmon (California coastal populations)	T	1,2,3,4,5	9,10	CA	FW, BRACKISH, MARINE
Salmonidae	Salvelinus	confluentus	bull trout (coastal populations)	V	1,2,3,4	4,7,9	AK,CA,OR,WA,BC	FW, BRACKISH, MARINE

[1] Status abbreviations found in Appendix 11. [2] Criteria information found in Appendix 11. [3] Codes for ecoregions found in Appendix 12. * Species is endemic to this freshwater ecoregion

APPENDIX 6: List of fishes found in the Death Valley freshwater ecoregion. Only fishes considered imperiled include information on status, criteria, ecoregional, state and province distribution. Species lists were obtained from the FEOW project; status, criteria, and distribution data was obtained from Jelks et al. 2008.

Family	Genus	Species	Common Name	Status [1]	Criteria [2]	Ecoregions [3]	States and Provinces	Habitat
Catostomidae	Catostomus	fumeiventris *	Owens sucker					FW
Cyprinodontidae	Cyprinodon	diabolis*	Devils Hole pupfish	E	1,5	15	NV	FW
Cyprinodontidae	Cyprinodon	nevadensis*	amargosa pupfish					FW
Cyprinodontidae	Cyprinodon	nevadensis mionectes *	Ash Meadows amargosa pupfish (subspecies)	E	1,4,5	15	NV	FW
Cyprinodontidae	Cyprinodon	nevadensis pectoralis *	Warm Springs amargosa pupfish (subspecies)	E	1,4,5	15	NV	FW
Cyprinodontidae	Cyprinodon	nevadensis shoshone *	Shoshone pupfish (subspecies)	E	1,4,5	15	CA	FW
Cyprinodontidae	Cyprinodon	nevadensis nevadensis *	Saratoga Springs pupfish (subspecies)	T	1,5	15	CA	FW
Cyprinodontidae	Cyprinodon	nevadensis amargosae *	Amargosa Valley pupfish (subspecies)	V	1,4,5	15	CA	FW
Cyprinodontidae	Cyprinodon	nevadensis calidae *	Tecopa pupfish (subspecies)	X	1,4,5	15	CA	FW
Cyprinodontidae	Cyprinodon	radiosus*	Owens pupfish	E	1,4,5	15	CA	FW
Cyprinodontidae	Cyprinodon	salinus*	Pupfish					FW
Cyprinodontidae	Cyprinodon	salinus*	Cottonball Marsh pupfish (subspecies)	T	5	15	CA	FW
Cyprinodontidae	Cyprinodon	salinus*	Salt Creek pupfish (subspecies)	V	5	15	CA	FW
Goodeidae	Empetrichthys	latos	Pahrump poolfish	E	1,4,5	15	NV	FW
Goodeidae	Empetrichthys	latos	Raycraft Ranch poolfish (subspecies)	X	1,5	15	NV	FW
Goodeidae	Empetrichthys	latos	Pahrump Ranch poolfish (subspecies)	X	1,5	15	NV	FW
Goodeidae	Empetrichthys	latos	Ash Meadows poolfish (subspecies)	X	1,4,5	15	NV	FW
Cyprinidae	Gila	bicolor	tui chub					FW
Cyprinidae	Gila	bicolor	Mohave tui chub (subspecies)	E	1,4,5	15	CA	FW
Cyprinidae	Gila	bicolor	Owens tui chub (subspecies)	E	1,4,5	15	CA	FW
Salmonidae	Oncorhynchus	mykiss	rainbow trout					FW
Cyprinidae	Rhinichthys	osculus	Long Valley speckled dace	E	1,4,5	15	CA	FW
Cyprinidae	Rhinichthys	osculus	Amargosa Canyon speckled dace(subspecies)	T	1,5	15	CA	FW
Cyprinidae	Rhinichthys	osculus	Amargosa River speckled dace (subspecies)	T	1,5	15	NV	FW
Cyprinidae	Rhinichthys	osculus	Owens speckled dace (subspecies)	T	1,4,5	15	CA	FW

[1] Status abbreviations found in Appendix 11. [2] Criteria information found in Appendix 11. [3] Codes for ecoregions found in Appendix 12. * Species is endemic to this freshwater ecoregion

APPENDIX 7: List of fishes found in the Colorado freshwater ecoregion. Only fishes considered imperiled include information on status, criteria, ecoregional, state and province distribution. Species lists were obtained from the FEOW project; status, criteria, and distribution data was obtained from Jelks et al. 2008.

Family	Genus	Species	Common Name	Status [1]	Criteria [2]	Ecoregions [3]	States and Provinces	Habitat
Acipenseridae	Scaphirhynchus	platorynchus	shovelnose sturgeon					FW
Catostomidae	Catostomus	clarkii	desert sucker					FW
Catostomidae	Catostomus	discobolus	Zuni bluehead sucker	E	1,2,4,5	17	NM	FW
Catostomidae	Catostomus	insignis	Sonora sucker	V	1,4	17,18	AZ,NM	FW
Catostomidae	Catostomus	latipinnis	Little Colorado river sucker	V	1,4,5	17	AZ	FW
Catostomidae	Catostomus	platyrhynchus	mountain sucker					FW
Catostomidae	Xyrauchen	texanus*	razorback sucker	E	1,2,4	17,18	AZ,CA,CO,NV,UT,WY,BCN,SON	FW
Centrarchidae	Lepomis	macrochirus	Bluegill					FW
Cottidae	Cottus	bairdii	mottled sculpin					FW
Cottidae	Cottus	beldingii	Paiute sculpin					FW
Cottidae	Cottus	armatus	staghorn sculpin					FW, BRACKISH, MARINE
Cyprinidae	Agosia	chrysogaster	longfin dace					FW
Cyprinidae	Couesius	plumbeus	lake chub					FW
Cyprinidae	Gila	cypha*	humpback chub	E	1,3,4	17	AZ,CO,NV,UT,WY	FW
Cyprinidae	Gila	elegans*	bonytail	E	1,3,4	17,18	AZ,CA,CO,NV,UT,WY,BCN,SON	FW
Cyprinidae	Gila	orcuttii	arroyo chub					FW
Cyprinidae	Gila	robusta	roundtail chub	V	1,3	17	AZ,CA,CO,NM,NV,UT,WY,BCN,SON	FW
Cyprinidae	Lepidomeda	vittata*	Little Colorado spinedace					FW
Cyprinidae	Pimephales	promelas	fathead minnow					FW
Cyprinidae	Plagopterus	argentissimus	woundfin	E	1,3,4	16,17,18	AZ,NV,UT	FW
Cyprinidae	Ptychocheilus	lucius	Colorado pikeminnow	E	1,3,4	17,18	AZ,CA,CO,NM,NV,UT,WY,BCN,SON	FW
Cyprinidae	Rhinichthys	osculus	Preston speckled dace	V	1,3,4,5	17	NV	FW
Cyprinidae	Rhinichthys	osculus	Kendall Warm springs dace	E	3,5	17	WY	FW

Cyprinidae	Rhinichthys	osculus	Moapa speckled dace	T	1,3,4	17	NV	FW
Cyprinidae	Snyderichthys	copei	leatherside chub					FW
Cyprinodontidae	Cyprinodon	macularius	desert pupfish	E	1,3,4	17,18,19	AZ,CA,BCN, SON	FW
Embiotocidae	Cymatogaster	aggregata	shiner perch					FW, BRACKISH, MARINE
Fundulidae	Fundulus	sciadicus	plains topminnow					FW
Fundulidae	Fundulus	zebrinus	Killfish					FW, BRACKISH
Gasterosteidae	Gasterosteus	aculeatus	threespine stickleback					FW
Gobiidae	Eucyclogobius	newberryi	tidewater goby					FW, BRACKISH, MARINE
Goodeidae	Crenichthys	baileyi	Springfish					FW
Goodeidae	Empetrichthys	latos	Pahrump poolfish					FW
Ictaluridae	Ameiurus	melas	black bullhead					FW
Ictaluridae	Noturus	flavus	Stonecat					FW
Percidae	Etheostoma	exile	Iowa darter					FW
Percidae	Etheostoma	nigrum	Johnny darter					FW
Petromyzontidae	Lampetra	tridentata	Pacific lamprey					FW, BRACKISH, MARINE
Salmonidae	Oncorhynchus	clarkii	Colorado River cutthroat trout	V	1,3,4	17	CO,UT,WY	FW
Salmonidae	Oncorhynchus	mykiss	Steelhead					FW, BRACKISH, MARINE
Salmonidae	Prosopium	williamsoni	mountain whitefish					FW

[1] Status abbreviations found in Appendix 11. [2] Criteria information found in Appendix 11. [3] Codes for ecoregions found in Appendix 12. * Species is endemic to this freshwater ecoregion

APPENDIX 8: List of fishes found in the Southern California-Baja freshwater ecoregion. Only fishes considered imperiled include information on status, criteria, ecoregional, state and province distribution. Species lists were obtained from the FEOW project; status, criteria, and distribution data was obtained from Jelks et al. 2008.

Family	Genus	Species	Common Name	Status [1]	Criteria [2]	Ecoregions [3]	States and Provinces	Habitat
Catostomidae	Catostomus	occidentalis	Sacramento sucker					FW
Catostomidae	Catostomus	santaanae*	Santa Ana sucker	T	1,4,5	11	CA	FW
Cottidae	Cottus	aleuticus	coast range sculpin					FW, BRACKISH, MARINE
Cottidae	Cottus	asper	prickly sculpin					FW, BRACKISH, MARINE
Cottidae	Cottus	gulosus	riffle sculpin					FW
Cottidae	Cottus	armatus	staghorn sculpin					FW, BRACKISH, MARINE
Cyprinidae	Gila	orcuttii*	arroyo chub	V	1,4,5	11	CA	FW
Cyprinidae	Hesperoleucus	symmetricus	pit roach					FW
Cyprinidae	Rhinichthys	osculus*	Santa Ana speckled dace	T	1,4,5	11	CA	FW
Cyprinodontidae	Cyprinodon	macularius	desert pupfish					FW
Embiotocidae	Cymatogaster	aggregata	shiner perch					FW, BRACKISH, MARINE
Fundulidae	Fundulus	lima*	Baja California killifish	E	1,4,5	11	BCS	FW
Fundulidae	Fundulus	parvipinnis*	California killfish					FW, BRACKISH, MARINE
Gasterosteidae	Gasterosteus	aculeatus	Santa Ana stickleback	E	1,4,5	11	CA	FW
Gasterosteidae	Gasterosteus	aculeatus	"espinocho" ("Baja California Threespine Stickleback")	T	1,5	11	CA,BCN	FW
Gasterosteidae	Gasterosteus	aculeatus	unarmored threespine stickleback	E	1,4,5	11	CA	FW
Gobiesocidae	Gobiesox	juniperoserrai*	peninsular clingfish	E	1,5	11	BCS	FW
Gobiidae	Eucyclogobius	newberryi	tidewater goby	E	1	9,10,11	CA	FW, BRACKISH, MARINE
Mugilidae	Agonostomus	monticola	mountain mullet					FW, BRACKISH, MARINE
Petromyzontidae	Lampetra	richardsoni	Western brook lamprey					FW
Petromyzontidae	Lampetra	tridentata	Pacific lamprey	V	1,2	1,4,5,6,7,8,9,10,11	AK,CA,ID,OR,WA,BC,BCN	FW, BRACKISH, MARINE
Salmonidae	Oncorhynchus	mykiss	steelhead (southern California populations)	E	1,2,3,4,5	11	CA	FW, BRACKISH,

								MARINE
Salmonidae	Oncorhynchus	mykiss	Baja California rainbow trout	V	1,3,4,5	11	BCN	FW, BRACKISH, MARINE

[1] Status abbreviations found in Appendix 11. [2] Criteria information found in Appendix 11. [3] Codes for ecoregions found in Appendix 12. * Species is endemic to this freshwater ecoregion

APPENDIX 9: List of fishes found in the Oregon Lakes freshwater ecoregion. Only fishes considered imperiled include information on status, criteria, ecoregional, state and province distribution. Species lists were obtained from the FEOW project; status, criteria, and distribution data was obtained from Jelks et al. 2008.

Family	Genus	Species	Common Name	Status [1]	Criteria [2]	Ecoregions [3]	States and Provinces	Habitat
Catostomidae	Catostomus	columbianus	bridgelip sucker					FW
Catostomidae	Catostomus	microps	Modoc sucker	E	1,4	10,12	CA	FW
Catostomidae	Catostomus	occidentalis	Goose Lake sucker	V	1	12	CA,OR	FW
Catostomidae	Catostomus	platyrhynchus	mountain sucker					FW
Catostomidae	Catostomus	warnerensis*	Warner sucker	E	1,4,5	12	OR	FW
Cottidae	Cottus	bairdii	mottled sculpin					FW
Cottidae	Cottus	beldingii	Malheur sculpin	V	1,5	7,12	OR	FW
Cottidae	Cottus	pitensis	pit sculpin					FW
Cyprinidae	Acrocheilus	alutaceus	Chiselmouth					FW
Cyprinidae	Gila	alvordensis	Alvord chub	V	1,4,5	12	NV,OR	FW
Cyprinidae	Gila	bicolor	tui chub					FW
Cyprinidae	Gila	bicolor	Sheldon tui chub (subspecies)	E	1,5	12,13	NV,OR	FW
Cyprinidae	Gila	bicolor	Oregon Lake tui chub (subspecies)	T	5	12	OR	FW
Cyprinidae	Gila	bicolor	Hutton Spring tui chub (subspecies)	E	1,5	12	OR	FW
Cyprinidae	Gila	bicolor	Summer Basin tui chub (subspecies)	E	1,4,5	12	OR	FW
Cyprinidae	Gila	bicolor	Catlow tui chub (subspecies)	V	1	12,13	OR	FW
Cyprinidae	Gila	bicolor	Goose Lake tui chub (subspecies)	T	1,4,5	12	CA	FW
Cyprinidae	Gila	bicolor	Cowhead Lake tui chub (subspecies)	E	1,5	12	CA	FW
Cyprinidae	Gila	boraxobius*	Borax Lake chub	E	1,5	12	OR	FW
Cyprinidae	Hesperoleucus	symmetricus	pit roach					FW
Cyprinidae	Rhinichthys	cataractae	longnose dace					FW
Cyprinidae	Rhinichthys	osculus	Foskett speckled dace	T	1,5	12	OR	FW
Cyprinidae	Richardsonius	balteatus	redside shiner					FW
Cyprinidae	Richardsonius	egregius	Lahontan redside					FW
Petromyzontidae	Lampetra	lethophaga	Pit-Klamath brook lamprey	V	1,5	9,10,12	CA,OR	FW
Petromyzontidae	Lampetra	tridentata	Pacific lamprey (Goose Lake population)	T	1,5	12	CA,OR	BRACKISH, MARINE, FW
Salmonidae	Oncorhynchus	clarkii	Alvord cutthroat trout	Xp	1,2,4,5	12	NV,OR	FW
Salmonidae	Oncorhynchus	mykiss	redband trout (Warner Valley populations)	V	1,2,3,4,5	12	CA,NV,OR	BRACKISH, MARINE, FW
Salmonidae	Oncorhynchus	mykiss	redband trout (Goose Lake populations)	V	1,2,3,4,5	12	CA,OR	BRACKISH, MARINE, FW
Salmonidae	Oncorhynchus	mykiss	redband trout (Catlow Valley populations)	V	1,2,3,4,5	12	OR	BRACKISH, MARINE, FW
Salmonidae	Oncorhynchus	mykiss	redband trout (Harney-Malhuer Lake populations)	V	1,2,3,4,5	12	OR	BRACKISH, MARINE, FW

Salmonidae	Prosopium	williamsoni	mountain whitefish					FW
Salmonidae	Salvelinus	confluentus	bulltrout					BRACKISH, MARINE, FW

[1] Status abbreviations found in Appendix 11. [2] Criteria information found in Appendix 11. [3] Codes for ecoregions found in Appendix 12. * Species is endemic to this freshwater ecoregion

APPENDIX 10: List of fishes found in the Lahontan freshwater ecoregion. Only fishes considered imperiled include information on status, criteria, ecoregional, state and province distribution. Species lists were obtained from the FEOW project; status, criteria, and distribution data was obtained from Jelks et al. 2008.

Family	Genus	Species	Common Name	Status [1]	Criteria [2]	Ecoregions [3]	States and Provinces	Habitat
Catostomidae	Catostomus	columbianus	bridgelip sucker					FW
Catostomidae	Catostomus	platyrhynchus	mountain sucker					FW
Catostomidae	Catostomus	spp.	Wall Canyon sucker	E	1,5	13	NV	FW
Catostomidae	Catostomus	tahoensis*	Tahoe sucker					FW
Catostomidae	Chasmistes	cujus*	cui-ui	E	1	13	NV	FW
Cyprinidae	Eremichthys	acros*	desert dace	T	1,4,5	13	NV	FW
Cyprinidae	Gila	alvordensis	Alvord chub					FW
Cyprinidae	Gila	bicolor	tui chub					FW
Cyprinidae	Gila	bicolor	Fish Creek Springs tui chub	E	1,4,5	13	NV	FW
Cyprinidae	Gila	bicolor	Sheldon tui chub	E	1,5	12,13	NV,OR	FW
Cyprinidae	Gila	bicolor	Independence Valley tui chub	E	1,4,5	13	NV	FW
Cyprinidae	Gila	bicolor	Newark Valley tui chub	T	1,5	13	NV	FW
Cyprinidae	Gila	bicolor	High Rock Springs tui chub	X	1,4,5	13	CA	FW
Cyprinidae	Gila	bicolor	Big Smoky Valley tui chub	E	1,5	13	NV	FW
Cyprinidae	Gila	bicolor	Charnock Springs tui chub	E	1,5	13	NV	FW
Cyprinidae	Gila	bicolor	Dixie Valley tui chub	E	1,5	13	NV	FW
Cyprinidae	Gila	bicolor	Duckwater Creek tui chub	E	1,5	13	NV	FW
Cyprinidae	Gila	bicolor	Hot Creek Valley tui chub	E	1,5	13	NV	FW
Cyprinidae	Gila	bicolor	Little Fish Lake Valley tui chub	E	1,5	13	NV	FW
Cyprinidae	Gila	bicolor	Railroad Valley tui chub	T	1,5	13	NV	FW
Cyprinidae	Gila	bicolor	Catlow tui chub	V	1	12,13	OR	FW
Cyprinidae	Relictus	solitarius	relict dace	V	1,4,5	13	NV	FW
Cyprinidae	Rhinichthys	osculus	speckled dace					FW
Cyprinidae	Rhinichthys	osculus	Big Smoky Valley speckled dace	E	1,4,5	13	NV	FW
Cyprinidae	Rhinichthys	osculus	Independence Valley speckled dace	E	1,4,5	13	NV	FW
Cyprinidae	Rhinichthys	osculus	Ash Meadows speckled dace	E	1,4,5	13	NV	FW
Cyprinidae	Rhinichthys	osculus	Clover Valley speckled dace	E	1,4,5	13	NV	FW

Cyprinidae	Rhinichthys	osculus	Grass Valley speckled dace	X	1,4,5	13	NV	FW
Cyprinidae	Richardsonius	balteatus	redside shiner					FW
Cyprinidae	Richardsonius	egregius	Lahontan redside					FW
Goodeidae	Crenichthys	nevadae*	Railroad Valley springfish	T	1,4,5	13	NV	FW
Salmonidae	Oncorhynchus	clarkii	Humboldt cutthroat trout	T	1,3,4,5	13	NV	FW
Salmonidae	Oncorhynchus	clarkii	Lahontan cutthroat trout (Whitehorse-Willow Creek/Coyote Lake basin population)	T	1,3,4	13	CA,NV,OR	FW
Salmonidae	Oncorhynchus	clarkii	Paiute cutthroat trout	E	1,3,4,5	13	CA	FW
Salmonidae	Oncorhynchus	mykiss aquilarum	Eagle Lake rainbow trout	T	1,2,3,4,5	13	CA	FW
Salmonidae	Prosopium	williamsoni	mountain whitefish					FW

[1] Status abbreviations found in Appendix 11. [2] Criteria information found in Appendix 11. [3] Codes for ecoregions found in Appendix 12. * Species is endemic to this freshwater ecoregion

APPENDIX 11

Status Categories and Abbreviations (*sensu* Jelks et al. 2008)

Endangered (E): a taxon that is in imminent danger of extinction throughout all or extirpation from a significant portion of its range.

Threatened (T): a taxon that is in imminent danger of becoming endangered throughout all or a significant portion of its range.

Vulnerable (V): a taxon that is in imminent danger of becoming threatened throughout all or a significant portion of its range. This status is equivalent to "Special Concern" as designated by Williams et al. (1989), and many governmental agencies and nongovernmental organizations.

Extinct (X): a taxon of which no living individual has been documented in its natural habitat for 50 or more years. Two additional subcategories of extinction are recognized.

Possibly Extinct (Xp): a taxon that is suspected to be extinct as indicated by more than 20 but fewer than 50 years since individuals were observed in nature.

Extirpated in Nature (Xn): where all populations of a taxon are presumed to have perished in natural habitats, but reproducing individuals are currently maintained in captivity.

Listing Criteria

The categories of threats to taxa on the list follow those used by the 1979 and 1989 American Fisheries Society lists with minor modification. Listing criteria are as follows:

1. present or threatened destruction, modification, or reduction of a taxon's habitat or range including sedimentation, chemical pollution, dewatering, and anthropogenic modifications to natural channels or flow regimes.
2. over-exploitation for commercial, recreational, scientific, or educational purposes; intentional eradication with ichthyocides; or indirect impacts of fishing pressure such as reduction or loss of host fish populations required by parasitic lampreys.
3. disease or parasitism.
4. other natural or anthropogenic factors that affect a taxon's existence, including impacts of nonindigenous organisms, hybridization, competition, and/or predation.
5. occurs in a narrowly restricted range.

APPENDIX 12: Codes for Ecoregions listed in Appendices 4 - 10

Code	Ecoregion
1	Aleutian-Bering Coastal
4	North Pacific Coastal
5	North Pacific Islands
6	Columbia Unglaciated
7	Columbia Glaciated
8	Upper Snake
9	Oregon and Northern California Coastal
10	Sacramento-San Joaquin
11	Southern California Coastal – Baja
12	Oregon Lakes
13	Lahontan
15	Death Valley
16	Vegas-Virgin
17	Colorado
18	Gila
19	Sonoran