International Council for the Exploration of the Sea

CM 1989/H:18 Ref. C+L
Pelagic Fish Committee
Ref. Hydrog./ Biol. Ocean. Com.

A POSSIBLE RELATION BETWEEN SARDINE FISHERIES AND OCEANOGRAPHIC CONDITIONS IN NW SPANISH COASTAL WATERS

J.M. Cabanas (1), C. Porteiro (1), and M. Varela (2)

Instituto Español de Oceanografia
(1) Centro Costero de Vigo. Apdo. 1552, 36280 Vigo, Spain
(2) Centro Costero de La Coruña. Apdo. 130, 15080 La Coruña, Spain

ABSTRACT

The NW of Spain is influenced by episodic upwelling which occurs more often between March and October. The consequent enrichment of the shelf waters is the origin of a very important fishery for sardine in the area.

Eggs and larval survival is directly related to the oceanographic conditions between the date of birth and recruitment. Larval survival seems to be related essentially to weak upwelling conditions since they favour the non-dispersion of eggs (larvae) and allow growth of medium sized phytoplankters as suitable food.

On the other hand, strong upwelling causes dispersion of eggs (larvae) and favours growth of very large phytoplankton species, mainly diatoms, that are thought to be un-suitable food for larvae. However, strong upwelling conditions are favorable for sardine adults, since the large phytoplankters growing during these upwelling events were found to be the main food supply, as shown by the study of stomach contents.

RESUME

Le NW de Espagne est influencée par afleurements épisodiques de l'eau que se montre le plus fréquemment dans la periode entre Mars et Octobre. Cet enrichement d'eau côtière est l'origine d'une important pecherie des sardines.

La survivance des oeufs (larves) est directement reliée avec l'oceanographie chez la date de naissance et le recrutement. La

survivance des larves parait être reliée avec un afleurement faible puisqu'il favorise la non dispersion des oeufs (larves) et permets la croissance du fitoplancton de dimension moyen que constitue un nourrissement bon à manger.

Au contraire, fort afleurisement cause dispersion des oeufs (larves) et favorise la croissance des espèces fitoplanctoniques grandes, la majorité diatomées, que constituen une faible nourrissement pour les larves. Cependant, des conditions d'afleurement fort son favorables pour les sardines adultes puisque, le fitoplancton grand qui grandi pendant ces épisodes d'afleurement, constitue le plus grande source de nourrisement, comme se trouve quand on analise le contenue des estomacs.

INTRODUCTION

Forecasting recruitment to mature or exploitable stocks has long been a central problem in fishery research. Stock-recruitment models have dominated this field. These models are based exclusively on biological interactions and integrate the entire life history into a single prerecruit class. There is an unknown error in the parent stock size, and they ignore potentially important abiotic influences on recruitment processes.

In coastal systems, short-term and long-term variations in the distribution, abundance and production of a variety of organisms have been related to the effects of abiotic factors, and to the impact of large-scale meteorological influences on the ocean environment (Lasker, 1978).

In the last 10 years, the oceanography of the west coast of the Iberian peninsula has been investigated (Fraga, 1981; Blanton et al, 1984). In this area, between April and September, there is a wind induced seasonal upwelling. This is the most northerly part of the north-east Atlantic upwelling system which extends between the Gulf of Guinea and the northem Iberian Peninsula (Wooster, 1976).

The relation between upwelling and biological production is strong, (Blanton et all, 1987; Dickson et al, 1988). There are two effects on coastal waters, the transport of surface coastal water to the open sea, and the supply of nutrients to the photic layer, which produce areas of high biological potential. In the pre-recruit period, most individuals are in the coastal upwelling areas, where the food supply is guaranteed.

Phytoplankton is a major component of the diet of sardines in upwelling areas (Blaxter and Hunter, 1982; Varela el al, 1988). In non upwelling periods, or in areas not affected by upwelling, zooplankton is the main component of stomach contents of adult sardines.

In this area we do not have historical data series of phytoplankton to try to establish a relationship between the distribution of phytoplankton and sardine recruitment. We only have data from two cruises carried out on the Galician continental shelf in 1984 (Varela et al, 1987a,b), and one cruise in 1985. We also have information during the sardine spawning season in April 1987 (Sarp-area cruise). However, the available information allows us to speculate about the type and size of phytoplankton that might serve as food for both larva and adult sardines, and the environmental conditions necessary for the growth of such kinds of phytoplankton.

FISHERY AND BIOLOGY OF IBERIAN SARDINE

The Iberian sardine (Sardina pilchardus, Walb.) is the target of an important fishery on the Atlantic Coast of the Iberian Peninsula, where most of the landing ports are located. The catch and its economical and social implications make it one of the most important fisheries of this area. Most of the catch is taken in summer and autumn. The period of maximum landings coincides with the main recruitment period.

At present, only one stock is considered in the assessment of this sardine, distributed from France to Gibraltar. Since 1979 this stock is evaluated by the W.G. on the assessment of pelagic stocks in divisions VIIIc and IXa of ICES.

Recruitment estimates using Virtual Population Analysis, show variability in the period 1976-1988. The 1983 year class was the strongest (34 514 * 10^-6) and that of 1986 was the weakest (7 998 * 10^-6). Table 1.

Acoustic surveys carried out in Spanish waters during March (spawning season) (Pastor et al 1986 a; Anon., 1989), found a major concentration of sardines in Cantabrian waters. These results are in agreement with the egg distribution found on ichthyoplankton surveys carried out in the same area (Sola, 1985; Garcia, 1988). On the other hand, cruises in August, during the upwelling season, show major concentrations, of adult and juvenile sardines in Atlantic waters, where more suitable food is present due to upwelling (Pastor et al, 1985, 1986 b).

The Iberian sardine has two main spawning areas, the northern Portuguese coast (spawn Dec-Jan) (Cunha, 1988), and the Cantabrian Sea (spawn March-April) (Sola, 1985). The recruits are mainly distributed on the west coast of the Iberian Peninsula. Year class I is concentrated in Portuguese waters and moves north as it grows. Year class 5 and higher are located in the Cantabrian Sea (Porteiro et al, 1988; Anon., 1988).

BIOTOPE CHARACTERISTICS

In the coastal waters of this area, we found three layers not always well defined (Fraga, 1982, 1985).

-The surface layer, limited by the thermocline (20 m), with Temperature (T) and Salinity (S) conditions varying according with meteorology.

-A mixed water layer between the thermocline and 60 m in the west (Galicia) or 250 m in the north (Cantabrian Sea), with homogeneous T, S, and nutrients. It is formed in winter by the mixing of surface water with NACW, and in summer on the west coast it disappears due to upwelling.

-NACW (North Atlantic Central Water),(11.5-13ºC, 35.5-35.7‰, 5-10 µM NO_3^-/l), between 60 (or 250) and 450 m, composed of two water bodies, one of which penetrates Biscay Bay from the NW and moves to the SW as far as Cape Finisterre, and another comes which from the south along the Portuguese coast to Cape Finisterre. Where they meet there is a poorly defined front. This water mass upwells on the west coast between April and September, and reaches the surface on the shelf and in the Rias.

The mass transport trends found in the 0-100 m layer are a function of the water mass characteristics and their dynamics, and are dominated by the winds (Bakun and Nelson, 1975). By Ekman`s theory, the total integrated mass transport of pure drift currents is given as:

$$\vec{Ve} = (1/f)*\vec{T}*\vec{k}$$

where:

$\vec{Ve}$ the total mass transport resulting from an applied local wind stress.

f the Coriolis parameter.

$\vec{k}$ the unit vector directed vertically upward.

$\vec{T}$ local wind stress.

In the northern hemisphere this transport is directed 90º to the right of the wind stress.

According to this and knowing the wind stress, we can estimate transport across the shelf. We calculated the transport in the East-West direction at three points along the northern coast. The wind stress was obtained from the pressure field show on daily meteorological maps (3 maps/day). Fig. 1 gives the average monthly wind induced transport for the period studied.

For the nearshore circulation, a simple numerical model of the wind driven component was developed by McClain et al (1986). Whith a wind stress of about 3 dy/cm2 from N and NW, they found a coastal jet to the west (Cantabrian) and south (Galicia) near the coast (0-10 Km), with progressive pycnocline elevation (upwelling) and an offshore poleward flow. The order of magnitude of these currents is 5-10 cm/s in the north and 3-7 cm/s in the west, with a transverse current due to upwelling < 2 cm/s (supposing an upwelling of about 500 m3/(s*Km), and a thermocline layer about 30 m deep).

PHYTOPLANKTON AND LARVAL DISTRIBUTION.

Nutrients enrichment of the photic layer during upwelling causes an important increase of production and phytoplankton biomass. However, the changes in the community are not only quantitative but qualitative (Varela and Costas, 1987). In non upwelling periods, phytoplankton biomass is very low. Small forms (nanoplankton, essentially microflagellates), are predominant. On the contrary, when upwelling occurs, there is a predominance of larger forms (netplankton), dominated by colony-forming diatoms. In fig. 2 we show the importance of both phytoplankton fractions: nanoplankton (less than 10 µm) and netplankton (bigger than 10 µm), in the two main types of stations we consider in Galician continental shelf in relation to upwelling. Oceanic stations are those not affected by upwelling events. Upwelling stations are those affected by upwelled water. In fig. 3 the size classes distribution of phytoplankton in the two types of stations previously described is presented.

In the oceanic areas, the phytoplankton biomass is low, and most of it lies in the smallest size classes considered: 3 µm of mean spherical diameter. This size is too small to serve as food for both larval and adult sardines. In upwelling areas, the increase of biomass coincides with a sift to larger size classes. In this case, an important percentage of phytoplankton biomass will be available as food for larva and adult sardines.

For sardine feeding, both larval and adult, the total amount of organic matter present in the water is no critical, but the distribution of that organic matter in the appropriate size range is very important. The size of the first food of the Iberian sardine is not known, but may be between 40 and 80 µm (P. Smith, pers. comm.). For adults, the minimum size is around 45 µm (Andreu, 1969), which coincides well with our own observations of stomach contents. Roughly, we can consider that the classes 35-70 µm would be available as food for larvae, and the classes larger than 45 µm for sardine adults.

Fig. 4 shows the distribution of less and bigger than 35 µm phytoplankton fraction, in oceanic and upwelling stations. Only in upwelling stations an important phytoplankton biomass would be available for larvae feeding.

When we compare the distribution of larvae and the distribution of chlorophyll (corresponding to phytoplankton, 40-80 µm size), the correlation is positive but too small (R=0.25) to draw conclusions. It may be that, besides phytoplankton, a significant amount of microzooplankton biomass exist, mainly planktonic ciliates, as observed during phytoplankton counting. This abundance has not been evaluated, but might greatly contribute to larval feeding.

On the other hand, the 40-80 µm range size is probably effective only for first feeding. Eventually, larvae probably feed on larger prey, such as copepod nauplii (Lasker, 1978), or even on macrozooplankton. This would explain the positive and significant relation (R=0.40) between macrozooplankton and larvae found on SARP-area cruises. Then, the relations between the 40-80 µm fraction and young larvae must be studied, as well as relations between the fractions larger than 80 µm and older larvae.

RELATION BETWEEN UPWELLING AND SARDINE RECRUITMENT

Using the upwelling index (Iw) as an indicator of mass transport and food availability in surface waters, and relating this to the year`s recruitment (YC), we can try to analyze how oceanographic conditions affect recruitment.

For the period 1976-1988, we study the possible relation using correlation analysis.

The variables considered are:

YC - annual year class strength (recruitment).
Iw - Upwelling index, calculated for a point 150 Km west of Cape Finisterre.

Initially we correlated YC with Iw for all months; in the months February (IwF), May (IwMy), and the average of April and May (IwAMy) and of April and September (IwAS) the correlations are significant. Table 1, fig.5; for the others months the correlation are poor, but the Iw for March and April (IwM, IwA) are considered too because it is the spawning period.

From the monthly correlation coefficients between Iw and YC we may deduce:

In February and March, (R positive, Iw negative); a higher in absolute value of Iw corresponds to a minor value of YC. This may be due to the fact that west winds disperse the larvae from the winter spawning (Dec.-Jan.) on the west coast.

In May (R negative, Iw positive); north winds intensify the circulation towards the west in the Cantabrian Sea, and may disperse the larvae from the spring Cantabrian spawning area in the corner of the Iberian Peninsula; only the larvae nearest the coast drift south and survive.

The correlation with IwAMy is negative; this may indicate that dispersion predomites over the other upwelling induced phenomena (such as suitable food) that favour the success of spawning.

DISCUSSION

The distribution and behavior of the Iberian sardine seem to respond to the upwelling regime in the area. Thus the timing and distribution of spawning are during non-upwelling conditions (March-May in Cantabrian Sea, November-December on the northern Portuguese coast) to avoid wind induced turbulence, which is greather during upwelling. These two spawning periods also seem to be related to water temperature, which reaches 13.5-14ºC earlier (December-January) on the Atlantic coast than in the Cantabrian Sea, where this temperature is reached in March-April.

Transport conditions in the upper water layer of the shelf are very important for recruitment because the spawning areas are in different places. Eggs spawned in Cantabria drift to Galician waters if the surface currents are favorable, and reach the upwelling area in May, where suitable food for larvae and prerecruits exists. This general circulation feature is very critical near Cape Finisterre, where under certain conditions (strong north winds) intense upwelling is produced, which can interrupted the nearshore circulation along the west coast and disperse offshore all matter that reaches the cape (Chesney and Alonso, 1988).

The results of the relationship between recruitment and the monthly upwelling indices show that for the March spawning in the Cantabrian Sea, the April-May period is critical for larval survival. Moderate upwelling on the Atlantic coast in this period produces good recruitment. If upwelling is intense the larvae are dispersed and recruitment is weak.

Thus upwelling seems to be related to recruitment of pelagic fish. If it is moderate at the beginning of the season (April-May), it favours transport from the spawning to the pre-recruit areas, does not disperse the larvae, and produces suitable phytoplankton that serve as food for larvae. After this period (June-Oct.) the larvae are older and remain in the upwelling area with abundant food.

REFERENCES

ANDREU B. 1969.- Las branquispinas en la caracterizacion de las poblaciones de Sardina pilchardus. Inv. Pesq. 33(2), 1-25.

ANONIMO 1988.- Report of the Planning Group for Acoustic Survey in ICES sub-areas VIII and IX, 9-12 Feb. 1988. ICES Doc. C.M. 1988/H:2

BAKUN A., C. NELSON 1975.- Climatology of upwelling related processes of Baja California. CALCOFI Rep. vol. XIX, 107-127.

BLANTON J.O., L.P. ATKINSON, F.F. CASTILLEJO, A. LAVIN 1984.- Coastal upwelling off the Rias Bajas, Galicia, NW Spain. I.- Hydrographys studies. J. Rapp. et Proc.-Verb. Reun. Cons. int. Exp. Mer 183, 79-90