

Sardine and anchovy crises in northern Spain: natural variations or an effect of human activities?

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Crises associated with the sardine and anchovy populations off northern Spain have been known and documented for centuries. From a review of the available historical and current literature relevant to this and other regions, it seems that most of the crises have been due to environmental factors, and only during the second half of the 20th century can the effects of fishing be viewed as having added to the recruitment failures observed in the populations of both species.

Keywords: anchovy, environmental variations, northern Spain, sardine.

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Introduction

Sardine (*Sardina pilchardus* Walbaum, 1792), and anchovy (*Engraulis encrasicolus* Linnaeus, 1758), are two very important resources for the purse-seine fleet of northern and northwestern Spain. Both species are suffering serious crises, and their catches have exhibited a dramatically decreasing trend during the last decade, similar to what has happened with other engraulid and clupeoid fishes in different parts of the world. No satisfactory explanation for the phenomenon has so far been found. The traditional production models and successive stock assessments have often failed to predict the yield from one year to the next.

The International Council for the Exploration of the Sea (ICES) has played an integral role in the study of these fisheries. The Council created the Sardine Committee in the 1950s to deal with the small pelagic fishes of the southern region of the ICES Area; these species were later included in the terms of reference of the Pelagic Fish (Southern) Committee in 1966 and the Pelagic Fish Committee in 1977. In response to a request by the Pelagic Fish (Southern) Committee, a working group to coordinate fish egg surveys in ICES Subareas VII, VIII, and IX for the appraisal of sardine and other clupeids was established in 1973 as a first attempt to assess the sardine stocks in the region. The group, which has existed ever since, is currently named the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy. These committees and working groups have been the determinant for the Spanish institutes of marine research to constitute

and retain teams of scientists to carry out projects to meet their recommendations and requirements.

In order to gain some historical insight into the events these fisheries have experienced over the last 150 years, a review of the available literature, the assessments of the relevant ICES working groups, and the relevant references on environmental/fishery relationships in ICES papers and other sources was conducted.

The sardine crises

The first reference to the fluctuations of sardines in Galicia (northwestern Spain) dates back to the mid-18th century; unfortunately, it was not possible to consult any reliable documentation about the crises at that time. Local fishermen thought, in most cases, that decreases in abundance were caused by overfishing. This concept, of course, had not yet been identified, but was known empirically. Only a crisis that occurred in 1755 was thought to have had an exceptional environmental cause: an earthquake in the Pontevedra estuary that, it was said, frightened the sardines away for three months.

The oldest document found regarding sardine crises in Spain was in a now-extinct periodical, *Revista de Pesca Marítima*. According to two articles (Anon., 1888; Vera, 1888), the decade of the 1880s was bad for Spanish fisheries in general; catches by the entire fleet were reported to be very low. The Basque vessels fishing for sardine and anchovy reportedly returned to their home ports "without having shot their nets" on many days during the 1885 season. This situation affected



Figure 1. Landings of sardines (t) in northern Spain, 1940–1997.

other areas in the Bay of Biscay as well. The January 1888 issue of the periodical translated a report by the French naturalist Gerville-Réach from the October 1887 issue of the *Journal Officiel* of the French Republic on the sardine crisis in Brittany which occurred that year. In Gerville-Réach's view, the use of new and very powerful fishing gear was the reason for the decline in the fishery in Brittany¹. The French scientists Vaillant and Henneguy (1888) also reported on the causes of the disappearance of sardines in the region, attributing it to the catch of large quantities of juveniles, the use of powerful gear, and the occurrence of poorly known environmental conditions, among which were the extremely severe winters of 1880–1882.

Inappropriate fishing practices were also thought to be the possible cause of the failures of the Spanish fisheries. According to Madariaga (1972), González de Linares, the founder of the Marine Biology Station of Santander, was consulted at the time about the sardine fishery decline in the eastern Cantabrian Sea in the 1880s. He deduced, from some well-based biological arguments, that the crisis was due to environmental factors that he was unable to define, however, since knowledge on the matter was scarce.

¹ General report on the sardine fishery, submitted to the Minister of the Marine and of the Colonies of the French Republic, on behalf of the Consultative Board for Marine Fisheries, by M. G. Gerville-Réach, member of the Parliament and chairman of the Board. *Revista de Pesca Marítima*, 30 June 1888, pp. 172–181, and 31 July 1888, pp. 195–206.

Sardine crises continued to exist well into the first quarter of the 20th century. They were particularly evident in the inshore fisheries in the estuaries of Galicia, together with crises affecting other pelagic species. De Buen (1927, 1929) analysed statistically the landings of sardine, sprat, horse mackerel, and anchovy and concluded that the crises were due to a "law of alternation of migratory species" and a "law of ichthyological compensation" that he derived from his study. According to these laws, the four species substituted for one another spatially and temporally; low abundance of any of them was compensated for by higher abundance of the others. The changes in abundance depended on environmental conditions, especially salinity and temperature; if they were favourable for sardines, they would be detrimental for the other species, and vice versa.

For his study, De Buen utilized landings data for the periods 1907–1914 and 1921–1928. His theory was incorrect, as other authors later demonstrated (Navaz, 1946; Anadón, 1950), but its background was right, i.e., environmental variability made the abundance of species vary in absolute or relative terms; this meant that occasional changes in the pelagic fish ecosystem, limited in both space and time, occurred.

Fluctuations in sardine abundance have also been continuous since the 1940s in northern Spain. Landings statistics make it possible to see that there was a long crisis between 1945 and 1957 and after recovering in 1958–1962, a steady downward trend between 1962 and 1967. Landings increased rapidly after 1978 and

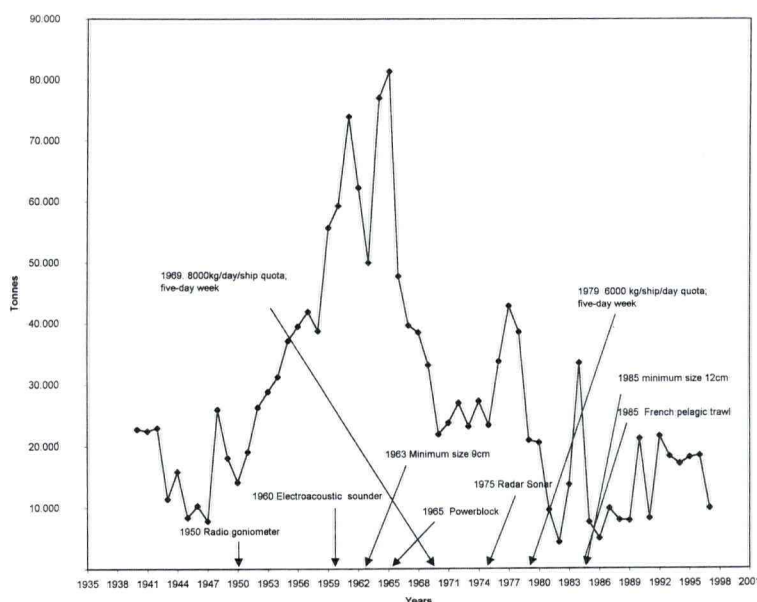


Figure 2. Evolution of anchovy catches since 1940, showing the years of adoption of technical improvements of the fleet and management measures. (Adapted from Uriarte and Motos, 1991).

reached a historical maximum of 108 000 t in 1984 (Figure 1). Several recruitment failures between 1979 and the mid-1980s (ICES, 1986) caused a decline that has continued since 1985. Average landings in the late 1990s fell to about a quarter of the 1984 maximum. In 1995, the stock was first determined to be outside safe biological limits (ICES, 1996), and this status has not changed since.

It is worth noting that crises affecting *Sardina* species and other clupeoids have coincided more or less in time and in quite different regions. Lluch-Belda *et al.* (1989) cited the following situations: Japanese sardines between 1950 and 1970 approximately; sardines off California during the same years; several clupeoids off Peru and Chile, also in that period, with small fluctuations over a 20-year period; and the fishery off southwest Africa between 1965 and 1970. Longhurst and Wooster (1990) described severe failures of oil sardines (*Sardinella longiceps*) off southwest India between 1941 and 1947, in the mid-1950s, and between 1969 and 1973, and sharp fluctuations since the late 1970s. British sardines and herring had important failures in the 1950s (Cushing, 1961; Southward, 1963), and it is well known that Icelandic herring almost disappeared in 1972 and 1973. A few years later (1977–1978) the big depletion of North Sea herring occurred when catches fell to practically nil. Ten years later, landings were about the same as in the mid-1960s, but dropped again in the late 1990s. In 1998, stock biomass was below the safe biological limit (ICES, 1999).

The anchovy crises

No explicit references to anchovy crises in northern Spain prior to the 1936–1939 civil war have been found in the scientific or other relevant literature, except for those in the *Revista de Pesca Marítima* about the generally bad situation with the small pelagic fish stocks in the region in the 1880s and the allusions of De Buen (1927, 1929) when he established his "laws". Based on landings since the 1940s (Figure 2), it is evident that anchovies have also undergone periods of serious crises following periods of abundance.

The first historic minimum in landings recorded in the last 60 years occurred in 1945–1947. Landings increased steadily from then until the mid-1960s before decreasing again until the poor period of 1970–1975. The increase between 1975 and 1978, when landings rose to levels unknown for 10 years, gave the impression that the stock was rebuilding quickly (Cort *et al.*, 1976). The evolution of the fishery proved this assumption to be wrong. The apparent improvement in landings did not correspond with an actual improvement in abundance. Porteiro and Fernández (1998), commenting on the current sardine crisis, stated that "when a stock shows signs of depletion, its distribution range diminishes and is restricted to the most favourable area". This results in an apparently higher density and an incorrect impression of a general improvement in the stock. This seems to have been the case for anchovies. The distribution range of the population has been reduced to the

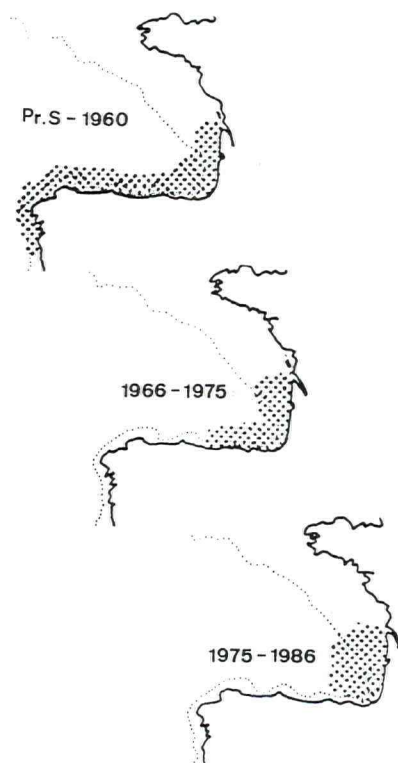


Figure 3. Reduction in the distribution area of anchovy in the Bay of Biscay between 1960 and 1986 (Junquera, 1991).

southeastern Bay of Biscay since the late 1960s, as shown in Figure 3 (Junquera, 1991). This author also noted that this process coincided with changes in the upwelling indices in the western Cantabrian Sea and Galicia during those years, but did not correlate both phenomena.

Since 1979, the trend in landings has been consistently declining, with occasional and very brief increases. Poor catches were not always due to the scarcity of fish, but were also caused by reductions in the actual number of fishing days owing to fishermen's strikes or rough weather occurring in some years. The reductions in fishing effort (i.e., fishing mortality) because of these circumstances did not result in any immediate improvement in the stock. It can be assumed that normal activity would not have produced different results nor changed the general tendency. It is possible that the occasional increases in landings were due to higher catchability because of the concentration of the stock in a smaller area.

Fishing power of seiners increased during these years because of technical improvements, but it is difficult to assess if this influenced the fluctuations in the anchovy stock. The successive regulations after 1965, such as minimum landing sizes, maximum catches per vessel and day, and a five-day fishing week, do not seem to have been very effective in improving stock abundance. Figure 2 depicts the evolution of catches and the years of adoption of various regulations and technical improvements. Catches increased or diminished after each of those events, but the variations were never consistent. The considerable reduction in the size of the fleet between 1966 (571 ships) and 1975 (390 ships) did not influence the downward trend of the stock. The most severe crisis occurred in 1981 and 1982 when catch per unit of effort and total landings dropped to their historically lowest levels. On the other hand, if the very high catches between 1957 and 1967, an average of 57 000 t yearly, might have influenced the subsequent decline in abundance (Cort *et al.*, 1976), it is reasonable to assume that the minimum in the 1940s was independent of the fishery, with moderate catches (about 22 000 t annually) and fishing activity considerably limited because of World War II.

In 1985, when the French fleet began to use semi-pelagic trawls in the anchovy fishery and the crisis of the early 1980s had not yet been overcome, Spanish fishermen feared that the increase in fishing effort would quickly deplete the stock. However, after some years of poor catches, the total catch of the French and Spanish fleets improved to the 1975–1978 level. From the available catch and age composition data, it is likely that the stock may stabilize at its current medium level, but the total biomass may be much lower than it was 30 years earlier.

Abundance fluctuations: what is the cause?

From the literature review and examination of landings from the fisheries, it is clear that crises in the sardine and anchovy stocks in northern Spain are not a recent phenomenon. There have been some attempts to attribute most of the sardine failures in the 19th century to improper fishing practices, but the low fishing power of the fleets suggests that fishing had very little, if any, influence. However, only occasional references to the influence of environmental conditions have been found in the literature.

Studies about relationships between the environment and the distribution, abundance, and recruitment of these species are numerous. It has not always been possible to quantify the actual influence of environmental factors, nor has there been unanimity about the time–space extension of the environmental phenomena influencing the recruitment of sardines and anchovies in northern Spain, but all investigators have found evidence of some kind of relationship.

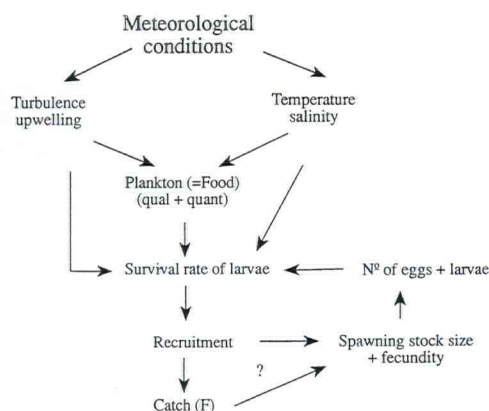


Figure 4. Diagram of the relationships between environment, stock, and catch.

Relative to sardines, Cuesta (1956) found a correlation between the spring upwelling on the northern Spanish shelf and spawning. Letaconnoux and Kurc (1962) cited unusually high temperatures in the Bay of Biscay as the possible reason for some differences observed in the composition of the French catches in 1961. Kurc (1964, 1969) and Vincent and Kurc (1969) observed that temperature changes influence sardine distribution and spawning. Kurc *et al.* (1965) correlated a high mortality of sardine eggs with very low temperatures in the winter of 1962–1963. Cabanas and Porteiro (1998) found a good correlation between recruitment and several large-scale hydrographic factors occurring in a large region of the Northeast Atlantic in spring and autumn, the two peak spawning seasons for the species. Robles *et al.* (1992) also found a good correlation between recruitment and the shift of Cantabrian-born sardine larvae to the upwelling area off the northwest coast of Spain where food is abundant. Lavín *et al.* (2000) stated that environmental conditions had brought the stock of Iberian sardine to the current crisis, but they mentioned fishing as an additional cause. Very recently, some evidence of a correlation between wind conditions and the catch of Iberian sardines has been found as well (ICES, 2000).

Most of the severe fluctuations in abundance of other pelagic species in the North Atlantic and elsewhere in the 19th and 20th centuries are partly connected with environmental changes. Icelandic herring is a clear case. Beverton (1998) demonstrated that even with a fishing mortality rate much lower than that exerted on the stock during the years prior to its collapse, catches would have fallen by half between 1965 and the years of the big

decline, which was overcome in the late 1970s owing to the combined action of the environment and strict fishery regulations.

The environment, therefore, highly influences sardine recruitment, but it appears not to be the only or perhaps the main cause of the declines of recent decades. The ICES Advisory Committee on Fishery Management (ACFM) reported "that stock size increased from the late seventies to the mid eighties because of a period of very strong recruitments" (ICES, 1999). However, poor recruitment and a decrease in stock biomass detected between 1979 and 1983 resulted in the rapid decline in landings shown in Figure 1. ACFM also noted that "fishing mortality was fairly stable between 0.13 and 0.2 from the 1970s to the mid 1980s", although it showed an increasing trend and "increased substantially to about 0.65 in 1997" (ICES, 1999). It appears likely, then, that the influence of the environment on recruitment and of excessive fishing mortality on the impoverished adult stock produced a combined adverse impact which resulted in one of the worst crises of the northern Iberian sardine stock.

Although the recent declines in anchovy abundance have been due to weak recruitment caused by the environment, it is uncertain which environmental factors have influenced abundance and recruitment of this species. Borja *et al.* (1996, 1998) observed that upwelling in the anchovy spawning area in the southeast part of the Bay of Biscay and during the spawning season favours good recruitment, but the positive correlation was less than 60%. More recently, Allain *et al.* (1999) correlated turbulence and upwelling with recruitment of anchovy: high upwelling indices favour recruitment, whereas turbulence has a negative effect, but again, the correlation was not sufficiently high. It is worth while mentioning that temperature may be an additional factor. According to Armstrong *et al.* (1999), anchovy abundance increased in the Irish Sea between 1991 and 1999, with the temperature regime thought to be the reason for the shift of the species into the region. Arbault and Lacroix (1978) defined the temperature ranges that determine spawning of anchovy and clupeoids in the Bay of Biscay.

The extremely high anchovy catches during the 1950s and 1960s and the subsequent poor recruitment in the early 1970s might have weakened the stock to a level very susceptible to recruitment failures such as those in the 1980s. The highly variable fishing mortality rate on anchovy between 0.41 and 1.3 since 1987 (ICES, 1999), the management measures, and the changes in efficiency of the fleet do not seem to have had any influence on the variations in the stock. The ICES Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy stated that "the assessment suggests that the current level of fishing mortality could be sustained in the long term provided that a step towards a more conservative approach is taken when the stock is at a low level", insisting further on the influence of environ-

mental factors on the large variability in abundance of the stock (ICES, 2001).

Uncertainties and needs

All the relevant studies have, so far, dealt with the relationship between macroscale environmental phenomena and pelagic fish populations; it seems consistent in the case of sardines. Relationships between the environment and anchovy recruitment are also evident, but there are some uncertainties about them. For a complete understanding of the system, population and fishery factors also have to be taken into account. A possible model to be developed is illustrated in the scheme in Figure 4.

There are some other environmental conditions to be considered. Sánchez and Gil (1994) found mesoscale thermic anomalies in the Cantabrian Sea that influence the distribution of juveniles of some demersal species. It is likely that mesoscale phenomena in the region are more important for small pelagic fishes than previously assumed. A thorough investigation of these phenomena during the anchovy spawning season would be needed to improve our interpretation of the relationships between the environment and the stock.

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