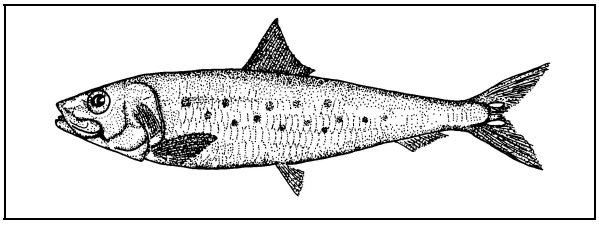

Pacific Sardine

Background

The Pacific sardine (Sardinops sagax) is an annual migrant to Canadian waters moving northward from California in the spring to feeding grounds off Vancouver Island and returning south in the fall. A single stock of sardine occurs in the eastern north Pacific and is distributed from northern Mexico to southeastern Alaska, although the main centers of concentration range from southern California - northern Baja to the southern portions of British Columbia. Two main spawning areas exist off southern California and Baja California. After collapsing to very low levels in the mid-20th century the abundance of the Pacific sardine population off California has increased exponentially since the early 1980s. Consequently, the abundance of sardines in Canadian waters has also increased after first re-appearing in 1992. The abundance and arrival of sardines in British Columbia is very difficult to forecast due to year to year fluctuation in environmental conditions. However, it appears from historical catch records and recent trawl surveys that on average about 10 percent of the sardine population migrates into Canada each year. The collapse of the sardine population in the 1940s was a result of overfishing in combination with unfavourable environmental conditions for sardine survival. The current management regime adopted by the United States ensures that a minimum spawning stock (150,000 tonnes) is preserved prior to considering a harvest and a conservative sustainable harvest rate of 5-15% is adopted depending on water temperature which has been directly linked to sardine survival. Canada has adopted the US harvest rate and is in the process of expanding the fishery in British Columbia after sardines were declared not at risk by COSEWIC in 2002.

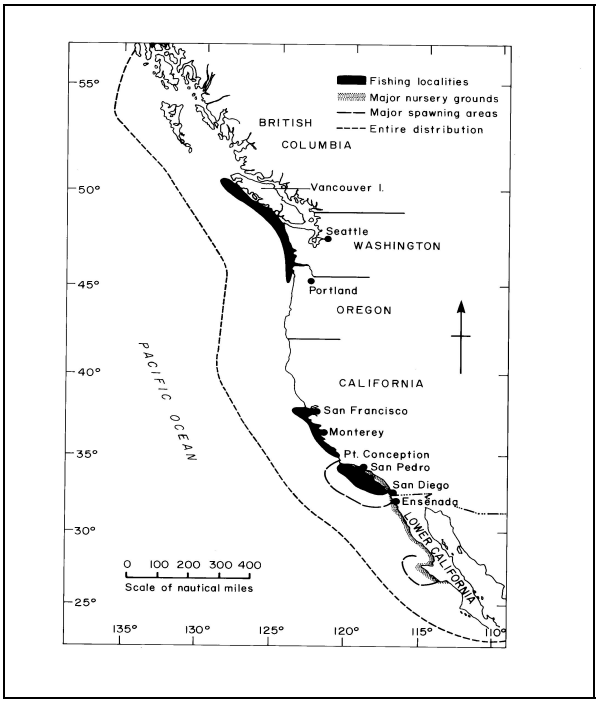

Figure 1. Distribution of the Pacific sardine, its major spawning grounds, nursery areas, and major fishery localities prior to 1950. Spawning also occurs in the Gulf of California but locations are unknown.

Summary

- Pacific sardine abundance from the U.S. assessment is forecast at 1.0 million tonnes for 2003.
- Recommended potential harvest for B.C. based on a 10% migration rate and 15% harvest rate is 14,998 tonnes.
- Recommended harvest does not represent any risk to the stock amounting to less than 2% of the total forecast stock biomass.
- The migration rate of sardine into B.C. is affected by water temperature and other poorly understood environmental factors

that could impact the availability of fish in 2003 if the current trend to cooler water temperatures continues.

Species biology

The Pacific sardine, *Sardinops sagax* (Family Clupeidae), is one of 18 species from three genera world-wide. Sardines are found in the waters of every continent but they are a warm water species whose global distribution is restricted to 60^0N and 50^0S latitude. In California, sardine schools have been found in temperatures ranging from 7^0C to 28^0C, but spawning is thought to be restricted to 13^0 to 22^0C. The Pacific sardine is distributed from northern Mexico to southeastern Alaska, although the main centers of concentration range from southern California - northern Baja to the southern portions of British Columbia (Figure 1). The major and northern spawning ground is between Point Conception and Ensenada. The other main spawning area, about half the size, is off central Baja California. An inshore fall spawning area also exists off central Baja and a winter-early spring spawning area within the Gulf of California. In the southern California offshore area spawning occurs between April and May at temperatures of 13 to 16.5^0C.

Evidence of sardine spawning in Canadian waters is largely circumstantial based on reports in unusually warm years of adults with ripe eggs or more recently, eggs and larvae. Age 0 juveniles (mean=10 cm) were subsequently collected in March and April, 1998 suggesting successful spawning in the area. Sardines are known to spawn off the coast of Oregon. Thus, it appears that in warm periods, such as during strong El Niño events, environmental conditions may be conducive to sardine spawning in Canadian waters. However, this does not appear to be an annual event.

The sardine is a schooling pelagic species, silvery on the sides and belly with a dark blue or green dorsal surface. It has fine striae on the operculum, specialized flaps on the tail fin, and black spots on the side of the body visible through the scales. Currently, in the Canadian fishery, few fish are older than age 9, and most are 3-7 years old. Pacific sardines are batch spawners: large fish (21 cm) release 30-65,000 eggs per spawning. A single large female can spawn about three batches, releasing almost 200,000 eggs per spawning season. Small fish (13-15 cm) appear to spawn about 30,000 eggs per season. The eggs are about 1.6 mm in diameter and take two to four days to hatch at 16 to 14^0C. The eggs are deposited and fertilized in mid-water, and remain pelagic until hatching. The larvae are about 3.5 mm in length and resorb the yolk sac after four to seven days. By the end of two to three months they are about 34 mm in length, and by the end of the first year they reach 115 mm. The length is about 31 cm for a fish 10 to 12 years of age. Females grow faster and larger than males. The diet of the sardine varies regionally, but as an omnivorous filter feeder it includes copepods, diatoms, a variety of other zooplankton, and occasionally fish larvae.

Each year, beginning in their second summer, sardines migrate northwards early in summer and travel south again in the fall. The migrations are complex, with timing and extent of movements being affected by oceanographic factors.

The Fishery

The fishery for Pacific sardine began in California in 1916-17 with a catch of about 25,000 tonnes primarily for the canned product to compete in the European markets where domestic production had been curtailed by the war. The catch for reduction to meal and oil increased substantially thereafter peaking in 1936-37 at 718,000 tonnes. It remained stable at about the 500,000 tonne level until 1945-46 when the fishery declined markedly to catches of 20,000 to 40,000 tonnes annually. It remained at this level until 1967 when legislation was introduced to limit pressure on the depleted stocks. In 1973 a moratorium on landings was instituted in California until the estimated spawning population increased to 20,000 tonnes.

In British Columbia the reduction fishery began in 1917-18 at 70 tonnes and increased rapidly to 44,000 tonnes by 1926-27, a level that was surpassed and sustained until 1947-48 when the population was collapsing and only 444 tonnes were landed in Canadian waters.

The factors causing the demise of the California sardine stocks are not well understood but appear to have been a combination of overfishing and unfavourable environmental conditions for sardine survival. As the stock collapsed, the range of the population contracted and fewer and fewer fish migrated to the Pacific northwest. At about this time the northern anchovy populations were beginning to increase in abundance and it remains uncertain whether interspecific competition with the anchovy was responsible for, or accelerated, the decline of the Pacific sardine stocks.

In the mid- to late-1980s there were indications that the sardine population was increasing rapidly. In 1986 it was estimated that the biomass off California had exceeded 20,000 tonnes which provided the opportunity for a small directed quota of 1,000 short tonnes for the California fleet. The fishery in the United States has continued to expand, with increasing sardine abundance.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) identified the Pacific sardine as a vulnerable species or one of special concern in 1987. As a result, no directed commercial harvest of this species was permitted despite the remarkable recovery of the California population. In the interim, beginning in 1995, an experimental B.C. fishery has been conducted to investigate the availability of sardines marketability of the product, viable fishing gears, and stability and economic viability of the market. About 20 tonnes were landed in 1995 and harvest increased slightly through 2000 when 1550 tonnes were landed. In 2002, COSEWIC reviewed the status of Pacific sardine and concluded that the stock was not at risk and as a result the fishery was expanded modestly to an allowable harvest of up to 5,040 tonnes although 15,864 tonnes was potentially available.

Resource Status

The annual assessment of sardine abundance is conducted by U.S. scientists using an age-structured model which includes two areas. It uses both fishery-dependent and fishery-independent data to obtain annual estimates of sardine abundance.

The U.S. stock assessment for 2003 estimated a total coastwide biomass of 1.00 million tonnes of sardines with 110,908 tonnes available for harvest by the U.S. This represents a slight increase from the estimated stock of 0.93 million tonnes in 2002.

The potential harvest of sardines in Canada is based on the U.S. estimate of total abundance, the U.S. estimate of the MSY harvest rate based on recent water temperature and an estimate of the migration rate.

The migration rate into Canadian waters based on the analysis of historical catch data and recent trawl surveys was estimated at 10%.

The maximum potential harvest based on this approach for 2003 is 14,998 tonnes, amounting to less than 2% of the total forecast stock biomass. It should also be noted that this represents a harvest ceiling and if July and August 2003 temperatures off the lower west coast of Vancouver Island are near, or below, the 12°C migration threshold, the biomass of sardines migrating to B.C. could be much lower than forecast.

Sources of uncertainty

Pacific sardine have occasionally been reported to over-winter in inlets of the British Columbia coast rather than migrating south. Co-incidentally, there have been reports of mass mortalities of sardines both recently and historically. Historical descriptions of the mortalities are similar to recent observations on the west coast of Vancouver Island and the Queen Charlotte Strait/Central Coast areas of British Columbia where sardines succumbed to VHS (viral hemorrhagic septicemia). The strain of VHS virus appears to be identical to that commonly observed in Pacific herring (*Clupea pallasi*) from the British Columbia coast. VHS has also been found in sardines off the California coast but it is unknown whether this is the same strain found in the B.C. samples.

While the proximate cause of death of these sardines was probably VHS infection, it seems likely that stress from reduced water temperature and possibly from food limitation triggered the disease outbreak. Water temperatures observed during die-offs in the Central Coast (Smith Inlet) in February, 1998 were measured at 7 and 8.5°C and literature reports indicate the lowest temperature at which sardine can survive is approximately 7°C. These sardine die-offs have been localized and limited in scope. As such, they do not appear to pose any immediate threat to the health of the population as a whole. However, should the virus spread more widely within the population it could have a larger impact on population viability.

Outlook

The most recent assessment of the sardine population indicates that the biomass remains at a level of about one million metric tonnes, a level approaching that in the 1930s. As with other short-lived pelagic species, the abundance of sardine is directly affected by recruitment of young fish which is determined by survival during the first few years of life. The recent dramatic increase in abundance is largely a function of strong recruitment beginning in the early 1990s that appears to be related to elevated sea-surface temperatures. Indications are that water temperatures at La Jolla have declined

over the past 4 years which may result in decreased recruitment and declining stock size.

As the California sardine population increased it expanded its range and as a result the sardine re-appeared in British Columbia waters in 1992. The abundance of sardine in Canadian waters has increased through the 1990s and may be approaching historical levels of 10% of the coastwide biomass. However, should water temperature in B.C. and off California continue to be moderate, overall stock size and the migration rate into Canadian waters may decline.

Management Considerations

The dramatic collapse and disappearance of the sardine from the west coast of North America during the mid-20th century stimulated research into a better understanding of the dynamics of this and other pelagic species that exhibit large fluctuations in abundance. Studies of sediment cores in the Santa Barbara Basin (California) have used fish scale deposition to reconstruct the relative abundance of pelagic species for the past two millennia. These data reveal cycles of approximately 60 year duration in the abundance of both sardine and northern anchovy *(Engraulis mordax)*; moreover, during sardine absence, anchovy tend to be more abundant and vice versa. The mechanism driving the fluctuations remains unclear. There may be a parallel response to large-scale environmental change or competition for food or other biological interaction. Nine major recoveries and nine subsequent collapses of the sardine population have occurred in the past 1700 years. The recoveries range from 20 to 70 years, with an average of 36 years, while the collapses range from 20 to 50 years, averaging 30 years in length. Thus, the recent collapse and recovery of sardines in the California Current system appears to be a recurring biological phenomenon that may be mediated by both climatic factors and biological interactions, and can be expected to recur in the future despite human intervention.

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