CALIFORNIA'S SALMON RESOURCE

Its Biology, Use and Management

drawing on the front cover, by Steven Cook, is
sed after an original Haida design by Bill Reid. The art
Haida Indians of the Northwest Coast is said to be
the finest in the world of primitive art.

CALIFORNIA'S SALMON RESOURCE
Its Biology, Use and Management

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Designed by Steven Cook

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by what is known about the sea and reflect a failure of the research scientist, the public and those in industry and government to communicate.

"This failure of communication between the scientist and the public is not restricted to marine science, of course, but is common in many fields. It thus becomes vital to develop insight into the complexities of this fundamental and general problem of our times, to engage in thoughtfully designed experiments, and to encourage and nurture ideas that may grow into meaningful bridges of communication across the gulf that now cleaves action from understanding.

"The Sea Grant Program has approached the problem of bridging this gulf in a number of ways. The Marine Advisory Program disseminates information on marine-related matters, and undertakes to advise on specific problems. Sea Grant-funded marine education projects attempt to inform children who may become decision makers in the future. The conventional lines of graduate student support and scientific publication remain, of course, important.

"The "Sea Grant Sampler" is a long-term experiment, an involvement of bright young science-writing students in the task of penetrating and explaining the aims, aspirations, and significance of a number of practically oriented research programs. By involvement of this sort there may develop an increasing cadre of those competent to strengthen the bridges of communication linking understanding and action.

"To develop the ocean's resources wisely, scientists and non-scientists alike must understand the potential of the ocean and the implications of developing that potential. This booklet is intended to educate and interest people in current ocean research."

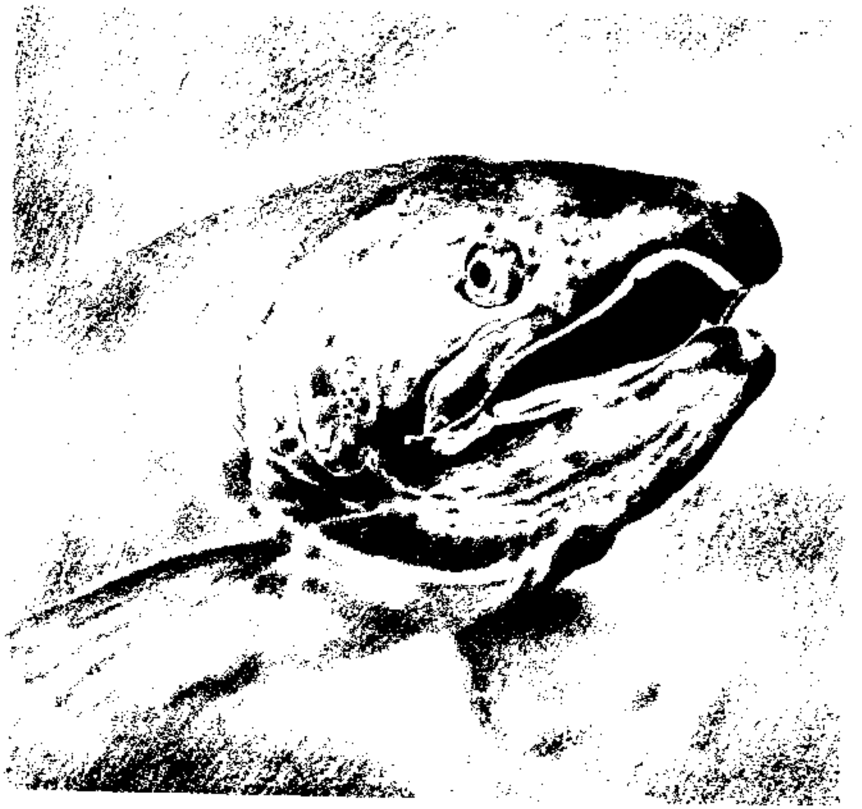
I regret John is not here to write the introduction to this volume for, in his earlier years, he was a commercial salmon fisherman and greatly admired the beauty and spirit of this beautiful specimen from nature's diverse family.

James J. Sullivan
Program Manager
California Sea Grant
College Program

Introduction

California's explosive population growth over the past 130 years was made possible by the state's abundance of natural resources: ores, lumber, agriculture and grazing land, fresh water, bays, wildlife and fish. California's salmon fishery is small economically in comparison to other resource industries and even to other fisheries of the state. Yet it supports thousands of commercial fishermen and businesses on the north coast, many of the native Americans living along the Klamath and Trinity Rivers and a substantial sport fishery.

Salmon are a renewable resource — as long as a large enough percentage of the population lives to reproduce every year, the fishery can continue indefinitely. However, the future of the resource is uncertain today. Conflicting uses of related resources, problems in management, heavy fishing and natural disasters have resulted in a tremendous decline in the number of California salmon.



In recent years, steps have been taken to safeguard salmon stocks. Laws have been passed to protect their environment and to mitigate past damage. Fish hatcheries have helped to maintain and rebuild populations. The ocean fishery must now be regulated in accordance with socioeconomic as well as biological factors. Still, much remains to be done, especially to reconcile the interests of different groups concerned with the resource.

This booklet discusses the biology and management of California's salmon resource and the environment that sustains it as well as the history of its use. It describes many of the unresolved problems that demand the attention of researchers, governmental agencies and those who use the resource for recreation or profit. The subject is interesting and important in its own right, but also serves as an example of the complexities involved in wise use of our natural resources.

California's Salmon Resource: Its Biology, Use and Management was written and produced by two science writing interns from the University of California at Santa Cruz, working with the California Sea Grant College Program. We hope it will be a useful resource for educators, decision-makers, resource managers and others who are interested in salmon.

Mature adult coho salmon weigh between six and twelve pounds. (UNH photo.)

Life Cycles of Coho and Chinook Salmon

Salmon are anadromous fishes. Hatched in fresh water, they spend up to one year in coastal streams before migrating to the ocean. After their ocean migration, they return to their native streams and run upriver to spawn. Although there are five species of Pacific salmon in the ocean, only two — coho (silver) and chinook (king)* — are found in significant numbers in California waters. These two species, whose ancestors spawned in rivers and streams centuries ago, are the focus of California's salmon fishery. For eons salmon have been living out their complicated life cycles. These cycles remain unchanged, whether they occur naturally or under artificial conditions in hatcheries.

All salmon start life as a small orange egg that, in the wild, is buried in the gravel underneath cold, swiftly flowing freshwater streams. Coho and chinook salmon spawn either in the spring, winter or fall, depending upon their genetic strains. The Sacramento River, for example, supports three separate spawning populations. Each female lays several thousand eggs at once but only one of ten will mature and eventually migrate to the ocean. Salmon eggs require temperatures ranging from 40° to 55°F. and sufficient water to clean and aerate them before they hatch.

"Because salmon are so finicky in their requirements," says Paul Jensen, head of the Anadromous Fisheries Branch of the California Department of Fish and Game, "their presence in a stream indicates the stream is in good ecological condition."

The first sign of life appears within a month, if all the conditions are right. Underneath the gravel a pair of black eyes is exposed through the skin of the egg. A month and a half later the eggs hatch into salmon larvae, called "alevins." Still fragile, the alevins rely on nourishment from the nutritive material in the egg yolk, which is contained in a sac and remains attached to their bodies as it was in the egg. The delicate alevins remain protected under the gravel, growing rapidly as they feed on their yolk sacs. The yolk sacs gradually shrink as the nutritive material they contain is absorbed by the alevins during the next few weeks.

The young salmon, now called "fry," emerge from the gravel and begin to forage about for food. Only an inch long, they are attractive prey to snakes, birds and fish. Instinctively, they hide under stones and in shaded areas during the day, swimming freely at night when they search for food. Fry consume a variety of microscopic organisms and grow slowly. When the salmon are about two inches long their backs are brownish, their bellies a light silver. Now referred to as "fingerlings" or "parr," the salmon blend inconspicuously into their background and begin moving freely. Fingerlings feed mainly on larger insect larvae and grow rapidly. Following this period of rapid growth the salmon begin changing physiologically for their next stage, which is life in the sea. This adaptation is a dramatic change for them.

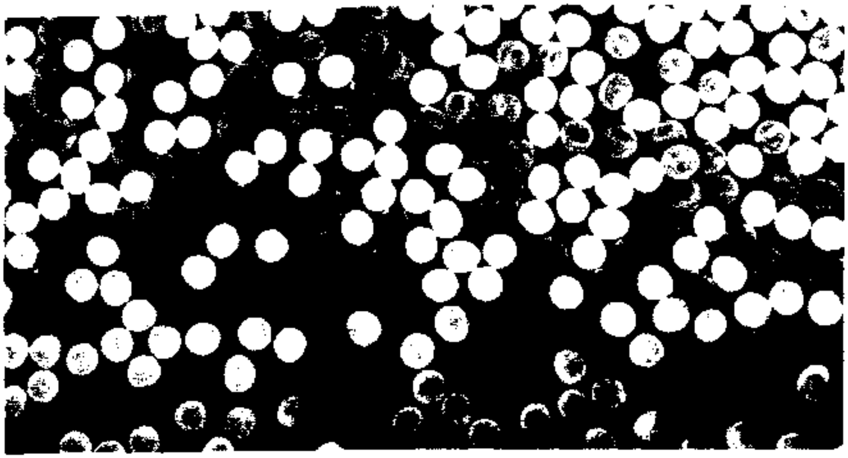
"The transformation from a freshwater fish to a saltwater fish is one of the most remarkable stages of the salmon's life cycle," says Howard Bern, a University of California, Berkeley professor of zoology. "To adapt to a life in the ocean the fish must undergo physical, anatomical, endocrinological, physiological and metabolic changes." Bern and his colleagues have been studying this transformation, called smoltification, to try to solve the problems of drastic stunting and mortality (up to 50%) that often occur in some coho salmon when they are transferred from freshwater to seawater net pens. Similar losses may occur undetected among hatchery-released fish.

Usually the salmon start to adapt about a month before they undergo smoltification. During this period the fish are extremely sensitive to odors, and odor information can be deposited, or "imprinted," in their memory.

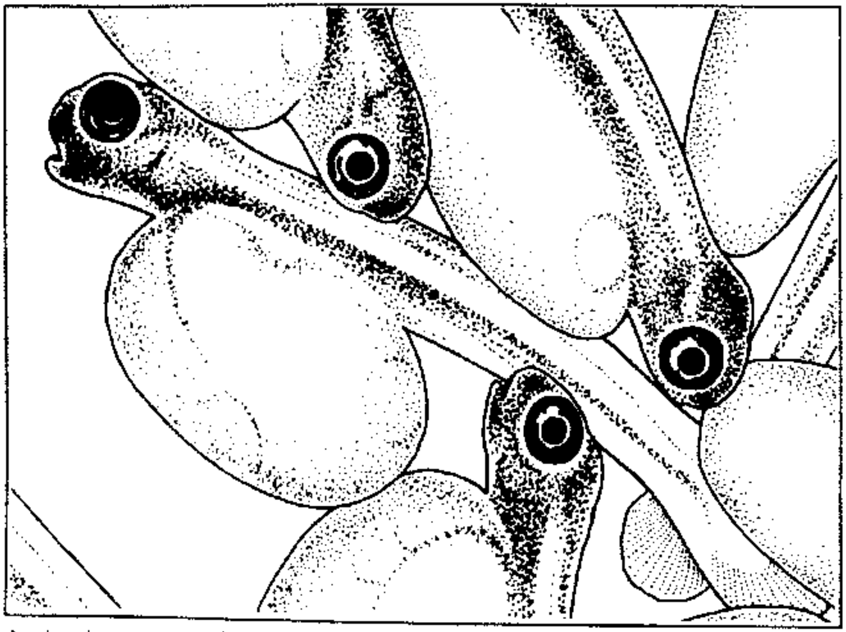
"The odors normally imprinted are those of their home streams," says Dr. Thomas Hassler, a Fish and Wildlife Service biologist at Humboldt State University. "The memory of this smell helps the fish to recognize its home stream when it returns as a sexually mature adult."

One of the most important physiological adaptations is the

*(*Oncorhynchus kisutch* (coho) and *Oncorhynchus tshawytscha* (chinook).



The developing salmon is visible through the translucent skin of the egg. (UNH photo.)



At the alevin stage, salmon continue to feed on nutritive material in their yolk sacs. (Drawing by Steve Cook.)

development of internal organs that are capable of getting rid of excess salts. Salmon, like most animals, maintain a proper level of body fluids by consuming water. In the ocean, their only source of water is highly saline. So before salmon can use the water they need they must be able to expel the excess salt.

"Most of the changes the fish goes through are internal, however there are certain visible ones," explains Bern. "But," he warns, "you can't tell if the smolts are ready to adapt to seawater by appearance only."

As smolts grow they become streamlined in appearance. Their skin turns a silvery color and becomes thinner, which can allow some scales to loosen and drop off. Their metabolism speeds up and their food needs increase. Following an instinctive internal cue, the salmon begin migrating downstream towards the ocean, staying near the surface to feed on insects.

Because smolting usually occurs around the same time among a group of salmon of the same age, the fish migrate downstream in schools. Many of the fish pause in estuaries, remaining there until the smoltification process is completed. Then they enter the sea, disperse and begin a period of rapid growth.

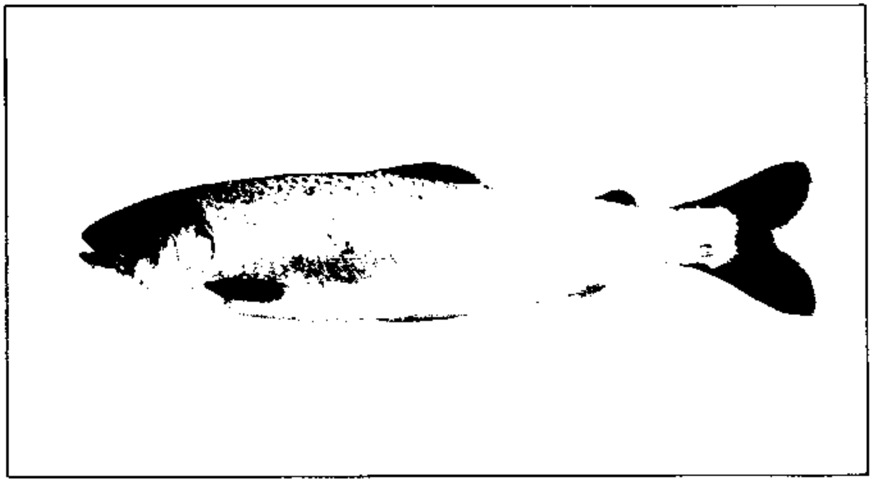
Migratory habits in the ocean are difficult to study. Tagged fish from all over the world have been captured thousands of miles from their point of origin, but it is difficult to obtain the type of data necessary to determine specific migration patterns. Fishermen and researchers have observed salmon traveling in schools of varying sizes, following currents which carry plankton and other foods. Young salmon eat plankton, larvae and small fish in or near the coastal areas. Older salmon move farther away from the coast, feeding on squid, invertebrates and larger fish. They are opportunistic feeders, according to studies done by the California Department of Fish and Game, and their diet varies seasonally, depending upon food availability. Larger sized salmon show a preference for fish, especially herring and anchovies.

The ocean offers an abundance of food and the chance for rapid growth. It also holds a variety of potential dangers, ranging from microscopic parasites to killer whales. There are forty-two known ocean parasites that can infect salmon, according to Hal Wolfe, pathologist with the California Department of Fish and Game. "Most of these will not kill the fish outright, but can weaken a salmon, making it vulnerable to predation," he says.

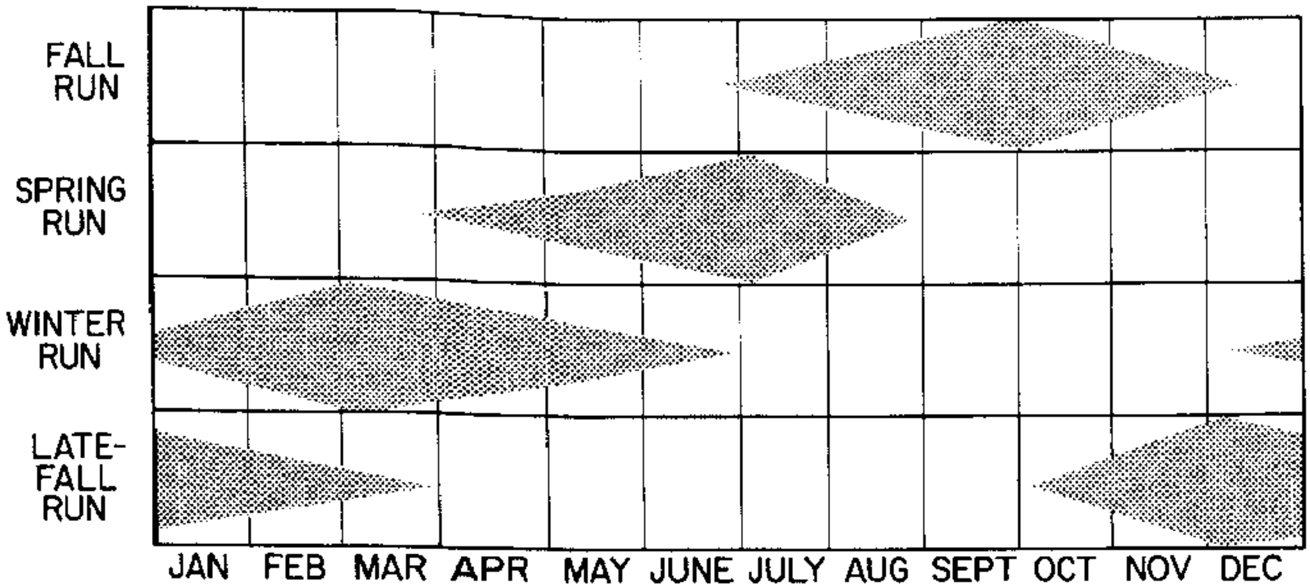
In addition to killer whales, larger predators include harbor seals, sea lions, fur seals, sharks and other fish.

Just as salmon respond to an instinctive cue to begin their migration to the ocean, instinct also triggers their return to fresh water to spawn. The age of salmon at the time of return varies from two to six years, depending upon the species. Ages of returning salmon can be determined by examination of their scales and confirmed by tagging studies. Ridges, like growth rings in a tree are visible on salmon scales; wide bands representing summer growth and narrow bands, winter growth. The ridges developed in fresh and salt water are also distinguishable.

Salmon fingerlings. *(UNH photo.)*



"The transformation from a freshwater fish to a saltwater fish is one of the most remarkable stages of the salmon's life cycle." *(Photo by Richard Nishioka.)*



General time of return to fresh water for Sacramento River adult king salmon. (R.J. Hallock, "Status of the Sacramento River System Salmon Resource and Escapement Goals," California Department of Fish and Game, Anadromous Fisheries Branch, p. 8.)

Returning salmon form schools as they approach land and congregate at the river mouths. When salmon recognize their home rivers, they reenter them and head upstream toward their hatching sites to spawn. Each salmon is specifically adapted to life in its native river and genetic strains have developed over the years. Each population has its individual growth rate, age at sexual maturity and resistance to specific diseases.

When the salmon are near sexual maturity they begin their arduous journey upriver. A sexually mature male is distinguished by longer teeth, thicker skin, a humped back and an elongated jaw that hooks its snout into a permanent snarl. Skin coloring of both males and females changes at maturity.

Once they reenter the river and begin to swim upstream the salmon stop feeding. Propelling themselves with strong tails, they surge upriver against the current and maneuver over and around many obstacles. Periodically the salmon seek a quiet protected pool to rest — but only long enough to regain energy before continuing on.

Salmon subject themselves to an incredible amount of pounding and abuse during their journey upriver. Their skin and flesh become discolored and the salmon lose most of their fat and oil content.

Once they reach their spawning grounds, the females begin to build their nests, called "redds," in the gravel of the stream bottom. Scooping out large saucer-shaped holes with their

The adult salmon's age can be determined from ridges on its scales. (from The Salmon, Their Fight for Survival *by Anthony Netboy, published by Houghton Mifflin Company. Copyright 1973 by Anthony Netboy. Reprinted by permission.)*

tails, they clear out loose gravel and sediments. After the redd is under construction a male courts the female. The female releases the eggs in small batches, which are fertilized by the male. Each batch of eggs is covered immediately with gravel and sediment. Female salmon lay thousands of eggs, the number depending upon the species and the size of the fish. Many of the eggs are lost to the currents, eaten by fish or birds, attacked by fungus or accidentally uprooted by another female digging her redd.

After spawning, the salmon remain in the vicinity of their redds for a few days. Pacific salmon die soon after spawning and their carcasses litter the streams. In smaller streams dogs, racoons, and other scavengers quickly eat the carcasses. Those left in the water are decomposed by networks of bacteria that break them down into nutrients that can be used to nourish future generations.

Salmon require a precise freshwater environment to survive and reproduce. Knowledge of the salmon's complex biology and life cycle will allow a clearer understanding of how and why many of the problems discussed in the following chapters reduce salmon stocks and complicate their management. The salmon's life cycle has affected the lives of many people who use the resource. The native American Indians, for example, depended heavily on the salmon and developed traditions celebrating the salmon's annual return. Today, the salmon's life cycle affects the design of management strategies and their implementation, which in turn affects all those who use the resource for food, whether it be for personal use or for the marketplace.

Soquel Creek, in Santa Cruz County is near the southern limit of the salmon's range. (Photo by Terri Morgan.)

Salmon are one of the most popular sport fishes among both inland and ocean fishermen in California. (Photo courtesy of the California Department of Fish and Game.)

The Salmon Fishery

Historical Use

The American Indians fished for salmon in California long before the first white settlers arrived. For centuries these native Americans, living along the rivers of northern and central California, caught and ate salmon. It formed the bulk of their diets and they celebrated the return of spawning salmon in the early summer with elaborate ceremonies and rituals.[1] Salmon was eaten fresh in the summer, dried and smoked for use during the winter or used as a barter item with inland tribes.

Indian tribes took great care to ensure that an adequate number of salmon escaped upriver to spawn. The Yuroks, who lived along the lower Klamath River, for example, would spend ten days building a weir in preparation for the salmon's return, following ancient customs during every step of the construction. The weir captured every fish struggling upriver for ten days. Then it was removed and no more salmon were harvested.

This practice continued until the first settlers came into the area looking for gold and stayed to harvest timber. Gradually the settlers claimed areas for mining, agriculture and timber and some Indians were relocated onto reservations. Attempting to compensate them for being dispossessed of their traditional lands, the federal government later granted the Indians subsistence fishing rights. Today, Yurok, Hoopa and Karok Indians living on the Klamath and Trinity rivers exercise these rights.

The early settlers quickly recognized the potential of a commercial salmon fishing industry. Commercial fishing began during the mid-1800s on the inland rivers and the first cannery opened on the Sacramento River in 1864. Twenty canneries were in operation by 1881 and intensified fishing efforts provided them with an ample supply of salmon for processing. The inland fishery reached its peak in 1882, when about twelve million pounds of salmon were caught. Shortly afterward the industry collapsed. By 1885, the annual catch was about six million pounds, only six canneries were operating and the canning industry continued its decline. By 1891 only two million pounds of fish were caught and in 1919 the last cannery shut down.[2] Since then most of the salmon caught in California has been sold fresh or frozen.

Around the time of the canneries' peak, mining wastes were entering the rivers. It is generally believed that the effect of the resulting pollution, combined with increased fish catches, caused a sharp decline in the salmon stocks. Fishing efforts shifted to the ocean, mainly because of the river population decline and the development of a light, salt curing process that required a higher quality of fish than could be caught in the rivers.

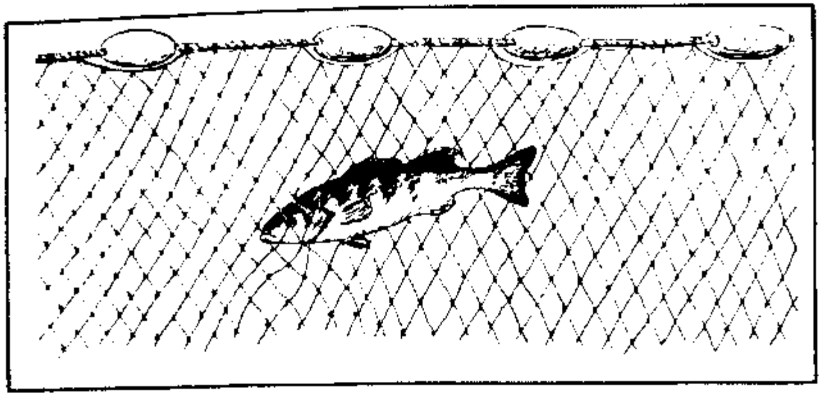
Beginning in Monterey in the 1880s, the ocean fishing industry spread northward up the coast. By 1916 it was practiced as far north as Crescent City. The early ocean fishermen fished for salmon from sailboats. Power boats were introduced in 1908, but the first boats were small and this limited the range of the fishermen.[3] As boats and equipment gradually improved, the efficiency of the ocean fishery increased.

Meanwhile, the inland commercial fishery declined along with the stocks and one by one the rivers were closed to commercial fishing. Sportsmen and native Americans, however, were allowed to continue fishing from these rivers. The first commercial fishing river closure came shortly after World War I and the last in 1957. The Klamath fishery was reopened for a short period in 1976, then closed again. Since that time the commercial salmon industry has been supported by ocean catches.

Today's Fishery

Today, approximately 6,000 commercial salmon boats and 9,000 commercial salmon fishermen work the coast between the Oregon border and Los Angeles. The largest catches of salmon are landed at Crescent City, Eureka, Fort Bragg and San Francisco because the majority of the salmon stocks are found north of San Francisco. Point Conception is normally the southern limit of the salmon's range, but a few fish are caught as far south as San Diego.

The average annual commercial salmon catch in California is about seven million pounds of salmon — almost 800,000 fish.[4] The State of California is the fourth leading supplier



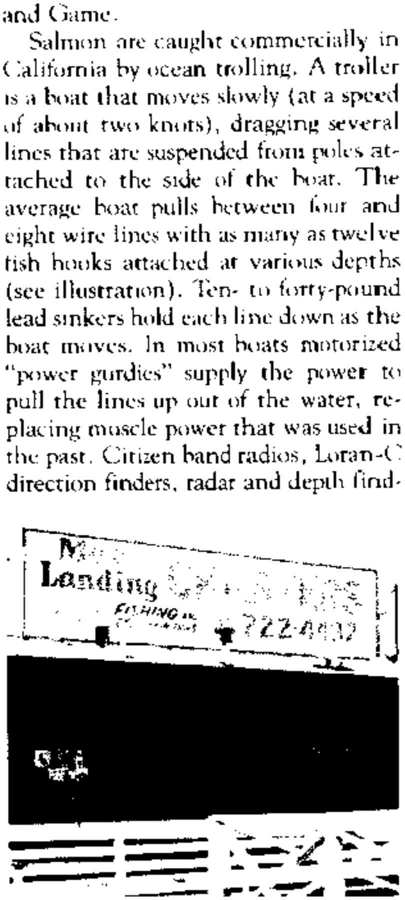
Reservation Indians living along the Klamath River use gill nets to ensnare salmon as they swim upriver. The nets are stretched across portions of the river and side tributaries. Floats, attached to the top of the nets, and weights, attached to the bottoms, hold them in place. (Illustration from Major Commercial Fisheries of California, *California Sea Grant Marine Advisory Program.)*

of salmon in the nation, following Alaska, Washington and Oregon. Most of the California catch is sold within the state. In 1979 fishermen sold their catches to wholesale buyers at prices ranging from $1.98 to $2.98 per pound, depending upon species, size, port and time of year.[5]

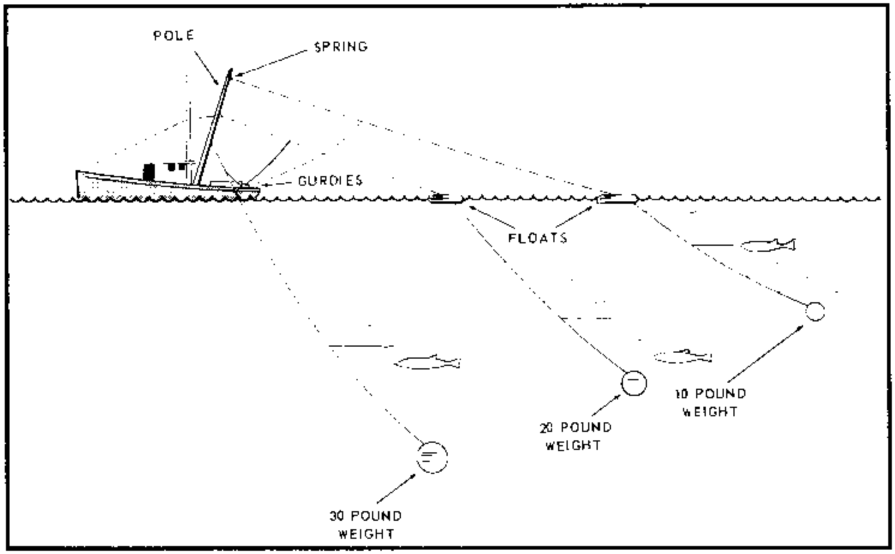
Commercial salmon boats comprise all sizes and shapes, from fifteen feet to more than sixty feet in length. Fishermen range from sportsmen, who fish commercially during their vacations, to third generation fishermen who inherited their boats and equipment from their fathers after a childhood of fishing experiences. Until recently, most commercial fishermen were following the occupation of their fathers.[6] Only within the last fifteen years has the trend begun to change. More frequently, sons of fishermen are choosing careers on land, and the void is being filled mainly by retired people starting a second career, sportsmen turning a hobby into their livelihood, young, often college-educated, men from middle class families and many others.

Commercial fishing regulations for all California ocean fish, which can include season opening and closing dates, size limits, gear restrictions, closed fishing areas and others, are established by the U.S. Secretary of Commerce, based on the recommendations of the Pacific Fishery Management Council in cooperation with the California Department of Fish and Game.[7] The council is one of eight regional bodies formed with passage of the federal Fishery Conservation and Management Act of 1976 to manage the nation's commercial and recreational fishery resources. These regulations often change from year to year. The commercial salmon fishing season is usually four to five months long, from April or May to the end of September, but the trend during the last few years has been toward shorter seasons with mid-season closures. Different size limits are set for cohos and chinooks and undersized salmon, called "shakers," must be released and returned to the ocean. Fishing licenses are required by the California Department of Fish and Game.

Salmon are caught commercially in California by ocean trolling. A troller is a boat that moves slowly (at a speed of about two knots), dragging several lines that are suspended from poles attached to the side of the boat. The average boat pulls between four and eight wire lines with as many as twelve fish hooks attached at various depths (see illustration). Ten- to forty-pound lead sinkers hold each line down as the boat moves. In most boats motorized "power gurdies" supply the power to pull the lines up out of the water, replacing muscle power that was used in the past. Citizen band radios, Loran-C direction finders, radar and depth find-



Charter boats cater to sport fishermen and attract many tourists into coastal areas. (Photo by Terri Morgan.)



All commercial salmon catches in California are from trollers moving at a speed of about two knots. Four to six lines, each with about six or more hooks, are hung at different depths and held in place by sinkers. The heavier sinkers, on the front lines, pull the lines down as deep as 350 feet and help keep the lines untangled. (Illustration from Major Commercial Fisheries of California, *California Sea Grant Marine Advisory Program.)*

ers make navigation and salmon fishing easier than it was in the early days of fishing when navigation equipment consisted of a compass and a chart.

Commercial salmon fishing is an economically important industry, especially in the sparsely populated areas of northern California. It is a major industry in Humboldt and Del Norte counties, providing employment for many people who would otherwise be unemployed. In addition to the fishermen, people are employed in the processing plants and many support businesses that supply fishermen with their equipment.[8]

Processing

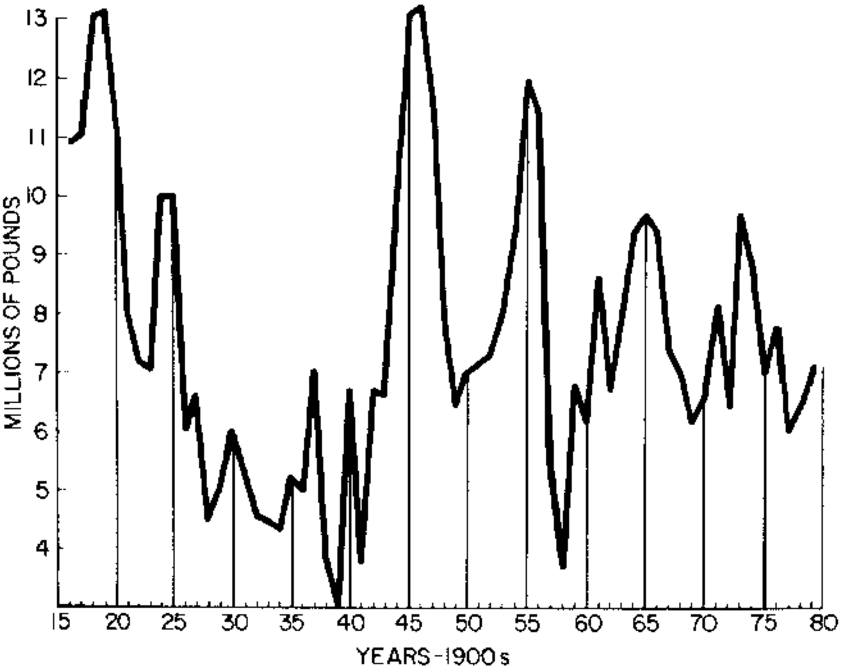
Since the last cannery closed in 1919, almost all of the salmon caught in California has gone directly from the fishermen to the buyers representing the processing plants. Most processing plants are located at the larger harbors, like Crescent City, Eureka, Fort Bragg and San Francisco, although there are a few inland in Santa Rosa and Sacramento. Salmon that are purchased at the smaller harbors are trucked to the processing plants where the fish are washed and re-iced, having already been cleaned and iced by the fishermen. Most of the salmon is refrigerated and sold immediately to restaurants, markets or to a fish broker, who may buy several loads of salmon to ship to Los Angeles, San Francisco, the Midwest or the East Coast. Salmon is also exported to Japan and Western Europe.

Fresh salmon has a shelf life of two to three weeks. But this shelf life may be extended in the near future. Sea Grant researcher W. Duane Brown at the University of California at Davis is experimenting with a storage process he calls "modified atmospheres." In the process, 60 to 80% of the refrigerated air around the salmon is replaced with carbon dioxide gas, which inhibits bacterial growth that causes spoilage. It extends the shelf life of the fish at least one week, while retaining high quality.

The remainder of the salmon is frozen, stored and marketed after the commercial season ends when no fresh fish are available. Commerical freezers are capable of maintaining extremely low temperatures and salmon can be stored in them for about a year. (Most home units are not as efficient and frozen salmon should be used within a month or two of the purchase date.) Freezing and storing can increase the cost of the salmon when it appears on the market.

None of the fish processing plants in California process salmon exclusively,

Some of the catch is served in local seafood restaurants. (Photo by Terri Morgan.)



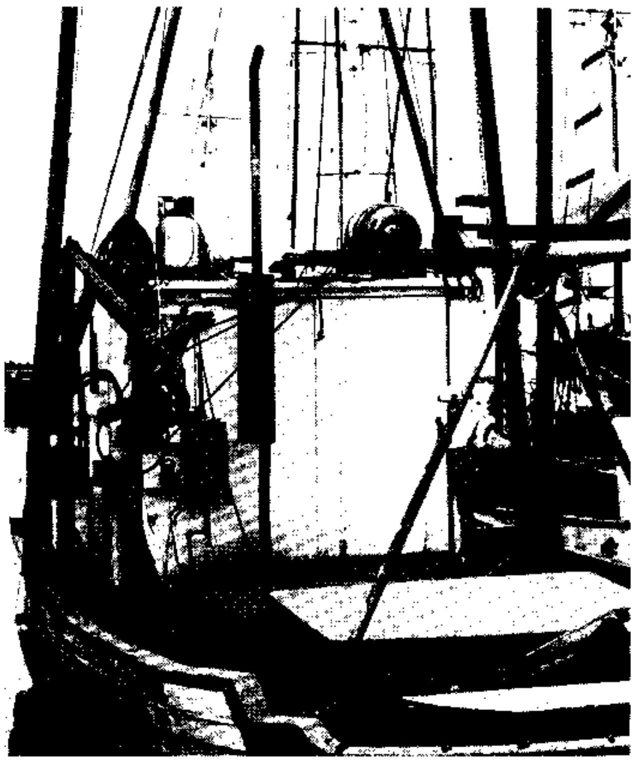
California salmon catches from 1916 to 1979. (A. Netboy, The Salmon, Their Fight for Survival *[Boston: Houghton Mifflin Company, 1974], pp 542-3. citing the California Department of Fish and Game.)*

The salmon sport fishing season is longer than the commercial fishing season but, as with commercial fishing, regulations are subject to change annually. The California Fish and Game Commission and the Pacific Fishery Management Council recommend sport fishing regulations to the Secretary of Commerce. Sport fishing is permitted on most inland rivers, provided the angler has purchased the proper licenses.

The Department of Fish and Game estimates that sportsmen are responsible for 15 to 20% of the total annual salmon catch. Despite the fact that sport catches bring in a lower percentage of the total catch, the sport industry has a significant impact on the state's economy. Tourism is an important industry, especially in many economically depressed areas of northern California, and sport fishing attracts many of these visitors. No conclusive figures are available to determine the contribution of sport fishing to tourism, or exactly how much money it generates.

Traditionally, sportsmen have been at odds with commercial fishermen. Both groups feel the other is taking more than its fair share of the resource. But California fishermen have come to recognize the need for resource protection and have set aside their differences to work together in organizations like Salmon Unlimited, an organization dedicated to the wise use of the salmon resource. Salmon Unlimited represents about 10,000 fishermen from twenty-two different organizations. Many other fishing clubs and organizations have been developed throughout the state and many fishermen are volunteering their time, money and labor to enhancement projects. Through such organizations members of the Tyee Club in San Francisco, for example, have worked with Roger Green of the National Marine Fisheries Service for five years on a coho salmon rearing project. Volunteers helped construct holding pens and fed and tagged salmon at the National Marine Fisheries Service facility in San Francisco Bay before they were released. Through their efforts Green was able to raise fish for enhancing the sport and commercial fisheries and collect data on the mortality rates of the salmon. Other volunteer projects include habitat assessment and stream clearing projects.

Today, commercial salmon fishing has become a tradition for many families in northern California, even though the industry has changed dramatically since the early days of the inland fishery.



Salmon troller in Eureka harbor. (Photo by Terri Morgan.)

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[1]A. Netboy, *The Salmon, Their Fight for Survival* (Boston: Houghton Mifflin Company, 1974), pp. 239-240.

[2]A. McEvoy, *Economy, Law and Ecology in California Fisheries to 1925* (San Diego: University of California, 1979), pp. 64-67, and H. W. Frey, ed., *California's Living Marine Resources and Their Utilization* (Sacramento: California Department of Fish and Game, 1971), pp. 43-44.

[3]*Ibid.*

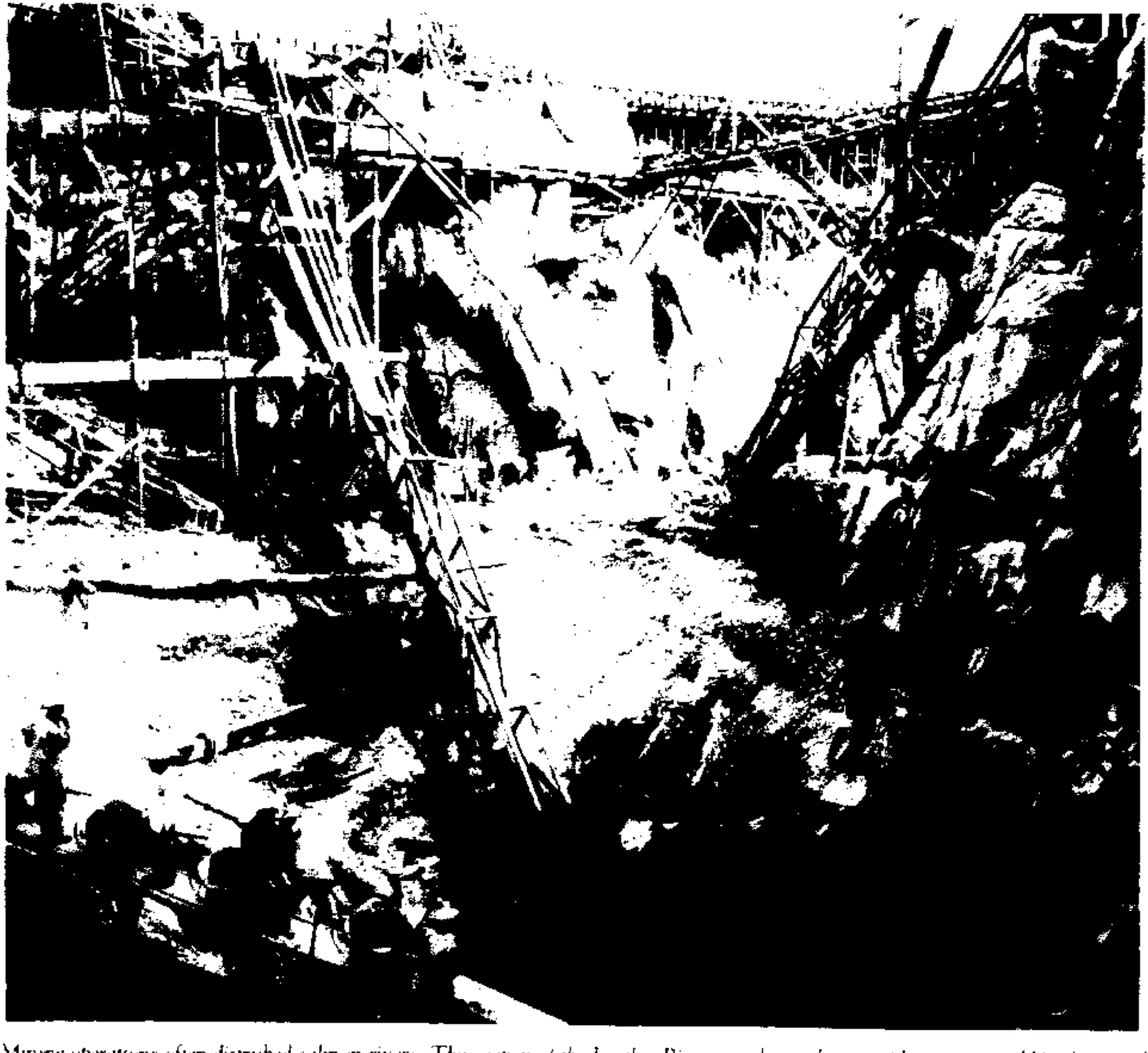
[4]*Proposed Management Plan for the Salmon Fisheries off the Coasts of Washington, Oregon and California* (Portland: Pacific Fishery Management Council, 1980), pp. 5-6.

[5]Statistics taken from various 1979 issues of *Fishery Market News Report* (Terminal Island, California: NOAA, National Marine Fisheries Service).

[6]*Socioeconomics of the Idaho, Washington, Oregon and California Coho and Chinook Salmon Industry*, 2 volumes (Corvallis, Oregon: Oregon State University Department of Agriculture and Resource Economics, 1978), vol. A, p. 32.

[7]Because salmon spend part of their life cycle in waters over which the State of California has jurisdiction the State Department of Fish and Game also provides recommendations concerning their management. Chapter 5 contains a more detailed discussion of the agencies involved in salmon fishery management in California.

[8]*Socioeconomics of the Coho and Chinook Industry*, vol. B, pp. 56-74.



Mining operations often distrubed salmon rivers. This section of the Feather River was diverted to provide access to gold in the gravel bed. (Photo courtesy of the Bancroft Library, University of California, Berkeley.)

Human Impact on the Habitat

Commercial and recreational fishing are not the only enterprises linked to the welfare of the salmon. The need for water is a common denominator of salmon and civilization. Mining; agriculture; municipal and industrial water use; urbanization and forestry have had an enormous impact on the salmon populations by changing the quality and quantity of water in the fish's traditional spawning streams.

The Wastes of Mining

Natural disasters — floods, droughts, fires, volcanoes — have always caused fluctuations in salmon populations. But human-induced damage to the salmon's habitat began in the 1800s when the "forty-niners" came to California. They used river water to wash down hillsides to carry mud, sand and gravel to sluice boxes, in which gold was separated from the rest. The earthen debris created by this hydraulic mining was discharged into the rivers, where it choked waterways, covered spawning gravels and smothered fish.

While miners were working in the mountains, other settlers brought farming to the Central Valley and San Francisco grew into a center of international commerce. The growth of agriculture and shipping finally spelled the end of hydraulic mining. Mining wastes had increasingly clogged the Valley rivers, causing flooding of farmlands and blocking steamboat passage through the inland waters of the San Francisco Bay Delta. The resultant conflict of interest was resolved in 1884 by outlawing the dumping of mining debris into streams. Even so, most of the sediment was not washed out of the rivers for another forty years. All told, hydraulic mining probably caused more damage to the Central Valley salmon populations than did the intensive inland fishery on the Valley rivers during the same era.

Changes in River Flow

The natural distribution of water determined the locations and types of the earliest settlements in California. After 1848, however, the continuing growth of agriculture and urbanization brought about a massive harnessing and redistribution of water. This wrought tremendous changes in the salmon's habitat. (See map).

Historically the Sacramento and the San Joaquin river systems carried water from the inland mountains southwest and northwest in the Central Valley to empty into San Francisco Bay. Hundreds of thousands of king salmon spawned in the branches of these rivers. Several smaller coastal systems, draining the wooded northwest corner of the state, supported more than half a million spawning salmon, chinooks and cohos.[1]

Since most of the rain and snow falls in the northern part of the state and in the Sierra Nevada, the northern Valley and the San Francisco Bay Delta were originally subject to seasonal flooding while much of the south Valley was a dry grassland. Part of the Delta was flooded daily at high tide. When the farmers arrived, they drained the wetlands and diverted rivers and dug wells to irrigate the dry lands.

The first water control efforts were independent and poorly coordinated so, eventually, they were taken over by the state and federal governments. Three projects built in the 20th century have succeeded in regulating the flow of the Sacramento River, providing water to irrigate the San Joaquin basin, and satisfying industrial and domestic water needs of the San Francisco Bay area and central and southern California cities. Dams have been built on virtually every major river of the Valley system, and most of the north coast rivers have been modified to control flows, supply domestic water or generate hydroelectric power.

Much less of the water from the Valley rivers now runs into the San Francisco Bay. A large portion of the water from the north is shunted south from the Delta and most of the San Joaquin River is used locally or further south. The transported water supplements the limited underground water stores for irrigation in the southern Valley.

Agriculture is the largest user of water in the state, taking 87% of the total amount of water withdrawn from rivers.[2] Irrigation has enabled California to become the leading agricultural state in the country. However, this reapportionment of water has been detrimental to a smaller California industry — the salmon fishery.

Water projects have dramatically

altered the natural ecology causing changes in sediments, nutrients, temperature and flow of rivers; in patterns of erosion and formation of floodplains and in distribution of native aquatic plants and animals.

The effect on the salmon has been multifaceted. Dams have cut access to traditional spawning areas. Below dams some spawning gravel has washed away or been covered with silt. At pumping plants, fish are attracted to the current of the water intakes and, if the inlets are not properly screened, the fish can be sucked through the facilities and killed, injured or disoriented. Before entrances to diversion channels were adequately screened, small fish were carried into irrigation ditches and stranded.

The flow of some rivers was severely reduced by storage and offstream use of water. In shallow rivers the water temperature can increase above the tolerance level for salmon. As the volume of flow decreases, pollutants are concentrated and silt accumulates. The gravel is not adequately flushed to carry metabolic wastes away from developing eggs and fry or to supply adequate oxygen. Problems for migrating fish are worst during the hot summer months when river flows naturally decrease.

Problems in Timberland Streams

The salmon rivers of northwest California issue from thickly forested mountains. These tracts of redwood and Douglas fir have high commercial value and have been extensively harvested. Before the use of modern logging techniques, cutting was done with little concern for soil conservation, stream protection or reforestation. The subsequent damage to the watershed

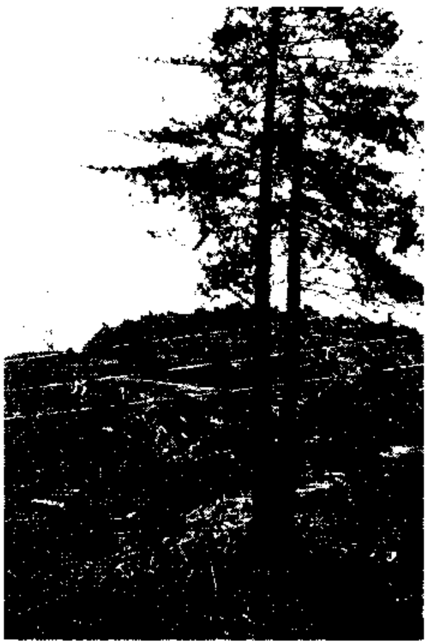
California's Water Projects

"Water and its development for human use forms the basis for California's modern prosperity, the framework of our history, and the substance of our existence."[3]

Three major water projects have dramatically changed the distribution of water in California.

The state Sacramento Flood Control Project (1911-1944), the federal Central Valley Project (begun in 1937) and the State Water Project (begun in 1960) have brought water where agriculture and urban development were favored, often to the detriment of native waterlife such as salmon.

California's Water Projects (Compiled from "Hallock, Status of the Sacramento River. . .," p. 2; Kahrl, *Water Atlas*, pp. 70-71 and Taylor, "Status of . . . Coastal Rivers," p. 3. See bibliography. Illustration by Noreen Bonker.)



Poor logging practices leave debris that finds its way into streams. (Photo by Terri Morgan.)

degraded the quality of the salmon habitat.

The use of heavy logging machinery disrupted slopes and streambeds. Removal of vegetation and cutting of access roads destabilized hillsides. Rain washed silt and leftover wood into waterways, creating log jams that blocked salmon migration, covering spawning gravel and filling in resting pools.

Particularly heavy rains in the mid-1950s and 1960s brought public attention to the problems in the watershed when swollen streams flooded towns with muddy water laden with logging debris. These disasters provided dramatic evidence that better forest management was needed and stimulated the adoption of harvesting techniques designed to protect the environment.

Alteration and Pollution of the Waterscape

While mining, water redistribution, and logging are large-scale undertakings that have changed the salmon's environment, innumerable smaller-scale activities throughout the state have also been damaging. For example, the construction of roads and railways frequently blocked or altered stream courses. Poorly planned land development for construction, agriculture and grazing resulted in increased erosion. Dredging often eliminated pools and bends in rivers that salmon need for resting spots. Countless domestic, industrial and agriculture sources fouled waterways.

Water pollution takes many forms. Siltation is considered one type of pollution. Water taken up for cooling in industrial processes and then discharged at a higher temperature decreases water quality for salmon. Inadequately treated sewage and organic commercial wastes may stimulate the growth of microorganisms that deplete the amount of available oxygen in the water. Chemical wastes in agricultural runoff and industrial effluent can be extremely toxic to fish.

The extent of the effects on salmon is unknown. Polluted areas, like physical obstructions, can stop or slow migration and weaken fish. Foreign chemicals in the water might interfere with olfactory homing. Many biologists believe that pollution has an indirect impact by changing the ecosystem that supports the salmon. However, we do not yet understand the effects of pollution on salmon or their habitat well enough to determine whether certain changes are harmful or not.

The Result

The settlement of California over the past 130 years has affected every salmon run. Degradation of stream habitat and fishing pressure have greatly decreased the California salmon stocks. The Central Valley river populations have been most affected by the development of water projects. The San Joaquin spawning population dropped from 100,000-300,000 to 8,000 salmon. The Sacramento system declined to around 200,000 spawners from 300,000-500,000. In north coast rivers environmental problems stemming mainly from forestry and urbanization have decreased salmon stocks by about half.

Since the damage began, a variety of efforts has been undertaken to make up for losses of salmon. Unfortunately, substantial harm was done before the trend really began to change toward a balance between protection of the resources and the requirements of the state's growth and development.

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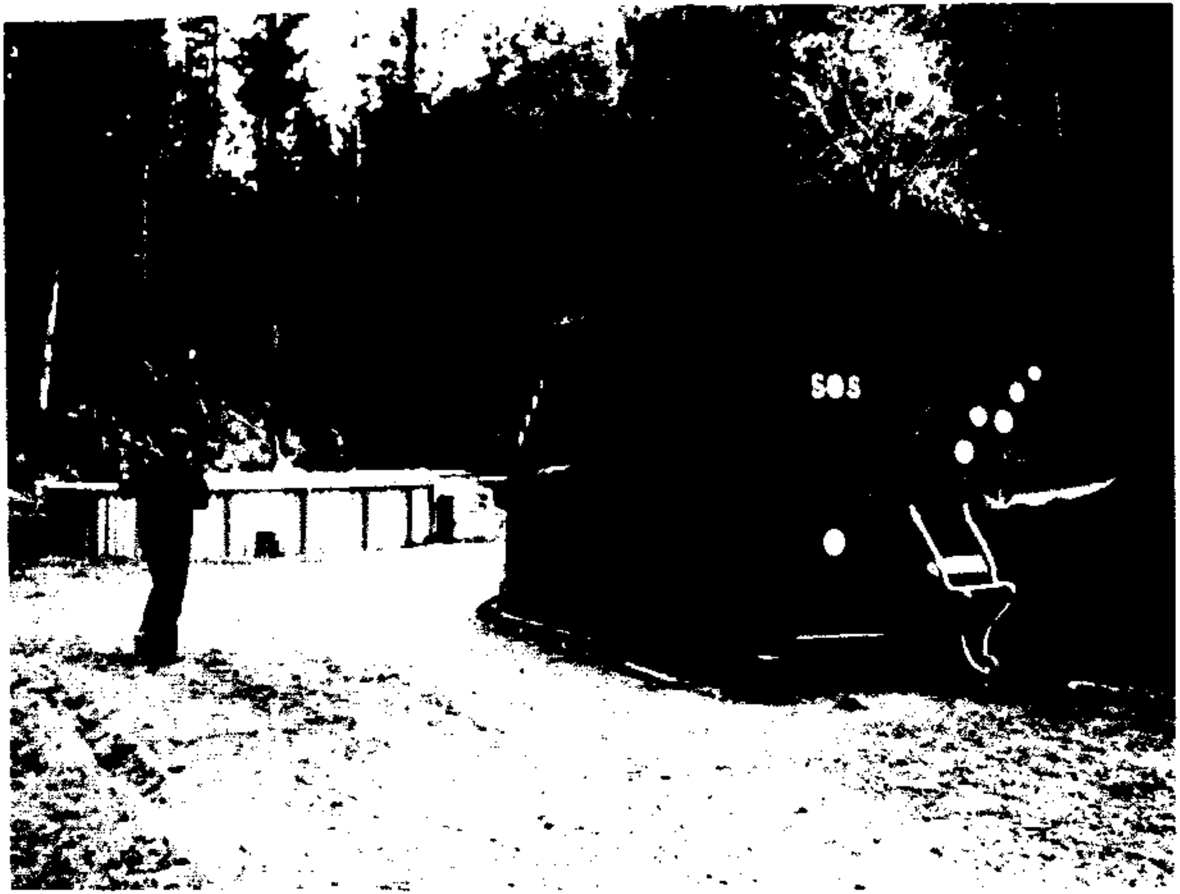
[1]The population statistics cited in this chapter are all taken from California Department of Fish and Game estimates in *Freshwater Habitat, Salmon Produced, and Escapements for Natural Spawning along the Pacific Coast of the U.S.* (Portland, Oregon: Pacific Fishery Management Council, 1979).

[2]W. L. Kahrl, ed., *The California Water Atlas* (Sacramento: State of California Office of Planning and Research and the Department of Water Resources, 1979), p. 3.

[3]*Ibid.*, p. 1.



Community organizations like Save Our Salmon have been raising fry to smolts for release into local streams. (Photo courtesy of Ron Kusma.)

Protection, Restoration and Enhancement

Ever since California became a state, laws have been passed to protect salmon as a resource important to the food supply and the economy. Many measures have been designed to regulate human use of the habitat to mitigate abuses. These regulatory activities have increased significantly over the past few decades through efforts of legislators, resource agencies, private industries and individuals to integrate conservation and enhancement of natural resources into the workings of our society.

Culturing Salmon

Hatcheries

One of the oldest methods used to increase salmon stocks is artificial propagation in hatcheries, begun in California in the 1870s. Adult salmon are trapped and their eggs and milt are collected and mixed by hand. The fertilized eggs are incubated in trays, and the young fish are kept in ponds or long raceways until they are ready to be released into a stream. The rates of fertilization, hatching, and fry survival are much higher in hatcheries than in the wild because the artificial environment is protected from natural predation and disturbance. Therefore, hatcheries can generate large releases from small spawning runs and have the potential to rebuild populations.

Currently there are eight salmon hatcheries in California, funded all or in part by state and federal wildlife agencies, the Bureau of Reclamation, utility companies or county government. Most of the facilities were built below dams that had disrupted natural reproduction by cutting off access to spawning gravels. The Department of Fish and Game has authority over all egg collecting in the state and operates the majority of the hatcheries.

While hatchery reproduction is a sound measure it has its share of problems. The crowded rearing conditions are ideal for epidemics of disease and parasites. The young fish planted into streams are not accustomed to avoiding predators, searching for food or orienting in a rocky stream. The Department of Fish and Game has found that fish are most likely to survive if they are held until they show signs of smolting. However, sometimes fry are released because hatchery space to grow fish and funds to feed them are limited.

As with naturally-spawned fish, only a small proportion of hatchery fish can be expected to survive to maturity.[1] About two-thirds of these will be caught by the ocean fishery.[2] This leaves a small percentage to return to the hatchery to start another cycle.

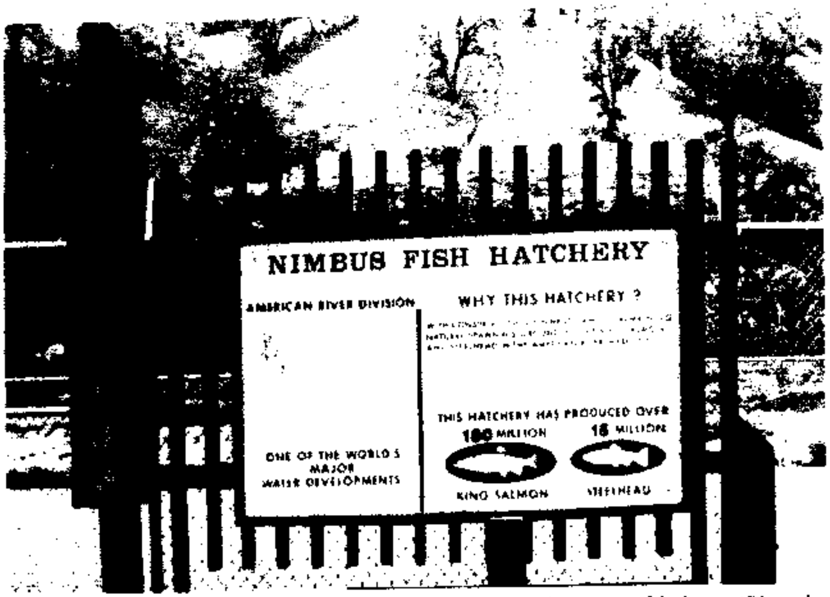
Ideally, artificially-reared fish should be planted into the native stream of their parents. This way, the salmon's inbred adaptations to specific stream conditions and homing instinct make the transition to the wild easier. But fish are often transplanted into other rivers to build up runs or to start new ones. In this case, it is best to transplant fish into streams that are similar in water quality and flow to their ancestral runs.

Care must also be taken that the introduced fish do not carry diseases into a new area. There is concern that transplants might stray to other streams as returning adults and interbreed with different stocks, introducing foreign traits into those populations. The potential result and extent of this mixing is not known. To minimize further impact, the effort is made to control the releases of transplants so they are separated from native stocks by location or timing. However, it is suspected that mixing has already occurred as a result of past transplanting.

Community Involvement

Lately, rearing space has been created for fry that are surplus to the Department of Fish and Game program's needs or hatchery capacity. The fish are being raised to the smolt stage in artificial ponds by community-run projects in the north coast area. These experiments are the result of interest by fishermen and the general public in replenishing local salmon stocks. The projects are run using relatively low-cost materials, with technical assistance from the Department of Fish and Game, Humboldt County's hatchery and the California Sea Grant Marine Advisory Program.

Problems arise in finding sites with an adequate supply of cool, clear water; establishing a returning run; coordinating management; raising funds and, of course, coping with natural



Salmon are reared at hatcheries built to make up for loss of their natural habitat. (Photo by Terri Morgan.)

mischance. One operation on the Garcia River has had its water system uprooted by wild pigs, clogged with salamanders, and broken by falling redwood trees.

Two community salmon rearing organizations sought and gained permission to do their own egg-taking to supply fry for their ponds. One project, on a tributary of the Eel River, is run by a fishermen's association and funded by four lumber companies. Such collaboration is an indication that fishermen and the lumber industry, traditional adversaries, have begun to work together.

Ocean Ranching

For many years, salmon hatcheries were built solely to raise fish to be caught in the wild by commercial and sport fishermen. However, over the past decade the business of profit-making and cooperative hatcheries (ocean ranching) has developed. The idea is to raise and release fish and then market the adults that return to the facility. While the rancher's salmon are at sea, they are public property, available to fishermen during the fishing season. Therefore, ocean ranching has the potential to increase the salmon resource without incurring more public expense. Ocean ranching, under proper resource management was favored in the recent draft of the National Aquaculture Plan.[3]

Setting up an ocean ranching venture can require a multi-million dollar investment, and financial returns are delayed several years until a salmon run to the site becomes established. However, once the facility is running at full capacity the profits can far exceed the outlay because most of the salmon's growth occurs at no cost in the ocean "pasture." The expense, time and expertise required to set up an operation, however, generally has limited ocean ranching to large-scale ventures.

Ocean ranching is strictly regulated while its ecological and economic impacts are being assessed. The rules governing ranching were designed to prevent interference with natural or state-propagated runs. In California authorization requires an act of legislation and the permit process is long and complex. Currently there is only one facility, on a creek in Santa Cruz county that contains little aquatic life and no salmon. The size and species of releases are regulated by the Department of Fish and Game and a percentage of the fish are tagged to determine their distribution and contribution to the ocean fishery.

Pond tender for Save Our Salmon and the local Sea Grant Marine Advisor. (Photo by Terri Morgan.)

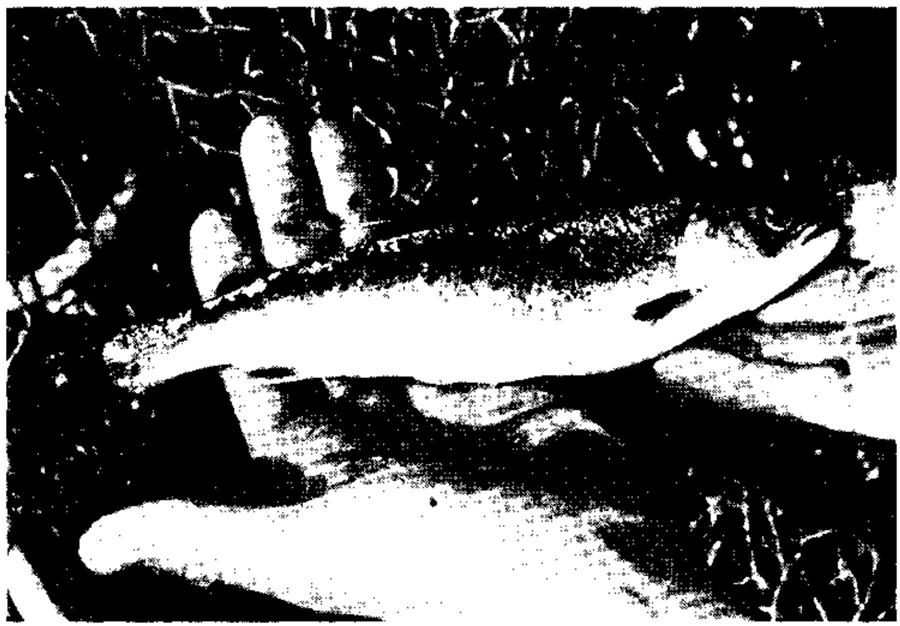
Members of the Salmon Trollers Marketing Association, Noyo, tagging fish raised in a pond on Ten Mile River near Fort Bragg. (Photo by Gary Beall.)

Ocean ranching has a firmer foothold in Oregon and Alaska. The Oregon Resources Agency considers its thirteen private hatcheries part of its overall salmon management program. In Alaska the state permits only nonprofit ranching in which the income is used solely to support the operations of six projects that are currently underway. Some of these are run by Alaskan fishermen's cooperatives to enhance their ocean catch.

Many biological questions remain about ocean ranching — questions that pertain to artificial propagation through the government's programs as well. There is concern that more needs to be known about the ecology of the fish and the ocean in general to confidently manage releases. Some question what the effect of additional large plantings of salmon would be on wild salmon and other species in estuaries and the open sea. It is possible that the supporting capacity of the ocean forage or food chain relations have changed since the days when salmon populations were much higher.[4]

Many fishermen are also apprehensive about ocean ranching for profit because they fear ranching might displace ocean trolling by increasing the supply of fish and driving down prices. They worry too that big business ocean ranching could use sophisticated salmon breeding or political influence to gain an advantage over trollers. Finally, some people object to any further developments of the shoreline.

In this atmosphere of controversy, it is unclear whether the ocean ranching business in California will grow, and what impact it will have.



The tagged smolts that survive to be caught as adults will indicate the rearing project's contribution to the fishery. (Photo by Gary Beall.)

Improvements on the Rivers

Safe Passage and Sufficient Flows

The early laws written to preserve salmon in the advent of water development projects were ineffective and compliance was lax. It became necessary to pass legislation to increase protections and rectify some of the harm done in the past.

Perhaps surprisingly, government water projects were not required to consider the habitat requirements of fish and wildlife in their plans until recently. In the 1950s and '60s preservation of fishery resources was finally added as a purpose of state and federal projects, to be considered along with flood control, navigation, irrigation, domestic use, reclamation and power generation.[5,6] Legislation was also passed to provide incentive for local water development projects to include fish population enhancement.

These enactments gave people working to improve inland conditions for salmon a much stronger base from which to act. It is up to the California Department of Fish and Game, the U.S. Fish and Wildlife Service, other researchers, fishermen and environmentalists to present government agencies with information on the value of salmon when new plans for water use are being evaluated.

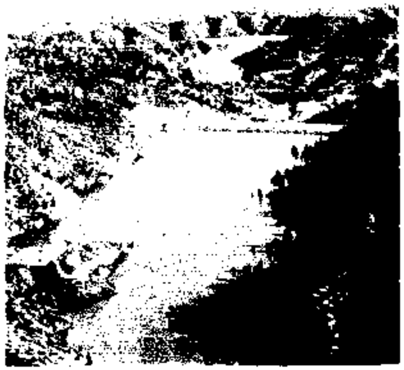
Various appropriations have been approved to install or improve fish screens, build and run artificial rearing facilities and fund other mitigation projects. Improvements on the Merced River of the San Joaquin drainage system are an example of successful actions.

The salmon runs on the Merced had dwindled to less than 100 fish per year in the early 1960s because of diversion of water for irrigation. But the possibility of increasing water releases for the fish arose when the Exchequer Dam was enlarged and its storage increased. Negotiations resulted in a flow commitment of enough water to support a run of 2000 spawners. A spawning channel and rearing ponds were constructed and six irrigation diversions were screened. Since then, as many as 1000 salmon in a season have used the channel and several hundred thousand yearlings have been raised in the ponds and released. Low spring flows, however, remain the limiting factor on the Merced and the other San Joaquin rivers.

Improvements like these help increase the number of salmon in waterways that have been greatly modified for human use. But the largest stocks of salmon still spawn naturally in rivers of the Sacramento system and the north coast that have less restricted flows. To protect fish and wildlife and the recreational and scenic values on underdeveloped rivers, the state Wild and Scenic Rivers Act was adopted in 1972.

The Act prohibited state assistance for construction of dams or diversion facilities, except for local needs, on segments of nine designated rivers. Though these rivers can still be utilized for domestic purposes, their free-flowing character is to be preserved. The legislation stopped plans to include some north coast rivers in the State Water Project and take some of their water south but did not preclude federal developments.

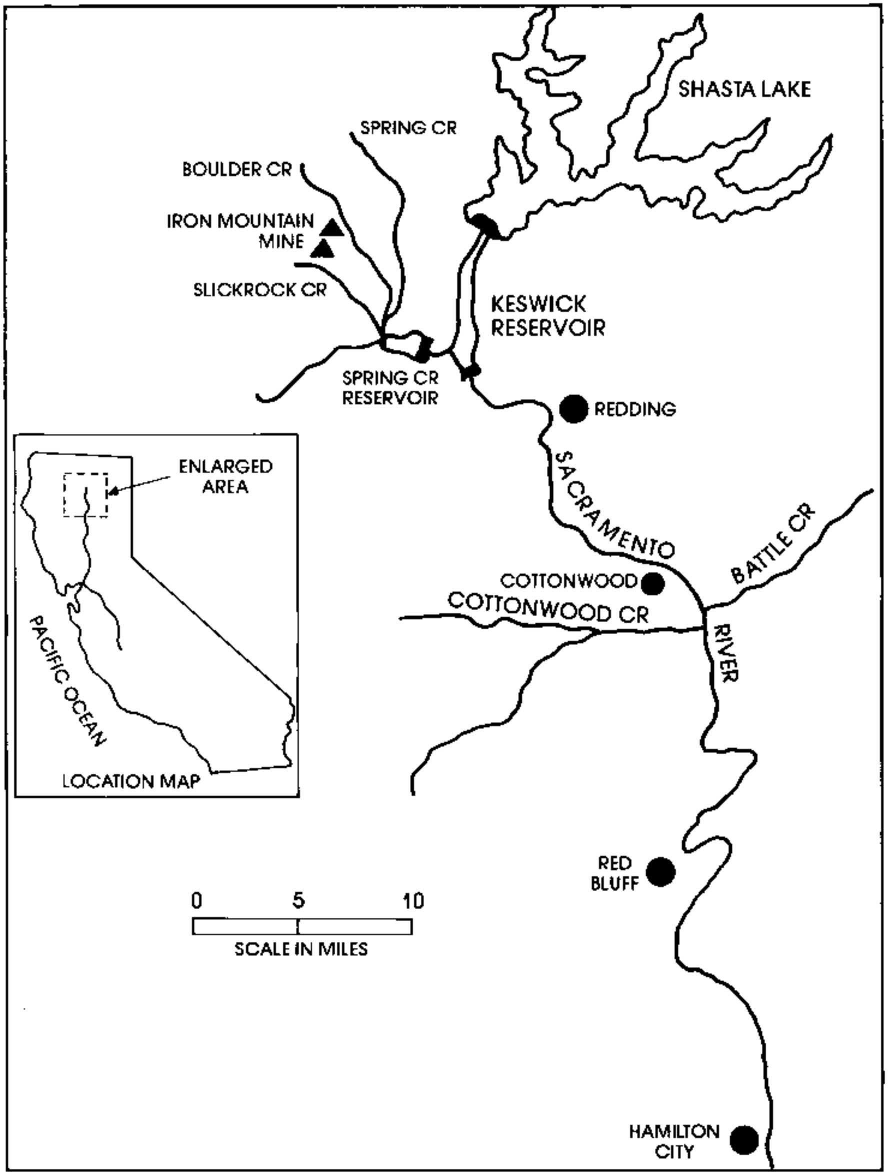
Currently, streamflow requirements for fish are considered on a case-by-case basis each time requests for offstream diversion are made. The Governor's Commission to Review Water Rights Law recommended in 1977 that flow standards be established for entire streams to ensure better protection of the fish. The legality of water allocation for this "instream use" is still being evaluated.



Spring Creek Reservoir and Debris Dam (foreground) with Keswick Reservoir beyond. Acid mine waste washed down from Spring Creek drainage has poisoned salmon in the Sacramento River. (Photo courtesy of the California Department of Fish and Game.)

Clean Water

The Department of Fish and Game was included in formulation and enforcement of water quality control plans by revision of the State Water Code in 1969.[7] The Department investigates the effects pollution has on fish and recommends water quality standards to regional control boards. Presently, Department of Fish and Game studies are helping find solutions to severe problems caused by heavy metal poisoning in the upper Sacramento River.



Location of Spring Creek drainage. (Redrawn from B. Finlayson and D. Wilson, "Acid-mine Waste – How It Affects King Salmon in the Upper Sacramento River," Outdoor California, *November-December 1979, p. 9. Illustration by Noreen Bonker.)*

Thousands of spawners and untold numbers of young salmon have been killed above Redding in the past twenty-five years by wastes of open pit mining washed down from Iron Mountain into Spring Creek and subsequently into the Sacramento River. Loss of spawning gravel, problems with fish passage at Red Bluff Diversion Dam and predation by other fish add to the troubles in the area. The salmon losses represent most of the decrease in the number of salmon in the entire Sacramento system during this time.

The trouble began when the Shasta and Keswick dams were built. Before that time, heavy metal contamination was diluted by high flow from the upper Sacramento. Also, many spawning grounds were above the contaminated area. However, the dams forced the fish to spawn further downstream and cut off most of the Sacramento's flow, concentrating the mine wastes.

To regulate the toxic flow from Spring Creek into the Sacramento a debris dam was constructed in the 1950s. Copper cementation plants were built to remove that metal from the water. Since large salmon losses continued to occur, the Department of Fish and Game took up investigations in 1978 to review the water quality standards it had proposed earlier when toxicity technology was less sophisticated.

Studies are expected to continue through 1981 and it is apparent that stricter discharge limits are necessary. The Central Valley Regional Water Quality Control Board is working to increase the efficiency of the copper cementation plants and is looking into ways to remove zinc and cadmium from the waste. Also, it will be important to secure adequate diluting flows from the Sacramento as needed and to maintain enough storage area in the Spring Creek reservoir to guard against spill-over of contaminated water in flood years.

The strategy for abating water pollution depends on its origin. For localized "point" sources, like Spring Creek dam or industrial plants and sewer outfalls, stopping or detoxifying wasteflow presents mainly a technological problem. For "non-point" pollution, coming from diffuse sources such as urban and agricultural runoff, control requires coordination of area-wide land use and drainage planning.

Better Forest Management

Inappropriate timber harvest practices and natural disasters caused damage to the watersheds in northern California that spurred adoption of stricter state and federal forestry codes in the 1970s.[8,9] Techniques were prescribed to keep logging to a minimal and repairable impact.

Wildlife and recreation were recognized as important values of forest lands along with lumber production. In economic terms, the value of the salmon produced in a stream can be comparable to the timber value along the stream's course. And salmon fishing along clear-running streams also has a substantial recreational worth.

When applications to log an area are made to the U.S. Forest Service (national lands) or the State Division of Forestry (state forests and private lands), the plans are reviewed by fishery biologists to determine the effect of the projects on stream life. To minimize avoidable damage, guidelines are set for limited use of tractors, careful road layout and construction, removal of temporary stream crossings, retaining shading canopy on streamsides and revegetation of cleared areas. Areas without "on-site" fishery value are important to protect because they are sources of high-quality water for fish downstream. The practices of logging companies have changed, from simply harvesting trees toward maintaining forests as a renewable resource.

County crew clearing a log-jammed creek. (Photo courtesy of Ron Kusina.)

In California, the U.S. Forest Service is conducting experimental rehabilitation programs to repair damaged streams by recreating lost spawning areas and resting pools, stabilizing eroding hillsides and removing logjams and tractor crossings. These enhancement efforts are considered demonstration projects. The U.S. Forest Service hopes to receive legislative approval for a five-year Salmon and Steelhead Habitat Improvement Program to continue its work. The Forest Service would also like to see private lumber companies take the initiative in similar stream restoration work.

A Forest Improvement Program has been initiated by the California Department of Forestry to help small land-owners improve the timber, soils, range, fish and wildlife resources on their property. The program provides cost-sharing funds from state forest revenues.

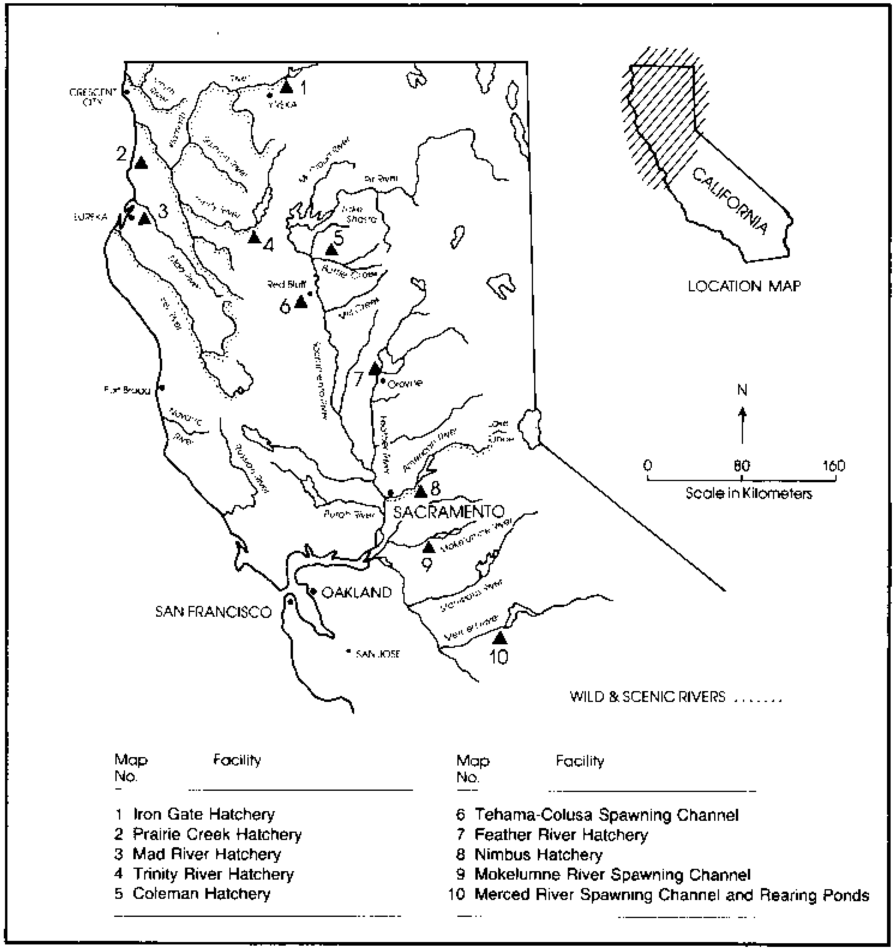
Local government agencies are working with lumber companies to rehabilitate damaged streams in Mendocino County, where forestry and fishing are both major contributors to the economy. The Country Center for Education and Manpower Resources hired and trained local residents to remove log jams on streams running through lumber company lands. The work is all done with hand tools to avoid damage caused by heavy machinery. The community benefits from increased employment and environmental improvement and a greater sense of involvement in the surrounding forest community.

Future Stocks

Recognizing that salmon are a "priceless and irreplacable resource of this state," the California legislature created the Citizen's Advisory Committee on Salmon and Steelhead Trout in 1970. The Committee brought together sport and commercial fishermen, processors and the general public for the first time to make a comprehensive assessment of the status of California's salmon and to identify the key areas for needed research and legislation. Many of their recommendations, such as strengthening the State Forest Practices Act and increasing federal funding of enhancement activities, were acted upon.

The potential of enhancing the state's salmon stocks, based on the remaining available habitat, was recently appraised by the Department of Fish and Game. Based on these findings, the State Resources Agency proposed a $55 million allotment for salmon as part of the larger Parklands and Renewable Resources Bond Act on the June 1980 ballot. Though the package initiative was defeated by a small margin (4%), the proposal in itself indicated the importance the state government places on its efforts to enhance the salmon resource.

Public and private investments in renewable resources, such as salmon, can give continuing returns. Salmon habitat improvements and protection can benefit not only these fish, but also the other residents and users of the streams.



California's artificial rearing facilities for salmon and protected Wild and Scenic Rivers. (Redrawn from Kahrl, Water Atlas, *pp. 70-71 and Wahle,* Rearing Facilities, *p. 31. See bibliography. Illustration by Noreen Bonker.)*

[1]One-quarter percent of chinook released as fingerlings; one-half to one percent small smolts and four to six percent older smolts. R.J. Hallock, "The Status of Inland Habitat and Factors Adversely Impacting Salmon Resources, Sacramento River System King Salmon Population Model," California Department of Fish and Game, Anadromous Branch, p. 4.

[2]*Freshwater Habitat, Salmon Produced, and Escapements for Natural Spawning along the Pacific Coast of the U.S.*, report of the Anadromous Salmonid Environmental Task Force of the Pacific Fishery Management Council (Portland, Oregon: PFMC, 1979) p. 6.

[3]Prepared by the Joint Subcommittee on Aquaculture of the President's Federal Coordinating Council on Science, Engineering and Technology, June, 1980.

[4]R.T. Gunsolus, "The Status of Oregon Coho and Recommendations for Managing the Production, Harvest, and Escapement of Wild and Hatchery-reared Stocks," Oregon Department of Fish and Wildlife, Columbia Region, July, 1978.

[5]Central Valley Project reauthorization, U.S. Code, Title 16, Section 695d.

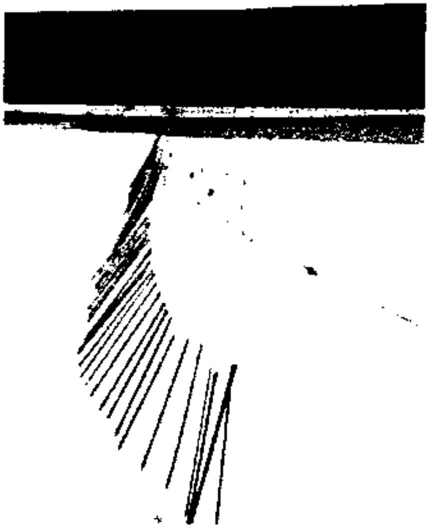
[6]Davis-Dolwig Act, California Water Code, Section 11900, et. seq.

[7]Porter-Cologne Water Quality Control Act, California Water Code, Section 13160, et. seq.

[8]Z'berg-Nejedly Forest Practice Act of 1973, California Resources Code, Section 4511.

[9]National Forest Management Act of 1976, U.S. Code, Title 16, Section 1600, et. seq.

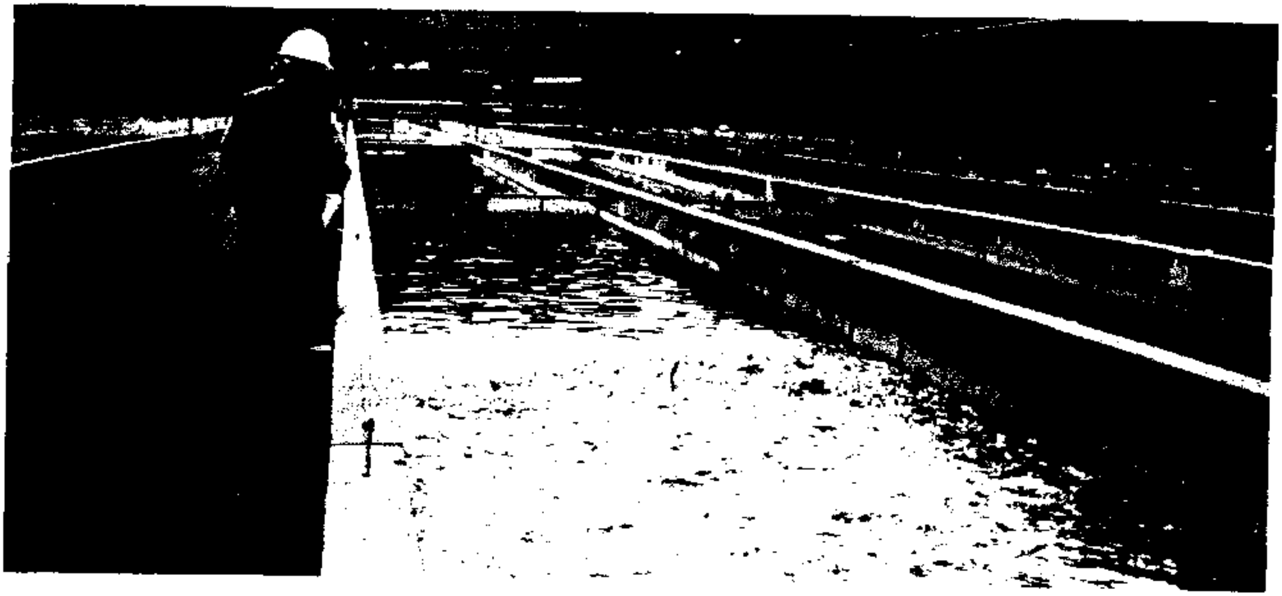
Views of a Salmon Hatchery



Weirs on the Mad River in Humboldt County deflect adult salmon, returning from their ocean migration, to the Mad River Hatchery.

The fish swim up fish ladders, which lead to holding ponds in the hatchery.

The salmon are killed, sorted and their eggs and milt are removed. The eggs are fertilized with the milt and placed into incubator trays. (Photo courtesy of the California Department of Fish and Game.)



After hatching, the young fish (called "fingerlings") are put into raceways. Hatchery personnel feed the salmon carefully balanced diets to ensure proper growth and development. River water is pumped into and circulates through the raceways. Fences and thin wires, strung above the raceways, discourage potential predators.

The fish are reared in the hatchery for about one year before they are released into streams. From there they make their way to the ocean.

All photos by Terri Morgan except as noted.

Fishing fleet, Eureka Harbor

(Photo by Terri Morgan.)

Salmon Management

The necessary complement to improving the salmon's inland habitat is better management of the ocean fishery to ensure an adequate escapement of spawners. One of the basic principles of fishery management is consideration of fishery stocks as units throughout their full geographic ranges. Salmon, like many other ocean species, are transboundary — that is, they cross over one or more state and national boundaries during their migratory period — and cannot be effectively managed on a state-by-state basis.

Solving these problems through a regional approach was one of the reasons the Fishery Conservation and Management Act was passed in 1976. The Act extended United States jurisdiction over fisheries — except highly migratory species like tuna — from three miles to two hundred miles out to sea. This includes jurisdiction over salmon originating in U.S. waters throughout their migratory range, except when entering another nation's waters.

The Act also created eight regional fishery management councils. As stipulated by law, the councils review the status of the stocks in their regions and, through the implementation of conservation and management strategies based on the best scientific information available, strive to achieve the optimum yield from each species. According to the Act, the term optimum yield from a fishery means "the amount of fish which will provide the greatest overall benefit to the nation, with particular reference to food production and recreational opportunities; and which is prescribed as such on the basis of the maximum sustainable yield from such fishery, as modified by any relevant economic, social, or ecological factors."[1]

The Pacific Fishery Management Council

California, along with Oregon, Washington and Idaho is part of the Pacific Fishery Management Council. The regional councils' chief responsibility is the preparation of management plans for each fishery in their respective geographical areas. The salmon plan contains information on the condition of the resource, the harvesting sector, the processors, the market and the consumers and recommends specific allocation of the predicted catch accordingly. These groups may participate in the process during council meetings and at public hearings, which are held throughout the states affected by the regional plans. After review and approval by the Secretary of Commerce, regulations are established and the plans are put into effect.

The 1980 salmon plan, according to the Pacific Fishery Management Council, was prepared by a team of scientists with special expertise on salmon with the advice of an advisory panel representing the various interests in the salmon fisheries.

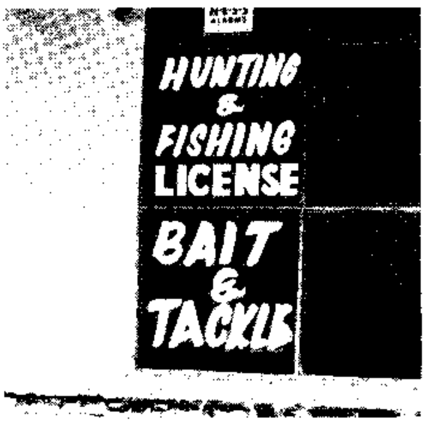
The plans recommend the opening and closing dates of the fishing season, what types of gear may be used, off limit areas and entry into the fishery. Before making final recommendations to the Secretary of Commerce, the Pacific Fishery Management Council is required to consider how these restrictions would affect the social and economic well-being of those who use the fishery.

Management of the salmon resource is an enormously complicated task and there are many problems involved. One of the major problems concerns the collection of data on which the reports are based. Insufficient funding, claim council members and the plan development team, is one of the reasons for this problem. The council, well aware of its limitations and of the complexity of the task, acknowledged this problem in the proposed 1980 plan:

"Time constraints set by administrative and legal procedures that require processing proposed plans and regulations at an early date to allow adequate review before implementing any regulations prevent complete consideration of the impact on the 1979 fishery. The spawning stocks cannot be fully addressed at this time, hence this assessment is based on incomplete data, yet they are the best available."[2]

Furthermore, the council can regulate only the harvesting of fishery resources and has no control over many other factors that directly affect the fishery, such as the condition of the habitat. This is a particular problem with the salmon fishery because the condition of the inland habitat is critical to the well-being of the stocks. Because salmon populations from different rivers fluctuate differently and the populations mingle in the ocean, accurately predicting the amount of fish that will be available for harvesting in any year is nearly impossible.

"It's hard to manage salmon in the ocean, because the fish come from mixed stocks. We don't know what river they're coming from or returning to," says Paul Jensen of the Department of Fish and Game. "When trying to build up stocks in a depressed area, you have to restrict all ocean catches since there is no way of telling what fish came from where."



Fishing licenses are required for both sport and commercial fishermen in California. (Photo by Terri Morgan.)

Another impediment to effective management of salmon is that the resource is in high demand by various user groups relative to its abundance.

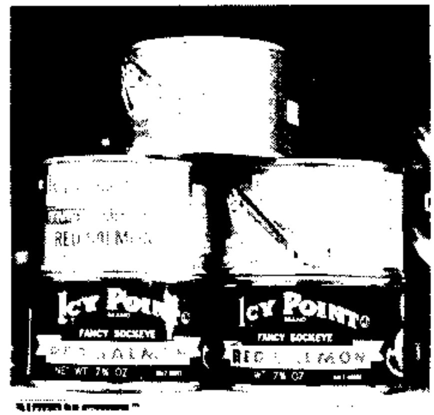
Many fishermen resent the new restrictions imposed by the council through quotas or season closures and are mistrustful of its intentions. They protest, for example, the fact that stringent regulations under which they must conduct their business affairs are based on admittedly inadequate and incomplete biological and socio-economic data.

"The strict regulations imposed on the ocean fishermen by the council are likely to force some fishermen out of the salmon business," says Alan Wyner, associate professor of political science and Sea Grant researcher at the University of California at Santa Barbara. Wyner has been studying the effectiveness of the Pacific Fishery Management Council as a regional management body. "Those restrictions, combined with rising fuel costs, will affect anyone who is marginal and susceptible to being affected by small decisions."

The Pacific Fishery Management Council is still in its infancy and many of the original data gaps are slowly being filled. The council has uncovered many areas where knowledge is lacking, however, suggesting research opportunities for biological as well as social scientists.

Limited Entry

The fishermen recognize the need for regulations to prevent overfishing because overfishing depletes the resource stock so considerably less fish are available for everyone to catch. Also, as the stocks decrease, the fishermen's catch effort must increase. This raises their costs per unit of effort, thereby decreasing their profits. According to the California Department of Fish and Game, the fishing effort for salmon in the state has almost tripled in the last fifteen years. Therefore, most fishery managers and many salmon fishermen see the need to limit fishing effort and generally support such programs as limited entry. Designed to keep the fishing effort in balance with the size of the fish stocks and to maintain fishing as an economically viable enterprise, limited entry restricts the number of boats or the number of fishermen.[3]



Canned salmon is imported from Alaska, Washington and Oregon. (Photo by Terri Morgan.)

In 1979, the California State Legislature passed a Commercial Salmon Fishing Moratorium for the 1980 and 1981 fishing seasons. Intended to prevent an increase in the number of commercial fishermen harvesting salmon, the moratorium allows only those who fished in previous years (1974-1979) to obtain salmon fishing licenses. The state of Oregon has also adopted a two-year moratorium for its salmon fishery. The purpose of such a moratorium is to halt the increase of fishing effort while the merits of a permanent limited entry program are examined. British Columbia, Washington and Alaska have been practicing various forms of limited entry in their salmon fisheries for the past few years (British Columbia since 1969, Alaska since 1973). California officials and salmon fishermen will be observing the impacts of these other programs before deciding whether to adopt a permanent program in California. If limited entry is established, the state must consider the potential economic, social and environmental impacts of such a program. By studying these impacts in other states California may be able to avoid making some mistakes. A study of the Alaskan limited entry program, for example, has indicated that limited entry caused a significant social impact on the native fishermen.[4]

Limited entry is a controversial issue and salmon fishermen are likely to participate in lively debates regarding the adoption and design of a program.

The Klamath River Fishery

Probably the most difficult management problem is associated with the Indian fisheries on the Klamath River. Salmon is one of the more important commercial fisheries in Humboldt and Del Norte Counties, and controversy surrounds the inland Indian fisheries. Reservation Indians on the Klamath River were granted fishing rights for subsistence by the Department of the Interior and are allowed to gill net salmon in the inland river system that runs through the reservation.

Recently, salmon runs on the Klamath have decreased and accusations have been made that the Indians are overfishing. Poor catch records have been kept and many complications surround the problem.

Confusion began when the federal government granted the Indians the right to subsistence fishing but did not define the term. To some, subsistence means fishing only for consumption by the fisherman and his family. Others interpret it as selling the catch to buy food to subsist on.

The three Indian tribes residing along the Klamath — the Yuroks, Hoopas, and Karoks — all use the salmon. Disagreement among and within the tribes has led to competition and internal problems. Most recognize that sufficient numbers of fish must escape upriver to reproduce and are willing to limit their harvest accordingly. A few others, illegally selling netted salmon for their personal gain, disregard the conservation efforts. Consequently, those who do allow salmon to pass their nets to conserve the stocks fully realize that these fish are likely to be caught by someone else further upstream. It is not surprising that conservation efforts are eroding in such a situation.

The Klamath River situation has the potential for violence and local law enforcement officials are reluctant to enter into it. This lack of enforcement apparently has allowed some non-Indians to overfish the sport limit without reprisals, further compounding an already complicated problem.

The inland fishery is causing problems for the Pacific Fishery Management Council which, by federal law, must allow sufficient escapement to the Klamath River. Because salmon escapement to the Klamath decreased, the council was forced to cut back the ocean salmon commercial fishing season in 1979 and 1980. This decision was unpopular with commercial fishermen who insist the gill netters will catch all the returning fish and not allow them to spawn upriver.

No one is sure what course will be taken to finally resolve these problems. Years of misunderstandings, mistrust and prejudice among the groups complicate the issue and compromise solutions will come slowly.

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[1] *Fishery Conservation and Management Act of 1976; Statutes at Large* Public Law 94-265.

[2] *Proposed Plan for Managing the 1980 Salmon Fisheries off the Coast of California, Oregon and Washington*, (Portland, Oregon: Pacific Fishery Management Council 1980).

[3] R.L. Stokes, "Limitation of Fishing Effort, An Economic Analysis of Options," *Marine Policy* Vol. 3 (October 1979): 289-301.

[4] Steve Langdon, *Transfer Patterns in Alaska Limited Entry Fisheries*, Final Report for the Limited Entry Study Group of the Alaskan State Legislature. (January 1980).

Soquel Creek, Santa Cruz County. (Photo by Terri Morgan.)

The Salmon's Future

The fate of the salmon resource is determined by three factors: the biology of the fish, the condition of their habitat and fishing pressures. Salmon have certain requirements for survival and a limited ability to adapt to or tolerate change. Their reproductive capacity can offset population losses to fishing and environmental stress up to a point. But the stocks will continue to decrease unless humans curb or compensate for habitat degradation and regulate fishing efforts.

The ocean salmon fishery is regulated on the basis of recommendations made by the Pacific Fishery Management Council. But management is not an easy task. While collecting biological, economic and sociological information on the salmon fishery for its original management plan in 1977, the council realized that many aspects of the resource were not well understood. In doing so they identified some problems that must be overcome before the fishery can be effectively managed.

One of the council's most important concerns is understanding how much of the resource is available for allocation. How many salmon are in the ocean? How many are in the rivers and streams? Comprehensive stream assessments are needed to take full account of the stocks. Migration studies are necessary to discover where the salmon now in the ocean originated and where their migratory routes take them. Salmon cross over state and national boundaries, complicating management. For example, Oregon boats can catch fish spawned in California, and California boats can catch fish spawned in Oregon.

Another major concern is to ensure adequate escapement. How many fish are necessary to replenish the salmon populations? Are we allowing too many or too few fish to return to spawn in fresh water? By taking stock of the resource and quantifying escapement needs, management officials can better decide how many salmon can be harvested. Yet precise figures may always be elusive until researchers discover what causes fluctuations in catch and escapement from year to year.

Before recommending fishing regulations, the council must consider what impact the regulations would have on the fishermen, the processors and the consumers. What economic impacts do season closures have on fishing communities? What effect would limited entry have on the fishery? While managing for escapement, the council must be sure that the restrictions are not so severe that they force the fishermen out of business.

Other important decisions that involve factors indirectly related to the salmon resource are not under the control of the council. The inland salmon resource competes with agriculture, dams, hydroelectric plants and many other industries for use of the water. Is it better to guarantee flows for fish to protect a renewable resource? Or to divert water for agriculture or to build stores for hydroelectric power? All protective measures entail financial investment or sacrifice, and decisions cannot be based on a simple right or wrong plan of action.

The power of arguments for allocating water to salmon decreases as other demands on the water supply grow. To meet the water needs of southern California, it may be necessary to bring more water from northern California south through the peripheral canal. This rerouting could decrease the salmon runs in the north.

How much effort is directed toward protecting salmon depends on its value in relation to the value of other resources. Salmon fishing is important as a food supply, as a means of livelihood, as a cultural heritage and for recreation. Additionally, many people see the clear running streams needed by the salmon as an essential part of a healthy environment.

Since we depend on our hatchery programs to help sustain the fishery, several hatchery-related problems must be resolved. Diseases cause the majority of hatchery mortalities and new vaccines and medications must be developed before disease ceases to be a significant problem. To minimize stunting and mortality among hatchery releases and pen-reared fish the smoltification process needs to be completely understood. If hatcheries continue to produce more and more salmon, the impact of hatchery fish on the environment must be understood. How do

Eureka Harbor, Humboldt County (Photo by Terri Morgan.)

hatchery-reared fish affect or interact with natural stocks? How does their release into rivers and streams affect the ecological balance of these environments? How does their introduction into the ocean environment affect other native populations?

Many basic biological questions about the salmon also remain unanswered. How do salmon recognize their home stream when they return to spawn? How do they time their return so accurately? What special mechanism do they use to navigate during their lengthy ocean migration? What happens to salmon when they enter the ocean; where do they go and why? Few studies of salmon have been done in the wild and population dynamics, mortality rates and predator/prey relationships are still unknown.

The more we discover about salmon as a renewable resource, the more effective management will become. Though much has been learned through years of research and investigations, many specific questions remain unanswered. Cooperative efforts among university and federal and state agency researchers and individuals will lead to a broader understanding of the resource and how it is used for economic, social and aesthetic benefits.

California Salmon Fishing Ports

GLOSSARY

anadromous fish — those that run upstream from the ocean to spawn in fresh water.

aquaculture — culture of freshwater or marine plants and animals. There are two types: in "extensive" aquaculture, the main part of the organism's growth is under low density conditions, and natural productivity of the water system provides for most of their requirements, e.g., rear-and-release operations like ocean ranching. In "intensive" culture, the organisms are grown in high density in a controlled environment with supplemental feeding, e.g., pen rearing.

escapement — the number of fish that escape harvesting by the fishery and return upriver to spawn.

estuary — a semi-enclosed coastal body of water that has a free connection with the open sea and within which seawater is measurably diluted with fresh water derived from land drainage.

hatchery — a facility where fish eggs are incubated to hatch. Salmon hatcheries often include an artificial waterfall ("fish ladder") to attract returning adults into the facility, a station for taking eggs and milt for artificial fertilization, and ponds for raising the young fish. Young fish are released to grow to adulthood in the sea.

imprint — the permanent memory of a home river scent that helps the salmon recognize its home site when it returns to spawn. Salmon are susceptible to imprinting just prior to smoltification.

maximum sustainable yield (MSY) — the maximum number of fish that can be harvested, while leaving enough fish to reproduce, so that the size of the population is maintained.

ocean ranching — private hatchery operations that are supported by sale of adult fish that return to the facility.

optimum sustainable yield (OSY) — MSY modified by consideration of economic and social factors in the fishery.

pen rearing — raising salmon in large floating net pens set into sea water at a protected location along the coastline. Pen rearing refers to two practices: Smolts held at a site for a few weeks will tend to become imprinted to return there as adults. Therefore, this technique can be used to establish a new run without a homestream. Also, salmon can be raised in pens until they are about 10 inches long. These fish, which are never released to the open sea, are sold as individual-portion, "pan-size," fish.

smoltification — the process by which a young salmon transforms internally and externally from a freshwater fish to one capable of living in salt water.

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Loading smolts for transport to the release site. *(Photo courtesy of Ron Kusano.)*

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