

Sardines in the Ecosystem of the Pacific Northwest

Richard D. Brodeur¹, William T. Peterson¹, Robert L. Emmett¹, Paul J. Bentley², and Todd Miller³

(1) National Marine Fisheries Service, Newport, Oregon; (2) National Marine Fisheries Service, Hammond, Oregon; (3) Oregon State University, Hatfield Marine Science Center, Newport, Oregon

The Pacific sardine (*Sardinops sagax*) has been one of the most dominant pelagic fishes in the California Current system over the last several millennia and its abundance has fluctuated greatly over time (Baumgartner et al. 1992). During peak abundance periods, this population is capable of supporting major fisheries. The main population and fishery is centered in central and southern California, but during periods of high abundance and warmer ocean temperatures, some portion of the population resides off Oregon, Washington, and British Columbia, with some schools or individuals making it as far north as southern Alaska (Hart 1973, Wing et al. MS). At these times, commercial fisheries develop for sardines, or pilchards as they are called locally, in the Pacific Northwest (PNW) and off British Columbia. In order to effectively manage a fish stock, it is necessary to acquire some basic biological parameters on the stock; however, we are generally lacking any such information on sardines in the PNW.

Sardines were first landed commercially in Oregon during the 1935-36 fishing season and a year later in Washington, well after the commencement of fisheries in both California and British Columbia (Chapman 1936, Schaeffer et al. 1951). Fish were landed in Gray's Harbor, Washington, Astoria and Coos Bay, Oregon, and were generally rendered to oil and fishmeal. Following the collapse of the fishery in the late 1940s, there have been few reports of sardine captures in the PNW. Reid (1960) reported the catch of a single male in Winchester Bay, Oregon in August of 1957. In purse seine surveys off the coast of Oregon and Washington from 1979-1985, five sardines were caught between June and September of 1984, all off central Oregon (Brodeur and Pearcy 1986, Pearcy and Schoener 1987). Ermakov and Stepanenko (1996) also reported that some sardines were caught in the PNW in the 1980s. These sporadic occurrences are apparently connected to warm ocean conditions and anomalous northward advection associated with El Niño (Pearcy and Schoener 1987). These warm years were generally followed by cool years that may have inhibited the growth of the northern sardine population.

Beginning in 1992, sardines increased dramatically in the PNW as first reported by Hargreaves et al. (1994), again apparently in response to 1992-93 El Niño. This time, however, they continued to increase and even reproduce in the PNW up to the present time (Bentley et al. 1996, McFarlane and Beamish 1999, Busby et al. MS). This change followed an apparent regime shift and coincided with a dramatic increase in overall pelagic fish biomass off the PNW (Emmett and Brodeur 2000). Using a variety of data sources, we describe biological characteristics such as the distribution, life history and ecological relations of sardines during this recent population increase.

Results

Egg and larval distribution related to environment – The National Marine Fisheries Service (NMFS) conducted ichthyoplankton surveys off the coast of Oregon and Washington for five years (1994-1998) sampling a similar grid of stations every July. The sampling consisted of a vertical tow with a CalVET net to a maximum depth of 70 m (Bentley et al. 1996). Sardine eggs were distributed over a substantial proportion of the study area and extending well offshore (Fig. 1). In some cases (e.g. 1995) the entire range of the distribution was probably not effectively sampled. Eggs were generally distributed between the 14° and 16° C isotherms, except in 1995 and 1997 when these isotherms were pushed close to shore (Fig. 1). The distribution of sardine larvae was similar to that of the eggs, although they were slightly farther offshore in most cases (Fig. 2).

Adult distribution and size – To describe the adult distribution of sardines, we used three different data sources more fully described in Emmett and Brodeur (in press). It should be noted that none of these surveys were specifically targeting sardines and the distribution of sampling effort was mostly at predetermined station locations.

The first comes from the NMFS West Coast triennial groundfish bottom trawl surveys that began in 1979 (data courtesy of Mark Wilkins, AFSC, Seattle). We examined catches only from the U.S.-Canada border south to 42° N, although many sardines were caught outside this region. Sardines were first caught beginning in the 1992 summer survey, with the highest catches mainly around the Columbia River (Fig. 3). Sardines were distributed mainly over the middle and outer shelf regions. In the 1995 survey, sardines appeared to be more spread out occurring both farther to the south and more inshore compared to 1992, although the overall abundance was lower. In 1998, catches were lower still and occurred predominantly in the vicinity of the Columbia River (Fig. 3). Biomass caught in this survey has shown a steady decline in both the U.S. Vancouver and Columbia statistical regions since 1992 (Fig. 5). Several age-classes are apparently represented in these catches in 1998 (Fig. 4). There is a progression of the dominant size mode from south to north, with a second smaller group appearing off northern Washington.

During the summer and fall of 1998 and 1999, NMFS conducted near-surface surveys for juvenile salmon along transects off the Washington and Oregon coasts (Emmett and Brodeur 2000). Sardines were collected in all five surveys although the catch varied greatly (Fig. 6). They were widely caught during the May, 1998 cruise from Gray's Harbor south to the Central Oregon Coast. The next three surveys caught relatively few sardines but by the September cruise, they again occurred in very high numbers, but at stations mainly north of the Columbia River (Fig. 6). The size distribution in 1998 was generally very broad compared to the 1998 triennial survey (Fig. 7). In 1999, however, there was a narrow range of individuals represented, although there were relatively few fish caught in May and June.

The last survey examined was a series of biweekly cruises in the area of the Columbia River plume in spring and summer of 1998 and 1999 (Emmett et al. MS). These generally used the same trawl as the salmon surveys but were targeting predators so they mainly fished at night. Sardines ranked third in abundance in 1998 but was the dominant species caught in 1999,

making up more than a third of the total catch. No sardines were caught in April or May but were caught rather consistently beginning in June through August (Fig. 8).

Food habits -- Collection of Pacific sardines from research trawls off of La Push (LP transect) and Willapa Bay (WB transect), Washington, during September 1999, has allowed for an initial investigation into the trophic role of sardines in this region. Immediately after collection, stomachs were preserved by either freezing or placing in 10% buffered formalin. Five sardine stomachs were analyzed from each station. The two anterior-most compartments were used in the analysis. Contents were removed and washed through a series of 500, 200 and 100 μ m sieves to separate phytoplankton from animal contents for volumetric measurement. Volume was measured by settling contents in a volumetric test tube for approximately 24 h.

Phytoplankton and marine-snow like material made up between 50 and 70% of the volume of total contents (Table 1). All stages of copepods (*Acartia* spp., *Paracalanus* spp. and *Pseudocalanus mimus*), euphausiid eggs, and the appendicularian, *Oikopleura* spp., were the primary animal prey items. Copepodites, copepod nauplii, and euphausiid eggs were found in higher abundance from offshore stomachs, while the appendicularian, *Oikopleura* spp., was generally found more frequently in nearshore stomachs (Table 1).

Table 1. Average percent phytoplankton and average number of animals per sardine stomach.

STATION	Phyto plankton (%)	Copepod (adult)	Copepod (cope podite)	Copepod (nauplii)	Copepod (egg)	Euphausiid (egg)	Appendicularian <i>Oikopleura</i>
WB 14	71	2	28	62	32	106	27
WB 19	62	27	38	101	17	189	14
LP 09	53	44	18	22	21	< 1	15
LP 22	63	15	33	70	3	55	12

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Figure Legends

Figure 1. Distribution of sardine eggs from NMFS 1994-1998 Ichthyoplankton surveys off Oregon and Washington. Also shown are isotherms at 3 m depth.

Figure 2. Distribution of sardine larvae from NMFS 1994-1998 Ichthyoplankton surveys off Oregon and Washington. Also shown are isotherms at 3 m depth.

Figure 3. Distribution of sardines from NMFS 1992, 1995, and 1998 triennial surveys off Oregon and Washington. Also shown is the 200 m depth contour.

Figure 4. Size distribution of sardines collected in the NMFS 1998 triennial trawl survey by degree of latitude.

Figure 5. Estimated minimum biomass of sardines off the U.S. Vancouver and Columbia Statistical regions. Numbers on graph are the coefficient of variation for the biomass. These are considered minimum since the trawl was mainly on the bottom and may not have sampled the full population of sardines which was mainly in midwater.

Figure 6. Distribution of sardines from NMFS 1998 and 1999 surface trawl surveys off Oregon and Washington. The + signs indicate locations of each trawl.

Figure 7. Size distribution of sardines collected in the 1998 and 1999 surface trawl survey by cruise.

Figure 8. Catch of sardines from the 1998 and 1999 NMFS predator surveys off the Columbia River by cruise date.