

23 Culture of Salmon



Salmon sorting at Mokelumne River hatchery. Photo credit: Department.

History

Different methods are used for aquaculture production of salmon. The three major techniques are salmon ranching, land based tank operations and net pen rearing. At salmon ranch hatcheries, adult fish are spawned, the eggs are hatched and the young are reared in tanks to increase their size and chances of survival in the wild. The salmon smolts are then released and grow to market size while at liberty in the ocean. After maturing at sea the salmon return to the hatchery where they are harvested. If at least three to five percent of the released salmon return to be harvested, a private salmon ranch may be profitable. However, it is not uncommon for 98 to 99 percent of the salmon to be lost to natural and fishing mortality before they can return to the hatchery so private operations often do not have enough fish return to be cost effective.

In contrast, the basic concept of public mitigation hatcheries is to produce enough fish to replace those lost due to human activities which have eliminated access of fish to spawning and rearing habitat. The purpose of these hatcheries is to provide for existing fisheries and also return enough adult fish to the hatchery to produce sufficient eggs to continue the process. In essence the 'profit' for a public mitigation hatchery is the continuation of spawning runs and the maintenance of recreational and commercial fisheries.

Land based tank operations maintain all of the fish at the facility until harvest. Fish are kept in tanks made of concrete, fiberglass or other materials. Round tanks are commonly used and are often in the range of 30 to 40 feet (9 to 12 meters) in diameter. Water is pumped through the tanks to maintain good water quality, and growth comes from manufactured feed provided by the aquaculturist. Captive broodstock programs

are operated in a similar manner and may be utilized to augment or reestablish depleted stocks of fish.

Net pen facilities use young fish produced in hatcheries, which are then placed into pens where they are fed until grown to market size. The pens are normally made from flexible netting material suspended from floats and are generally a few hundred square feet at the surface. Pens are often linked together to form large units of up to many acres. The net pens are usually placed in sheltered saltwater areas where protection from ocean storms is provided and good water quality is maintained by natural currents. Technologies are being developed to create large scale enclosed ocean rearing systems in order to address concerns about disease and effluent discharge and their effects on wild fish and local ocean environments.

Salmon have been produced in California by both private and public hatcheries. While the history of private trout production in California is strong and dates back to the 1800s, private commercial production of salmon in California has been intermittent and never very substantial. The beginning of recent interest in commercial salmon production was the authorization by the California Legislature in 1968 for the first (and only) private salmon ranching operation. In 1979, the legislature authorized the operation's move to a site on Davenport Landing Creek (Santa Cruz County), where the operation was active for several years.

In California, land based tank operations were tried in the 1980s and 1990s and accounted for some limited private aquaculture production of salmon. Most commercially produced salmon were from tank rearing operations located in northern California, where cold water suitable for salmon culture is more readily found. Fish were grown to market size in tanks using either fresh or salt water. Steelhead trout, *Oncorhynchus mykiss*, were produced from domestic broodstock maintained by California aquaculturists, whereas coho salmon, *O. kisutch*, and Atlantic salmon, *Salmo salar*, eggs or fingerlings were imported from out of state to California farms. Salmon culture has not been a major component of the California's private aquaculture industry and never contributed more than 5 percent to the total value of the industry's production. Currently there are no commercial salmon culture operations in California.

Conversely, public salmon hatchery operations play a key role in the management of California's natural resources. Hatcheries have been built and operated to supplement natural salmon resources or to mitigate for the loss of natural production that occurs when water and power generation projects eliminate salmon spawning habitat. Thus, hatcheries help provide for the multiple beneficial use of the state's water resources. Public hatcheries produce approximately 40 million fish each year and are critical to maintaining the state's recreational and commercial salmon fisheries. Recent research suggests that hatchery produced fish provide a substantial percentage of the ocean fishery off the central California coast.

Public hatchery production of salmon in California dates back to 1872 with the establishment of Baird Hatchery on the McCloud River in the upper Sacramento River drainage. Several other salmon hatcheries and egg taking stations also began operations in the late 1800s and early 1900s. Baird originally operated as an

independent hatchery, then as an egg collecting station for salmon and trout reared at Mount Shasta Hatchery (then called Sisson Hatchery). After the construction of Shasta Dam, Mount Shasta Hatchery and the upper Sacramento spawning grounds were separated from the lower Sacramento River and the Pacific Ocean. Coleman National Fish Hatchery was built in 1942 to mitigate for lost spawning habitat above Shasta Dam. It replaced many of the early hatcheries, including most of the salmon operations at Mount Shasta. Coleman Hatchery is on Battle Creek, a tributary of the Sacramento River at Anderson (south of Redding). Livingston Stone Hatchery, located north of Redding at Shasta Dam, was constructed to help in the recovery of listed winter-run Chinook salmon, *O. tshawytscha*. These two facilities are the only federally operated fish hatcheries in California. Today there are six California Department of Fish and Game (Department) operated salmon mitigation hatcheries, two of which also raise fish for recreational and commercial fishery enhancement. The Department is also involved in a multi-agency captive coho salmon rearing program at Warm Springs Hatchery to recover depleted Russian River coho stocks. All six of these state operated hatcheries have been built since 1955. The mitigation hatcheries are located on central valley and north coast rivers downstream from dams constructed for water or power development.

Hatchery Location

Iron Gate	On the Klamath River below Copco Lake (Siskiyou County)
Trinity.....	On the Trinity River below Trinity Lake (Trinity County)
Feather River	On the Feather River below Lake Oroville (Butte County)
Mokelumne River.....	On the Mokelumne River below Camanche Reservoir (San Joaquin County)
Nimbus.....	On the American River below Folsom Lake (Sacramento County)
Warm Springs	On Dry Creek below Lake Sonoma (Sonoma County)

The Department also operates the Merced River Fish Installation below Lake McClure (Merced County) to rehabilitate fall run Chinook salmon in the Merced River and there is a non-profit salmon and steelhead enhancement hatchery on the Smith River at Rowdy Creek (Del Norte County). It operates under an individual category in the California Fish and Game Code. One hundred percent of current (2009) Rowdy Creek production is to be coded wire tagged to evaluate performance and potential impacts on wild populations.

Status

Nationally, and internationally, net pen rearing of salmon has proven to be the most successful method of private aquaculture production of salmon for the seafood market but has been criticized for its effects on wild stocks of fish due to increased nutrient loading, release of drugs and therapeutants to the environment, disease and concentration of parasites, and escape of fish which are genetically distinct from local populations. Legislation passed in 2003 prohibits, with minor exceptions, the culture of

salmonids in California coastal waters and currently there is no private aquaculture of salmon being conducted in the state.

Ocean salmon acclimation and imprinting pen programs have been attempted in California with the intent of increasing local ocean harvest. In these programs fish from public hatcheries are kept for a period of time (days or weeks) deemed sufficient to acclimate the fish to local conditions with the assumption that they will remain in the general area after release. Saltwater pen operations in recent years have been located at Tiburon, Port San Luis, Monterey and Santa Cruz. The intent of these net pen programs is to enhance local ocean fisheries, but evaluation of tagged fish released in the early 1990s suggests that they may exhibit more movement than formerly thought. Current (2008) California Fish and Game Commission policy calls for the tagging of these fish and development of a monitoring plan to evaluate performance.

State and federal hatcheries produce Chinook and coho salmon using the same production techniques as other salmon ranching operations. Returning adults are artificially spawned and the offspring are reared to smolt or yearling size before they are released at the hatchery or at other freshwater or brackish/saltwater sites to migrate to the ocean where they grow to adults. Chinook salmon return to be spawned, usually three or four years after release. Coho generally spend one year in freshwater and return from the ocean to spawn as three-year olds.

A 'Constant Fractional Marking Program' for Central Valley fall run Chinook was instituted in 2006. The objectives of this program include evaluation of contribution rates of hatchery fish to overall salmon populations, exploitation rates of hatchery and naturally produced fish in ocean and inland fisheries, effects of water project operations on fall run Chinook salmon, and effects of hatchery produced fish on naturally produced populations. Twenty-five percent of all fall run fish released from Central Valley hatcheries will be coded wire tagged. Tags will be recovered in the ocean and inland fisheries, during carcass surveys and other monitoring operations, and from fish returning to the hatcheries.

Hatchery Genetic and Management Plans (HGMPs) are being prepared for all stocks propagated at public hatcheries in response to recent Endangered Species Act (ESA) listings of several Pacific salmon and steelhead stocks. These will be submitted for federal review by the National Marine Fisheries Service to evaluate potential interactions with listed stocks. Public hatchery production is currently based on the 'Goals and Constraints' guidance document for each hatchery and remains relatively constant; therefore years of low natural production result in harvests with a larger proportion of hatchery fish. Most of the public hatchery production of salmon in California is intended to mitigate for the loss of habitat caused by construction of dams for water and power development. The concept of providing mitigation for losses to fish and wildlife caused by the building of a government project was originally established by the U.S. Congress when it enacted the Fish and Wildlife Coordination Act of 1934. The need to replace the natural fishery resources eliminated by these projects continues to have high priority with the people of California.

Walter J. Beer

California Department of Fish and Game

WBeer@dfg.ca.gov

Further Reading

Barnett-Johnson R, Grimes C, Royer C and Donohoe C. 2007. Identifying the contribution of wild and hatchery Chinook salmon (*Oncorhynchus tshawytscha*) to the ocean fishery using otolith microstructure as natural tags. Can. J. Fish. Aquat. Sci. 64:1683-1692.

California Advisory Committee on Salmon and Steelhead Trout. 1988. Restoring the balance: 1988 Annual Report. 84 p. Available from:

http://www.fishcalendar.net/cac/CACSST_1988_Restoring_the_Balance.pdf

Leitritz E. 1970. A history of California's fish hatcheries 1870-1960. Calif. Fish Bull. 150. 86 p.

Leitritz E and Lewis RC. 1976. Trout and salmon culture – hatchery methods. Calif. Fish Bull. 164. 197 p.

Thorpe JE (editor). 1980. Salmon Ranching. New York, NY: Academic Press. 441 p.