11. PACIFIC HERRING

Pacific Herring, *Clupea pallasi* Photo Credit: Ryan Watanabe

Review 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 (3,632 metric tons), 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, *Sardinops sagax*; landings during this period peaked in 1952 at 9.5 million pounds (4,313 metric tons). 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 developed along the West Coast of North America from Alaska to California to supply the demands of the Japanese market. This occurred after domestic Japanese herring stocks crashed due to overfishing and Japan and the Soviet Union agreed to ban the harvest of sac-roe herring in the Sea of Okhotsk. 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 industry) 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, 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 valued for their unique golden coloration.

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. These areas are managed separately by the California Department of Fish and Game (DFG). San Francisco Bay has the largest spawning population of herring and produces 90 to nearly 100 percent of the state's annual herring catch. Annual catch quotas for San Francisco are based on the latest population estimates from spawning-ground surveys. Quotas are adjusted annually and are generally set between 10 to 15 percent of the amount of herring expected to return to spawn during that season at each spawning area. Quotas are set to maintain a sustainable fishery as well as providing sufficient Pacific herring to conserve living resources of the ocean that utilize herring as a food source. Currently Tomales Bay, Humboldt Bay, and Crescent City have fixed quotas of 350 tons (318 metric tons), 60 tons (54.5 metric tons), and 30 tons (27.2 metric tons), respectively. Quotas are set at levels thought to be sustainable for these areas and can be reduced if fishery managers note declines in returning biomass estimates.

The herring sac-roe fishery is managed through a limited entry system, which was implemented during the 1973-1974 season when 17 permits were issued. During the 1990s the number of herring permits peaked at over 450 with over 120 vessels participating. In contrast, during the 2006-07 season permit renewals fell to 250 and only 25 vessels elected to participate. This reduction of effort is only one of the many changes this fishery has undergone through history. 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 a gillnet only fishery. This was done to help alleviate gear conflicts and prevent quota overage due to the large net-sets. When it was clear that attrition alone would not retire all the round-haul permits, DFG then developed a five-year conversion plan which was completed during the 1997-1998 season. This marked the beginning of a gillnet only fishery. The most recent change in the sac-roe fishery occurred during the 2004-2005 season when the industry requested a mesh size reduction from 2⅛-inches (54-millimeters) to 2-inches (51-millimeters) in an attempt to access more of the available herring biomass. Fisherman sought this change due to a smaller size-at-age trend and lack of older age classes (larger fish) in the herring population. As would be expected, this regulation change is being closely monitored to determine any potential impact to the age structure of the population.

In California, sac-roe herring landings have peaked three times since the opening of the fishery with landings exceeding 20 million pounds (9,080 metric tons) during the 1982, 1989 and 1997 seasons (Figure 11.1). However, over the last decade landings have declined dramatically with total landings for the 2004-05 season the lowest on record at 362,000 pounds (164 metric tons). The value of the landings is based on the percentage of ripe skeins in the catch. Herring buyers calculate this by collecting several random 10-kilogram (22-pound) samples from each landing. Each fish sampled is sexed and ripe skeins are extracted and

weighed. The total weight of the ripe skeins is then divided by 10 kilograms (22 pounds), resulting in the “roe count” or roe percentage.

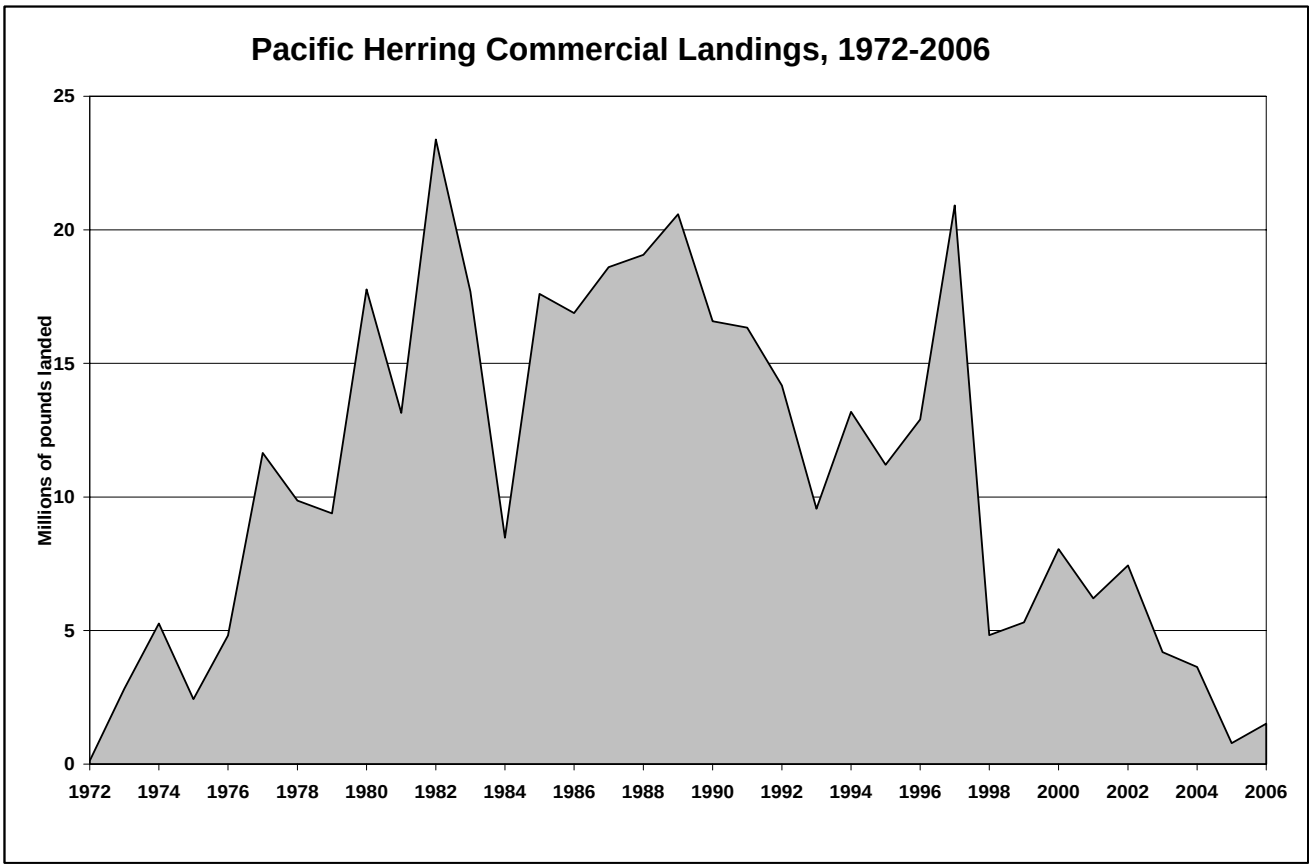

Figure 11.1. Commercial landings of Pacific herring in pounds from 1972 through 2006.
Data Source: CDFG commercial landing receipts.

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. 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. For the 2006-2007 season, the base price for California herring with 10 percent roe yield was an estimated $400 per ton of whole fish, and an ex-vessel price of $560 per ton when adjusted for roe percentage.

The California sac-roe fishery has experienced a steady price decline in recent years, mostly due to the changing markets and individual tastes. During the 1995-96 season, the ex-vessel seasonal value of the sac-roe catch in the San

Francisco fishery reached its peak at over 19.5 million dollars. Fishing revenue from the 2006 commercial harvest of Pacific herring was about $426,000 (ex-vessel 2006 dollars). The contribution to total business output, for the State, from this 2006 commercial harvest is estimated to be $822,000. Likewise, total employment and wages from Pacific herring is estimated to be the equivalent of 15 jobs and $378,000, respectively.

As the primary buyer of sac-roe, the decline in value can be traced back to Japan. Changing demographics have moved kazunoko from a traditional holiday gift to an everyday product. Increased competition from Russia, Canada, Alaska and Europe has also contributed to lowering ex-vessel prices for California sac-roe herring.

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, *Macrocystis pyrifera,* were 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 available for the fishery in San Francisco Bay; which are available to permittees willing to trade their sac-roe permits for roe-on-kelp permits.

The giant kelp used in this fishery is harvested from Monterey Bay, along the Ventura County coast, and the Channel Islands. The kelp is trucked to San Francisco Bay, suspended from floating rafts or longlines beneath piers. Rafts are positioned and anchored in locations where herring spawning is expected to occur. When spawning begins, suspended kelp is left in the water until several egg layers have been deposited or spawning ends. Preliminary roe-on-kelp product grading is conducted by the permittee prior to harvest to determine if coverage warrants harvesting. Once the product is harvested, grading begins. Price is determined by several quality factors; uniformity of egg coverage, thickness or number of egg layers, kelp condition, presence of eyed embryos, and the presence of silt. Roe-on-kelp has a per pound value much higher than herring roe, with current ex-vessel prices ranging from $7 to $18 per pound. As of 2007, there were 4 roe-on-kelp permits participating in the in San Francisco Bay fishery.

Throughout the history of this fishery, regulations have changed and expanded yearly. Management concepts new to commercial fishing in California were introduced as the herring fishery developed. These include limited entry permits, 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 conversion of round haul permits to gillnet permits. Controversy has surrounded management decisions, but they have proven to be effective solutions to socioeconomic conflicts. In the future, the Pacific herring fishery will continue to undergo significant changes, and as fishing opportunities,

markets and ocean conditions change, it must continue to adapt in order to remain viable and sustainable.

Status of Biological Knowledge

Pacific herring are found throughout the coastal zone (waters of the Continental Shelf) from northern Baja California on the North American coast, around the rim of the North Pacific Basin and Korea on the Asian coast. In California, herring are found offshore during the spring and summer months foraging in the open ocean. Beginning as early as October and continuing as late as April, schools of adult herring migrate inshore to bays and estuaries to spawn. Schools first appear in the deep water channels of bays to ripen (gonadal maturation) for up to two weeks, then gradually move into shallow areas to spawn. School size varies, but can be as large as tens of thousands of tons and miles in length. 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. The largest spawning aggregations in California occur in San Francisco and Tomales bays.

Most of these spawning areas are characterized as having reduced salinity, calm and protected waters, and spawning-substrate such as marine vegetation or rocky intertidal areas. Salinity is an important factor in the success of fertilization and embryonic development, and reduced salinity may act as a cue for spawning. Spawning occurs in the intertidal and shallow subtidal zones, when males release milt into the water column. A pheromone in the milt causes the females to extrude adhesive eggs on a variety of surfaces including: vegetation, rocks, and man-made structures such as pier pilings, boat bottoms, rock rip-rap, and breakwaters.

Fecundity is 226 eggs per gram of body weight, and a large female herring may lay 40,000 to 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 is generally shallower than 30 feet (9 meters) deep, but has been found to a depth of 60 feet (18.3 meters) in San Francisco Bay. A large spawning run may last a week and can result in 20 miles (32 kilometers) or more of the shoreline being covered by a 30-foot-wide (9-meter-wide) band of herring eggs. Immediately, after spawning, the adult herring leave the bay. Embryos (fertilized eggs) typically hatch in about 10 days, determined mainly by water temperature.

Herring Eggs on Eelgrass, *Zostera marina* Photo Credit: Ryan Bartling

During the incubation period, 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 toxic anti-fouling agents such as creosote on pier pilings. Herring embryos hatch into larvae, which metamorphose into juvenile herring. The distribution of larval herring in bays and estuaries is not well documented, but juvenile herring from San Francisco Bay have been found as far the Delta Pumping Plant in Tracy, approximately 80 miles (129 kilometers) inland from the spawning grounds. Juveniles may remain in the bay until summer or early fall, when they migrate to the open ocean.

Their distribution while in the ocean is not well understood, though Canadian research conducted on herring in Georgia Straight, British Columbia (BC) suggests that 1- and 2-year old herring occupy inshore waters and older herring occupy shelf waters. In BC waters, during summer months, juvenile herring were found in shallow nearshore waters of less than 164 feet (50 meters), all of which were comprised of similar-sized individuals. Based on the same BC data, Pacific herring may have little direct competition for food between age classes, and the first opportunity for direct interaction may be when herring sexually mature and join the spawning stock. Some herring reach sexual maturity at age two when they are about 7-inches (18-centimeters) in length; all are sexually mature at age three. California herring may live to be 9 or 10 years old and reach a maximum length of about 11-inches (28-centimeters). However, it is extremely rare to find fish that are older than 7 years of age.

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 and Stellar sea lions *Zalophus californianus* and *Eumetopias jubatus*; harbor seals, *Phoca vitulina richards*i, invertebrates and a variety of fishes (including sturgeon in San Francisco Bay) feast on adult herring and embryos.

Status of the Population

The size of herring spawning populations in Tomales and San Francisco Bays are estimated annually from spawning-ground surveys. Beginning with the 1982-1983 season, hydroacoustic surveys were also used in San Francisco Bay. As of the 2003-2004 season, the department reverted to using only spawning-ground surveys. This followed a peer review which indicated hydroacoustic surveys often overestimated the spawning biomass and are a poor predictor of returning herring stocks. The review panel recommended that the spawn survey be used as the primary index of abundance and as the biomass estimate for setting the fishery quota until an integrated catch-at-age model can be developed and verified for San Francisco Bay. Due to staffing changes, no spawning biomass assessment or commercial catch assessments were conducted in Tomales Bay during the 2006-2007 season. However, spawning ground surveys and fishery monitoring is planned for the 2007-2008 season. Starting with the 2007-2008 season the Department will conduct Pacific herring spawn assessment surveys on a 3-year cycle in Humboldt Bay with the next spawn assessment survey to be conducted during the 2009-2010 season. A spawn assessment survey may be conducted sooner if the Department receives data that raises concern about the health of the Humboldt Bay Pacific herring spawning population. For Crescent City Harbor, individual spawning runs have been estimated, but no seasonal population estimates have been made for this area. Effort has been historically low and only occurs when significantly large schools make fishing profitable.

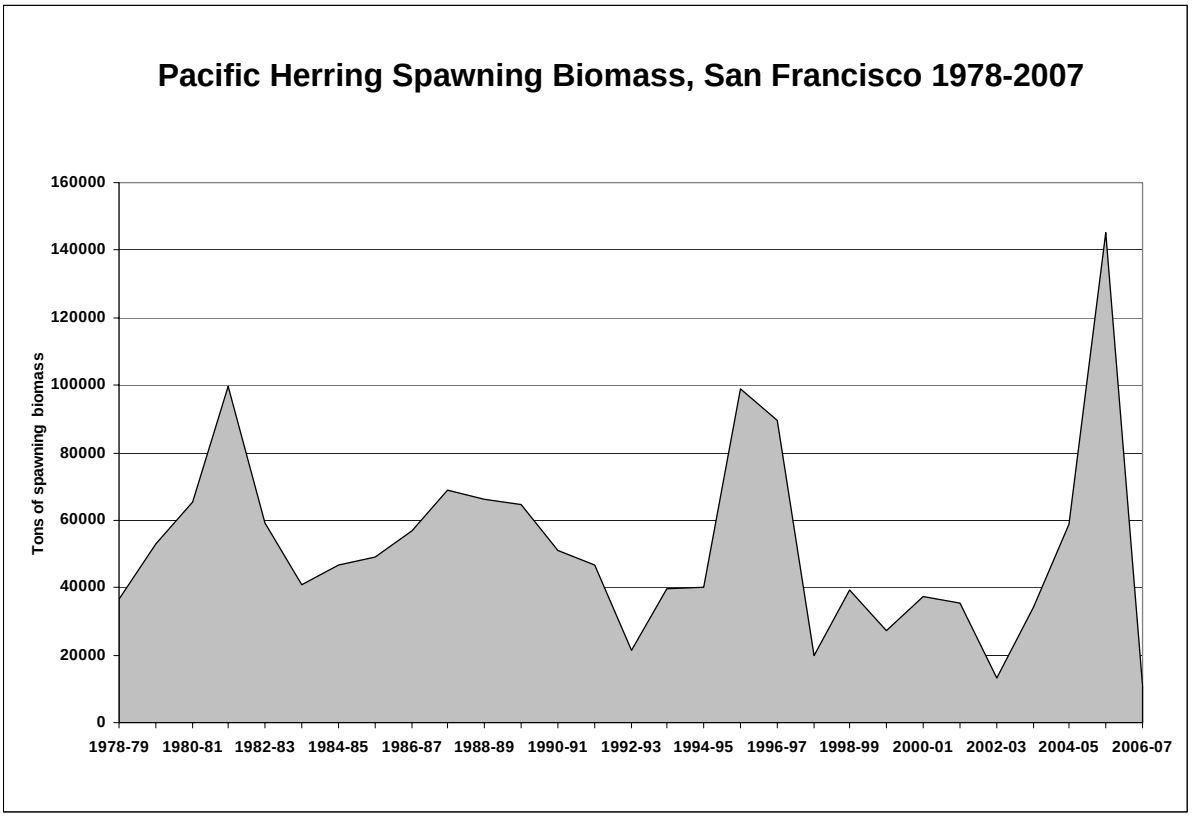

Figure 11.2. The spawning biomass of Pacific herring (in tons) in San Francisco Bay from 1978 through 2007. Data Source: CDFG Spawning Ground Surveys

All herring spawning areas in California have experienced a wide fluctuation in spawning biomass throughout the history of the fishery (Figure 11.2). In San Francisco Bay, herring biomass has ranged from a high of 145,000 tons (131,660 metric tons) to a low of under 11,000 tons (9,988 metric tons), with peaks occurring in 1982 (99,600 tons (90,436 metric tons)), 1988 (68,900 tons (62,561 metric tons)), and 1996 (99,050 tons (89,937 metric tons)). The lowest biomass estimates have occurred during or just after El Niño events: 40,800 tons (37,046 metric tons) in 1984; 21,000 tons (19,068 metric tons) in 1993; and 20,000 tons (18,160 metric tons) in 1998. For the 2006-07 season, the spawning biomass estimate was 10,900 tons (9,897 metric tons), a 92 percent decrease over the previous season's record high estimate of 145,000 tons (131,660 metric tons). This estimate is the lowest recorded in the history of the roe herring fishery and follows the pattern of low biomass estimates during El Niño events. The Tomales Bay spawning biomass estimates have ranged from a high of 22,200 tons (20,158 metric tons) in 1978 to a low of 345 tons (313 metric tons) in 1990 with an average of 4,900 tons (4,449 metric tons) per season since 1972. During the California drought, which lasted from 1987 to 1992, the herring spawning population severely declined in Tomales Bay. Due to

the low returning biomass, the Department closed the Tomales Bay commercial herring fishery from 1990 through 1992 to speed recovery. Since reopening, the returning biomass in Tomales Bay has continued to fluctuate from year to year. The last spawn estimate in 2005-2006 recorded 2,000 tons (1,816 metric tons) of herring, down from the previous five seasons. Due to the low exploitation rate, current levels of harvest do not seem to be a factor in the biomass decline for Tomales Bay. Since 1974, there have been 11 spawning biomass surveys conducted in Humboldt Bay with the average biomass estimate for those surveys of 386 tons (350.5 metric tons). The upper range for that period is a 950 ton (863 metric ton) estimate from the 2001-2002 season with the lowest estimate recorded at 7 tons (6.4 metric tons) during the 2006-2007 season. Historically, this population supported a small, but successful fishery with a 60-ton (54.5-metric ton) quota for many years. However, with the observed decline in the spawning population, fishing effort has also declined. No fishing effort has occurred since the 2004-2005 season.

Management Considerations

Herring abundance fluctuates greatly due to large variations in spawning recruitment. This is influenced by complex environmental factors that operate on various time scales such as short term storms, middle term El Niño-Southern Oscillation (ENSO) events and long term Pacific Decadal Oscillation events. Recently, it has become clear that abundance may be tied to multiple events and not simply an El Niño period. Examples include changing ocean conditions (i.e. low primary productivity, increased temperature and decreased upwelling), potential displacement by sardine populations, and increased predation. Each of these factors needs to be studied further to better understand their impacts on the population. It would also be desirable to conduct genetic studies of California Pacific herring populations. Within each California bay where herring fishing occurs, management presumes that the spawning population is a separate stock, although this assumption is unproven genetically. Results of tag and recovery studies from Canada indicate that 25 percent of herring may stray between adjacent spawning areas in British Columbia. If California herring populations are more homogeneous than previously thought, the current management strategy for setting seasonal quotas from bay to bay may benefit from reevaluation.

Due to the reduction of fishing effort and below average landings in recent years, the impact of the commercial fishery on the overall abundance of herring stocks in California is thought to be minimal. However, recent data does suggest that there is a trend for decreasing in length-at-age in recent years. This could be due to long or short term environmental factors which result in poor ocean conditions, low food availability, poor health, increased competition, or other factors. Length-at-age for herring may be an indicator of the populations response to current ocean conditions.

The greater concern is the truncation of age classes. It is unknown why this pattern continues to persist with commercial harvest remaining so low. Rebuilding of the age class structure, especially in the older age classes (4-6 year-olds), has not occurred and it appears that oceanic mortality may be responsible. Research is needed to understand how environmental factors affect herring survival, particularly during different stages of their life history, so that we may better predict year-class strength.

The Department is striving to incorporate an ecosystem approach to management of its marine resources. The harvest level used for Pacific herring to some extent takes into consideration this species' role in the marine food web and its connection to environmental factors, but these relationships are not well understood. Most aspects of herring biology and ecology would benefit from further scientific research to improve existing herring management and further incorporate an ecosystem approach.

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Further Reading

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