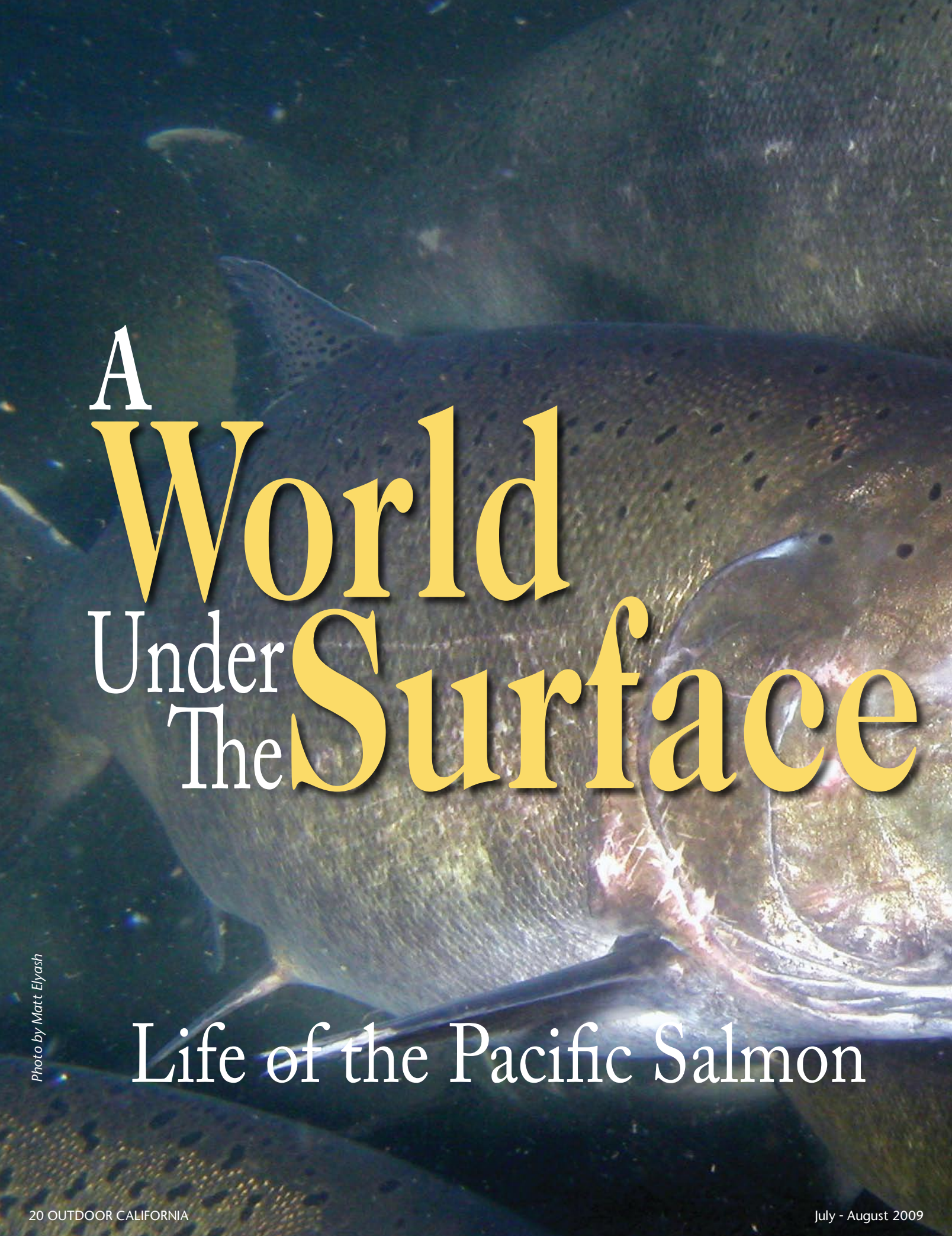

A World Under The Surface

Life of the Pacific Salmon

Photo by Matt Elyash

Story by Robert Titus

Of the more than 27,000 species of fish that live worldwide, salmon are among the most well known and highly sought after species. The Pacific salmon in particular are comprised of seven species that migrate to the northern Pacific Ocean from tributaries that begin just south of San Francisco Bay in California and range north through Oregon, Washington, Canada and Alaska. Salmon bearing tributaries continue over the Arctic Ocean and extend southward on the Pacific coast of Asia through the coastal Russian provinces, Japan and Korea. Five of the seven salmon species occur in North America, and while all five have been observed in California, only two—the Chinook, sometimes referred to as the king salmon, and the coho, or silver salmon—have occurred in the state with enough persistence and high enough abundance to support both commercial and popular sport fisheries.

Pacific salmon, like all members of the salmon and trout family of fishes called the Salmonidae, are relatively archaic fishes that are easily recognized by their streamlined, torpedo-shaped body, forked tail and a small, fatty fin on the back called the adipose fin. The body shape allows efficient swimming in river currents and at cruising speed in open ocean waters. Generally, Pacific salmon are cryptically colored as juveniles

California supports the southern most population of Chinook and coho salmon. Above, Chinook, also known as king, can grow to nearly 90 pounds before they return to spawn. Both Chinook and coho grow humps and the males will develop canine teeth.

While typically considered a top predator in the ocean, Pacific salmon are also an important resource for large predatory fishes; sea birds such as cormorants, gulls, terns and murres; marine mammals such as seals, sea lions and whales. All salmon change color over the course of their life, from silvery blue in the ocean to the brighter red seen on coho, above, at spawning.

in streams, which afford them protection against predators, and then bright silvery in color while in the ocean. Spawning adults gradually lose the silver coloration, replaced by olive brown and maroon in Chinook and reds and deep pinks in coho. Males of both species have hooked jaws, enlarged teeth and slightly humped backs as secondary sexual characteristics. Contrasting gum coloration can be used to distinguish between Chinook and coho. Where the gums of the lower jaw in coho are dark except for a conspicuous white band on the crown of the gum at the base of the teeth, the gums of the Chinook's lower jaw are completely dark, including at the base of the teeth.

In the case of Pacific salmon, adults run up coastal streams and rivers from the Pacific Ocean to spawn. This migration and the spawning that result starts the anadromous life cycle, where salmon are hatched and spend part of their life in fresh water as juveniles, migrate to the ocean to grow and mature, and then return to their stream of origin to spawn.

Pacific salmon are prized not only for the quality of the flesh as food but also because of their relatively large size. The size of Chinook salmon is what distinguishes them as the "king" of salmon. The world record Chinook is a 126-pounder taken in Alaska in 1949. California's 88-pound record came from the Sacramento River in 1979. A similarly sized adult male Chinook was found in Battle Creek during a 2008 Department of Fish and Game spawning survey. The average weight at spawning in California is about 20 pounds, although individuals regularly exceed 50 pounds in the Sacramento River system.

Coho salmon average 7 to 12 pounds at spawning. The California record is a 22-pounder taken in Papermill Creek in Marin County in 1959. Reports of record sizes for coho outside California exceed 30 pounds.

Pacific salmon achieve their large size by assuming what is called an anadromous life history. This term comes from the Greek anadromos, which means literally "running upward." In the case of Pacific salmon, adults run up coastal streams and rivers from the Pacific Ocean to spawn. This migration and the spawning that results starts the anadromous life cycle, where salmon are hatched and spend part of their life in fresh water as juveniles, migrate to the ocean to grow and mature, and then return to their stream of origin to spawn.

That Pacific salmon home back to the stream in which they were spawned has fascinated biologists for generations. This ability is dependent upon the juvenile salmon, called a smolt, migrating downstream from its

natal rearing area through the sequence of river reaches to the Pacific Ocean. During this journey, the smolt is "imprinted" with the sequential "smell" of each river reach. Visual cues are also incorporated into the homing memory of the fish. While still not fully understood biologically, this imprinted road map information is used by returning adult salmon to "sniff" their way home.

Are their advantages to being anadromous? The answer lies in understanding the costs, risks and benefits associated with the behavior. While freshwater streams provide a protected environment for salmon eggs and embryos in gravel nests, called redds, food availability for young salmon is limited, thus limiting growth and ultimately the size they attain as adults. To grow faster and reach a larger adult size, Pacific salmon smolts migrate to the ocean to take advantage of normally abundant food resources like krill and small forage fishes such as herring, anchovies and sardines. Attaining a larger size at maturity translates into reproductive advantages such as production of a greater number and larger eggs for females and greater competitive ability among males during spawning.

One of the unique characteristics of anadromous fishes is that they are physiologically adapted to live in both freshwater and saltwater environments. A similar ability is found in lampreys, sturgeon, shad, steelhead rainbow trout, and striped bass.

However, there are risks associated with making freshwater migrations over several hundred miles. One of the unique characteristics of anadromous fishes is that they are physiologically adapted to live in both freshwater and saltwater environments. A similar ability is found in lampreys, sturgeon, shad, steelhead rainbow trout and striped bass.

The energetic costs of swimming so far are high. In addition, once the young salmon leaves the security of the natal stream environment, it's exposed to various predators during its journey to the Pacific Ocean. Migration at night and in synchrony, allowing thousands of fish to "swamp the predator," is an adaptive behavior that increases the survival chances of migrating smolts.

Human activities have introduced a variety of other perils for migrating salmon that compromise their survival. Water diversions, insufficient river flows, elevated water temperature and other types of water pollution all contribute to juvenile salmon mortality. When these anthropogenic factors are combined with natural fluctuations in California's environmental conditions—especially precipitation and other weather-related phenomena—they amplify variation in salmon survival. All of these result in poor recruitment of individuals to the adult population, as occurred during 2007 and 2008.

Ecological and Evolutionary Significance

California is distinguished in supporting populations of Chinook and coho salmon at the southern extent of their geographic range. In this respect, these populations represent an important part of the evolutionary history of the species because they occur at the limit of their environmental tolerance. As coldwater fishes, probably the single most limiting factor in their distribution is water temperature, with water temperature exceeding suitable levels for Pacific salmon in most south-central and Southern California streams and rivers. Another important factor is stream flow and breaching of sandbars that close the mouths of most small coastal streams during low-flow periods in summer and fall. Coho salmon are especially vulnerable to blocked stream entry during the late fall and early winter period of upstream migration. If winter rains come later than this time period, sandbar breaching occurs late, leaving fish unable to access the stream. This factor, in addition to water temperature, often determines whether a particular stream is able to support Pacific salmon.

Coho have occurred in most coastal streams and river systems from northern Monterey Bay in Santa Cruz County to the Oregon border. They also use streams that flow to San Francisco Bay. However, recent surveys suggest that 40 percent to 50 percent of California coastal streams have lost coho populations due to the effects of logging and other land uses on stream habitat. These industry effects can worsen the influence of natural climatic variation on salmon production. While DFG biologists have recorded coho in the Sacramento River, there are no persistent populations in California's Central Valley. In the ocean, coho have been caught as far south as Baja California off the coast of Mexico.

Chinook tend to run up larger coastal streams and rivers from the Russian River in Sonoma County to the Smith River near the Oregon border. In contrast to coho, Chinook occur in the Central Valley, with the southernmost populations of the species found in the San Joaquin River system and the largest California populations occurring in the Sacramento River system to the north. The Sacramento River supplies the majority of Chinook caught in ocean fisheries off the coasts of California and Oregon, with the Klamath River population on the north coast being the next greatest producer. Chinook are caught in the Pacific Ocean as far south as southern California.

From an ecological perspective, Pacific salmon occur along important north-to-south environmental gradients in California. Both coho and Chinook range in coastal drainages from the relatively cool and wet Klamath/North Coast bioregion to the Bay/Delta bioregion around San Francisco. Coho range even farther south from the San Francisco Bay into the warmer and drier Central Coast bioregion. Chinook also occur along a

significant inland ecological gradient within the Central Valley. With temperature increasing and precipitation decreasing, the gradient stretches from the Sacramento Valley bioregion south through the San Joaquin Valley bioregion.

While people generally associate Pacific salmon with larger coastal waterways like the Russian, Eel, Klamath, Trinity and Smith rivers, as well as the Sacramento, American and Feather rivers in the Central Valley, both coho and Chinook will use small coastal and tributary streams as well. These streams may not maintain large enough salmon populations to support major fisheries; however, they do represent important components of Pacific salmon biodiversity in California.

A Central Valley example is Dry Creek, a Placer County tributary to the Sacramento River near Roseville that continues to support a small population of Chinook salmon. Dry Creek remains unique as a true Sacramento Valley foothill stream with its origins at relatively low elevation. Headwater streams to Dry Creek—Secret and Miners ravines—originate at about 1,200 feet elevation near Auburn, in the Sierra Nevada foothills. Most tributaries to the Sacramento River that support Chinook, though, have origins at much higher elevation in the Sierra Nevada, Cascade and Coast ranges.

An example along the coast is Fort Ross Creek, north of Sonoma County's Russian River. This tiny drainage exemplifies the union of land, fresh water and the sea that is characteristic of the dramatic northern California coastline. In a landscape dominated by redwood forest and coastal prairie, Fort Ross Creek is used by coho salmon in years when the sandbar at the mouth of the creek is breached in time to allow entry by adult spawners. Baby coho salmon can be observed in the lagoon of the creek during late spring.

In addition to providing salmon habitat, small streams such as these are important because they provide a variety of other ecosystem functions. They serve as natural water filtration systems by trapping sediments and recycling nutrients that runoff surrounding land. They deposit water back into underground stores, making it available to plants and animals during dry periods. Small creeks also provide important habitat not only for Pacific salmon but for a variety of other wildlife, including insects, various fishes, amphibians, reptiles, birds and mammals.

Pacific salmon are able to exploit these various stream and river types as habitat by assuming different life histories. This is especially evident in Chinook in several ways: through variation of the season they enter fresh water on their spawning migrations; the length of time they rear in fresh water as juveniles; the time of year they migrate as smolts toward the Pacific Ocean; and the number of years they spend in the ocean before maturing and returning to their natal stream to spawn. Central Valley Chinook enter fresh water on their spawning migration during fall, late-fall, winter and spring, thus providing the names for the four seasonal runs biologists recognize in the Sacramento and San Joaquin river systems. As juveniles, fall-run Chinook spend between a few days to a few months in fresh water before migrating from their natal stream to the Pacific Ocean. In contrast, juveniles of the other runs may spend several months to more than a year in fresh water prior to their seaward migration. Once in the ocean, California Chinook may spend between two to five years there before returning to spawn. Most spawning adults are between 3 and 4 years old, though.

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California Fish Commission
Report to the Governor, 1872

One of the most dramatic aspects of Pacific salmon life histories is that adults die shortly after spawning. This all-or-nothing reproductive strategy is part of what defines the role of salmon in the ecology of the streams they use for spawning and juvenile rearing. Salmon carcasses in streams are consumed by scavengers and broken down by various invertebrate animals and bacteria, thus making the marine-derived nutrients contained in salmon bodies available to stimulate biological production not only within the stream but on land adjacent to the stream as well. In serving this function, Pacific salmon in effect sacrifice themselves as adults to stimulate the food chain that later supports their offspring.

History and Uses of Salmon in California

The first report from the California Fish Commission to Gov. H. H. Haight in 1872 stated with resounding clarity the importance of Pacific salmon to Californians.

"The salmon is the most important visitor to our rivers," commissioners wrote. "It has appropriately been called the 'king of fish.' The richness of its flesh, its large size, the certainty of its annual return from the ocean, the rapidity with which, under favorable conditions, it is multiplied, all render it an important article of human food. It has probably been the chief source of subsistence to more people than any other fish."

Exponential population growth started with the rush of miners to the California gold fields in 1849. Statehood came a year later. As population increased, so did the demand for natural resources including lumber, water and food. Impacts to salmon habitat and

abundance were recognized by authorities immediately and the first law to protect salmon was enacted by the Legislature in 1852. The law, recognizing the need to protect the anadromous life cycle, prohibited obstructions to salmon runs. Unfortunately, the law set no provision for enforcement.

The fish commissioners also recognized the impact hydraulic mining had on salmon habitat. They wrote, "Probably the most serious cause for the decrease of salmon in our rivers arises from mining."

In his 1990 book on California's salmon and steelhead, author Alan Lufkin noted, "(a)n estimated 1.5 billion cubic yards of debris (enough to pave a mile-wide super-freeway a foot thick from Seattle to San Diego) were sluiced into waterways and swept downstream, causing flooding and vast destruction of natural salmonid habitat as well as towns and farmland." The effects of the mining legacy in California are still felt today. Sediments continue to move through Central Valley river systems all the way into San Francisco Bay. These sediments contain mercury, a toxin used to extract the gold ore from the earth washed from the Sierra Nevada mountainsides.

As early mining operations ruined salmon habitat and waterways became blocked by construction of dams, commercial fishing pressure on salmon resources only increased. In fact, the West Coast salmon canning industry started near Sacramento in 1864, using salmon caught in gill nets in the Sacramento-San Joaquin River Delta and San Francisco Bay. The industry peaked in 1882 with the processing of 200,000 cases of salmon, representing 11 million pounds of fish. Salmon salteries and canneries expanded along the north coast, utilizing fish netted on the Klamath and Eel rivers and in Humboldt Bay.

About the same time river gill-net fisheries peaked in the 1880s, the first commercial ocean trollers launched in Monterey Bay. Replacing small sailboats with motorboats, the commercial ocean fishery expanded north to Fort Bragg, Eureka and Crescent City. The

development of commercial ocean salmon fishing became the defining element of entire communities along California's north coast.

While commercial salmon fishing continues off California's coast, it has become more restricted since the late 1980s with the overall decline and large fluctuations in salmon abundance. The pullback by the industry avoids salmon stocks that are now protected under both state and federal endangered species acts. Recreational fishing for salmon continues with great popularity in the ocean, bays, tidal waters and rivers of California.

As the story of the Pacific salmon unfolded, so shaped by California's history, so did the evolution of the agencies charged with protection and management of the salmon resource. The California Fish Commission was established in 1870 and became the California Division of Fish and Game in 1927. Over the next several decades, professional biologists were recruited from Cornell, Stanford and the University of Washington to help manage California's diverse fishery resources. That responsibility continues today as the Department of Fish and Game—changed from a Division in 1951—works with the Fish and Game Commission and the Legislature to maintain the state's natural assets, not only for their intrinsic values but also for sustainable utilization. Indeed, gaining an appreciation for how the life of the Pacific salmon links California's water supply, the watersheds in which the people build their communities and the ocean that defines the coastline should motivate citizens to join in this mission.

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