Review of hydrographic environmental factors that may influence anchovy habitats in northwestern Mediterranean*

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SUMMARY: This paper is a review of the hydrography of the northwestern Mediterranean. It examines, at several scales from basin-scale to local processes, water mass distribution, circulation and driving mechanisms and their variability. It is focused on those aspects that may influence the success of spawning and recruitment of anchovy: stratification processes, continental influence, frontal instabilities, mesoscale events and shelf-slope exchanges.

Key words: Hidrografía, revisión, Mediterráneo noroccidental, anchoa.

RESUMEN: REVISIÓN DE LOS FACTORES AMBIENTALES HIDROGRÁFICOS QUE PUEDEN INFLUENCIAR LOS HÁBITATS DE LA ANCHOA EN EL MEDITERRÁNEO NOROCCIDENTAL. – En el presente trabajo se hace una síntesis de los principales aspectos hidrográficos del Mediterráneo Noroccidental. Se detalla la distribución de masas de agua y se examinan los mecanismos que influyen en la circulación y su variabilidad, desde la escala local a la global. El trabajo se centra en los aspectos que podrían tener mayor influencia en las primeras fases de desarrollo de la anchoa: procesos de estratificación, influencia continental, inestabilidades de los frentes y otros procesos de mesoscale así como los intercambios de agua entre talud y plataforma.

Palabras clave: Hidrografía, revisión, Mediterráneo noroccidental, anchoa.

REGIONAL CHARACTERISTICS

The marine region known as the northwestern Mediterranean covers an area of around 200000 km², between the northern continental coast and a line from Cape la Nau to the Balearic islands, then to Corsica, and the Corsica channel to Livorno (Fig. 1). Within the region there are four definite entities: the Ligurian and Catalan seas, the Gulf of Lions and the northern part of the central western Mediterranean basin, open to the rest of the basin through the wide (450 km) and deep (2800 m) passage between Menorca and Corsica.

The Ligurian Sea is a deep basin (around 2800 m) open to the west, between Corsica and Toulon (180 km). It communicates with the Tyrrenian Sea through the Corsica sill (60 km, 400 m). The Catalan Sea is like a deep valley open to the NE, with depth increasing from around 800 m at the Eivissa sill (80 km) to 2600 m between Menorca and C. Sant Sebastià. There are another two sills between the Balearic islands: Mallorca (75 km, 650 m) and Menorca (50 km, 100 m) that also allow water exchanges with the southern part of the western basin. The Gulf of Lions has a wide continental...
shelf, less than 200 m deep, and the shelf break is aligned between Toulon and C. Creus. Within the region there is only one other wide continental shelf, the Iberian shelf, in the Gulf of València. The rest of the coast has narrow or even no continental shelves. Along the continental slopes there are canyons of variable width and depth. The most conspicuous of these are located from Toulon to Blanes.

The orography of the continental coast presents mountain ranges higher than 1000 m not farther than 100 km inshore. Only the Rhône valley, the Carcassonne gap and the Ebro valley cut this structure. This last river, however, reaches the sea in a narrow passage through the coastal mountain range. Because of this orography all the rivers are short (less than 300 km), except the Rhône and Ebro. Nevertheless, this region receives a major input of fresh water in the Western Mediterranean (more than 70%) due to the contribution of the rivers that drain all the southern side of the Pyrenees and the eastern side of the Alps (Béthoux, 1979).

The dominant winds blow from the northern sector (Tramuntana, Mistral, Gregal, etc) along the main valleys and the Carcassonne gap. During winter they are more frequent, strong, dry and cold, and can persist for several days (Reiter, 1975; May, 1982). These dominant winds produce a clear shear line in the middle of the western side of the region (Jansà, 1987) and the more exposed area is centred around 42° N, 5° E (MEDOC Group, 1970). These winds used to be associated with a deep low pressure centre in northern Europe or, more commonly to a high pressure in the NE Atlantic and low pressures in the Gulf of Genova, (Colacino, 1992). It is well known that, during winter, the northwestern Mediterranean is one of the world’s major centres of cyclogenesis (Pettersson, 1956).

The other winds are local and variable. They are associated with local storms, passage of Atlantic fronts or induced by the orography (Fontserè, 1948; Jansà, 1980). During summer the wind regime is characterised by calms and coastal breezes (Reiter, 1975).

Evaporation plays an important role in the dynamics of the Mediterranean Sea enhancing the winter convection processes (Stommel, 1972). Due to the strong and dry northerlies, the levels of evaporation in the Western Mediterranean reach their maximum in the northwestern region (Bunker, 1972). These maximum values usually occur in autumn and winter, when surface waters are gener-

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**FIG. 1.** – Map of the northwestern Mediterranean. The bathymetry of coastal regions is indicated by 200 m and 1000 m isolines.
ally warmer than air. In spite of the high fresh water input from rain or rivers in the region, the water lost by evaporation is not balanced at the annual cycle (Hopkins, 1978). The maximum amount of precipitation is received in autumn and spring (Colacino, 1992). It is also important in winter on the mountains, but its effect is not appreciable until spring, when snow melts. Only during spring the evaporation is balanced by rain and riverine inputs (Béthoux, 1979). As will be discussed later, the seasonality of water deficit plays an important role in controlling the water transported by the main currents.

The amplitude of the astronomical tide in the Mediterranean is low (10-30 cm) and tides have almost no dynamic role. However, sea level oscillations, due to atmospheric forcing or heat exchanges with the atmosphere, have comparable or higher amplitudes than the astronomical tides but longer periods. Oscillations due to episodes of cyclogenesis, cooling and evaporation are important in the northwestern region, and they play a role in modifying the inputs of water into the region (Manzella and La Violette, 1990).

WATER MASSES

The water column is structured in three layers: The surface layer up to a depth of around 150 m, characterised by a minimum subsurface temperature. The intermediate layer between 200-350 and 600-800 m is occupied by the Levantine Intermediate Water that presents a relative maximum of temperature and salinity. Water in the deep layer, below 600-800 m to the bottom, is almost homogeneous in potential temperature and salinity (Furnestin, 1960; Lacombe and Tchernia, 1972; Hopkins, 1978). Within the deep layer, the lower 200-300 m are occupied by a water with slightly higher density representing the newly formed Deep Water (Lacombe et al., 1985). The characteristics of the water masses are variable according to the conditions under which they were formed. The current pattern and the existence of sills inside the basin further affect the local vertical structures at different locations. Thus, the water mass structure is a combined effect of climatology, topography and circulation.

According to their origin we can identify five water types that dominate the water mass structure in the region (Salat and Cruzado, 1981):

- Surface Atlantic water (a)
- Levantine Intermediate water (i)
- Western Mediterranean Deep water (d)
- Winter Intermediate waters (w)
- Continental Coast Surface waters (c)

(a) is the surface water of the Atlantic Ocean, (i) is formed in the eastern Mediterranean, and the rest are originated locally.

In the Straits of Gibraltar the upper layer is occupied by the surface Atlantic water and the North Atlantic Central Water (NACW), which enters the Mediterranean. The depth of the surface that separates the inflow from the outflow in the Straits of Gibraltar oscillates from 150 to 200 m (Farmer and Armi, 1988). From this point ahead, the surface currents distribute the Atlantic waters through the Mediterranean. The original characteristics of the NACW are progressively modified, increasing its salinity, into a water mass usually called Modified Atlantic Water (MAW). It is the lightest water in the basin (except close to the mouth of the main rivers) and can extend vertically up to the maximum depth of the surface that separates inflow from outflow at the Straits of Gibraltar. In the northwestern basin, however, it is unusual below 130 m (Salat, 1995).

The typical TS signature of the upper layer with MAW is a straight line of mixing between surface water and the underlying Mediterranean water, roughly perpendicular to the $\sigma$ isolines, called Atlantic-Mediterranean Interface Water (A-MIW) by some authors (Gascard and Richez, 1985). Strictly speaking, MAW is used as a generic term to identify the water present almost everywhere in the Mediterranean surface (La Violette, 1994). However, after a long period of residence in the Mediterranean, MAW becomes “old” so that the salinity difference with the water beneath is decreasing, or, in other terms, A-MIW tends to disappear. Thus, the degree of development of the A-MIW is a good indicator for the “age” of the MAW.

The “youngest” MAW reaches the northwestern basin through the Eivissa channel (García Lafuente et al., 1995; Salat, 1995) and is deflected eastward by the cyclonic circulation in the Catalan Sea. A well defined density front, the north Balearic front, is formed, located at the northern side of the Balearic islands (Font et al., 1988). The north Balearic front (Fig 2) presents a meandering structure with strong mesoscale variability (García et al., 1994). Slightly “older” parcels of MAW come into the northwestern basin through the
FIG. 2. – Schematic map of fronts and water mass distribution: 1. Coastal waters with continental influence; 2. Recent MAW; 3. Maximum surface salinity; 4. Areas of frequent upwellings

FIG. 3. – Scheme of circulation: Path of main currents and eddies: 1. Anticyclonic eddies; 2. Cyclonic eddies
channels between the Balearic islands and through the gap between Menorca and Corsica (Millot, 1987). Again, the denser waters at the centre of the basin force this water to proceed towards the eastern Ligurian Sea, following the west coast of Corsica in a well formed current (Béthoux et al., 1982; Taupier-Letage and Millot, 1986). Surface waters entering the Ligurian Sea from Tyrrhenian, through the Corsica channel, usually have higher temperature than those from west Corsica (Nyffeler et al., 1980).

The surface circulation from the eastern Ligurian Sea to the Catalan Sea (Fig. 3), following the edge of the continental shelf, entrains river water discharges (c) from the Arno to Ebro (Astraldi et al., 1994; Béthoux et al., 1988; Millot, 1987; Castellón et al., 1990) with a maximum river runoff in the inner shelf of the Gulf of Lions, corresponding to the Rhône. A coastal water mass, formed from MAW with the contribution of (c) water, is present in the upper layer along the continental side of the shelf edge current. The space and time fluctuations in the amount of runoff water contribute to the high variability of this coastal water, which always has lower salinity and temperature than the water offshore (Salat and Cruzado, 1981). These differences may be around 2°C in temperature and 0.5 in salinity in winter (Salat and Font, 1987). The sections across the continental slope show a well definite shelf/slope front (Fig. 4) located 30 to 90 km offshore at the surface, with marked density differences between 0.2 and 0.5 kg/m³. The slope of isopycnals at the front is induced by the current, over which the effect of coastal waters is superimposed. The vertical influence of the coastal water mass can reach a depth of 350 m at the continental slope (Font et al., 1988; Salat, 1995).

The presence of density fronts at the two sides of the northwestern Mediterranean basin contributes to the classical image of doming of isopycnals in the cross sections (Furnestin, 1960; Prieur, 1979; Font et al., 1988). In the Catalan Sea, although both the north Balearic and Continental fronts are not stationary, the latter, related to the topography, is much less variable than the former (López-García et al., 1994). In the Ligurian Sea the west Corsica front and the Liguro-Provençal fronts are both more stable (Sournia et al., 1990; Boucher et al., 1987; Nyffeler et al., 1980).

As the presence of fronts around the basin is almost permanent (Font et al. 1988), the common way for MAW to reach the central part is after a long peripheral course, except under some mesoscale events discussed later. Then, after such a path surface salinity has substantially increased to the maximum values in the basin. Typical surface salinity in the central part are from 38.0 to 38.20 in summer and from 38.10 to more than 38.40 in winter (Nyffeler et al., 1980; Salat and Cruzado, 1981).

Winter Intermediate waters (w) are formed during winter convection over the continental shelves and slopes, following the frontal structures. The TS characteristics of these waters ranges from 12.5 to 12.9°C in temperature and from 38.1 to 38.25 in salinity (Salat and Font, 1987; Sparnocchia et al., 1995). The
spreading mechanism of these waters has not been completely described but (w) waters are present at the bottom limit of the surface layer, producing a relative minimum of temperature found everywhere in the basin, at depths ranging from 150 to 350 m (Lacombe and Tchernia, 1972; López-Jurado et al., 1995).

The Levantine Intermediate water type (i) originates in the Levantine basin of the Eastern Mediterranean (Hopkins, 1978). It forms a well defined water mass (LIW) that flows through the Sicilian channel at a depth from 250 m to the bottom (Manzella et al., 1988) and from this point it spreads into the Western basin. The main path of LIW water follows the continental slope of the Tyrrhenian Sea, to the Sardinia channel and reaching the northwestern region through to the continental slope west of Corsica. To a lesser extent this water also reaches the Ligurian Sea through the Corsica channel (Astraldi et al., 1996). In our region LIW water is found at 300-400 m showing a classical TS signature of a “scorpion tail” (Tchernia, 1958) with a relative maximum of temperature (13-13.8°C) and an absolute maximum of salinity (38.48-38.60) depending on how “old” the water is (Salat and Cruzado, 1981).

During winter, a deep convection occurs at certain points of the central part of the northwestern basin (MEDOC Group, 1970; Prieur et al., 1983; Salat, 1983). This occurs where surface salinity is maximum, by a combined effect of the strong, cold and dry northerlies and the cyclonic circulation. This is the process known as Western Mediterranean Deep Water (DW) formation. It is a complex mechanism (Gascard, 1977; Leaman and Schott, 1991) which also entrains Levantine Intermediate waters, leading to the production of a dense water (d) that can rapidly sink to the deepest layer and become a parcel of newly formed deep water. During this process the water column may be homogeneous from the surface to its maximum depth (2800 m). The amount of (d) water type produced and its TS characteristics present slight variations from one year to another, but its usual range of temperature is from 12.7 to 12.9°C and salinity from 38.42 to 38.48. Its potential $\sigma_t$ is very stable around 29.1 kg/m³ (Béthoux et al., 1990).

**GENERAL CIRCULATION**

General circulation in the Mediterranean basin is thermohaline. The circulation in the northwestern basin has been described as dominated by a central cyclonic gyre that establishes a doming of isopyc-

nals (Allain, 1960; Ovchinnikov, 1966). More recently, several authors (Millot, 1987; Font et al., 1988) have related this circulation to the geostrophic adjustment of the frontal structures separating the water bodies above described (Fig. 2) over which the effects of deep water formation are superimposed (Madec et al., 1991). There is also a main surface current that follows the northern side, from the eastern Ligurian Sea to the Gulf of Valencia, following the shelf-slope front (Millot, 1991; Albérola et al., 1995), and a southern current, following the north Balearic front (Fig. 3).

The Liguro-Provençal-Catalan current, formed at the eastern Ligurian Sea, is composed of the west Corsica Current, flowing on the western side of Corsica, and the Tyrrhenian current, flowing through the Corsica channel (Béthoux et al., 1982). The Tyrrhenian current displays an important seasonal variability while the flow of the West Corsica current is more stable (Astraldi and Gasparini, 1992). The Liguro-Provençal-Catalan current may reach a maximum intensity of around 60 cm/s (Castellón et al., 1990; Albérola et al., 1995).

On the southern side of the region the current is adapted to the North Balearic front. It is formed at the Eivissa channel, then follows north of the Balearic islands to the northwest of Corsica (Hopkins, 1985). In the north of Baleares, the stream lines of this current are very variable, as is the position of the front, with a remarkable meandering structure (García et al., 1994). This southern current can reach a maximum intensity of 75 cm/s, but it has less thickness than the shelf-slope current (Pinot et al., 1994). These two main currents dominate the general circulation such that the total transport of water associated with this circulation pattern has been evaluated to range from 0.8 to 1.6 Sv (Albérola et al., 1995).

The two fronts are characterized by the frequent occurrence of mesoscale eddies, filaments and mid-depth intrusions. In the central part of the region, away from the frontal structures, there is no defined circulation pattern but cyclonic vortices are frequent (La Violette et al., 1990). However, the meandering of the North Balearic current (Pinot et al., 1994; López-García et al., 1994) and filaments of coastal waters that cross the shelf-slope front (Wang et al., 1988) give a high variability to this central area.

The northern current roughly follows the continental slope, which runs very close to the coast in most of the northwestern Mediterranean region
because of the narrow continental shelves. However, where the shelves are wider, mainly in the Gulf of Lions and the Iberian shelf, the northern current flows far from the coast. Over these continental shelves there is no well defined circulation pattern, but some anticyclonic vortices may develop (Salat et al., 1990; Font et al., 1990). Local events like wind stress and vorticity, vertical mixing, upwelling, surplus or deficit of fresh water inputs, and shelf-slope exchanges, have a major influence on the circulation patterns in the coastal strip (Millot, 1978; Masó et al., 1990). This variety of processes produce a wide spectrum of situations that characterise the coastal circulation over the continental shelves.

TIME AND SPACE VARIABILITY

The behaviour of the Mediterranean Sea is strongly influenced by seasonality due to its position in mid latitudes. In the northern basin, the surface temperature annual oscillation may reach 15°C. However, at a depth below 200 m this annual oscillation is not higher than 1°C. Salinity values are more constant with variations lower than 1 unit (Picco, 1991), except at the surface near to rivers where salinity can reach values under 30, mainly by the end of spring.

An example of the annual cycle of the upper layer is shown in Fig. 5. The typical cycle can be summarized as follows (Lacombe and Tchernia, 1972): In winter, there are episodes with vertical homogeneity (December to mid April) followed by the development of a thermocline in spring (from April to July). The surface mixed layer above the thermocline becomes thicker during summer. By the end of summer and during autumn, due to heat loss of water, the surface temperature decreases. This reduces the temperature gradients at the thermocline up to the total homogeneity, at the end of the stratification period (November to December).

All the processes involved in the annual cycle work in short time steps which confer to the above typical cycle an irregular and rough aspect (Pascual et al., 1996) with high spatial variability (Béthoux et al., 1982) and important interannual differences (Astraldi et al., 1994). Local winds, rain and fresh water inputs, currents and mesoscale activity induce the main perturbations over the smooth solar cycle which drives the annual cycle (Fig. 6). In the following paragraphs some of those effects will be described.

Where surface waters are affected by continental waters there is a surplus of buoyancy that can have different effects according to the season. In autumn and winter, buoyancy enhances surface cooling and produces inversions of temperature, while in spring and summer, it enhances the stratification and allows the continental waters to spread over large areas (Castellón et al., 1985).

Winds always work to reduce stratification in two ways: by cooling and increasing salinity due to evaporation, and by direct stress: Ekman effect and inertial waves.

The presence of frontal structures and their associated dynamics has a complex interaction with the spatial variability of the stratification development. The transport of waters from one place to another, exposed to different local events and thermohaline conditions, contributes to the spatial differences of stratification. In turn, this spatial pattern of different stages of stratification modifies horizontal gradients which affect the position of the fronts and the path and intensity of the associated currents. In particular mesoscale activity in the northern current is enhanced in autumn and winter (Albérola et al., 1995; Font et al., 1995).

Part of the flow variability of the northern current is controlled by the marked seasonality of the fluxes through the Corsica channel: strong in winter and weak in summer (Astraldi et al., 1992). The increase of intrusions of warmer Tyrrenian water into the Ligurian Sea in winter is, again, driven by the different thermohaline conditions existing in the two basins during this season. The North Balearic current presents a similar dependence on the seasonali-
ty of the exchanges through the Eivissa channel, which are controlled by thermohaline differences between the southern and northern basins. In particular the input of recent MAW from the southern basin is reduced in winter due to the incursion of winter intermediate waters from the north (García Lafuente et al., 1995).

During the stratified period, stability internal waves can reach 10 m of amplitude (García Lafuente and Lucaya, 1994). These waves play a role in primary production at the deep chlorophyll maximum, by introducing cyclic changes of light conditions in these layers (Estrada and Salat, 1989; Dickey et al., 1991).

In coastal areas and over the continental shelf, winds are one of the most important sources of variability (Font, 1990). Events of strong winds, which occur at time scales of about three days to a week, may produce local upwellings (Fig. 2) in the Gulf of Lions (Millot, 1978). Eastern wind storms (Llevantades) on the western side of the basin are associated with heavy rain (Fontserè, 1929). N and NW wind episodes are related to vertical mixing along the coast. Wind pulses of a few hours produce inertial waves over the shelf, when water is stratified. Then they can contribute to the formation of the surface mixed layer or to sinking motions (Salat et al., 1992; Tintoré et al., 1995).

In the central area the sources of variability are associated with the seasonal cycle of development and dissipation of the stratification and several kinds of mesoscale features of the north Balearic front and eddies as well as filaments of continental shelf waters (Tintoré et al., 1990). These structures have a fast evolution (5-15 days) (López-García et al., 1994).

Within the shelf-slope front, an analysis of its fine internal structure reveals a long period mixing (10 days) between its central and peripheral zones (Boucher et al., 1987). This mechanism may contribute to the winter water formation and spreading, and may enhance the primary production in the frontal area. The water is exposed to the surface for periods of 1 to 5 days at about 5 km off the frontal zone and less than one day at the front.
COUPLING OF COASTAL AND OPEN SEA WATERS

Coupling mechanisms have a major role in biological processes (Sabatés and Masó, 1992; Astraldi et al., 1995). However, on the southern side of the basin, coastal waters around the islands are not significantly different from open sea waters because they have almost no land influence, except at a very local scale like in some bays. The islands’ continental shelves are very narrow and there are no regular rivers on the islands.

Along the northern coast of the basin, the continental front is the result of dynamic coupling of coastal and open sea waters. The time and space variability of this coupling is one of the factors that contributes to the mesoscale activity of the front (Font et al., 1995). The continental front is a boundary for coastal waters. It has a major role restricting the exchange of waters to the events of mesoscale activity. Among those, surface filaments, mid-depth intrusions and the spreading mechanism of winter intermediate waters could be cited as good examples of exchange (Rojas et al., 1995). Through surface filaments low salinity shelf water is subducted along the front and exported to open sea. Mid-depth intrusions of offshore waters are due to the interaction between the flow associated with the Continental front and the bottom topography, especially where the continental slope is irregular, like in the canyons (Masó et al., 1990).

During the period of maximum stratification, in summer, the surface layer is almost uncoupled from the rest of the water column by a strong thermocline. This thermocline acts like a virtual in isolating surface circulation. Indeed, the surface signature of the main fronts can be erased (Font et al., 1988). Under such circumstances, incursions of offshore waters to the coast have been recorded (Masó and Tintoré, 1991).

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Coupling processes are more relevant at the continental shelf of the Gulf of Lions and the Iberian shelf, because these shelves consist on large shallow areas which receive an important input of continental waters. The path of the Liguro-Provençal-Catalan current follows the shelf-slope front until it meets the shelf and its core is deflected offshore by the change in orientation of the continental slope. However, waters in the upper layer of the current tend to proceed over the continental shelf interacting with the local waters (Millot, 1990). Their interaction with the wind induced circulation over the shallow areas, dominated by northwesterlies during winter, results in a complex pattern of currents and upwelling phenomena (Millot, 1990; Font, 1990).

Inertial oscillations have been reported to be associated with wind pulses near the coast. In the vicinity of a large scale current, the interaction between these inertial oscillations and the mean current field gives rise to significant horizontal and vertical shears and a downward transfer of energy (Salat et al., 1992).

Other processes like winter water formation and “cascading” can involve waters from the coastal side of the front. The so-called “cascading” phenomenon is an alternative mechanism related to deep water formation, typical of high latitude continental shelves, that some authors (Fieux, 1974) have reported to be present in the northern Catalan Sea and the Gulf of Lions.

ANCHOVY HABITATS

In the northwestern Mediterranean anchovy spawns from April to October, with a maximum peak in June-July (Palomera, 1991). This is a clear indication that it prefers well stratified waters. Concerning the availability of suitable food organisms for the larval development, stratification and abundance of organisms are commonly opposing issues. Nutrients are generally supplied by vertical motions but, in stratified waters, vertical motions are severely restricted. In these conditions only significant shears associated with frontal structures or wind storms, like inertial oscillations, can involve vertical motions or mixing (Éstrada and Margalef, 1988). Another alternative for nutrient supply, especially relevant in the stratified season, is the input of continental waters.

During the stratified season, maximum values of chlorophyll concentration, as indicative of the presence of primary producers, used to be found in a thin layer below the thermocline, known as deep chlorophyll maximum (Éstrada, 1985). Within this layer, the values of chlorophyll are higher at the
vicinity of the frontal structures (Estrada and Margalef, 1988) while, at the surface, high values are only detected in the presence of continental waters (Blanc et al., 1969). Limits and spreading of continental waters, shear regions, the fine structure of the front, and other relevant processes have been analyzed in the previous sections. It has been found that most of them occur along the continental coast preferably in the vicinity of the Gulf of Lions and the Iberian shelf.

The surveys of eggs and larvae appear to confirm that the zones under continental influence are preferred for spawning (Palomera and Sabatés, 1990). The peaks of anchovy spawning are coincident with maximum spreading of continental influence on waters, taking advantage of the stratification at the end of spring. Egg production abundance is associated with the development of stability, and survival is influenced by the amount of continental waters (Palomera and Lleonart, 1989).

As previously mentioned, mesoscale events are an alternative source for nutrient supply and hence for food abundance. These events, however, may have an adverse effect on larval development of the anchovy because, in such circumstances, larvae can be involved in dispersion processes (Sabatés and Masó, 1992). The observed vertical migrations of larvae (Palomera, 1991) may help, at least partially, to elude the dispersion problem.

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