

Sardines Return to British Columbia Waters

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“The Indians have told of catching pilchards in years long forgotten. None were around when white men first set their nets; then they came back, and nobody knows why. They crowded the waters along the West Coast of Vancouver Island in ever larger numbers after 1916. The late twenties brought the big catches, and pilchard reduction plants sprang up between Kyuquot and Barkley Sound.”

Forester and Forester, 1975

Sardines (*Sardinops sagax*) constituted the largest fishery in British Columbia from the mid-1920s to the mid-1940s. During this period catches averaged 40,000 t annually (Figure 1). The fishery off British Columbia collapsed in 1947 and sardines disappeared totally from British Columbia waters. The collapse of this fishery has been described as a classic example of over-fishing (Hilbourn and Walters, 1992). The complete absence of sardines in Canadian and northern U.S. waters was never recognized as a consequence of changes in species distribution. Instead it was believed that overfishing in some way eliminated every single fish. It was also generally believed that there was little prospect for the recovery of the fishery off the British Columbia coast because supposedly it was the genetically distinct northern migratory stock that had been overfished (Murphy, 1966; MacCall, 1979). The remaining biomass of this genetically distinct stock was considered to be too small to rebuild.

Another explanation for the changes in abundance of sardines was proposed by Kawasaki and Omori (1988). They recognized that there was a synchrony in the trends of abundance of sardine populations off Japan, California and Chile (Figure 2). The collapse of sardine stocks off Canada and the United States in the late 1940s corresponded with the collapse off Japan. Beginning in the late 1970s the stocks off Japan, California and Chile increased dramatically. The synchrony persisted when stocks declined off Chile and Japan in the late 1980s and

early 1990s, while off California the stocks have not yet declined. The results of Kawasaki's studies indicate that large fluctuations in sardine populations are a consequence of changes in ocean habitat. Shifts in climate/ocean regimes are now recognized as important factors affecting the abundance trends of a variety of fishes (Beamish et al., 1998; Mantua et al., 1997; Minobe, 1997).

Historically, sardines entered British Columbia waters in mid-June and returned to southern spawning grounds (California) in mid-October. Most spawning occurred from April to June in the southern California Bight. It was primarily the older, larger sardines, which migrated north to feed off

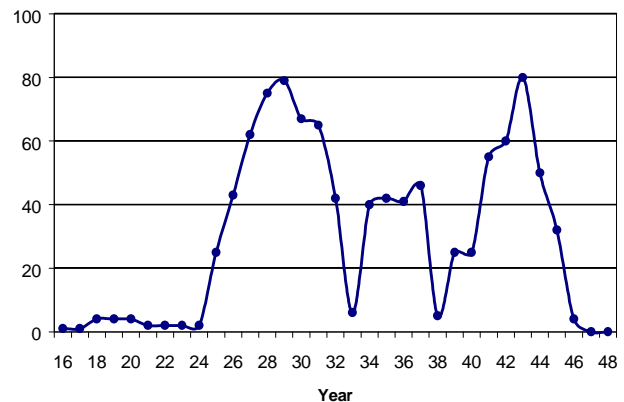


Figure 1. Catches (tonnes) of Pacific sardine from Canadian waters, 1917 to 1947.

British Columbia. Hart (1943) noted that in a few years, some sardines remained in the inlets off the west coast of Vancouver Island throughout the winter.

In 1992, sardines reappeared in British Columbia waters (Figure 3, Hargreaves et al., 1994) after a total absence of over 40 years. Sardines were first reported in 1992 in both commercial and research catches of Pacific hake (*Merluccius productus*). The catches in the hake fishery have continued through to 1998, but are not an indication of sardine abundance as hake are fished at depths greater than 80 m, well below the concentrations of sardines in the surface waters (Figure 4). The sardines probably were captured in the hake fishery when the nets were pulled through the surface waters. In our research surveys that began in 1997 we caught large numbers of sardines in the surface waters relative to the catches in the hake fishery (Figure 3). This may indicate that sardines were abundant in the surface

waters prior to 1997 and this is supported by the initiation of an experimental commercial fishery in 1995 (Figure 3). Movement into the Canadian zone may be continuing because sardines continue to move farther north each year (Figure 5).

The abundance off British Columbia appears to be increasing. During July 1997, we estimated abundance using large surface trawls (Beamish and Folkes, 1997) from the Columbia River to the tip of Vancouver Island at 135,000t, of which approximately 60,000 t was present off the west coast of Vancouver Island. The 60,000 t represent approximately 250,000,000 sardines. For comparison, a catch of 1,800,000 coho salmon in the same area was considered to satisfy conservation needs and meet fishery expectations (DFO, 1985). This would be equivalent to approximately 9,000,000 sardines (the weight of 1 coho = the weight of 5 sardines). The numbers of sardines present in 1997 indicated that the abundance of fishes in the surface waters had not only changed, but had increased.

The large abundance of sardines in the Canadian zone in 1997 was observed prior to the major increase in temperature (August, September) of the surface waters as a result of the 1997 El Niño. The large abundance persisted off British Columbia through 1998. At the same time as large numbers of sardines appeared off British Columbia, the total abundance off California was considered to be unchanged (400,000 t). Catches off California have been maintained although there are indications that catches have decreased in 1998. This indicates that

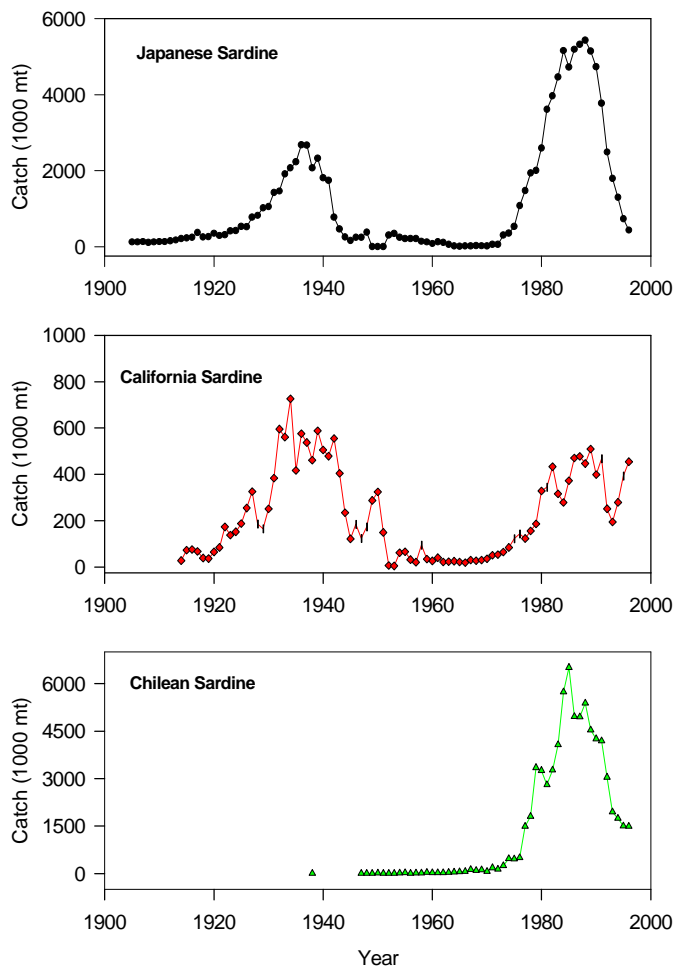


Figure 2. Catch of sardines (1000 tonnes) from the three major stocks in the Pacific ocean (updated from Kawasaki). Note the synchrony in catch trends.

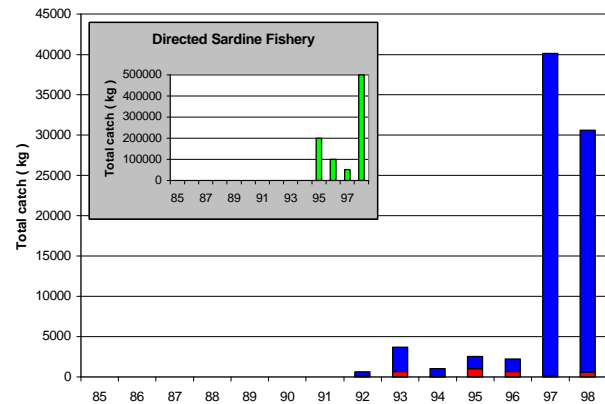


Figure 3. Recent catches (kg) of Pacific sardine in the Pacific hake fishery (red) ($x = 0$ catch), research surveys (blue), and an experimental sardine fishery off the west coast of Vancouver Island (green). The experimental fishery was initiated in 1995 in response to fishers' comments of large schools of sardine in inlets off the west coast of Vancouver Island.

the distribution of sardines may have shifted northward in 1997 and 1998. Sardines moved into the Strait of Georgia late in 1998. Additionally, large numbers of other species (Pacific hake and Pacific mackerel) have moved into the Canadian zone in larger numbers and are also moving farther north each year (Figure 6) and spawning.

Another change in behaviour was the documented spawning of sardines off the west coast of Vancouver Island (Figure 7). Sardines in spawning condition were sampled off southern Vancouver Island in July 1997, and large numbers of young of the year were captured in the same area in February, March and April of 1998. In February 1998, 31 sets were made in the top 30 m off the west coast of Vancouver Island. The catches of sardines from the 1997 year class were twice that of catches of the 1997 year class of herring (*Clupea harengus*) in the same sets indicating that these juvenile sardines were a common component of the fish community in the surface waters off Vancouver Island. The young fish have remained off the coast and have been captured throughout British Columbia waters including the Strait of Georgia, northern Hecate Strait and Alaska. Sardines remained abundant and spawned off the west coast of Vancouver Island in 1998 even though El Niño conditions did not persist. Two prior instances of sardine spawning near the British Columbia coast have been recorded (Williamson, PBS unpublished report, 1929; Hart, 1943). In both instances, 1929 and 1939, the authors reported one-year-old sardines in the catch, but the presence of young-of-the-year sardines was always considered to be rare.

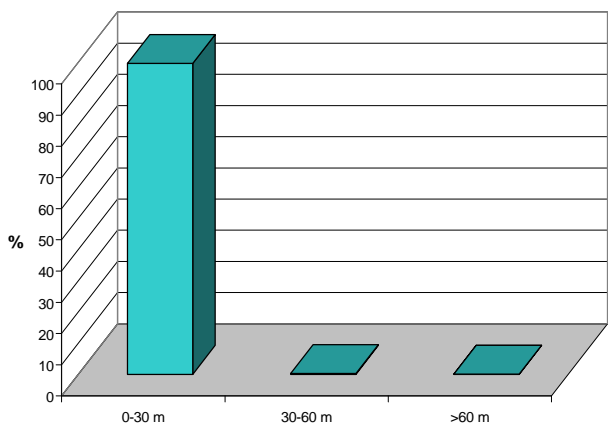


Figure 4. Percentage of the catch by fishing depth during research surveys conducted during 1997.

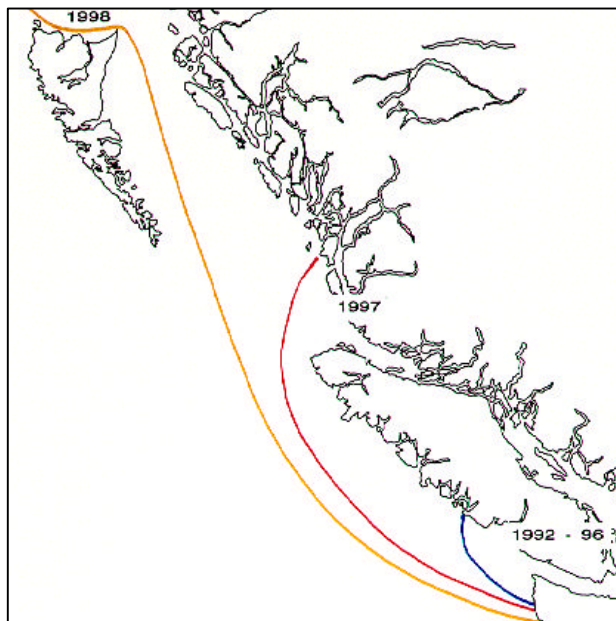


Figure 5. Distribution of sardines in Canadian waters in 1992–1996, 1997 and 1998.

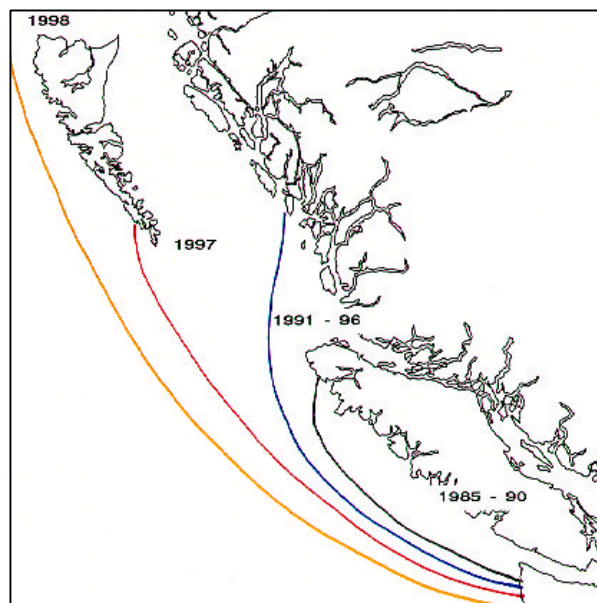


Figure 6. Distribution of Pacific hake in Canadian waters in 1985–1990, 1991–1996, 1997 and 1998.

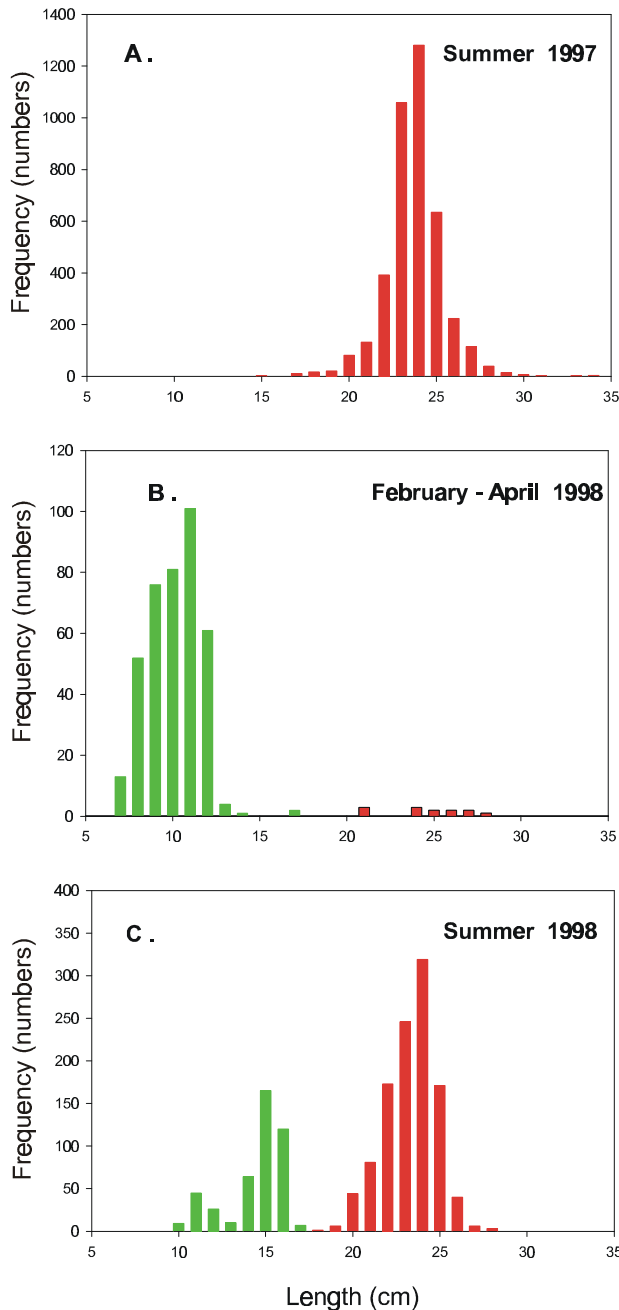


Figure 7. Length frequency of Pacific sardine (A) summer 1997, (B) February–April 1998, (C) summer 1998. Note the abundance of 7- and 8-month-old sardine in the winter.

Sardines were feeding mainly on phytoplankton (diatoms) and zooplankton (copepods and euphausiids) (Figure 8). In 1997, all fish examined (140) were feeding. In 1998, about 28% had empty stomachs (97 out of 347). In addition, during February

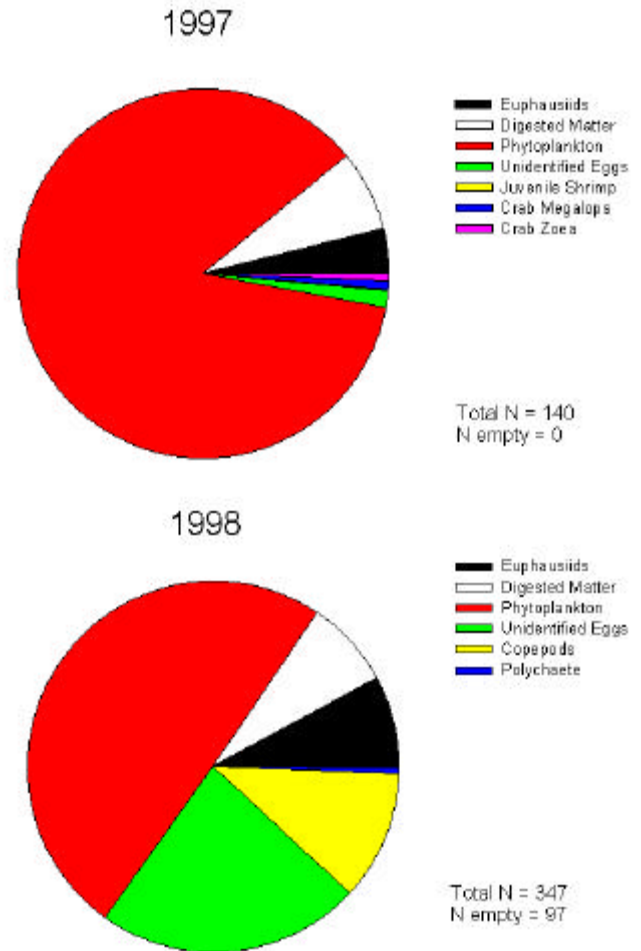


Figure 8. Stomach contents of Pacific sardine, captured off the west coast of Vancouver Island in 1997 and 1998.

to April 1998, juvenile sardines were a common prey of salmon captured off the west coast of Vancouver Island.

Conclusions

Sardines have increased in abundance in waters off British Columbia and are a dominant species in the surface waters. The unexpected large abundance of sardines has changed our thinking with respect to the cause of the collapse of sardines in the 1940s. The traditional explanation of overfishing as the principal cause for the collapse needs to be reexamined as it is clear that ocean conditions affected both distribution and survival. Also, it is illogical that overfishing would eliminate every single fish for over 40 years. The spawning of sardines in 1997

and 1998 also represents a change in their behavior. This change may be related to El Niño, but is also likely to be related to other changes in the ecosystem, as the El Niño events in the 1950s through to the 1980s were not associated with sardine movement and biology. It is worth remembering that the California Cooperative Oceanic Fisheries Investigations (CalCOFI) studies were initiated in an attempt to explain the collapse of the sardine stocks in the late 1940s. A lot of information has been collected about the ocean ecosystem since, but we still do not understand the mechanisms that are responsible for the fluctuations in sardine abundance. We propose that, in order to understand how to manage sardine stocks, we must understand how they are regulated naturally. These animals are an excellent indicator of ecosystem change. This means that the population dynamics of other species, such as coho (*Oncorhynchus kisutch*) and chinook (*O. tshawytscha*) salmon could also change for natural reasons. We believe that the changes we have seen in sardine distribution, abundance and spawning (and the same changes in other fish) indicates a major shift in the dynamics of the ecosystem that occurred in waters off British Columbia in the early 1990s. A key to understanding why large fluctuations in sardine abundance occur may be by understanding why they have shifted their range northward. Thus it may be as important to study the impact of the upcoming La Niña on sardines as it was to study the impact of the 1997 El Niño.

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