Pacific Herring

History of the Fishery

Pacific herring (*Clupea pallasi*) landings peaked three times during the past century in response to market demands for fishmeal, canned fish, and sac-roe. During the intervening years, herring catches were low, when most of the herring catch was used as pet food, bait, or animal food at zoos. The herring reduction fishery peaked in 1918 at eight million pounds, but this fishery ended in 1919 when reduction of whole fish into fishmeal was prohibited. From 1947 to 1954 herring were canned to supplement the declining supply of Pacific sardines; landings peaked in 1952 at 9.5 million pounds. Canned herring, however, proved to be a poor substitute for sardines and limited demand led to the demise of this fishery by 1954.

In 1973, sac-roe fisheries along the West Coast of North America from Alaska to California developed to supply the demands of the Japanese market. This occurred after domestic Japanese stocks crashed and Japan and the Soviet Union agreed to ban the harvest of sac-roe herring in the Sea of Okhotsk. The ban was enacted after these stocks were depleted by overfishing. The Japanese government also liberalized import quotas, which opened the sac-roe market to United States and Canadian exporters. Since then, herring in California have been harvested primarily for their roe, with small amounts of whole herring marketed for human consumption, aquarium food, and bait.

Herring ovaries (commonly referred to as "skeins" by those in the fishing indusrty) are brined and prepared as a traditional Japanese New Year's delicacy called "kazunoko." Brined skeins are leached in freshwater overnight and served with condiments or as sushi. Most herring taken in California are trucked from the port of landing to a processing plant for removal of skeins and brining and grading. Skeins are graded by size, color and shape, packed in plastic pails, exported for sale, and auctioned. Some herring are frozen and exported to China for processing where labor costs are low. Herring skeins from San Francisco Bay are typically smaller in size than those produced in British Columbia and Alaska but are highly valued for their unique golden coloration.

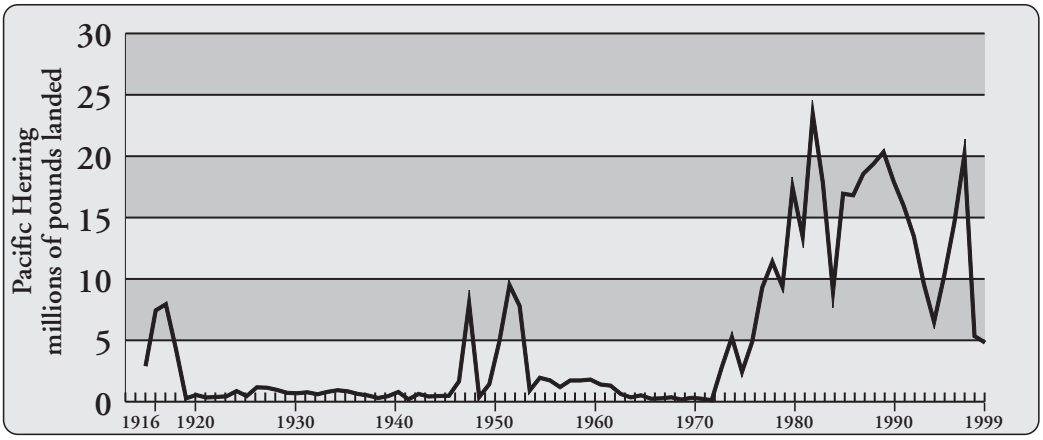
Pacific Herring, *Clupea pallasi*
Credit: DFG

California sac-roe herring landings peaked in the 1996-1997 season at 23.6 million pounds, and then fell to a record low harvest of four million pounds the following season. Ocean conditions due to the 1997-1998 El Niño produced herring in poor condition which were less susceptible to gillnet gear resulting in reduced landings. In addition, herring may have been displaced by changes in ocean currents, which are also attributed to El Niño, resulting in downswings of stock size. Stocks showed signs of rebuilding in the 1998-1999 season but declined again in 1999-2000 in spite of favorable La Niña conditions. Landings increased, however, to 6.8 million pounds in 1999-2000 season due to much improved physical condition of fish from the previous season.

The sac-roe fishery is limited to California's four largest herring spawning areas: San Francisco Bay, Tomales Bay, Humboldt Bay, and Crescent City Harbor. San Francisco Bay has the largest spawning population of herring and produces more than 90 percent of the state's herring catch. The four spawning areas are managed separately by the California Department of Fish and Game (DFG); catch quotas are based on the latest population estimates from acoustic surveys and spawning-ground surveys. Quotas are adjusted annually and are generally set at about 15 percent of the amount of herring expected to return to spawn at each spawning area. Since quotas are set before the start of the spawning season, they are conservative and allow for potential declines in herring biomass. If the herring biomass declines, and spawning escapement is less than expected, the landings may approach the department's recommended maximum harvest rate of 20 percent.

The sac-roe fishery is managed through a limited-entry system, which was implemented in the 1973-1974 season with 17 permits issued. Since 1983, only five new permits have been issued, and the number of annual herring permits has stabilized at just over 450. Approximately 400 of the permits are for the San Francisco Bay fishery in which an estimated 120 vessels participate. During the 1979-1980 season, the Fish and Game Commission decided not to issue any new round haul permits for the San Francisco Bay fishery with the intent of converting the sac-roe fishery to gillnet only by attrition. When it was clear that the number of round haul permits would not decline further due to the transferability of permits in 1988, the DFG developed a five-year conversion plan, which was implemented in the 1993-1994 season. The 1997-1998 season marked the completion of the San Francisco Bay sac-roe fishery conversion to a gillnet only fishery.

The sac-roe fishery, like many quota fisheries, is extremely competitive among fishermen and buyers for a share of the catch. Competition tends to breed innovation, especially with respect to gear, boats, and fishing practices



Commercial Landings 1916-1999, Pacific Herring
Data Source: DFG Catch Bulletins and commercial landing receipts.

in this potentially lucrative and high-pressure fishery. One of the more noticeable changes has occurred in boat design. The composition of the San Francisco fleet slowly evolved from converted wooden and fiberglass stern picking salmon trollers to fast state-of-the-art welded aluminum bow pickers, many outfitted with multiple jet drives and the latest in fish finding electronics. One piece of equipment that increased the efficiency of the gillnet fleet was the net shaker, a hydraulically driven drum with fins, working in concert with the net drum. This device shakes the net free of fish, eliminating the need to shake the net by hand. As a result of these and other changes, the sac-roe fleet has become very efficient.

Herring buyers pay fishermen based on the percentage of ripe skeins in the catch. This is calculated from several random 10-kilogram samples per landing taken by roe technicians. Each fish sampled is sexed and ripe skeins are extracted, placed on a scale and weighed. The total weight of the ripe skeins is then divided by 10 kilograms, resulting in the "roe count" or roe percentage. A typical "roe count" for the San Francisco fishery in January is 13 to 14 percent. The ex-vessel price paid is based on 10 percent yield, and is adjusted for percentage points above or below. A yield of 10 percent or higher is considered the minimum acceptable by the sac-roe buyers. In the year 2000, the base price for California herring with 10 percent roe yield was an estimated $500 per ton of whole fish. The base price for 10 percent roe count fish peaked at an estimated $2,000 per ton in 1979, when landing values reached as high as $4,000 per ton when adjusted for roe percentage. In recent years, the base price has ranged between $500 and $2,000 per ton. Since 1980, the ex-vessel seasonal value of the sac-roe catch in California has ranged from two million to 19.5 million dollars.

Another aspect of California's herring industry is the roe-on-kelp fishery. Beginning in 1965, scuba divers harvested species of algae with herring eggs attached from Tomales and San Francisco Bays. In the 1984-1985 season, a sac-roe permittee received a permit on an experimental basis to harvest roe-on-kelp using unenclosed floating rafts from which fronds of giant kelp are suspended. This product known as "komochi kombu" or "kazunoko kombu" is also a Japanese delicacy and prepared similarly to kazunoko. There are 11 roe-on-kelp permits for the 2000-2001 fishery in San Francisco Bay. Permits are available to permittees willing to trade their sac-roe permits for roe-on-kelp permits.

Currently, giant kelp is harvested from the Channel Islands off southern California or Monterey Bay, brought to San Francisco Bay, suspended from floating rafts or longlines hung beneath piers. Rafts are positioned in locations where herring spawning is expected to occur and then anchored. Once spawning has commenced, suspended kelp is left in the water until egg coverage is sufficient, or spawning has ended. In some instances, suspended kelp is harvested prematurely with less than optimum coverage because freshwater surface runoff may cause product deterioration.

Preliminary roe-on-kelp product grading is conducted by the permittee prior to harvest to determine if coverage is ample enough to warrant harvesting. Once the product is harvested, grading criteria such as the dimensions of the kelp blade, uniformity of egg coverage, thickness or number of egg layers, kelp condition, presence of eyed embryos, and the presence of silt are all used to determine the price paid to the fisherman. Roe-on-kelp has a per pound value much higher than herring roe. Ex-vessel prices range from $4 to $20 per pound.

Herring regulations changed yearly as the fishery expanded and new conflicts or issues were addressed. Management concepts new to commercial fishing in California were introduced as the herring fishery developed, such as limited entry, permits issued by lottery, individual vessel quotas, quota allocation by gear, the platoon system used to divide gillnet vessels into groups, the transferability of sac-roe fishery permits, and the conver-

sion of round haul permits to gillnet permits. Many of these were controversial management decisions, but they have proven to be effective solutions to socioeconomic conflicts in a congested fishery.

Status of Biological Knowledge

Pacific herring occur within the coastal zone (waters of the Continental Shelf) from Baja California to Alaska and across the Pacific rim to Japan and China. Known spawning areas in California include San Diego Bay, San Luis River, Morro Bay, Elkhorn Slough, San Francisco Bay, Tomales Bay, Bodega Bay, Russian River, Noyo River, Shelter Cove, Humboldt Bay, and Crescent City Harbor. California's largest spawning population of herring utilizes San Francisco Bay. Most spawning areas are characterized as having reduced salinity, calm and protected waters, and spawning-substrate such as marine vegetation or rocky intertidal areas; however, man-made structures such as pier pilings and riprap are also frequently used spawning substrates in San Francisco Bay.

Results of tag and recovery studies from Canada indicate that 25 percent of the herring may stray between adjacent spawning areas in British Columbia. The problem of stock identification has not been resolved in California, and it is not known whether adjacent spawning areas contain genetically distinct stocks. However, each spawning area in California where herring fishing is allowed is managed on the assumption that its spawning population is a separate stock.

During the spawning season (November through March), schools of herring enter bays and estuaries, where they may remain up to three weeks before spawning. School size varies but can be as large as tens of thousands of tons and miles in length in San Francisco Bay. Salinity is an important factor in the success of fertilization and embryonic development, and reduced salinity may act as a cue for spawning. When a school is ready to spawn, male herring initiate spawning by releasing milt. A pheromone in the milt triggers spawning by females which lay their adhesive eggs on suitable substrate. Fecundity is 220 eggs per gram of body weight, and a large female herring may lay 40,000-50,000 eggs. Female herring come in contact with the substrate while spawning, extruding a strip of adhesive eggs that is two to three eggs wide. Repeated passes by thousands upon thousands of females can build the eggs up to a thickness of four to five layers. Spawn depth distribution generally is shallower than 30 feet deep, but has been found to a depth of 60 feet in San Francisco Bay. A large spawning run may last a week and can result in 20 miles or more of the shoreline being covered by a 30-foot-wide band of herring eggs.

During the incubation period (about 10 days) embryos are vulnerable to predation by marine birds, fish, and invertebrates. They may also die from desiccation or freezing if exposed during low tidal cycles. Normally, between 50 and 99 percent of herring embryos die before hatching. Human induced causes of mortality at this stage include smothering caused by suspended sediments from dredging, and anti-fouling agents such as creosote.

Herring embryos hatch into larvae, which eventually metamorphose into juvenile herring. The distribution of larval herring in bays and estuaries is not well known, but juvenile herring from San Francisco Bay have been found as far inland as the Delta Pumping Plant at Tracy. Juveniles may remain in the bay until summer or early fall, when they migrate to the open ocean.

Some herring reach sexual maturity at age two when they are about seven inches in length; all are sexually mature at age three. California herring may live to be nine or 10 years old and reach a maximum length of about 11 inches, although fish older than seven are rare. Adult herring leave the bay immediately after spawning, and their distribution while in the ocean is not well known. Herring are sometimes caught in Monterey Bay in the summer, and are also caught by groundfish trawlers off Davenport (north of Santa Cruz) just prior to the spawning season.

While in the ocean, adult herring feed on macroplankton such as copepods and euphausiids. Larval and juvenile herring are believed to feed on molluscan larvae and other zooplankton while in bays and estuaries. Herring are a forage species for a diverse group of marine fishes, birds, and mammals. Spawning events in particular provide an opportunity for feeding. As herring move into shallow water to spawn, a feeding frenzy may commence which can last for several days. Gulls, cormorants, pelicans and other marine birds, California sea lions and harbor seals, a variety of fishes (including sturgeon in San Francisco Bay) and invertebrates feast on adult herring and embryos.

Status of the Population

The size of herring spawning populations in Tomales and San Francisco Bays is estimated annually from hydroacoustic and spawning-ground surveys. Abundance fluctuates widely due to variations in recruitment (the first appearance of young fish, primarily two-year-olds, in the spawning population) caused by environmental factors that affect primary productivity, especially El Niño events. Since 1979, the San Francisco Bay herring biomass has ranged from a high of 99,050 tons to a low of 20,000 tons, with peaks occurring in 1982 (99,600 tons), 1988 (68,900 tons), and 1996 (99,050 tons). The lowest biomass

estimates have occurred during or just after El Niño events – 40,800 tons in 1984, 21,000 tons in 1993, and 20,000 tons in 1998. The lack of upwelling and associated warm water conditions that occur during El Niño events reduces the production of food for herring, which can affect their condition and survival. It also may displace herring to areas of colder water. San Francisco Bay's population has not yet recovered from the affects of the 1997-1978 El Niño; spawning biomass was estimated at 27,400 tons in 2000.

The Tomales Bay spawning biomass estimates have ranged from a high of 22,163 tons in 1978 to a low of 345 tons in 1990 with a 26-year average of 4,671 tons per season. The season following the 1983 El Niño spawning biomass declined about 90 percent suggesting the herring population had not escaped the effects of that strong oceanic event. The next four years the population remained unstable with spawning escapement in Tomales Bay alternating between average and very poor. During the California drought, which lasted from 1987 to 1992, the herring spawning population severely declined in Tomales Bay. Consequently, the department closed the Tomales Bay commercial herring fishery from 1990 through 1992 to hasten the recovery of the stock. Spawning biomass in Tomales Bay averaged approximately 2,817 tons per season from 1993 through 1997; however, during the intense 1997-1998 El Niño, spawning biomass dropped to 586 tons. Although the Tomales Bay population rebounded to near normal levels the following season, the spawning biomass fell to 2,011 tons in 2000. Preliminary aging of Tomales Bay herring, caught during the 1999 and 2000 seasons, shows five- and six-year-old herring under represented in the spawning population. Because the Tomales Bay herring fleet has had a very low exploitation rate since the 1997-1998 season, the scarcity of older fish in the population is most likely related to oceanic conditions – not overfishing.

Humboldt Bay's spawning population has not been assessed since the 1990-1991 season, when 400 tons was estimated to have spawned. This population supported a small, but successful fishery with a 60-ton quota for many years. However, over the last 12 years fishermen have observed a decline in the spawning population, and in the last five years fishing effort has also declined. Only one of the four permits issued for Humboldt Bay has been used to fish in the last three seasons. It has been suggested that aquaculture impacts to eelgrass, the primary spawning habitat for herring in Humboldt Bay, may have contributed to the observed decline.

Individual spawning runs have been estimated in Crescent City Harbor, but no seasonal population estimates have ever been made for the area. The success of the small fishery that occurs there depends on the size of schools that appear. Because of the fishing methods used and large local populations of harbor seals and sea lions, it is very difficult for fishermen to catch fish from small schools.

Management Considerations

See the Management Considerations Appendix A for further information.

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