LESSON 7

SARDINES AND THE CALIFORNIA CURRENT

On a Cold Current Running South

1 Fish in a cold offshore current
2 Regime shift
3 The concept of upwelling
4 The link to biological production
5 CalCOFI: linking fisheries and physics
6 The discovery of El Niño Norte
7 El Niño: a new paradigm
8 A new look at fisheries management

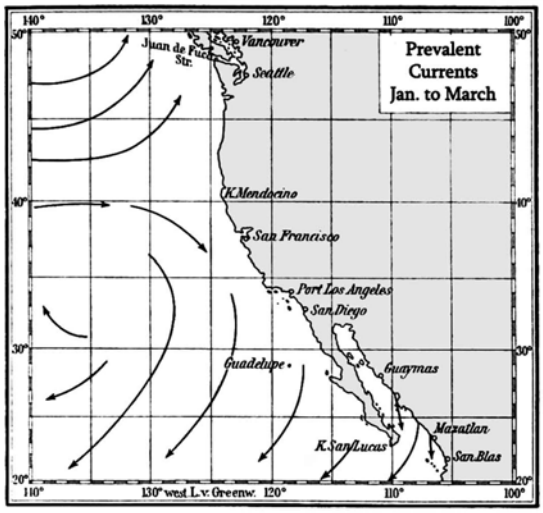

Fig. 7.01. Currents off California according to H. Thorade, as given in Kruemmel (1907). Note the offshore component of the flow.

The California Current brings cold water south along the sunny parts of the West Coast, and it does so while moving surface waters offshore (Fig. 7.01). As a consequence, additional cold water rises from the thermocline and below, producing a narrow cold strip of highly productive waters in sight of the land. The processes involved (referred to as “upwelling in an eastern boundary current”) are responsible for the rich sea life supported by the Current, including seabirds such as cormorants and pelicans, and mammals such as the California sea lion and the elephant seal.

Productivity varies through the decades. There was a time when the coastal ocean off the shores of California was famous for its rich harvests of sardine (Fig. 7.02). John Steinbeck, in his book *Cannery Row* (published in 1945), celebrated the hustle and bustle of the period. “Cannery Row in Monterey in California is a poem, a stink, a grating noise, a quality of light, a tone, a habit, a nostalgia, a dream” – thus the opening line of his book (1).

At the time Steinbeck wrote the story, which features “Doc,” the spirited marine biologist collecting worms, mollusks and crabs (2), Cannery Row’s twenty-four canneries were already on the path to extinction. In Monterey, the business of canning had started in 1902, following the example set by San Francisco (1889) and San Pedro (1893). By 1920, the canneries were producing fishmeal and fertilizer at an ever-increasing pace. In the 1936-1937 fishing season well over 700,000 tons of sardines were hauled into California harbors, an all-time record

(Fig. 7.02). This was about one-quarter of the U.S. tonnage of fish. Scientists at the California Department of Fish and Game warned about the dangers of overfishing, but with no appreciable effect on fisheries regulation (3). The fishery shrank to a shadow of its former glory after 1945 and never recovered.

Scientists at Scripps began systematic studies on the productivity of the California Current in 1938, along offshore transects laid out by the new director, Harald U. Sverdrup, and by Oscar E. Sette of the U.S. Bureau of Fisheries. One important goal was to provide the scientific underpinnings for managing the sardine fishery (4). Eventually, this effort resulted in great advances in the understanding of *coastal upwelling* and *mixing*, processes that govern the productivity of the sea. The California Current became the best-studied high-production region in the world, thanks to the collaborative project arising from these initial efforts, after WWII (the CALCOFI program: California Cooperative Oceanic Fisheries).

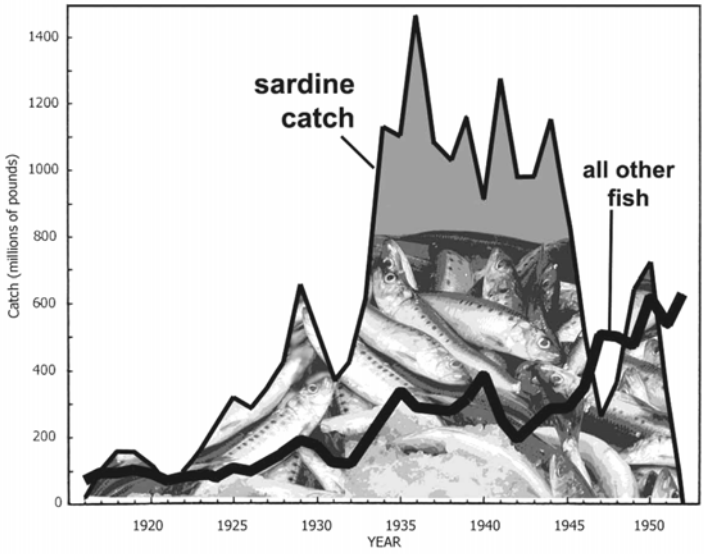

Fig. 7.02. Rise and fall of the California sardine fishery in the first half of the 20th century, according to CALCOFI records. Note the more or less steady increase of "all other fish," as a result of increased fishing efforts.

Perhaps the most important insight gained was the realization that this productive system is highly variable, on various scales from a few years to centuries. This variability greatly impacts any attempt to provide for intelligent management of fisheries. In fact, fisheries management anywhere in the world has been greatly frustrated in trying to meet the challenges posed by the combination of ever-increasing fishing pressures and a highly variable physical environment.

Notes and references

1. John Steinbeck, 1945. Cannery Row. Viking Press, New York. In the preface, Steinbeck paints a picture of frenzied activity revolving around the processing of the sardine harvest from the California Current.
2. The character "Doc" in Steinbeck's novel was inspired by his friend Edward F. Ricketts, marine naturalist and commercial collector who supplied marine specimens to academic institutions. (See Lesson 2.)

3. A. F. McEvoy III, 1979. Economy, Law, and Ecology in the California Fisheries to 1925. PhD Dissertation, University of California, San Diego, 484pp.
4. From 1938 to mid-1941 scientists on the institution's research vessel, the *E. W. Scripps*, repeatedly occupied a predetermined grid of 40 stations within the California Current system. At each station, plankton samples were taken, temperatures recorded, and seawater samples collected for analysis of phosphate and oxygen.

Images

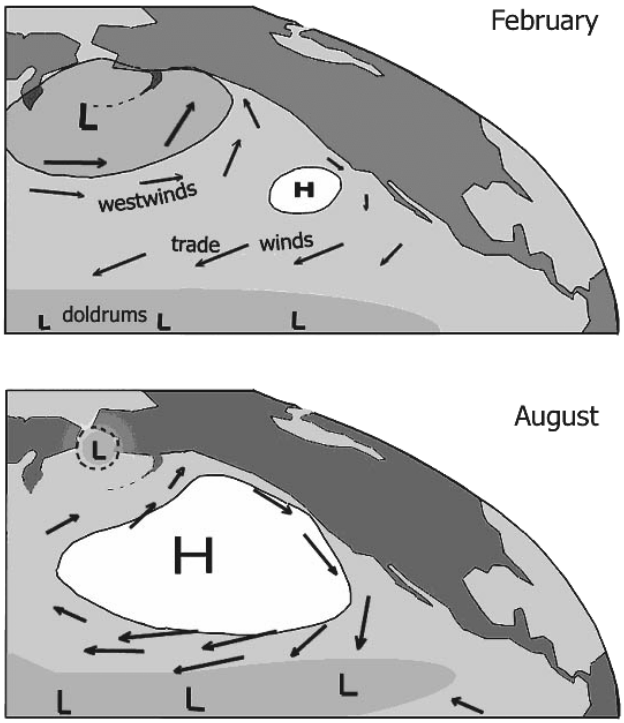

Fig. 7.03. Seasonal changes in the distribution of high and low atmospheric pressure and the response of the California Current. (After Dietrich et al., 1975.)

Fig. 7.04. Surfing in the wind blowing parallel to the coast, north of Point Conception.

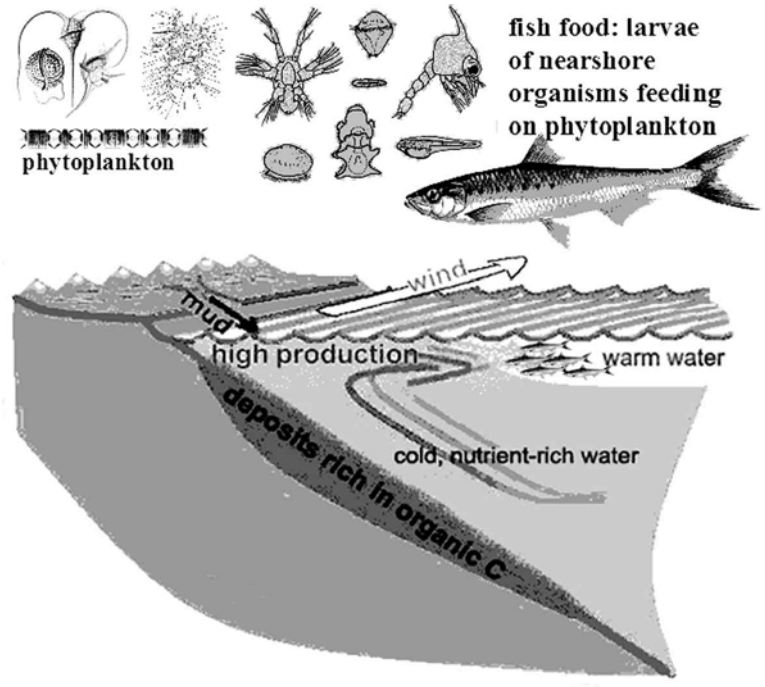

Fig. 7.05. Herring-like fishes (such as sardines) feed on diatoms, dinoflagellates and small zooplankton, including larvae of nearshore organisms. The fishes filter the water through structures within the gills. The growth of phytoplankton depends on the nutrients supplied by upwelling.

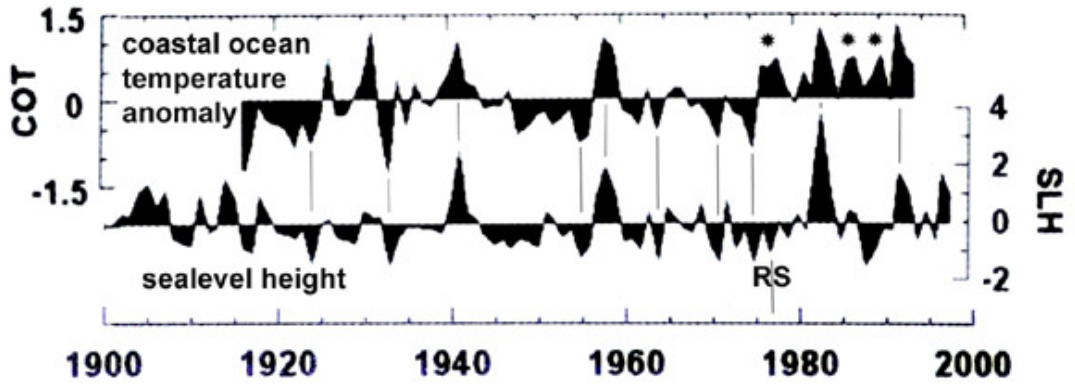

Fig. 7.06. Comparison of the histories of the coastal temperature anomaly of the California Current with sealevel height along the coast. Traditionally, warm anomalies (in deg. Celsius) go together with increased sea level (in cm) and *vice versa*. Since 1974, this correspondence has greatly weakened, for reasons unknown. RS, regime shift.

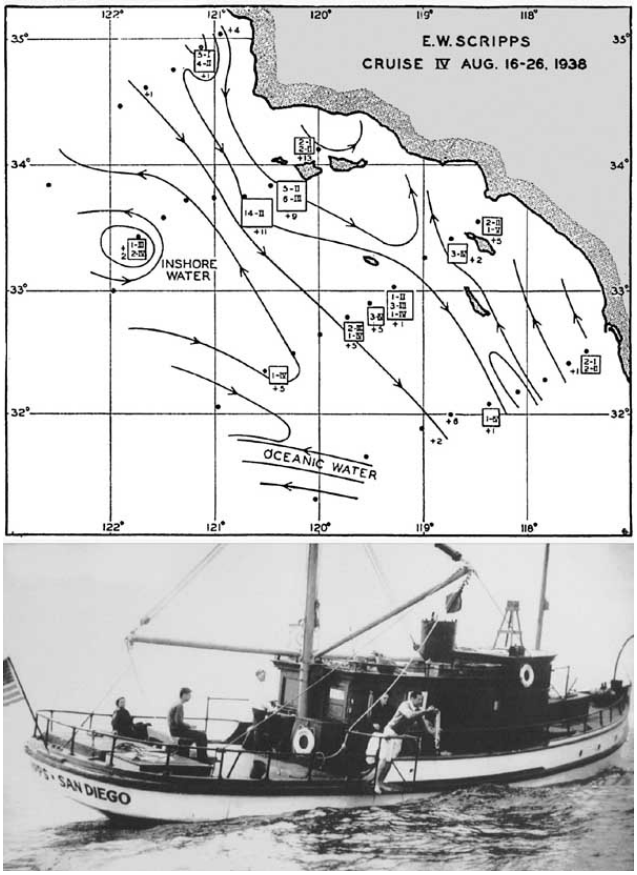

Fig. 7.07. Early results based on surveys with the motorized sailing vessel *E.W. Scripps* showed that the California Current has a complicated, ever-changing structure. Note the northward flow in the Southern California Bight.

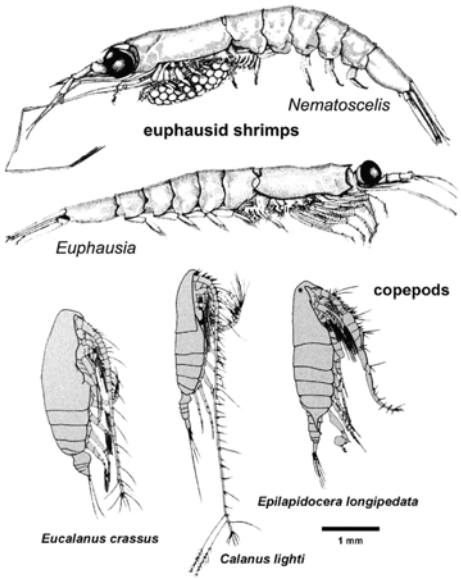

Fig. 7.08. Pelagic crustaceans, food for fish: euphausids and copepods.

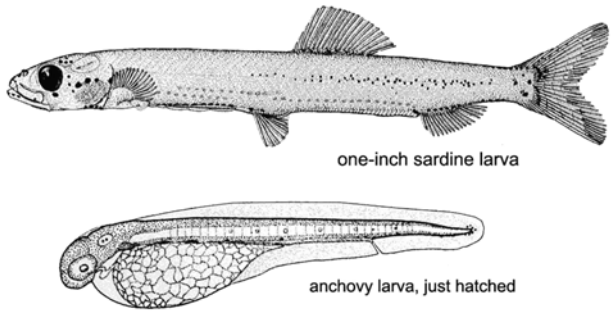

Fig. 7.09. Planktonic larvae of sardine and anchovy, at different stages of development.

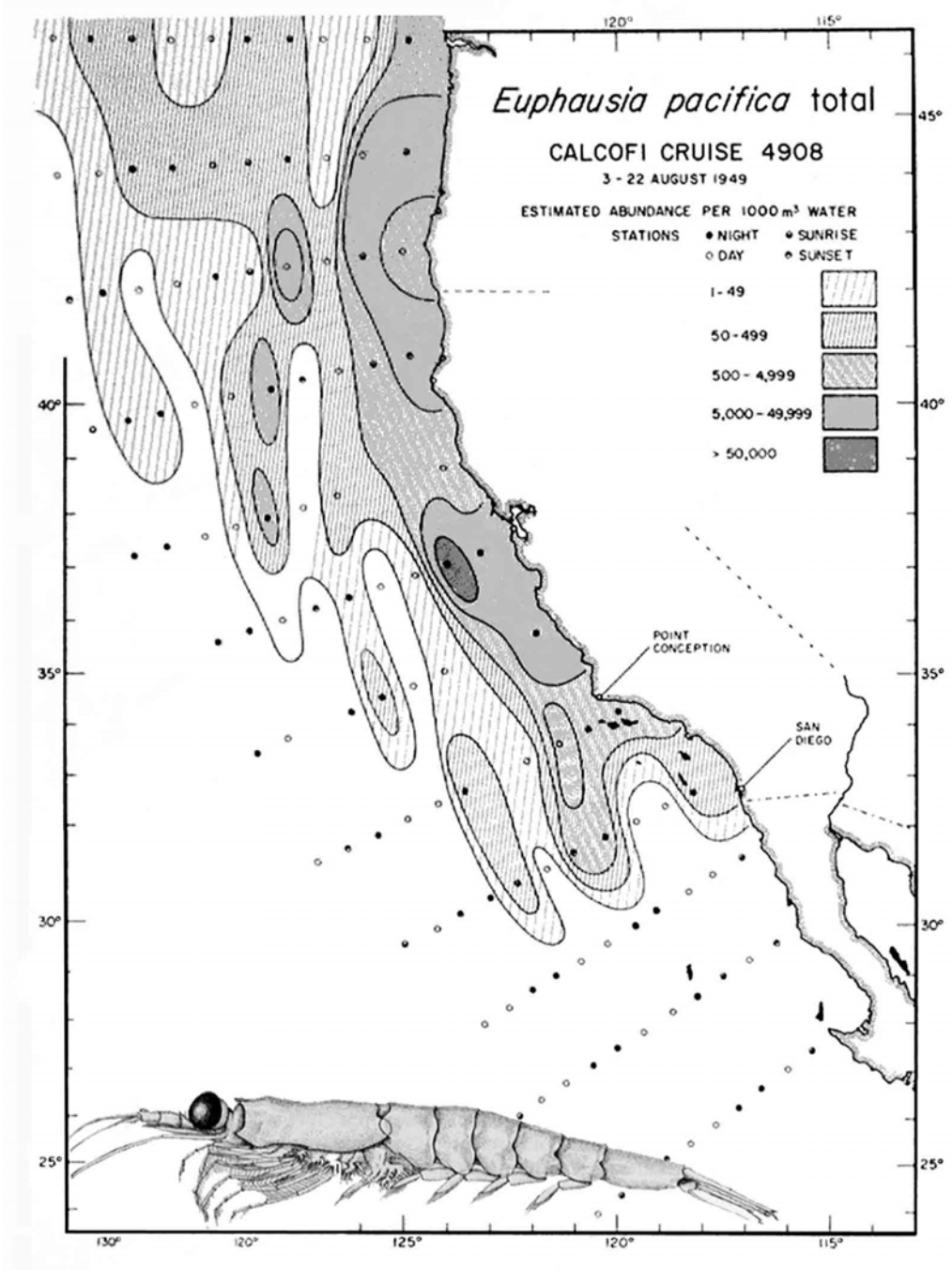

Fig. 7.10. Example of the abundance distribution of an important planktonic food organism, mapped by the CALCOFI program. Note the break between a northern and a southern region of the California Current.

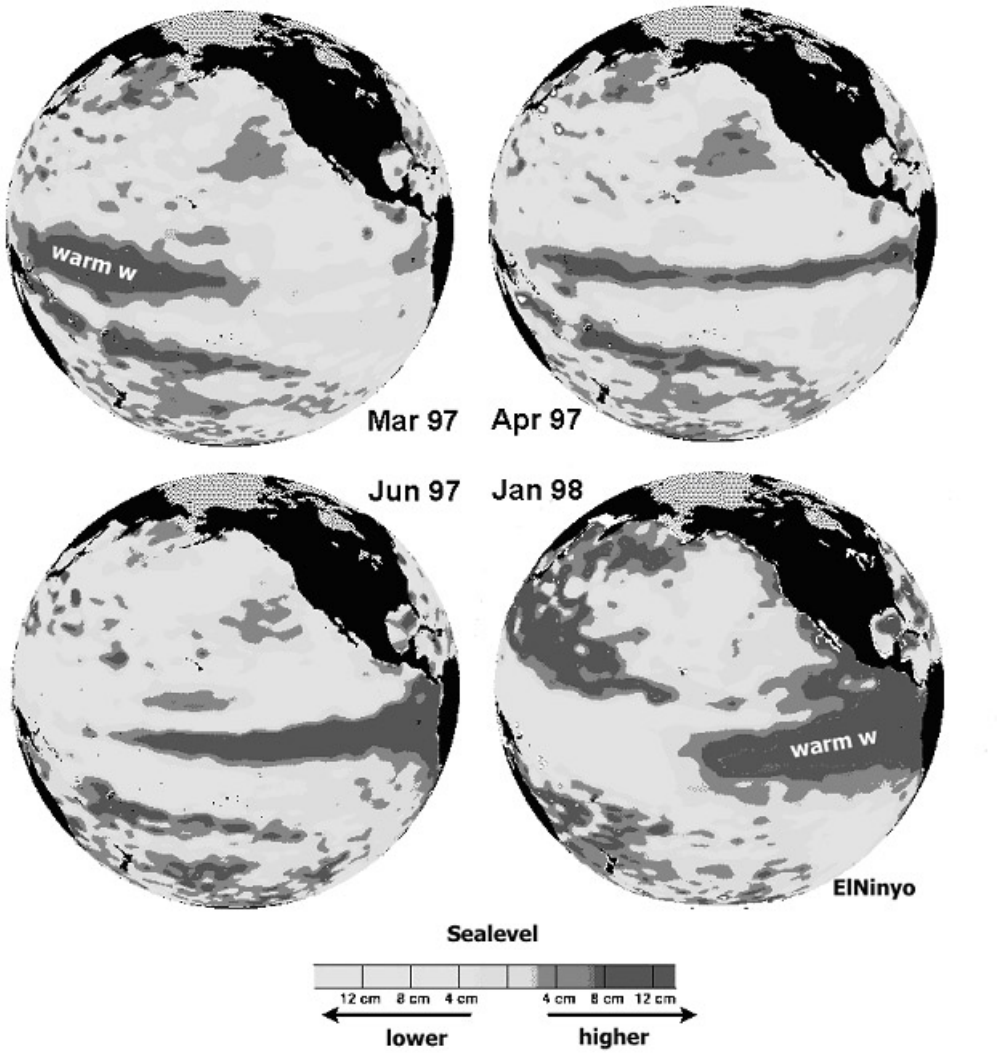

Fig. 7.11. Sealevel changes in response to the change from normal conditions (warm water in the west, upwelling in the east) to El Niño conditions, as seen in satellite surveys. Warm water has the higher sea level. Note the west-to-east seesaw motion of the warm water body in the equatorial Pacific.

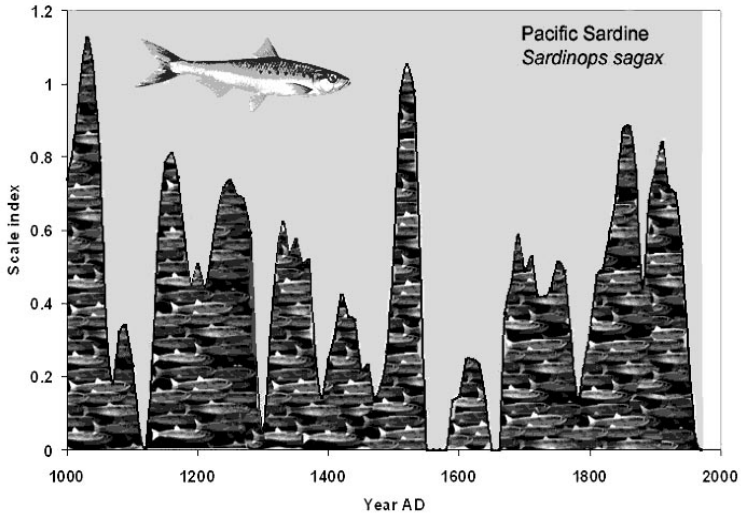

Fig. 7.12. Changes in abundance of fish scales in the marine sediments off Santa Barbara suggest large natural variations in the abundance of the Pacific sardine.

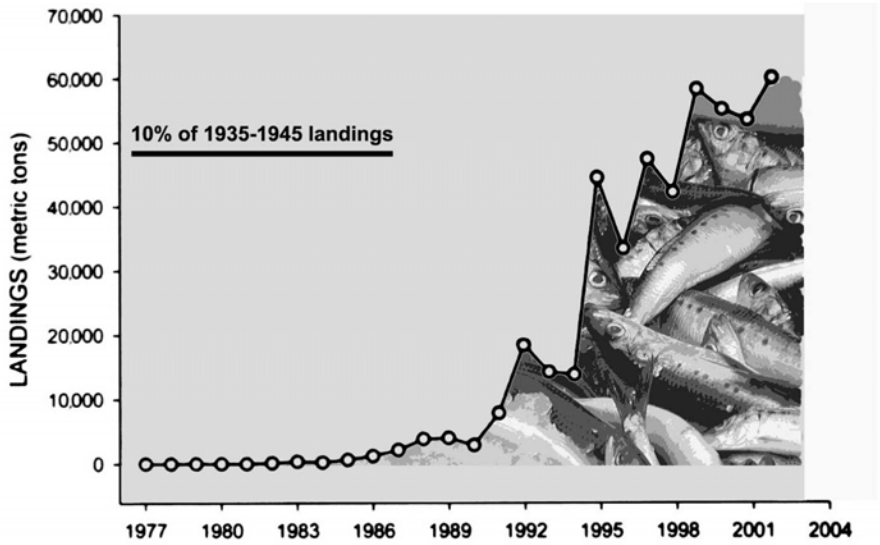

Fig. 7.13. Comeback of the sardine, since 1990. The level is modest, compared with the landings in the 1930s and 1940s.

Figure sources (where based on sources in the literature, on the web or in museum exhibits: figures are considerably modified and adapted for present purposes, using Adobe Photoshop; drawings and photographs by the author are marked "orig."):
1, H. Thorade in Krűmmel 1907; 2, California Department of Fish and Game, McEvoy 1986, CalCOFI and orig. photo; 3, Dietrich et al., 1975; 4, orig.; 5, orig. and drawings from E. Haeckel (see Ch. 1 for reference), Sverdrup et al. 1942 (see Ch. 2 for reference), and H. Murayama (see Ch. 1 for reference); 6, Lluch-Belda et al. 2003; 7, Sverdrup et al. 1942 and SIO archives; 8, CalCOFI; 9, CalCOFI; 10, CalCOFI; 11, NOAA; 12, J. Isaacs and A. Soutar; 13, CalCOFI. **References**: O. Krűmmel, 1907, *Handbuch der Ozeanographie*, Bd. 1, J. Engelhorn, Stuttgart, 526pp; A.F. McEvoy, 1986, *The Fisherman's Problem: Ecology and Law in the California Fisheries 1850-1980,* Cambridge Univ. Press, Cambridge and New York, 368pp.; California Cooperative Oceanic Fisheries Investigations, Atlases and Reports (SIO); Dietrich, G., K. Kalle, W. Krauss, G. Siedler, 1975. *Allgemeine Meereskunde, Eine Einführung in die Ozeanographie.* Gebrüder Bornträger, Stuttgart, 593 pp.; D. Lluch-Belda, D.B. Lluch-Cota, S.E. Lluch-Cota, 2003, CalCOFI Rep., 44, 76; National Oceanic and Atmospheric Administration, U.S. Department of Commerce; J. D. Isaacs and A. Soutar, cited in Baumgartner, T. R., A. Soutar, V. Ferreira-Bartrina, 1992. *Reconstruction of the history of Pacific Sardine and Northern Anchovy populations over the past two millennia from sediments of the Santa Barbara Basin, California.* CalCOFI Rept., v. 30, pp. 24-40, data here re-plotted; California Department of Fish and Game, 2003, CalCOFI Rep. 44, 10.