California's Rivers
A Public Trust Report
Executive Summary

Prepared for the

California State Lands Commission

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Acknowledgements

California State Lands Commission

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Foreword

The State Lands Commission holds title to and manages some four million acres of sovereign land held in trust for the people of California. These lands, consisting of coastal and tidelands and all navigable rivers, streams and lakes, became state sovereign or public trust lands when California joined the Union in 1850. Because the Commission holds these lands in trust, they cannot be sold and must be used for water-dependent or water-oriented purposes such as navigation, boating, recreation, fishing, natural habitat and ecological preservation. In managing these sovereign lands under applicable trust principles, the Commission is a trustee or steward, charged with preserving the unique and irreplaceable character of the lands for the use and enjoyment of current and future generations.

This report is another of a series which examines the status of and trends affecting the public trust lands under the jurisdiction of the Commission. The series of reports has three purposes: 1) to mark the status of the public trust resources of California's rivers, lakes, bays, estuaries and tidelands; 2) to explore the likely future of those resources if present trends continue; and 3) to identify means by which such resources can be protected and restored.

The most recent of these reports was published by the Commission in 1991 when it released *Delta Estuary—California's Inland Coast: a Public Trust Report*. The *Delta Estuary* report detailed the historical and current land and water use activities in the region and documented the need for better coordinated and more comprehensive approaches to the management of its resources. The Legislature responded with the passage of the *Delta Protection Act of 1992* which recognized the significance of the Delta region and established a 19-member commission to prepare a resource management plan for its protection and preservation.

As the Delta report characterized the region's unique and vital public trust resources and various dependent uses, so does this report for the rivers in California and their watersheds.

It is worth noting that the terms of the trust which govern the management of sovereign or trust lands, whether in the Delta, riverbeds or elsewhere, are found in the statutes and the decisions of the judiciary and collectively comprise what is commonly referred to as

the Public Trust Doctrine. This Doctrine originated in early Roman law and, as incorporated into English common law, held that certain resources were available in common to all humankind by "natural law." Among those common resources were "the air, running water, the sea and consequently the shores of the sea." Navigable waterways were declared to be "common highways, forever free," and available to all the people for whatever public uses may be made of those waterways.

In California, the Public Trust Doctrine historically has referred to the right of the public to use California's waterways to engage in "commerce, navigation, and fisheries." More recently, the doctrine has been defined by the courts as providing the public the right to use California's water resources for: navigation, fisheries, commerce, environmental preservation and recreation; as ecological units for scientific study; as open space; as environments which provide food and habitats for birds and marine life; and as environments which favorably affect the scenery and climate of the area.

The Doctrine was described by the California Supreme Court in its historic *National Audubon Society v. Superior Court* (1983) decision as "an affirmation of the duty of the state to protect the people's common heritage of streams, lakes, marshlands and tidelands, surrendering the right of protection only in rare cases when the abandonment of that right is consistent with the purposes of the trust."

The *Audubon* decision also stated the principle that the State has "an affirmative duty to take the public trust into account in the planning and allocation of water resources, and to protect public trust uses whenever feasible."

The importance of maintaining irreplaceable public trust resources was eloquently expressed by the State of Oregon Court of Appeals:

> The severe restriction upon the power of the state as trustee to modify water resources is predicated not only upon the importance of the public use of such waters and lands, but upon the exhaustible nature of the resources and its fundamental importance to our society and to our environment. These resources, after all, can only be spent once.
>
> Therefore, the law has historically and consistently recognized that rivers and estuaries once destroyed or diminished may never be restored to the public, and accordingly, has required the highest degree of protection from the public trustee. *Morse v. Oregon Div. of State Lands,* (1979).

It is with these judicial declarations and admonitions in mind that the State Lands Commission has undertaken its examination of how the public's trust resources have fared since statehood.

As indicated, the subject of this report is the condition of the rivers of California and their watersheds. The report documents the causes of their alteration and the nature and extent of their degradation; it identifies the means by which their degradation can be reduced, if not avoided; and it suggests some measures to be taken for their restoration.

The report clearly demonstrates the health of California's rivers to be stressed and their viability as sustainable ecosystems in peril. It should no longer be disputed that there exists an urgent need for state agencies to undertake a comprehensive program of river basin and watershed protection and restoration. Until such a program can be enacted or adopted, individual agencies should undertake to phase out or alter those activities presently permitted or tolerated which are revealed to be degrading the state's rivers and their watersheds; concurrently, such agencies should sponsor and implement actions conducive to the restoration of such rivers and watersheds.

Recently, the prestigious National Research Council released its seminal study and report entitled *Restoration of Aquatic Ecosystems*. In it, the Council urged a new national priority be given to the restoration and protection of the nation's rivers. The Council is the principal operating agency of the National Academy of Sciences in providing services to the government, the public, and the scientific and engineering communities. California should heed the data and analysis provided by the Council and accept the opportunity afforded by the call for a new national priority for the protection and restoration of rivers as ecosystems by establishing its own river restoration and protection program.

The Legislature should schedule public hearings to consider the findings and recommendations of this report and the National Research Council's report on *Restoration of Aquatic Ecosystems*. All federal and state agencies whose activities directly or indirectly affect rivers, together with academic and scientific groups and private sector interests, should be asked to participate in the hearings and to recommend actions for the protection and restoration of California's river resources.

Executive Summary

CHAPTER ONE

California Rivers: Then and Now

A river is more than an amenity, it is a treasure.
Justice Oliver Wendell Holmes, *New Jersey v. New York*, 283 U.S. 336, 342 (1931).

Native Californian Settlements on the Rivers

It was the rivers and streams that appealed to the Natives[1]; these rivers included the Klamath River of the northwest, the Sacramento River and its tributaries in central California and the Colorado River. The South Coast area is the exception, with an ocean orientation of the native people.

Native Americans depended mostly upon plant sources for food, especially acorns, but fish, shellfish and game were also important, depending upon local conditions[2]. The Native Americans with the most sophisticated social organization appear to be those who relied upon fisheries, such as the natives of the lower Klamath River in the northwestern part of the state[3].

Seasonal variation provided abundant game, fish and plants to California's Native Americans. Riparian forests and river valley marshes provided many plants used for food, clothing, implements, baskets and other objects. The Pomo, renowned for their basketry, used resources of the Russian River and coastal rivers in what are now Sonoma and Mendocino counties. Their basket making made use of the strong yet pliable branches of the sandbar willow, a common riparian species of the area's rivers and streams[4].

Chowchilla, Cosumnes, Cuyama, Gualala, Huasna, Kaweah, Klamath, Mattole, Mohave, Mokelumne, Napa, Noyo, Otay, Petaluma, Shasta, Sisquoc, Truckee, Tuolumne, and Yuba are river names derived from the Native Americans[5].

The rivers became especially important for the tribes that took up residence in the northwest part of the state. The old Hokan-speaking tribes of Karok, Chimariko and Shasta and the newer Athabascan Tolwa,

Hupa, Mattole, Wailaki and Algonkin Yurok considered the rivers central to their existence. These tribes' life cycles, religions and wars focused on rivers particularly the rivers' salmon.

The somewhat unpredictable, cyclical nature of the salmon's annual migrations over the centuries profoundly influenced Yurok life. Religion, lore, law and tribal technology all evolved from the Natives' relationship with their fishery resources[6].

Exploration and Exploitation—The Coming of the European

European exploration and use of rivers is best viewed through their activities on the Sacramento-San Joaquin Delta. These waterways activities began early, but grew slowly. In 1772, Father Juan Crespi and Don Pedro Fages stood on the top of Mount Diablo and described the confluence of what are now called the Sacramento and San Joaquin rivers. Exploration of these rivers was marked when, in 1811, Fathers Abella and Fortini took a short trip up the "northern river of San Francisco," and then explored the mouth of the San Joaquin River. Land expeditions by the Spanish Fathers and soldiers through 1820 wandered about Montezuma Slough, up the Sacramento as far as present-day Redding, and along the southern edge of the Delta to where the City of Stockton now stands. Other Europeans entered the picture soon thereafter. The Russians, under Captain Kotzebue, sailed up the Sacramento in 1824.

Real river commerce depended on settlement, and by the early 1840s settlers had surrounded the Delta. Dr. John Marsh was first, settling at the foot of Mount Diablo in 1837. John Sutter built New Helvetia on the American River in 1841. In 1842, Juan Pena and Juan Vaca settled Lagoon Valley, near the present day City of Fairfield. The Berryessa brothers obtained a grant of land on Cache Creek in 1843 and Charles M. Weber settled first at French Camp in 1844, then founded Stockton on the San Joaquin River a few years later.

Although major ocean-going sailing ships regularly docked at Sacramento, and later at Stockton, everyone realized that steam power was needed for efficient navigation on the rivers. The "steam era" began on a summer day in 1847 when the Russian bark *Nasednich* dropped anchor in Yerba Buena cove and began unloading her "general cargo"—the disassembled 37 foot steamboat *Sitka*.

But it was gold that finally brought the world to California, and the gold was in the rivers, at least at first. In the Sierra, too, it was the water that attracted the gold seekers. Every river, stream and rill was buried under the hordes that came from every corner of the globe, settling on the bends, bars and flats of the Mother Lode. When the panning died out the miners turned to dredges and then to hydraulic mining.

Hydraulic mining involved directing a high-pressure jet of water onto an exposed placer deposit (gravel, sand or silt) and running the dislodged sediment through sluices to remove the gold.

From the 1850s until it was prohibited in California by court decisions in 1884 (*People v. Gold River Ditch and Mining Co.*, 66 Cal. 138 1884), hydraulic mining was intensively practiced on placer deposits in the Sierra Nevada, especially in the Yuba, Feather and American river drainages[7].

Large portions of mountains were washed away, leaving canyon-like landscapes, some of which are now state historic parks (Malakoff Diggings and Columbia). The sediment was washed through sluices and thence into steep canyons, from which the sediment was readily flushed by high flows, especially the record floods of 1862, into lower reaches of the rivers in the Sacramento Valley. This influx of hydraulic mining debris increased the sediment load of the rivers beyond their transport capacity, resulting in extensive deposits of tailings in the Sacramento Valley. The "debris plain" of the Yuba River was particularly noteworthy, covering over 40 square miles. As river channels filled with sediment, navigation was affected and rivers flooded farmland, inundating many fields with fresh deposits of hydraulic mining debris. It was agricultural interests which successfully halted the practice of hydraulic mining in the courts.

The flood plains of many California rivers display a distinctive pattern of parallel ridges and swales, with relief commonly ranging up to 40 feet. These features are the tailings piles of gold dredgers, large floating barges that reworked alluvial deposits for gold. The dredgers operated in artificial ponds and created layers of fine sediments overlain by coarse sediments. The resulting ridges are made up of well-drained cobbles and gravel on which vegetation is typically unable to establish. In between the ridges, near-surface water tables may support riparian plant species.

Fishing and Fisheries

Native Americans had the ability to change their world, to significantly influence the natural environments they inhabited and the resources they utilized, including fisheries. Where fisheries were an important part of the resource base, such as on northwest rivers, native culture included especially elaborate social or legal controls over fishing, as well as major ceremonies, rituals and other spiritual traditions centered on the rivers and their fish[8].

Natives Americans fished over most of the state, from lakes, rivers and streams, and the ocean. Salmon was the predominant catch on the larger rivers from Monterey Bay northward. Lamprey eels and sturgeon were also caught, especially in the North Coast region[9]. Native Americans in the Delta fished a number of warm water fish, including the Sacramento perch, thicktail chub, and hitch, which inhabited the lakes, marshes, backwater sloughs and valley lowlands[10]. On the Colorado River, the native fishes were rather bony and mushy-fleshed, but were caught and eaten by the Yuma and Mohave people[11].

Salmon provided a large portion of the diet of the Yurok, Karok, and Hupa (Hoopa) peoples of the lower Klamath and Trinity rivers. As a consequence, the salmon fishery of these northwestern natives was an integral part of all aspects of their culture, including religion, economics, and law[12]. McEvoy's (1986) analysis of Native American fishing concluded that they developed and maintained a productive salmon fishery that divided the resources among many peoples and was sustainable in the long term. This is in dramatic contrast to the Euro-american societies which followed.

The huge influx of settlers in central California after the start of the Gold Rush found a natural world teeming with wild game and fish of which they quickly took advantage. Hunters, especially those in the market trade, wiped out whole species, including the grizzly bear, pronghorn and tule elk. Fish were hauled easily out of the rivers, caught in gill-nets, fyke traps or seines[13].

River fishing in the Central Valley ended almost as soon as it had started. By 1852, the sediment from the mines—not over-fishing—nearly destroyed spawning grounds and resting pools on the Sacramento River. Gills clogged with mud impaired the adult salmon's ability to complete their journey upstream. If the fish survived to reach the spawning ground, their eggs were either covered with mud or exposed to air because of low water levels caused by mining water diversions. The system's tributaries also began losing their salmon to similar fates, the Yuba in 1853, the Mokelumne in 1855, and the Feather and American in 1862[14].

State regulation of the right to fish was incorporated into the California Constitution by Article I, Section 25 (1910), which gave the Legislature increased power to control fishing. The U.S. Supreme Court's decision in *Hughes v. Oklahoma* 441 U.S. 322 (1979) suggests that under current state and federal law, wildlife is deemed to be incapable of *private* ownership, and that a state has a public trust responsibility to manage and protect its wildlife resources for the benefit of the public and the long-term protection of the species[15].

In the decades surrounding the turn of century, Central Valley and Bay-Delta fishery populations fluctuated wildly, reflecting the effects of over-harvesting, mining and pollution, as well as variations in weather and ocean conditions[16].

The declining Central Valley river fisheries during the period of 1890 to 1920 led to the successful use of fishing boats powered by engines rather than wind. This opened up a new area for exploitation —the Pacific Ocean.

In the Klamath basin, the 1920s brought new rail and road access to the North Coast which opened up ocean and sport river fishing to the area[17]. Commercial trollers lined up at the mouth of the Klamath to intercept fish before their river migration. A new phenomenon began occurring: huge congregations of recreational salmon fishers at the mouth. Subsequent competition between commercial and sport fishers

and the Native Americans of the area resulted in increased pressure on the precipitously declining salmon fishery.

The earliest fluctuations in the state's fisheries attributed to excessive takings and destruction of habitat by mining sediment and marsh reclamation were dwarfed by the environmental changes wrought during the post-depression economic boom in the state. By the 1940s, Shasta and Friant dams of the federal Central Valley Project eliminated much of the state's historic salmon spawning grounds. Water diversions, primitive flood control measures and other water management practices degraded downstream habitat. By 1951, after water diversions started in earnest at Friant, the San Joaquin River spring-run salmon was wiped out.

As the North Coast region became more accessible, the lumber industry began intensive logging of the forests on inland watersheds. Lands that had been logged or criss-crossed by dirt roads were vulnerable to erosion during the not-uncommon heavy rainfall years of the North Coast. By the 1960s, logjams and sediment clogged most of the area's salmon and steelhead habitat. Much of the area has not recovered still.

As documented in the report, aquatic habitats in California have been severely damaged in the past and, unfortunately, continue to be degraded, by a multitude of human activities notably logging, grazing, agriculture, urbanization and the water development projects built to support them.

Navigation

The steamboat trade was born, as was so much else in California, of the Gold Rush. The era of the big boats ended in 1878. The gold mines, which were responsible for the beginning of the era also killed it through the influx of sediment from hydraulic mining. Dry years in the 1850s kept the hydraulic mining debris—sand, mud and tailings—in the upper reaches of the rivers until the floods of 1862, 1875 and 1878. These floods brought down the whole accumulated mass—destroying fishing, covering agricultural lands, wrecking water supplies, and significantly raising the beds of the Feather, American, Bear and Sacramento rivers. For example, Steamboat Slough averaged 12 feet deep in 1853. In 1879, it was only five feet deep, and it was closed to the steamboats. The Sacramento River lost 15 feet of depth. Suisun Bay was virtually filled.

Logging and Grazing

With the advent of Euro-american cultures in California, riparian forests and woodlands experienced immense losses. After the start of the Gold Rush in 1849, Sacramento Valley riparian forests were rapidly cut down for fuel, especially for steamships, as well as

for fencing and other uses. By 1868, an early writer on California noted that the riparian woods were nearly gone in many areas on the Sacramento River and lower tributaries[18]. Extensive clearing for agriculture followed the Gold Rush period, further decimating much of the Central Valley riparian forests by the early part of this century.

In the redwood forests of the Central and North Coast California, the speed with which the forests were logged, as well as the location of the activities, were functions of the logging technology of the day. Huge stands of ancient redwood forests were cut as fast as possible. Logging on the North Coast continued with the steady growth of the state, until World War II. After the war, accelerated economic growth spurred a tremendous burst of logging on the North Coast, this time in the Douglas-fir forests inland of the redwoods. Logging practices in the 1940s to 1960s led to significant watershed and stream damage in the North Coast area and compounded the big floods in 1955-56 and 1964 which hit the region[19].

From the beginning, logging was carried out without restriction or regulation. Little thought was given to the protection of other forest values or the health of streams and rivers. The State's first forest practices regulations in 1945 addressed protection of the forest productivity for timber production, but little else.

Similarly, by the late 1880s, livestock grazing had invaded almost every region of the state with devastating results, including soil erosion and the conversion of grasslands into range dominated by poor-quality weedy species. Although some government control over public lands was begun in the 1930s, overgrazing impacts to watersheds and streams continued unabated until the public's environmental awareness developed in the 1970s and 1980s.

Water Development for Farms and Cities

By the 1890s, irrigated orange groves and vineyards dominated agricultural activities within Southern California. In addition, urban Los Angeles was growing rapidly[20]. A series of dry years at the turn of the century, in combination with urban and agricultural expansion, led the City of Los Angeles to search far afield for a water supply. William Mulholland found it—in the Owens River hundreds of miles away on the other side of the mountains. The Owens River was tapped by the Los Angeles Aqueduct in 1917.

However, the first artificial water system conceived for a city was not for Los Angeles, but rather for the City and County of San Francisco. Growth as a result of the Gold Rush left the future of San Francisco dependent on imported water. Plans in 1901 called for dams and reservoirs on the Tuolumne River in the Hetch Hetchy

Water Management Distribution Projects in California.

Valley of Yosemite National Park, established by President Lincoln in 1864. Conservationists vigorously opposed the desecration of what many have observed was a valley more beautiful than the Yosemite that remains. They lost. The first water to flow in the 186 mile aqueduct reached San Francisco in 1931. Other major projects included the Pardee Reservoir on the Mokelumne River to bring water to other regions of the Bay Area.

The most auspicious water project—the Central Valley Project (CVP)—grew out of a 1920 proposal of Robert Bradford Marshall, chief hydrographer of the U.S. Geologic Survey. The concept seemed simple, redistribute water from the wet north to the dry south with a series of canals. Barely approved by voters in 1931, bonds were not aggressively marketed, in part, because of the Great Depression. The project was taken up by the Roosevelt administration and promoted as a New Deal program to provide water for small farm development in the San Joaquin Valley.

Following the CVP, the State Water Project (SWP) originated as the Feather River Project—a flood control program to "manage" the 3,600-square-mile Feather River watershed. The SWP was touted as the most elaborate system of water control in the world[21].

California water policy makers embraced "big dam" building from the early 1920s through the 1970s. O'Shaughnessy Dam, on the Tuolumne, was first in 1923 and Hoover Dam, the largest at the time, was built on the Colorado in 1936. Shasta was next, in 1945, controlling the Sacramento River and flooding most of the lower Pit River. Then the streams of the Sierra's west slope were tapped, with Pine Flat on the Kings (1954), Friant on the San Joaquin (1942) with Mammoth Pool above that, Oroville on the Feather (1968), New Bullard's Bar on the North Yuba (1970), Don Pedro on the lower Tuolumne (1971), and New Melones (1979) on the Stanislaus. The Kings River now ends in a series of dikes and sinks and channels, rather than filling Tulare Lake, once California's largest lake.

There are some 3,700 entities collecting and distributing water to users in California[22], the majority of which are local water districts. The two largest entities are the federal CVP and the SWP, both consisting of dams, power plants, canals, pipelines and pumps. This assemblage of hardware extends from Plumas to Riverside counties. The SWP alone has 648 miles of aqueducts for water movement[23]. It distributes the runoff from Northern and Central California to agriculture, homes and industry in the Central Valley, Bay and southern metropolitan areas. Four additional major water entities are the Pacific Gas & Electric Company, with reservoirs and power plants, San Francisco Water District, East Bay Municipal Water District and the Metropolitan Water District which wholesales water to other Southern California water retailers.

Dams Throughout California.

Source: DWR Division of Dam Safety, 1992.

The U.S. Bureau of Reclamation and State Department of Water Resources (DWR) operate the CVP and SWP, respectively, to meet water contractor demands. Additionally, they are responsible for flood control, and are supposed to assure water quality and to provide fish habitat in the Delta and its tributary rivers and streams. Maintaining excess reservoir capacity for spring run-off and preventing or reversing salinity encroachment in the Delta are the management tools of choice. This "plumbing system" operates amid a mosaic of other agency jurisdictions, contracts, laws, lawsuits, court decisions and political pressures.

All in all there are about 1,400 federal, state and private dams in California each at least 25 feet high or holding back a minimum or 50 acre-feet of water[24]. One hundred and one of these dams contain 90% of the total capacity of all California dams. Including dams on the Colorado River, these dams are able, collectively, to impound 42.2 million acre-feet of water. This is enough water to cover all of California south of San Luis Obispo, Kern and San Bernardino counties, to the Mexican border with over a foot of water.

Other public works for water management include flood control. Channelization—the straightening and paving of river channels—has been the traditional engineering solution to flooding. The intent is to move flood waters as quickly as possible. Rivers and streams are lined with concrete or riprap, natural meanders are eliminated, trees and vegetation are removed for construction, and revegetation is limited on the levees in the general belief that the trees and shrubs will damage these structures or impair their functioning.

While channelization has been the standard method of flood control, its single-purpose approach has been questioned in recent years by growing numbers of engineers and the public. The traditional designs may not work as intended and may fail during floods. The public has also become increasingly dissatisfied with the environmental destruction associated with river channelization.

Recreation

Californians have flocked to the state's rivers searching for recreation in ever-increasing numbers since the end of World War II as California's population grew and as the prospering post-war economy afforded more leisure time and money.

Nearly all facets of California's economy in some way are influenced by or related to recreation and leisure activity[25]. Dollars pumped into California's economy from river recreation include not only the direct value of licenses for fishing, registration of boats, equipment purchased and hiring of guides or rafts, but also the value of lodging or campsites, money generated by travel to and from the rivers, and the maintenance and repair of river-related equipment. The National Forest Service estimates that the sport fishery resources

of the National Forests of California generate $309 million and support approximately 8,657 jobs through associated expenditures. California anglers provided $34 million from license fees, exclusive of Pacific Ocean licenses, in 1992. This figure was up from 1988 figures by approximately $1,182,000. Boater registration fees were $6,495,000 in 1991/92. Bird watchers, pursuing their interests in bird counts and sightings, contribute to the economy by spending an estimated $13 per day[26].

Sport fishing is an extremely popular outdoor recreational activity in California which contributes substantial money to the state's economy. Expenditures for sport fishing, such as travel, food, lodging, gear, guides and rentals, provide in excess of $2.2 billion to the state[27]. The yearly economic gain from salmon and steelhead recreational fishing on rivers is over $100 million, according to values used by Meyer (1988) in a report to the California Advisory Committee of Salmon and Steelhead.

The primary inland fisheries include anadromous fish, resident trout and warm-water game fishes. The most significant species of the anadromous group is the salmon family (salmonids). California salmonids commonly sought today are steelhead, chinook (king salmon) and coho (silver salmon).

Sport fishing for steelhead is also very popular on the North Coast rivers. Steelhead were once found in all coastal rivers and most coastal streams of decent size, but now approximately 90 percent of the state's wild steelhead occur north of San Francisco Bay[28].

Other important anadromous game fish are the nonnative striped bass and American shad, found primarily in the Sacramento River system and Delta. Today, striped bass support an extensive sport fishery in the Sacramento River, Delta, San Francisco Bay, and in ocean waters. Angling for stripers occurs year-round from shore and private and charter boats.

For a century after they were first introduced into the state, striped bass populations were abundant, supporting first a commercial, then later a huge recreational fishery. However, the Delta population declined rather suddenly in the 1980s, with adult bass numbers only one-quarter to one-third of levels in the 1960s[29]. For years, the striped bass has been considered an indicator species for the Bay-Delta Estuary. Department of Fish and Game biologists believe the decline in striped bass is due to a complicated set of human-caused influences, the primary being diversions from the Delta and reduced Delta outflows[30].

California rivers provide all manner of boating experiences from white water rafting to yachting in the twisted channels of the Sacramento and San Joaquin rivers in the Delta. Riparian vegetation and excellent fishing make some rivers a boater's paradise. The number of boats in California has increased more than 16 percent during the last five years and now total in excess of 800,000, mostly recreational craft.

Scenic appreciation of rivers has been noted in various studies. Scenic beauty is regarded as a resource to be protected because it is intrinsic to recreational and cultural experiences on rivers. It may be that the public subconsciously evaluates quality of life or the state of our resources in an integrative way and scenery may be a prime indicator of that evaluation[31].

Camping along rivers is often a recreational activity of Californians. The State Park system includes 170 miles of rivers and streams associated with parks, reserves, recreation areas and unclassified units. These 170 miles is approximately 22 percent of river units under California Department of Parks and Recreation administration, and there is a strong and fast growing interest in restoring degraded urban rivers and streams. Other park units are on the ocean and lakes. Attendance figures for day use and camping facilities have been increasing steadily for all state-run units.

With these uses and activities have come consequences for the quality and health of California's river systems. While the nature and extent of human effects vary within and between river basins, the following discussion is illustrative and representative.

CHAPTER TWO

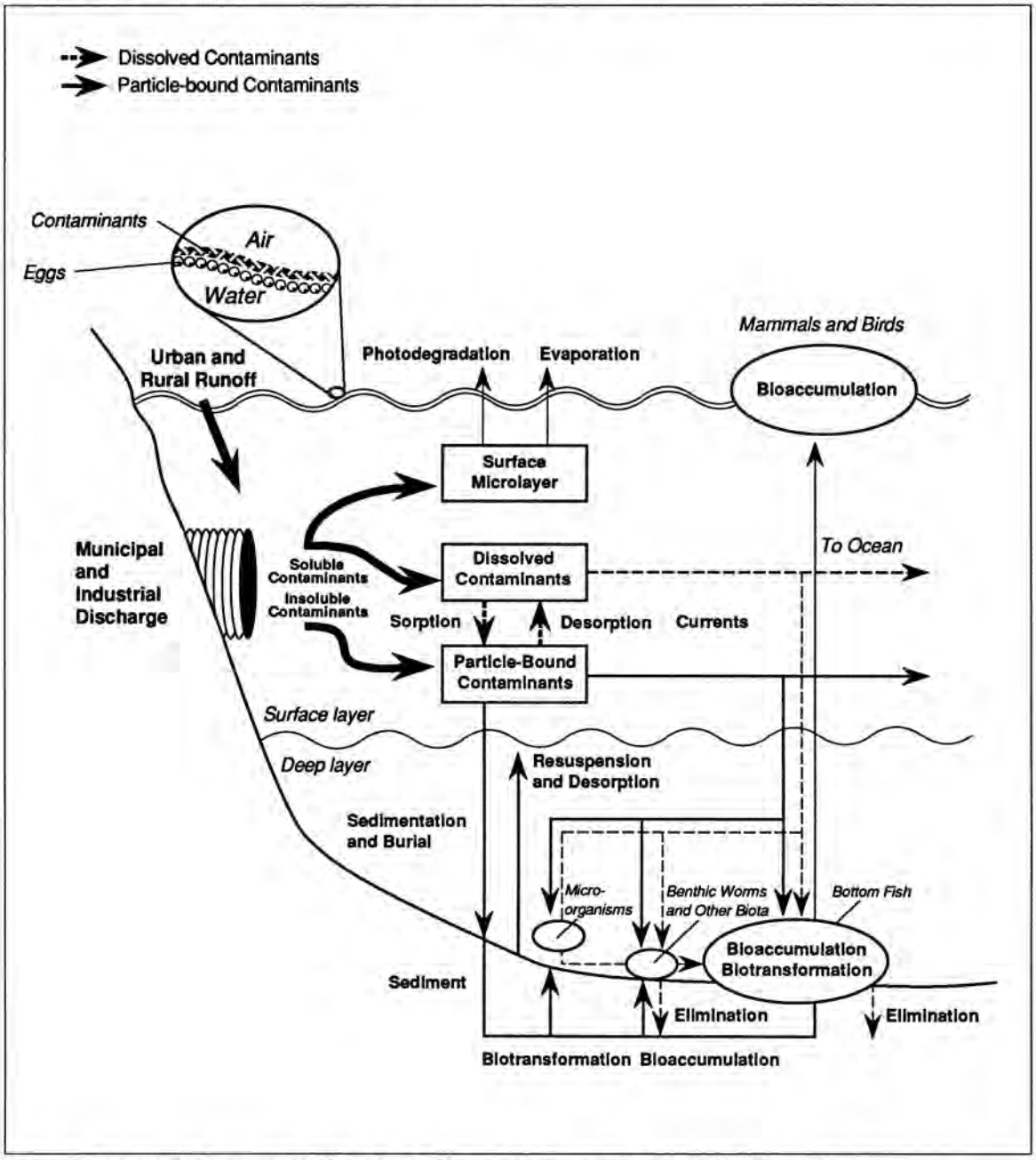
California Rivers: Effects And Consequences

> *Here in the U.S. we turn our rivers and streams into sewers and dumping grounds, we pollute the air, we destroy forest, and exterminate fishes, birds, and mammals—not to speak of vulgarizing charming landscapes with hideous advertisements. But at last it looks as if our people were awakening. Many leading men, Americans and Canadians are doing all they can for the Conservation movement.*—Theodore Roosevelt, *Our Vanishing Wildlife: Literary Essays* (Works of T.R. nat. ed., Vol.12, originally appeared in *The Outlook*, Jan. 25, 1913).

The primary cause of water quality degradation in California's rivers and other impaired water bodies is nonpoint source pollution. Nonpoint sources include agricultural, forestry (logging) and urban runoff[32]. Urban areas produce primarily point-source pollutants, including storm drains, in lower amounts than nonpoint agricultural sources, but they may cause locally severe effects, especially with high amounts of industrial discharge.

The most extensive source of water pollution that impairs and threatens the state's rivers and streams is associated with agriculture and consists primarily of excess nutrients, pesticides, herbicides, sediments and the consequences of habitat modification[33]. Other types of river pollution include elevated water temperature and toxic chemicals. Sources of these contaminants include municipal sewage and storm water runoff; resource extraction, such as mining; and silviculture, including logging[34]. Hydrologic habitat modification is a consequence of water diversions, flood control and urbanization.

Diagram of Transport and Fate of Pollutants in Water.



Source: State of the Estuary, 1992. U.S. E.P.A. and the Assoc. of Bay Area Governments.

Effects of Mining

Instream and Terrace Aggregate Mining

Aggregate is derived principally from pits in active flood plains, pits in inactive river terrace deposits, or directly from the active river channel. The great majority of aggregate is derived from active channels and adjacent alluvial deposits.

Map of Instream Aggregate Mining Sites.

Legend

▲ = Existing mining sites from Department of Conservation, Division of Mines and Geology; and State Lands Commission data bases.

The term "replenishment rate" is commonly applied to instream gravel mining to characterize acceptable levels of sustained yield. The premise is that if the rate of aggregate extraction does not exceed the rate at which coarse sediment is delivered from upstream, the extraction can be sustained without adverse impacts on the channel system. However, when viewed in the larger context, this extraction site can be seen as the "upstream" from which downstream reaches derive their coarse sediment supply. If the sediment in transit through the system is extracted, the flow of gravel is interrupted and downstream reaches are deprived of their portion of the sediment load. One effect of this is the creation of essentially "hungry water" downstream of the extraction sites. When this imbalance occurs, the river will typically expend its excess stream power by eroding bed and banks in the downstream segment. Channel incision and instability may result downstream of extraction sites even if the extraction rate does not exceed the replenishment rate.

Incision into the river channel has many direct effects, notably the undermining of bridge piers and other structures, which has occurred under the Highway 299 Bridge over the Mad River and bridges over the Russian River. Channel degradation can also induce channel instability, bank erosion and channel migration in formerly stable reaches. The physical alteration of the stream channel may further result in the destruction of existing riparian vegetation and the reduction of the area available for seedling establishment.

By altering the natural channel configuration, even low-volume gravel bar skimming operations can reduce habitat diversity by producing a wide, shallow channel lacking in pools and cover needed by fish, and by potentially increasing water temperatures.

Hard Rock Mining Pollution

Mine discharge into surface waters is a near statewide problem[35]. Unfortunately, only 94 mines have been studied for their threats to water quality; the magnitude of toxic discharge of the other thousands of mines is unknown.

Effects of River Navigation Improvements

Keeping navigational channels open and clear has been the U.S. Army Corps of Engineers' chief responsibility since it was established in the Department of Defense. In California, with the exception of dredging in the major harbors, this has meant work on the San Joaquin and Sacramento rivers.

After completing the two deep-water channels to Stockton (1950) and Sacramento (1963), the Army Corps of Engineers ceased its general navigation dredging of the other channels of the Sacramento River, the Delta and the San Joaquin River. Now, the only

dredging outside of the two main channels is an occasional removal of "hazards" to navigational boating. Navigation within the Petaluma and Napa rivers is still maintained by the Corps.

Initial dredging and maintenance dredging affects water quality by increasing turbidity and possibly releasing toxic substances from the bottom sediments.

The removal of snags and other large debris from waterways in the interest of navigation eliminates underwater structures that are biologically significant. These "structures" and other channel irregularities create back eddies which collect organic debris, and provide cover and surfaces for algae and invertebrates to colonize. The value of snags and submerged elements as habitat creates a conflict of priorities between those responsible for river navigation—commercial and recreational—and those protecting the rivers' ecology.

Effects of Logging and Grazing

Logging

Ninety percent of the state's annual water runoff originates from forest and rangelands[36].

Logging and associated activities like road and landing construction alter watersheds and have a number of effects on rivers. Such effects may include increased flood peaks from a basin, decreased summer base flows, increased upland erosion rates, and subsequent increased delivery of fine sediment to stream channels. Such activities can also damage or destroy riparian habitat and adversely affect water quality.

In the past, logging virtually devastated some watersheds and rivers, choking small drainages with debris, ruining spawning gravels and other habitats with siltation, altering natural runoff patterns, and destroying riparian vegetation. Today, state and federal enforcement of regulations of forest practices addresses these problems. However, many rivers and streams are still in a degraded condition from past impacts and imperfect current practices.

A marked increase in the extent of clear-cutting over the past two decades, especially on National Forest lands, has drawn attention to the cumulative effects of many individual timber sales within a drainage basin over a period of years. These cumulative watershed effects (CWEs) are manifest in erosion of gullies, especially below landings and logging roads, delivery of fine sediment to stream channels with deleterious effects on aquatic life, increased flood peaks for a given storm or snow melt resulting in erosion of channel bed and banks as the channel adjusts to the higher peak flows, and decreased summer base flows resulting in a reduction in aquatic habitat and increased summer temperatures. These effects would also occur in a watershed with small, scattered privately owned parcels undergoing conversion or logging.

Logging itself is one of the most visible, though not major, culprits in producing CWEs. The tracks left by equipment in the course of removing cut trees can also serve to concentrate flow, resulting in the development of gullies.

The construction of logging roads and landings produces the greatest hydrologic effects, and in some forest areas contributes the single largest source of excessive sedimentation because all precipitation runs off bare, compacted surfaces. The roads also alter the natural drainage pattern, intercepting small drainages and diverting them to others, which results in increased flow down fewer channels. Seemingly subtle alterations of the drainage network can result in large gullies downslope. The effect of roads is persistent because unless roads are physically removed, which is rarely done, their hydrologic effects continue, although erosion rates from the roads themselves can be expected to decline if they are not heavily used[37].

Increased erosion from logging and road building results in elevated suspended and bedload sediment loading in streams and rivers downslope and downstream of the activity, adversely affecting aquatic biota[38]. This is especially true for sites with steep slopes, fine-textured erodible soils and high rainfall, or where shallow soils overlay impervious soils or substrata. A direct effect of heavy siltation is the smothering of incubating salmonid eggs or emerging alevins in spawning gravels. Long-term degradation of gravels and other habitat features also occurs until excess sediments are washed through, if ever. Silt-laden waters also reduce the abundance and diversity of other aquatic organisms.

Unless an undisturbed buffer strip of forest and riparian vegetation between the stream and the logged areas is maintained, large amounts of logging debris may end up in the waterways of a logged area. This material robs the aquatic ecosystem of its oxygen supply as the material decomposes. Such conditions are particularly damaging to aquatic life during the summer, especially under low flows and with temperatures in the upper tolerance range and when salmon, steelhead and trout eggs are developing and hatching in the gravels.

Another effect of logging riparian habitats is increased water temperatures in the affected watercourse. Tree canopies greatly moderate the daily temperatures and reduce summer maximum temperatures on the forest floor and its streams. Water temperatures in headwater streams are a major determinant of the downstream temperatures of mid-size streams and rivers. The cumulative effects of temperature increases in tributaries could cause adverse changes in the environment of downstream reaches, which are often important salmonid rearing habitats. Buffer zones, if wide enough, can significantly ameliorate potential temperature effects of logging[39].

Grazing

Livestock grazing is recognized as a major cause of increased erosion rates and degradation of water quality[40]. Livestock eat tree seedlings and trample vegetation along stream banks, resulting in a decline in riparian vegetation and the loss of the vegetation's functions of bank stabilization, shading and filtering fine sediment from runoff. Loss of vegetation also reduces food sources such as leaf litter and insects for aquatic animals. Livestock chisel banks with their hooves, breaking down the banks and introducing sediment directly to the stream. To a certain degree, livestock waste can directly impair water quality by introducing pathogens and excess nutrients into the surface water.

Completely fencing off riparian areas from livestock has been successfully used as a basic first step in encouraging the natural recovery of degraded stream channels[41]. In some instances, grazing can be allowed in riparian areas without significant harm to stream banks and riparian trees and shrubs, but the timing and intensity of the grazing must be carefully monitored and managed.

Effects of Dams, Water Diversion, Flood Control and Channelization

Dams and Water Diversion

Dams in California are built and operated primarily for flood control, water supply, the production of hydroelectric power or combinations of these uses. Recreation, and fish and wildlife are also sometimes additional stated purposes for dam-reservoir projects, albeit subservient to flood control, water supply and power. Smaller dams may be built for purely recreational uses. These are often installed seasonally. Patterns of flow releases out of a dam depend upon the project's purpose(s) and the weather.

Most water supply and flood control dams operate by decreasing high flows by the storage of runoff peaks from winter rains and spring snow melt. Water stored in reservoirs from runoff peaks is released downstream over the dry season. In California, agriculture uses 85 percent of developed water sources; thus releases usually coincide with crop demand. Rivers which normally would be quite low in flow in summer may have their flows augmented and once natural river channels are used as canals for water transfer to downstream users.

The most obvious effects from dams on river systems are the loss of free-flowing waterways and the inundation of river aquatic, riparian and upland habitats by the formation of reservoirs. Dams frequently completely block upstream passage by fish, other biota and human users. Anadromous fish are particularly affected by these

physical barriers. Over 95 percent of the historic salmon and steelhead spawning habitat in Central Valley river systems has been eliminated, primarily due to the construction of large dams on every major river[42].

Other direct effects of large dams on fish and other aquatic biota are unnatural increases and decreases in flows, and changes in water temperature. Rivers can be defined partly on the basis of a more or less predictable and lengthy flood pulse, as opposed to the brief and unpredictable floods of smaller streams[43]. Native aquatic biota have evolved and survived under certain environmental conditions, and artificial changes to their environments usually have detrimental effects. For example, sudden flow decreases may dry up gravel spawning sites, or strand fish in backwater pools. Sudden increases can scour away spawning beds or the algal and invertebrate communities growing on bottom surfaces. Other unnatural flow reductions can prevent fish from receiving appropriate migratory cues. Flows also affect water depth and temperatures, influencing the amount and quality of aquatic habitat, and the passage of fish over instream obstacles such as shallow riffles. Generally, the higher the flows, the cooler the instream water temperature.

The most dramatic example of the impacts of dams on salmon is Friant Dam on the San Joaquin River. The dam's construction resulted in the extinction of the largest spring-run chinook population in the state. The dam blocked upstream spawning grounds. Downstream of the dam, the San Joaquin River flows in spring, summer and fall are minimal, and the riverbed completely dries up every year in the reach upstream of the Mendota Pool in Fresno County.

Water diversions can directly affect aquatic life when organisms are sucked into intake pipes. Some diversions have screens which are meant to prevent fish from being entrained, but these are often ineffective, especially for eggs, larvae and juveniles of salmonids and other anadromous fishes. Most individual diversions, numbering in the hundreds in Central Valley rivers, are unscreened. Up to 10 million juvenile salmonids are estimated to be lost to unscreened diversions on the Sacramento River alone[44].

Some of the most significant impacts dams and diversions have on the character and functioning of rivers in California are through changes of geomorphic processes. To understand the nature of these changes, it is helpful to view them in terms of the independent variables that control alluvial channel geometry: flow regime and sediment load. Changes in these variables will produce adjustments in alluvial channels, the nature of which will depend upon the precise nature of the flow regime and sediment load, and how they are changed. However, some general trends can be expected.

Dams disrupt the longitudinal continuity of the river system, interrupting the action of the "conveyor belt" of sediment transport. Upstream of the dam, all bedload sediment and most suspended

load is deposited in the quiet water of the reservoir, while downstream, water released from the dam possesses the energy to move sediment, but has no sediment load. Clear water released from the dam is known as "hungry water," because the excess energy is typically expended on erosion of the channel bed and banks for some years following dam closure. For example, on Stony Creek, a tributary to the Sacramento River, since the closure of Black Butte Dam in 1963, the channel downstream has undercut and migrated laterally, annually eroding enough bedload sediment to compensate for about 20 percent of the bedload now trapped annually by the dam[45].

Downstream of a reservoir, the river may respond to the reduction in flood scour by narrowing its channel with encroachment of riparian vegetation into parts of the active channel from which vegetation formerly was scoured annually, and by depositing sediment along channel margins.

If dams impede natural geomorphic processes to a significant degree, riparian vegetation regeneration over the flood plain will be affected. Channel narrowing has been greatest below reservoirs that are large enough to swallow the river's largest floods, such as on the Trinity River and Anderson Reservoir on Coyote Creek. Coyote Creek, which flows through the urbanized San Jose area, was dammed for water supply in 1936 and 1950. Its channel has since narrowed to less than 50 percent of its pre-dam width, and a riparian forest has encroached upon the surface of the formerly active channel[46].

In some cases, fine sediment delivered to the river channel by tributaries accumulates in spawning gravels because there are no more natural floods to flush the river bed clean.

Flood Control and Channelization

Complete channelization converts an irregular, typically meandering, natural channel into a straight, geometrically simple canal. Channelization produces a plethora of negative ecological effects, mostly related to the loss of habitat diversity created by bends, pool/riffle sequences, sunken woody debris and other irregularities. The rectangular- or trapezoidal-engineered channel lacks the cover, food sources, instream nutrient detention and protection from high velocities afforded by the natural channel. Often, fish migration is hindered by uniformly high velocities across the channel. Commonly the channelized reach is devoid of bank vegetation to reduce hydraulic roughness (resistance to flow) and for easier maintenance. As a result, riparian habitat is lost, and the shading and food production provided by overhanging vegetation is lost to the aquatic community.

Perhaps the most adverse effect of channel stabilization is its impact on riparian plant community succession. One of the most important river processes determining riparian succession is the

erosion and deposition which naturally occur as the river migrates over its flood plain. Anything which interferes with the establishment of new sand and gravel bars, and over bank depositions of sediment, will also interfere with the establishment and subsequent development of the various plant communities that make up riparian habitat.

The use of straightened, often concrete-lined, channels to achieve flood control has been the mainstay of what has been referred to as "single-objective flood control," the goal of which is to convey floodwater as efficiently as possible and leave as much land as possible for development. This approach leaves little room for aquatic or riparian habitats.

Effects of Agriculture

California is the national leader in agricultural production, and has been for more than 40 years. The state's $18.5 billion a year agricultural industry[47] is noted not only for its high value, but for its great diversity of products. California leads in over 60 different crop and livestock commodities, which fall under all major categories: livestock, fruits, nuts, vegetables, field crops (including cotton), and nursery products and flowers. Farming and ranching land use occupy 30.6 percent of the state[48].

Present farming practices not only increase the introduction of pollutants into streams, but also alter the physical structure and function of river-riparian ecosystems. Over 163 million pounds of pesticides/herbicides were used in 1990 by California growers[49]. This is nearly one-third of all pesticide applications in the entire United States. Also, agriculture changes the landscape from natural vegetation to croplands. The reduction of this natural vegetation, in combination with activities associated with croplands, results in more pollutants being released to the rivers. Pollutants include sediment, animal waste, nutrients and pesticides. The State Water Resources Control Board (SWRCB) identified agriculture as contributing to over 58 percent of the pollution to California's rivers statewide[50].

Effects of Urbanization

When watersheds are urbanized, problems may result simply because structures are placed in the path of natural processes, or because the urbanization itself has induced changes in the hydrologic regime, which in turn impact structures.

The simplest case involves settlement on a flood plain or on an alluvial fan downstream from an undisturbed watershed. The flood plain settlements are vulnerable to large floods that may occur once every 50 to 100 years. The interval between floods is too long for the average home buyer to recognize or believe the danger, unless the event has just occurred, and even then, the home buyer may treat it

as a random "Act of God"or a piece of bad luck, rather than a recurring natural event, predictable in its frequency over the long term. The distribution of large floods over time reflects the precipitation and runoff region of the watershed, and large floods are natural and necessary for the drainage of the watershed and maintenance of the river channel. Urbanization of the upstream watershed itself produces fundamental changes in watershed hydrology. Infiltration is reduced by the creation of extensive roof areas and pavement and runoff moves more quickly from upland to stream through storm sewers.

At almost every point that urban activity touches the watershed, nonpoint source pollution (NPS) is created. Sediments washed from the urbanscape include trace metals such as cadmium, copper, lead and zinc which are deposited in river waters. The SWRCB identified polynuclear aromatic hydrocarbons (PAHs) from cars' gasoline and oil that leaks onto roads and parking lots as a significant source of pollutants[51]. These, together with pesticides, herbicides and fertilizers, contaminate drainage waters. Urban activity also yields sediments transported to rivers which cause turbidity, concentrate toxic pollutants and destroy fisheries.

Urban runoff, nonurban runoff and riverine sources are shown to be many times more significant than point sources of pollution such as municipal and industrial sources. Using the Bay-Delta Estuary as an indicator, the California watershed at the urban interface appears to be under considerable stress from pollution loads.

Marinas: A Question of Carrying Capacity

Marina development within rivers creates several problems. Too many marinas within a river reach generates a "tunnel effect," where marinas reach out from both banks of the river. These marina rows are visually unattractive and often are a visual barrier for the river. Residential piers, though individually less intensively used than commercial marinas, can have substantial cumulative impacts on the riverine environment[52]. Power boats must keep their speed down to five miles per hour to avoid causing wakes that could damage the marinas or moored boats that they pass. Marinas add to the boat traffic on rivers which at times resembles urban traffic congestion. The boat traffic interferes with, and sometimes endangers, people fishing. Finally, marina development may require the removal of riparian vegetation, dredging, both for construction and maintenance, and cause the destruction of fisheries.

Marinas and boats can also be significant sources of pollution. Although boats are required to have proper sewage disposal systems, few marinas use proper handling methods or are equipped with pump-out facilities. Sewage is often disposed of directly into the rivers, an action that is now illegal, but not effectively enforced.

Nonpoint pollution from marina-based and recreational boating activities may also result in detectable adverse environmental effects to the nearby water column and benthic resources.

Riverside Development

Today, at least 80-90 percent of riparian habitat in most western states has been eliminated[53] and the remaining pieces are threatened by development. The cutting of riparian habitat for fuel wood is now minimal and agricultural clearing does not occur to the same extent. However, urbanization poses a serious threat to the riparian habitat remaining. The placement of homes or businesses along rivers and within their flood plains results in the twofold removal of habitat because of the siting of the developments themselves and the flood control protection that is subsequently justified to protect such developments.

While these impacts are evident statewide, their nature and severity must be placed within the context of the "river regions" in which they predominate. Rivers integrate much of the living resources (biotic) and nonliving (abiotic) environment over an entire watershed. It is especially appropriate that river management, including ecosystem restoration, is done using a regional approach which recognizes both the interrelationships between watershed and river and the significant differences between different ecoregions[54].

For the primarily descriptive purposes of this discussion, the state has been divided into seven river regions, based on a combination of geomorphic or physiographic province[55], major hydrologic basin or drainage unit, distribution of fish[56] and composition of riparian woodlands[57].

CHAPTER THREE

California Rivers: Regional Perspectives

Each ecosystem has intrinsic value. Just as a country treasures its finite historical episodes, classic books, works of art, and other measures of national greatness, it should learn to treasure its unique and finite ecosystems, resonant to a sense of time and place. E.O. Wilson, *The Diversity of Life*, 1992.

Within California's borders are lands and waters which encompass an enormous variety of environments—including a broad range of climates, soils, topography and oceanographic features. The incredible natural diversity within California is typified by the desert Mojave and Amargosa rivers, almost entirely dry, to the constantly cold, spring-fed Pit and McCloud Rivers above Shasta Dam.

There are about 7,800 miles of rivers in California[58]. The distribution of rivers and size of area for each region discussed in this report is summarized in the following table.

Distribution of Major Rivers by Region.

Region	Length of Major Rivers		
	Miles	Rel.%	Acreage (mill.)
North Coast/Klamath	1,381	18	13.5
Central Valley	3,863	49	33.5
Modoc/Cascade	399	5	4.5
Central Coast	611	8	9.1
Eastside/Great Basin	369	5	6.6
South Coast	571	7	6.9
Desert	606	8	27.2
TOTAL	7,800	100	101.3

Source: Bern Kreissman, *California, An Environmental Atlas & Guide.*

North Coast/Klamath Region

The North Coast/Klamath region is typified by some of the most rugged mountains in the state, heavily forested with coniferous trees. With its high rainfall, the region contains many large rivers—the Smith, Klamath, Trinity and Eel—and includes most of California's Wild and Scenic River segments. Most rivers draining this region have high slopes, flow through steep-sided, confined gorges, and carry exceptionally large sediment loads. The area's geomorphology, and thus its river systems, varies between two subregions: the Coast Ranges in the south and the Klamath Mountains in the north.

The North Coast/Klamath region overall has the highest rainfall in California, but its distribution is strongly controlled by location, especially relative to topography.

The Eel, Smith and other large rivers and streams of the northwest created alluvial plains and deltas at their ocean mouths. At one time these delta plains were sites of thick black cottonwood, willow and red alder forests, often mixed with Sitka spruce and redwood[59]. All the thickest and most productive forests which formerly existed in the North Coast/Klamath region were cleared for agriculture and urbanization, and in the coastal plains of Humboldt and Del Norte counties, extensive areas of redwood and Sitka spruce were logged for timber.

The flood plains of the Russian and Napa rivers are renowned for their vineyards, now growing where riparian woodlands once stood. Along rivers flowing through narrow and frequently scoured channels, riparian habitat remains substantially in its natural state, except for localized impacts due to logging, mining, grazing and other development activities.

The North Coast/Klamath region is known for its salmon and steelhead resources, long important to humans in the region. As earlier indicated, much of the Native American culture centered around rivers and their fish, with salmon as the most important. The region's major salmonid species include chinook and coho salmon, steelhead and coastal cutthroat trout, and resident trout in headwater areas. The rivers of northwestern California support about one-third of the state's chinook, almost all of the coho and steelhead, and all of the coastal cutthroat.

Coniferous forests are predominant over the area, and logging is the main upland land use. As a consequence of logging, massive surface erosion and land sliding have occurred, drastically increasing sediment delivery to downstream channels. Although most existing impacts were due to past, unregulated forest practices, there is still a significant threat from modern logging which adds to cumulative watershed effects.

The plentiful fisheries resource attracted Americans from the East and European immigrants during the 1800s. After the start of the Gold Rush, salmon were exploited at unsustainable rates by in river netting. Such early commercial harvest, coupled with habitat destruction by logging, nearly destroyed the salmon fisheries of the North Coast. With the advent of fishing regulations, populations were able to stabilize, and even recover, to a large degree. However, much of the habitat damage from the earliest logging remains.

Instream gravel mining is also increasing in the region, and its effects on river geomorphology and biological resources only recently are being documented. Even though the northwest is still famous for its fishery resources, the area has experienced at least 80 percent declines in salmon and steelhead since the 1950s[60].

The coho, steelhead and coastal cutthroat have also suffered population declines. The coho, summer-run race of steelhead and coastal cutthroat are all California Fish Species of Special Concern[61].

Central Valley Region

The Central Valley is dominated by the Sacramento and San Joaquin rivers, which join in the Delta to flow into San Francisco Bay and eventually into the Pacific Ocean. These are the state's largest rivers with historically the most extensive riparian systems and greatest fish resources. The southernmost rivers in the San Joaquin Valley—the Kern, Tule, Kaweah and Kings—do not actually flow into the San Joaquin River, but flow into two closed basins at the south end of the valley; their flows are heavily diverted to support agriculture.

The rivers in the region flow from the Sierra Nevada mountains, traverse the range in high gradient channels cut into steep canyons, pass through the foothills, and emerge onto the valley floor. With the decrease in channel gradient, the rivers adjust to a more sinuous, meandering pattern, flanked by broad flood plains which formerly supported extensive riparian forests. Thus, the same rivers display very different characteristics along their length. Runoff is derived almost exclusively from the higher elevations, and seasonal runoff patterns reflect both snowmelt and rainfall runoff peaks.

Mature riparian forests of the Central Valley are California's version of a rain forest. Katibah (1984) has estimated that the Central Valley floor historically contained about 922,000 acres of riparian vegetation, including growth along the Sacramento and San Joaquin rivers, their tributaries, and the rivers and streams of the southern San Joaquin valley such as the Kern, Kings and Kaweah. Warner (1985) estimated riparian vegetation covered a total of 1.6 million acres of the Central Valley, suggesting that the amounts given by Katibah for the area from the Kings River south were too low. As of the early 1980s, about 102,000 acres in the valley remained, with about one-half that in a highly degraded condition[62]— a decline of 90 percent or more.

The largest salmon runs in the state were from the Sacramento/San Joaquin river systems, estimated at up to 1 million fish in peak years, with average yearly runs at 600,000[63]. Historically, of the four races of chinook salmon in the Central Valley—winter, spring, fall and late-fall runs—the spring-run was the most abundant. Before the drought of 1987-1992, chinook river populations in the Central Valley averaged about 272,000; over 85 percent of this consisted of fall-run from the Sacramento River[64].

With the exception of the Cosumnes River, all Central Valley rivers of any size have been dammed. Some of these dams were constructed by local irrigation districts or for municipal water supply, but the biggest structures were erected either as part of the CVP of the U.S. Bureau of Reclamation in the 1940s or the SWP of the Department of Water Resources in the 1960s. In addition to these large foothill reservoirs, most basins have a network of smaller dams and diversion canals for hydroelectric generation in their upper watersheds.

The construction of dams in the foothills has effectively prevented anadromous salmonids from reaching historic spawning grounds upstream. Before water development, there were about 6,000 miles of anadromous fish spawning habitat in the Central Valley. In a steady progression of water development, valley rivers were dammed one at a time and their waters diverted for flood control, power generation and water supply. Less than 300 miles of spawning area remain—just five percent of the historic amount[65].

Also, irrigation siphons, intake pipes and high-capacity diversion pumps along valley waterways, including the Delta, directly kill millions of salmon eggs, larvae and young, and other fish resources every year. There are an estimated 300 intakes on the Sacramento River and 1,800 in the Delta. Only a handful are screened, and those still cause significant mortality[66].

Modoc/Cascade Region

This region is underlain by volcanic rocks and its two principal rivers, the McCloud and Pit, are notable for their cold, steady flows fed by prolific springs issuing from the slopes of volcanic mountains. The rivers are typically cut into steep-sided canyons within the volcanic uplands and riparian habitat is limited.

Prior to the construction of Shasta Dam, the Upper Sacramento, McCloud and Pit rivers supported vast runs of anadromous salmonids. The clear, cold, steady spring flows provided ideal spawning and rearing habitat for salmon, and supported runs of hundreds of thousands of fish, primarily spring-run[67]. The McCloud was the historic spawning grounds for the now-endangered Winter-run chinook. With the construction of Shasta Dam in 1940, sea-run fish could no longer reach these sites, and entire races adapted to the specific conditions of particular rivers

disappeared. Shasta Dam eliminated one-half of the natural spawning and rearing habitat for salmon and steelhead in the Sacramento River system[68]. The first fish hatchery in California was built in 1872 on the McCloud River for chinook salmon; ironically the site was later flooded by Shasta Lake[69].

The resident fisheries of the Upper Sacramento River and its tributaries, the Pit, McCloud and Fall rivers, are still of tremendous importance, with rainbow and introduced brown trout being much sought after as game fish.

The lower Pit River is now heavily developed for hydroelectric power production, and much of its course is a staircase of hydroelectric power plants, impoundments and diversion canals. Aquatic habitats have been drastically altered.

Central Coast Region

The Central Coast region lies within the southern Coast Ranges, from San Francisco Bay south to the Santa Ynez River in Santa Barbara County. It includes the Central Coast Basin and southern portion of the San Francisco Bay Area Hydrologic Basin. In this region, mountain ranges alternate with elongated alluvial valleys, such as the Pajaro, Salinas, Santa Maria and Santa Ynez river plains.

Central Coast rivers maintain a base flow in their mountainous reaches. Under natural conditions, base flow was sustained over the length of their alluvial valleys through all but the longest of droughts and high alluvial water tables were maintained throughout. However, valley base flows have been reduced or eliminated in most years by human extraction of underflow, the shallow groundwater recharged by the river.

The Salinas River is the Central Coast region's largest river, flowing through the longest intermountain valley in the state. It originates in the mountains to the east of City of San Luis Obispo and flows 170 miles northward to Monterey Bay, largely paralleling U.S. Highway 101.

Eastside/Great Basin Region

The Eastside/Great Basin region includes most of the California extent of the Great Basin (also called Basin and Range) Province, exclusive of the Mojave Desert. All waterways in this area deadend in lakes or dry sinks.

The Lahontan Cutthroat trout was formerly wide-spread throughout much of the region, primarily inhabiting the Great Basin lakes and spawning up their tributary rivers including the Truckee, Carson and Walker. These fish were once so abundant they supported a commercial fishery in the area[70]. Because of dams, diver-

sions and the introduction of other trout species, the Lahontan Cutthroat is now exceedingly rare and is a federal threatened species.

All of the rivers in this region have been dammed and diverted for agricultural or municipal water supply. The Truckee River, regulated by Lake Tahoe, is an important water source for Reno, Nevada and for agricultural interests in the region. As a result of diversions, its inflow into Pyramid Lake has been reduced and the lake level has fallen as evaporation has exceeded inflow.

The Owens River is probably the best known river in this region, because of the controversy overuse of its water by the City of Los Angeles. In the gorge, the river has been diverted into penstocks which effectively dewater the channel through the gorge, formerly a superb trout fishery. When Los Angeles diverted the river into its aqueduct, the Owens Lake, a once-huge saline lake, dried up. Except in wet years, the lake remains dry.

South Coast Region

This region juxtaposes short but rugged mountain ranges with intensely developed plains and valleys. Urbanization and agricultural land use, on what used to be river flood plains, has led to widespread damming and channelization of the region's natural waterways.

Most South Coast rivers are perennial in their mountainous headwaters, but intermittent or ephemeral, that is, they flow only in direct response to intense rainfall and usually dry up within days or weeks, downstream in the alluvial basins and coastal terraces. This is especially true now because of extensive groundwater withdrawals from the alluvial basins.

The broad natural channels of sand and gravel characteristic of these rivers reflect not only the extreme variation in discharge, but also their high sediment loads. Debris flows are frequent occurrences in the mountainous headwaters of these river systems, posing a chronic risk and management problem to the heavily urbanized canyons and foothills of Los Angeles. Sediment transport is now highly regulated by reservoirs, debris basins and flood control channels.

Remarkably, numerous South Coast rivers and streams, all the way through to San Diego County, once supported steelhead runs of 5,000 to 20,000 adults. Now, all runs are lost except remnant populations in the Ventura and Santa Clara River systems and Malibu Creek in the Santa Monica Mountains[71].

The Desert Region

The Desert region of California encompasses the Mojave and Colorado (Sonoran) desert areas. This combines the southern part of the Lahontan Hydrologic Basin with the Colorado River Basin.

The exceptional river in the desert region is the Colorado River, which drains 242,000 square miles of the Rocky Mountains and Colorado Plateau. Seven states share the length of the river's 1,700 miles as it falls nearly two vertical miles. The Colorado River passes California, forming the state's border with Arizona, then flows into Mexico and the Sea of Cortez (Gulf of California).

With an unimpaired average annual flow of 15 million acre-feet, the Colorado River, in its natural state, is second only to the Sacramento River in size. The lower Colorado River, below Hoover Dam, was formerly an actively meandering river system which was bordered by extensive riparian forests and wetlands. It flowed into the Sea of Cortez through its enormous migrating delta system below Yuma.

The lower Colorado ecosystem was a rich and diverse area of river channels, sloughs and small back channels, marshes, arrowweed and willow scrublands, cottonwood and willow flood plain forests and mesquite bosques. There were at least 5,000 acres of cottonwood communities along the lower Colorado in the 1600s[72]. The fish fauna was small but unique, including Bonytail, Colorado Squawfish and Razorback Sucker, which were all probably quite abundant[73]. In addition, Desert Pupfish were found in pools and marsh channels in the backwaters of the river[74].

Today, it is hard to imagine a river with more alterations to its natural system and more conflict over its waters than the Colorado. Its silt-laden floods are now almost completely tamed by a sequence of massive reservoirs upstream, including Lake Mead (Hoover Dam) and Lake Powell (Glen Canyon Dam). The lower river is almost completely artificial, with channel cuts, levees and over a half dozen smaller impoundments from Needles to Yuma. Essentially all of the flow of the Colorado is appropriated for consumption, divided among seven states and Mexico under the Colorado River Compact. California takes by far the largest share of water from the Colorado, which supplies more than one-half the water used in southern California.

The Colorado River has more species unique to it which are at critical risk of extinction than any other river in California. For example, along the entire lower Colorado, recent surveys have observed only a few successful breeding pairs of the Western Yellow-billed Cuckoo[75] and Gila Woodpecker[76]. The Desert Pupfish and Colorado Squawfish no longer exist naturally in the lower Colorado and the Bonytail and Razorback Sucker are on the verge of extirpation.

There must be a fundamental understanding of river ecosystems before restoration of these stressed California rivers is undertaken. Without knowledge of river ecosystems, which incorporate the physical/chemical environment, biological organisms and processes, and the close interactions between and among them, restoration efforts may be misguided, ineffectual or as harmful to a river basin as those activities presently occurring.

CHAPTER FOUR

California Rivers: Their Nature, Function and Restoration

> *A river seems a magic thing. A magic, moving, living part of the very earth itself–for it is from the soil, both from its depth and from its surface, that a river has its beginning.*
> Laura Gilpin, *The Rio Grande.*

In river ecosystems, the most important physical and chemical components are: 1) geomorphology, the landscape and land-forming processes; 2) hydrology, the flow and occurrence of water over time and space; and 3) water quality, the chemical and related properties of water as a liquid.

River ecosystems include both aquatic and riparian living resources, or biota. Important living resources of California river systems include the fishes of the aquatic environment and the woody plants, trees and shrubs, and associated wildlife of the riparian environment.

Within a river ecosystem the riparian vegetation, the aquatic biota and the environment are closely interrelated. For example, cottonwood trees growing on river banks produce an abundant biomass of woody branches, trunks and roots. This plant growth casts shade over the water to cool it and supports insects which fall into the water and are eaten by the fish. Tree roots or fallen trees, exposed by water erosion, provide hiding places for fish in their aquatic world.

Geomorphology and Hydrology

The dynamic nature of river channel features is of enormous importance in understanding the effects of human activities on river channel stability. A river is composed of three closely linked elements: the drainage basin or watershed, the channel and flood plain, and the water[77]. Rivers can be examined by their physical components as integrated channel-flood plain systems; or by their biological components as riverine-riparian ecosystems[78]. Physically, in rivers subject to annual flow variation, the active channel includes the permanently submerged bed, often called the low-flow channel, and a near zone of seasonally exposed sand and gravel bars which are frequently modified by floods. Ecologically, the "active channel" is also the riverine zone, and contains aquatic habitats[79].

The land area drained by a given river is termed its drainage basin or watershed, and is separated from adjacent watersheds by topographic high points termed drainage divides. Drainage divides can be defined on many scales, from large rivers such as the Sacra-

mento River at Sacramento with a drainage basin of 23,500 square miles, to its tributary Cottonwood Creek, with a drainage basin of 922 square miles. Of the precipitation that falls on land, most is lost to evaporation or transpiration by plants. The remainder, typically less than half, runs off, draining via networks of stream channels to larger rivers and thence to inland lakes, sinks or oceans.

The basin is actually drained by the drainage network[80], the system of branching waterways which combine into larger and larger streams, eventually forming rivers. Confined reaches occur mainly in mountainous, steep-gradient areas and have relatively straight, well-defined channels with narrow flood plains. Unconfined reaches are typical of low-gradient reaches in downstream parts of the basin; they typically have broad valley floors with wide flood plain and riparian zones[81].

Watersheds are viewed as the fundamental landscape units because processes occurring upstream can affect downstream reaches and, to a lesser extent, vice versa. For example, clear-cutting of forests and construction of roads in the upper drainage basin can increase rates of erosion and sediment delivery to stream channels, overwhelming downstream channels with sediment and causing the channel to aggrade or build up its bed with sediment. This has occurred in the North Coast region, notably in Redwood Creek in Redwood National Park, where timber harvest in the upper watershed caused the downstream channel to aggrade, threatening the integrity of the tall trees grove[82]. Conversely, if the level of the sea or a lake drops, tributary channels may incise or erode their beds downward to adjust their profiles.

Much of a river's excess energy is used to move sediment, the soil and rock fragments eroded from the watershed. Viewed over a long time period, runoff erodes the land surface and the river network carries the sediment away. Along the length of the river system, the size of sediment changes from coarse gravel-boulder in steep upper reaches to dissolved materials, sands and silts in low gradient reaches.

Natural rivers tend to develop complex beds with alternating deep and shallow areas, called pools and riffles, often with sand or gravel point bars deposited on the inside (convex) bank. Unconfined rivers typically have a sinuous form, illustrating the river's own formation and movement of bends as it meanders or migrates across its flood plain.

Large lowland rivers, such as the Sacramento River below Red Bluff, often shape their channels and flood plains by large-scale meandering. Over centuries, the Sacramento River has moved laterally over its flood plain, creating a mosaic of land forms[83]. Rivers create meander loops by eroding to one side and depositing point bars on the other. As the river erodes, it enlarges the loop, building the older sections of the point bar higher as the river continues to move sideways. Eventually the river may cut off the loop in a short straight chute, and then begin

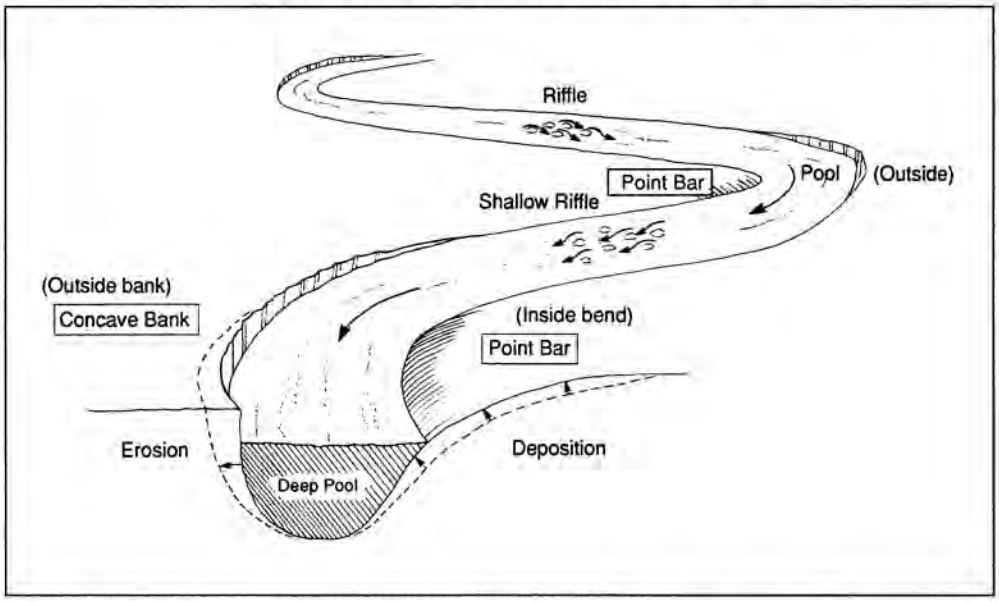
eroding another bank to form a new loop. Old loops may become quite isolated from the river channel, creating oxbow lakes.

Another geomorphic phenomenon on many meandering rivers is the formation of natural levees, which are zones of higher ground adjacent to the channel. Natural levees form as floodwaters leave the channel, and the coarse sediments deposit first along the channel margins. The natural levees of the middle Sacramento River are up to 10-15 feet high and several miles wide in places[84].

Thus, the flood plain is a dynamic feature closely related to the channel. In fact, the channel and the flood plain are best viewed as a single unit hydrologically and geomorphically, just as the watershed is a single landscape unit. Unfortunately, the natural functions of flood plains have frequently been ignored, with disastrous effects.

River landforms are a result of the interaction of the watershed—its topography, bedrock, and soil-vegetation mantle—with the system's hydrologic regime—low and high flow amounts and occurrence. At any point in time, most streams in a natural condition seem to tend toward a dynamic equilibrium condition, balancing the amounts of sediment entering and transported through the system to maintain what appears to be a stable channel and flood plain form. To put it simply, erosion in one place or time is balanced by deposition in another place or time. "Stability" of rivers is only relative, however, and must be considered in the context of temporal and spatial scales[85]

Characteristic Channel Morphology for a Meandering Reach.



The different geomorphic structures of a river system—its deep pools, shallow riffles, eroding banks, freshly deposited pointbars and flood plain surfaces of various elevations—all create a

diverse complex of river habitats for living organisms. Natural river systems support diverse and abundant biotic communities, including riparian gallery forests, hundreds of wildlife species and rich aquatic life, most of which not only can endure the dynamic nature of rivers but require it for best survival and development.

Water Quality

Truly aquatic biota, from fish down to the simplest bacteria and fungi, are closely dependent upon the physical and chemical nature and quality of the water they inhabit.

Factors which influence water quality include: 1) turbidity, the relative opaqueness of water; 2) sunlight, not only for photosynthetic production, but as the major determinant of water temperature[86]; 3) dissolved gases, of which in river waters the most important are oxygen (O2) and carbon dioxide (CO2); dissolved inorganics such as magnesium, calcium, sulfur, iron, sodium, potassium, silica, phosphorous, nitrogen, copper and zinc; and 4) dissolved and particulate organic matter[87]. Stream ecologists distinguish between Dissolved Organic Matter (DOM) and Particulate Organic Matter (POM)[88].

The amount of total dissolved solids (TDS), both inorganic and organic, is often used as an indicator of water quality, especially its suitability for human consumption, irrigation or industrial use. Salinity refers to the concentration of those substances which are in ionic form, a subset of TDS. The electrical conductivity (EC) of water is a commonly measured index of salinity. Salinity is normally not high in California rivers except near the ocean, where rivers meet the sea in estuaries. However, agricultural runoff has increased the salt concentrations of certain rivers, notably the lower San Joaquin River, to levels which seriously impair water quality for human use and sensitive river biota.

Living Resources: Organisms and Communities

Within ecosystems, living organisms each have a particular function, which is a combination of what they do—niche, and where they live—habitat. The niche of an organism refers to its role in a variety of interactions and processes, such as its place in the food chain, or in other direct interactions such as competition or parasitism. An organism's habitat is the particular place which provides environments suitable for survival. Organisms in a particular geographic location or type of place are often referred to as a community.

Ecosystems are defined in large part by the relative closeness of organism interrelationships. For example, in river ecosystems, trees on flood plain lands and fish underwater may be closely linked through trophic and habitat relationships. Cottonwood trees, perhaps California's most important riparian plants, live in a mostly

terrestrial habitat, but one with a high water table and which is subject to occasional major flood events. Fish require a water-covered habitat of suitable temperatures and quality, and a plentiful food supply. Many native fish species require underwater structures such as boulders or large woody debris for cover and feeding. Cottonwood trees support high insect populations which can fall into the water of adjacent channels and provide food for fish. Branches and roots which extend over or under water, and even whole fallen trees, provide cover and shade for fish.

The smallest organisms of ecosystems—bacteria, fungi and protozoans—are frequently overlooked in ecosystem descriptions, but play some of the most critical roles in energy and matter processing and cycling. Microorganisms are also significant to humans as pathogens[89].

Bacteria and fungi, especially in aquatic environments, are important decomposers of organic material[90]. Microbes break down large pieces of animal and plant tissue into fine or dissolved organic materials which can feed zooplankton, insects or other invertebrates. While bacteria can break down cellulose, only fungi can break down lignin, the skeletal material of leaves and wood[91]. Decomposition by bacteria and fungi is an important step, transforming the input of leaves and woody debris from riparian vegetation into energy and nutrients available for aquatic food chains and webs[92]. Decomposer bacteria and fungi together with plant and animal debris and the organisms which feed on this material form the detrital community on stream and river bottoms.

In river systems, the most important groups of green plants are aquatic algae and riparian trees and shrubs. Rivers as a rule do not support much growth of large aquatic plants such as pondweeds[93]. One reason is that smaller rivers and headwater regions have currents too swift, especially in winter floods, for these type of plants to survive. In larger lowland rivers, the current disturbances might be less, but the water is usually too deep and turbid to allow light to penetrate to the bottom.

Rivers contain both benthic algae, species which are attached to the bottom and other surfaces, and phytoplankton, species which are free-floating in the water column. Generally, in small rivers and upstream reaches, attached algae are common, but plankton are rare. In downstream large river reaches, the increased turbidity and depth limits the growth of attached algae, but the increased nutrient concentration allows for an abundant phytoplankton community.

Riparian zones owe a major part of their character to their vegetation which is, in relatively arid climates such as California, usually very different from nearby upland areas. Broad-leaved, winter-deciduous trees and shrubs dominate riparian vegetation, especially in unconfined, meandering river systems. Lush and green in the summer and bare in the winter, riparian corridors can easily be recognized from a distance. In California, the most common species

are cottonwoods, willows, alders, sycamore and valley oak, although there is considerable variation in species composition of the vegetation throughout the state.

Riparian tree and shrub species share a unique set of ecological characteristics, most of which explain why they are limited to or highly successful in river environments, they: 1) are broad-leaved and winter-deciduous; 2) are fast-growing and often short-lived; 3) require high soil moisture due to high transpiration (water loss) rates; 4) are able to produce suckers, sprouts and new root systems; and 5) are tolerant to seasonal flooding and to some degree require the high water and physical buffeting of the river environment.

In meandering river systems, flood plain riparian vegetation includes many different types such as gravelbar willow scrub, mid-terrace mixed forest and high-terrace mature forest. Many of these communities are related to each other successionally, which means one community evolves into another over time in a predictable sequence. Plant succession is this change in composition of the dominant species over time.

The fauna, or animal life, of rivers includes diverse forms representing all major taxonomic groups on earth. Of particular interest is the traditional grouping of fish, reptiles, amphibians, birds and mammals which is usually meant by the term "fish and wildlife." However, invertebrates, including zooplankton, worms, molluscs, crustaceans and insects are equally important components of river ecosystems.

Aquatic insects are the most important group of primary consumers in stream and river food chains and webs linking plants to fish[94].

Three species of invertebrates associated with California rivers have been listed as threatened or endangered by the state or federal government: the Valley Elderberry Longhorn Beetle, California Freshwater Shrimp and the Shasta Crayfish. The small number of listed invertebrates does not mean that many more are not at risk, but probably indicates instead a lack of adequate information[95]. Two aquatic crustaceans, California Freshwater Shrimp and Shasta Crayfish, are both State and Federal Endangered Species.

California native fish fauna are extremely varied, from the once abundant runs of salmon and steelhead swimming the waters from mountain streams to the Pacific Ocean, to tiny species of the most limited distribution and numbers in desert oases. About half of all native fish species and subspecies are found only in California[96].

Fish are perhaps the most important indicator of aquatic biodiversity. Not only are fish the best studied of all aquatic organisms, they are excellent indicators of environmental conditions and have major influences over other aquatic life[97]. Over two-thirds of the 116 native California fishes have already declined to the extent they are considered species of concern, including a number which are

extinct entirely or eliminated (extirpated) from their native ranges within this state[98].

The decline of native fish fauna is indicative of both habitat degradation and the introduction of nonnative fish species[99]. In California at least 48 nonnative species have become established[100]. The western United States have fish fauna comprised of 30 to 60 percent introduced species, compared to about 10 percent for the East[101].

The Pacific salmon, more than any other fish, is vitally important to human culture in western North America. Knowledge of their life history is critical to understanding some of most significant issues of river management in California. The Salmon family (Salmonidae) includes both anadromous and freshwater forms. The major native salmonids found in California rivers are all closely related, belonging to the same genus, Oncorhynchus[102]. They are the chinook (king) salmon, coho (silver) salmon, and several forms of steelhead/rainbow trout and cutthroat trout. Salmon, steelhead and sea-run coastal cutthroat are anadromous, while the rainbow trout and other types of cutthroat trout are resident species.

Historically, anadromous salmonids were found throughout the Central Valley drainages and in coastal streams and rivers the entire length of the state. The chinook is the largest Pacific salmon and its distribution in California is correlated with the state's biggest rivers. The largest runs of the chinook are in the Sacramento-San Joaquin systems of the Central Valley, with other major populations on the Klamath, Smith and Eel rivers of the North Coast[103]. Coho typically spawn in smaller coastal streams and tributaries from Monterey Bay north[104]. Coastal cutthroat are fish of the Pacific Northwest rain forest belt extending south in California only down to Humboldt Bay[105].

Steelhead once migrated up all significant streams of the state which had a connection to the ocean, including most southern California rivers. Of all the major California salmonids, steelhead have suffered the most dramatic decline in distribution. They currently occur mainly in northern California rivers and streams, having been all but eliminated from the Central Valley and South Coast[106].

Native populations of anadromous salmon, steelhead and coastal cutthroat are in serious decline in the western United States—Washington, Oregon, Idaho and California. The American Fisheries Society Endangered Species Committee[107] has identified 214 naturally spawning Pacific salmonid stocks threatened with extinction, of which 39 are in California. At least another 106 major populations, 21 in California, have already been lost.

The most economically important runs in the state are the Sacramento and Klamath Rivers fall-run chinook. The Klamath system chinook are also highly valued culturally by native peoples. In 1991, the total river population of the Sacramento fall-run chinook was about 110,000 fish[108], compared to a peak of 403,000 in 1953,

observed shortly after counts began in the river[109]. About 31,000 of the Klamath fall run in 1991, only 15 percent of a recent high of 204,000 in 1987, were not caught at sea[110]. Tragically, estimates of run numbers are continually becoming outdated as populations continue to collapse.

Without question, high bird species diversity and abundances are a major characteristic of California riparian habitats. The aquatic and riparian habitats of rivers are used by a broad variety of species, but river avifaunas are typically dominated by passerine species—smaller perching birds, such as flycatchers, warblers and swallows. Herons and egrets are also common along rivers, utilizing the tall trees of riparian forests for rookeries, and feeding on fish and other aquatic organisms in the channel. In northern California, Ospreys and Bald Eagles take advantage of salmon spawning. Riparian woodland and forests have been noted to support a greater number of bird species than any other habitat type of the state[111].

Many bird species, including a number at extreme risk of extinction or extirpation, have declined in response to losses of up to 95 percent of riparian vegetation in the western U.S. In a national review of imperiled and extinct birds of the United States and Canada, Ehrlich et al., (1992) state:

> Habitat loss and degradation pose the greatest threat to North American birds. From forests to wetlands, avian habitats are everywhere endangered. Riparian areas (corridors of water-loving vegetation along streams and rivers) are especially vulnerable and of critical importance.

Currently, at least 40 bird species on California rivers are considered to warrant special concern. Examples of riparian species in California which are most endangered include the Least Bell's Vireo and Western Yellow-billed Cuckoo.

While many mammal species are not limited to stream and river ecosystems, riparian forests and woodlands provide habitat for significant concentrations of species diversity. As examples, out of 181 mammal species (excluding whales and porpoises) found in the state, Central Valley riparian communities are habitat for 55 species[112], and in southern California, riparian habitats support 44 different mammal species[113].

The most widespread river- or stream-dependent mammals are river otter, beaver, mink and muskrat[114]. Other species with a strong dependency or preference for riparian habitats include many furbearers, such as ringtail, raccoon, mink, grey fox, red fox, coyote and skunks[115].

Riparian environments found on California rivers provide suitable habitat for about one-half the amphibians and one-third the reptiles found in the state[116].