Spawning pattern and batch fecundity of the European hake (*Merluccius merluccius* (Linnaeus, 1758)) in the western Mediterranean

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SUMMARY: The spawning cycle of the European hake (*Merluccius merluccius*, (Linnaeus, 1758)) was studied in two western Mediterranean areas, the Catalan Sea and the northern Tyrrhenian Sea, including observation of the monthly seasonal variation of the gonad maturity and the gonadosomatic index (GSI). The estimation of the maturity stages by GSI gave similar values in the two study areas: the spawning stage (IV) was easily distinguished from the other maturity stages and its range of variation showed a low overlap with stage III and no overlap with other stages. Although in both study areas active females were present during all the sampled months, the peak of reproductive activity was concentrated from February to May in the northern Tyrrhenian Sea but from August to December in the Catalan Sea, which was subjected to winter cascading events. Batch fecundity gave similar values in the Catalan and northern Tyrrhenian Seas: 204 and 202 eggs per gonad-free female gram, respectively. An asynchronous oocyte development is suggested for *M. merluccius* in the western Mediterranean.

Keywords: *Merluccius merluccius*, cascading events, spawning pattern, fecundity, western Mediterranean.

INTRODUCTION


*M. merluccius* is a commercially and ecologically important species in the Mediterranean, where catches increased until 1995 and then abruptly declined to less than half from 1995 to 2002 (52000 to
21000 t), being at present similar to the level of the 1980s (FAO, 2005). Nevertheless, it is still the second most important demersal fish species by landings (after blue whiting, *Micromesistius poutassou*) and one of the most important target species of the western Mediterranean trawl fleet (Sánchez et al., 2007). In the Catalan and northern Tyrrhenian seas, recruits and juveniles are caught by bottom trawls, while the adult population, representing a percentage of between 37 and 46% of the total landings (Sartor et al., 2001), is also caught with longlines and gillnets (Aldebert et al., 1993; Sbrana et al., 2007). In both study areas, as in many zones of the Mediterranean, growth overfishing can be assumed (the hake stock shows signals of growth overexploitation) (Aldebert et al., 1993; Aldebert and Recasens, 1996; Lleonart et al., 2003; FAO, 2005).

Due to its commercial importance, some recent biological studies on this species related to fish and larval distribution, growth, feeding and recruitment have been carried out in the Mediterranean Sea (Bozzano et al., 1997; Morales-Nin et al., 1998; Belcari et al., 2001; Sartini et al., 2002; Maynou et al., 2003; Olivar et al., 2003; Belcari et al., 2004, 2006). The life cycle has been investigated in some areas of the western Mediterranean such as the Gulf of Lions (Recasens et al., 1998) and Santa Pola bay (García-Rodríguez and Esteban, 1995) and studies of some reproductive aspects have been studied in the northern Tyrrenian Sea (Sbrana and Belcari, 1993; Biagi et al., 1995; Nannini et al., 2001). In Atlantic waters, *M. merluccius* is classified as an asynchronous, indeterminate and batch-spawning species (Murua and Saborido, 2003; Murua and Motos, 2006). A complete study of the reproductive biology of this species in the Mediterranean using a macroscopic and microscopic approach (histology) is still lacking.

The aim of the present work is to study the histological structure of the ovary and the spawning cycle of Mediterranean hake populations, identifying the spawning peaks, and determining females length at first maturity and fecundity parameters. It thus contributes to our knowledge of the general spawning pattern of Mediterranean hake, its variability within the study area and the reproductive potential of this species.

**MATERIALS AND METHODS**

Adult sampling was carried out in two different areas of the western Mediterranean with a similar latitude: the Catalan and northern Tyrrenian seas (Fig. 1a,b). In the Catalan Sea, the sampling was carried out on a monthly basis between November 1997 and December 1998 at the port of Vilanova (Table 1a). Specimens were gathered at the port from longline and gillnet boats catching adult hake between 100 and 300 m depth (Fig. 1a). The total number of females sampled was 635, ranging from 24 to 74.5 cm TL (total length). In the northern Tyrrenian Sea, the sampling was carried out between February 1998 and December 1999 at the ports of Marina di Campo (Elba Island) and Porto Santo Stefano (Table 1b). Specimens were obtained on board gillnet boats targeting hake between 100 and 300 m depth (Fig. 1b) and at ports sampling commercial landings of trawlers. The total number of females sampled was 2729, ranging from 13.5 to 91 cm TL. For each specimen the following parameters were taken:
total length to the lowest half cm, total weight (TW) to 0.1 g, and gonad weight (0.01 g). Macroscopic and microscopic maturity stages were determined according to the Sarano scale (1986), which defines eight stages for hake: I, virgin; II, maturing; III, prespawning; IV, ripe; II+, partial postspawning; V and VI, postspawning; and VII, resting. For fecundity studies ovary-free weight defined as total weight minus gonad weight was also obtained.

**Histology**

A total of 1574 female gonads, 635 from the Catalan Sea and 939 from the northern Tyrrhenian Sea, were removed, weighed and fixed in buffered 10% formalin. From these, 743 ovaries chosen by length-stratified sampling taking 10 individuals minimum per 2 cm length class (254 for the Catalan Sea and 489 for the northern Tyrrhenian Sea) were selected for histology.

The histological analysis was performed to verify the macroscopic classification, to confirm the partial spawning and to ensure that spawning had not yet started. For each ovary, after dissection and preservation, three subsamples were taken from different parts (anterior, middle and posterior) and exposed to dehydration and inclusion in paraffin. The thickness of the section was about 10 μm. The sections were coloured by treatment with Carazzi’s Hemalum and eosine contrast (Hunter and Macewicz, 1985). The ovarian stages, up to 8, were defined according to the developmental stage of the most advanced oocyte inside the ovary (Sarano, 1986).

**Spawning cycle**

The spawning cycle of the species was studied. Adult females were used (520 and 1278 in the Catalan and in the northern Tyrrhenian Sea, respectively). Juvenile females were not considered. The monthly evolution of the gonad maturity stages and the gonadosomatic index (GSI, calculated as a percentage of gonad weight in relation to total fish weight) were used to determine the spawning peaks. To ensure the adequate use of GSI the independence of this index in relation to fish size was verified. The isometric relation between gonad weight and fish mass was also verified.

**Length at first maturity**

Length at first maturity was defined as the length at which 50% of the specimens had already matured at least once, and was estimated considering females in stages higher than stage II. The maturity was determined macroscopically. In the Catalan Sea the fe-
Fig. 2. – Histological sections of ovaries of *Merluccius merluccius* in different maturity stages. A) stage I, immature; B) stage II, in maturation; C) stage III, prespawning; D) stage IV, spawning; E) stage II+, partial postspawning; F) stage V, total postspawning; G) stage VI, regression; H) stage VII, resting (*P* = previtellogenic oocytes; 1V, 2V, 3V = 1st, 2nd, 3rd vitellogenic stages; *I* = Hydrated oocytes; *POF* = postovulatory follicles; *A* = atretic oocytes).
males included 115 juveniles and 520 adults, whereas in the northern Tyrrhenian Sea they included 1680 juveniles and 1278 adults. For each length class the percentage of adult females was calculated.

Length at first maturity was estimated by means of a logistic model fitted to the percentage of pre-spawning and spawning specimens per length class (Yeates, 1974), whose equation is:

\[ f(x) = \frac{1}{1 + e^{-a \times b 	imes x}} \]

where \( f(x) \) represents the percentage of mature specimens, \( M \) the maximum value of \( f(x) \), \( x \) the length, \( a \) and \( b \) parameters of the curve, and \( e \) the natural logarithm base.

**Fecundity**

Fecundity was estimated as batch and relative fecundity. Batch fecundity was defined by the number of eggs released for an individual in each spawning event. Females in advanced maturity stage IV were used. Relative fecundity was calculated as the value of batch fecundity per gram of fish ovary-free body weight (fish weight without ovary).

In order to ensure that the location of tissue samples did not affect the batch fecundity estimation, a two-way ANOVA analysis was carried out. For this purpose a total of 20 individuals were used. Three 0.1 g samples of ovary tissue were taken from each ovary, right and left (the positions of the sample were anterior, middle and posterior of the ovarian lobes).

Only ovaries that showed absence of recent postovulatory follicles in the histological analysis, meaning that the current batch had not yet started, were used (Hunter et al., 1985, 1992; Schaefer, 1996). The hydrated oocytes of 3 samples (0.1 g each) per ovary of female in maturity stage IV were counted. Mean value was calculated, expanded to the total ovary weight and expressed as number of oocytes per ovary. A total of 58 ovaries from the Catalan Sea and 81 from the northern Tyrrhenian Sea were analysed.

Relationships between relative fecundity, batch fecundity, fish total length and fish gonad-free weight were estimated by fitting power functions.

**RESULTS**

**Histology**

The histological analysis allowed each maturity stage to be characterised following Sarano (1986) (Fig. 2): immature (stage I) (Fig. 2A), in maturation (stage II) (Fig. 2B), prespawning (stage III) (Fig. 2C), spawning (stage IV) (Fig. 2D), partial postspawning (stage II+) (Fig. 2E), total postspawning (stage V) (Fig. 2 F), regression (stage VI) (Fig. 2G), and resting (stage VII) (Fig. 2H). Detailed characteristics of oogenesis are listed in Table 2.

The ovary of the spawning females contained oocytes in all development characteristics, hake showing an asynchronous ovary development. The histological analysis was used to determine the minimum oocyte sizes at the beginning and end of vitellogenesis: 150 µm and 870 µm, respectively. A low incidence of oocyte atresia (degeneration of oocytes) occurred throughout the spawning season, but became marked as the spawning season ended and the remaining advanced oocytes in the ovary were reabsorbed.

Concordance between histological maturity stages and macroscopic analysis of the gonads was found for 73% in the Catalan Sea and 59% in the northern Tyrrhenian Sea. Differences in maturity stage determination were centred in stages III and II+, whereas stage IV always showed a good macroscopic and histological concordance. Detailed macroscopic and histological characteristics are listed in Table 3.

<table>
<thead>
<tr>
<th>Oocyte</th>
<th>Diameter (µm)</th>
<th>N/C</th>
<th>Microscopic characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>PO</td>
<td>≤ 20</td>
<td>0.8-0.5</td>
<td>Small round cells</td>
</tr>
<tr>
<td>P</td>
<td>100-120</td>
<td>0.5-0.3</td>
<td>Spherical, large nucleus, basophilic cytoplasm</td>
</tr>
<tr>
<td>1V</td>
<td>150-380</td>
<td>0.4-0.2</td>
<td>Lipid globule deposition starts</td>
</tr>
<tr>
<td>2V</td>
<td>300-700</td>
<td>0.3-0.15</td>
<td>Yolk eosiophilic granules appear</td>
</tr>
<tr>
<td>3V</td>
<td>530-870</td>
<td>------</td>
<td>Nucleus irregular, animal pole migration, oil drops start fusion</td>
</tr>
<tr>
<td>I</td>
<td>1050</td>
<td>------</td>
<td>Nucleus disintegrated. Hydration begins</td>
</tr>
</tbody>
</table>

Table 2. – Oocyte development in European hake of the Mediterranean following the description of Sarano (1986) and Murua et al. (1998, 2006). PO, Primary oocytes, -primary growth; P, previtellogenic; 1V, 1st vitellogenic stage (cortical alveoli stage); 2V, 2nd vitellogenic stage; 3V, 3rd vitellogenic, migration stage; I, hydration stage. N/C, nucleus/cytoplasm relationship.
Spawning cycle

There was no relation between fish size and GSI index (Fig. 3). On the other hand, the relationship between fish weight and gonad weight (Fig. 4) was isometric. The t-test carried out with the slope (b = 1.0119) shows that b does not differ significantly from 1 (t = 0.48, df = 518, prob = 0.63).

Female gonadosomatic index (GSI) for each macroscopic maturity stage ranged from a minimum of 0.53-0.68 (maturity stage I) to a maximum of 12.7-12.9 (maturity stage IV), and subsequently decreased after spawning (Fig. 5). Running ripe stage (IV) was easy to distinguish from the other maturity stages and

TABLE 3. – Correspondence between microscopic and macroscopic maturity ovary staging characteristics.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Microscopic characteristics</th>
<th>Macroscopic characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Juvenile</td>
<td>Only unyolked oocytes: oogonia, primary oocytes growth, previtellogen oocytes</td>
<td>Thin and transparent gonads</td>
</tr>
<tr>
<td>II In maturation</td>
<td>Vitellogenesis has started. Oocytes in 1st (cortical alveoli oocytes) and 2nd vitellogenic phase can be observed</td>
<td>Orange and bigger gonads. Granulated appearance</td>
</tr>
<tr>
<td>III Prespawning</td>
<td>Dominance of oocytes in 2nd and 3rd vitellogenic phase. Migration stage</td>
<td>Orange gonads occupying whole abdominal cavity. Oocytes visible</td>
</tr>
<tr>
<td>IV Spawning</td>
<td>Mainly hydrated oocytes are present. Hydration stage</td>
<td>Hydrated oocytes visible, occupying the whole gonad</td>
</tr>
<tr>
<td>II+ Partial postspawning</td>
<td>Postovullatory follicles (POF) and oocytes in vitellogenic stage for next batch</td>
<td>Big gonads. Hydrated oocytes present, vascular system conspicuous. Pale orange appearance</td>
</tr>
<tr>
<td>V Total postspawning</td>
<td>Many POFs are present. Most oocytes do not exceed 250 µm</td>
<td>No hydrated oocytes. Blood spots, vascular system conspicuous. Bloody appearance</td>
</tr>
<tr>
<td>VI Regression</td>
<td>Oocytes &gt; 150 µm in degeneration</td>
<td>Smaller gonads. Bloody appearance</td>
</tr>
<tr>
<td>VII Resting</td>
<td>Oocytes in previtellogenesis and in 1st vitellogenic phase</td>
<td>Tubular opaque gonads. Pale orange colour.</td>
</tr>
</tbody>
</table>
its range of GSI variation showed a low overlap with stage III and no overlap with other maturity stages.

In both study areas, the monthly evolution of the mean GSI (Fig. 6) and the maturity stages (Figs. 7 and 8) showed that females in advanced maturity (III), spawning (IV) and partial postspawning (II+) were present all year round, but there were considerable differences in the spawning peaks: in the northern Tyrrhenian Sea the reproductive activity was concentrated from January to May, with spawning peaks in February and May, while in the Catalan Sea the main reproductive season occurred from August to December, with spawning peaks in September and December.

**Length at first maturity**

Length at first maturity was determined as 35.8 cm in the Catalan Sea and 35.1 cm in the northern Tyrrhenian Sea (Fig. 9a,b). The length at which all the females matured at least once was 45-50 cm in both areas.
In the northern Tyrrhenian Sea, the minimum size at which specimens were mature was 26.5 for a female of stage II. In the Catalan Sea, a female of 31 cm and stage III was the smallest one in maturation.

**Fecundity**

The position of the samples of hydrated oocytes within the ovaries had no significant effect on oocyte density. Hydrated oocytes were homogenously distributed within the ovary, so samples could be taken from any location, right or left, without bias (Table 4).

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**Table 4.** – Two-way ANOVA of No. eggs/g of ovary tissue in hake. Effect of the position of ovarian tissue samples on the number of hydrated eggs per unit sample weight (g). Positions of the sample were anterior, middle and posterior of ovarian lobes. ns = not significant

<table>
<thead>
<tr>
<th>Effect</th>
<th>df effect</th>
<th>Mean square effect</th>
<th>df error</th>
<th>Mean square error</th>
<th>F</th>
<th>p-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right vs left ovary</td>
<td>1</td>
<td>1604.44</td>
<td>84</td>
<td>144707.5</td>
<td>0.011</td>
<td>0.916</td>
</tr>
<tr>
<td>Position within ovary</td>
<td>2</td>
<td>2080.00</td>
<td>84</td>
<td>144707.5</td>
<td>0.014</td>
<td>0.985</td>
</tr>
<tr>
<td>Interaction</td>
<td>2</td>
<td>1524.44</td>
<td>84</td>
<td>144707.5</td>
<td>0.011</td>
<td>0.989</td>
</tr>
</tbody>
</table>

**Table 5.** – Catalan and northern Tyrrenian Sea fecundity values for hake. SD, Standard Deviation.

<table>
<thead>
<tr>
<th></th>
<th>Catalan Sea</th>
<th>SD</th>
<th>minimum</th>
<th>maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batch fecundity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tyrrhenian Sea</td>
<td>185821</td>
<td>132411</td>
<td>25238</td>
<td>562440</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative batch fecundity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catalan Sea</td>
<td>204.29</td>
<td>87.87</td>
<td>53.07</td>
<td>461.9</td>
</tr>
<tr>
<td>Tyrrhenian Sea</td>
<td>202.35</td>
<td>83.12</td>
<td>80.05</td>
<td>568.6</td>
</tr>
</tbody>
</table>

**Fig. 10.** – Relative fecundity (eggs number/g) of *M. merluccius* in both areas. a) Catalan Sea; b) Northern Tyrrhenian Sea.

**Fig. 11.** – Catalan Sea. Relationships between batch fecundity (eggs number/female) and a) total length (cm); b) female gonad-free weight (g). Number of females = 58.

The estimations of the batch fecundity were similar in the two zones. In the Catalan sea it ranged from 17296 for a female of 35.5 cm TL to 681489 for a female of 66 cm TL. In the northern Tyrrhenian Sea it ranged from 25238 for a female of 31.5 cm TL to 562440 for a female of 66.5 cm TL.

In the Catalan Sea the mean relative batch fecundity was 204 eggs g⁻¹ (gonad free female weight) (Table 5), whereas in the northern Tyrrhenian Sea it was 202 eggs g⁻¹ (gonad free). Concerning the relationship between relative batch fecundity and the size of hake, the results indicate that relative fecundity is not size-dependent (Fig. 10) in either area.
Fecundity relationships were established for females with hydrated oocytes. Batch fecundity was related to fish length and fish weight (gonad free). The results show a positive relation between these variables and similar values in both areas (Figs. 11 and 12).

DISCUSSION

Histological observations of the maturity stages of the ovaries showed certain differences from the macroscopic evaluations of the gonads (73% agreement in the Catalan Sea and 59% in the northern Tyrrhenian Sea) caused by a more subjective assignment of the macroscopic stage, indicating the importance of the histological approach in performing studies of maturity assessment. This problem could be solved through the joint consideration of reproductive stages such as pre-spawning (III), spawning (IV) and partial post-spawning (II+), and also total post-spawning (V) and regression (VI). The results indicate asynchronous ovary maturation for this species, in which oocytes at all stages of development are present at the same time throughout the reproductive season. The contemporary presence of developing yolked oocytes and postovulatory follicles in the ovaries of many females indicated that *M. merluccius* is a partial spawner, as was suggested previously in the Tyrrhenian Sea (Biagi *et al.* 1995; Nannini *et al.* 2001) and is in agreement with Atlantic populations (Sarano 1986; Murua *et al.* 1998; Murua and Saborido, 2003).

In the Mediterranean, hake populations seem to have an active reproduction throughout the year, as is shown in this paper and has been reported previously (Papaconstantinou and Stergiou, 1995; Recasens *et al.* 1998). The same protracted spawning pattern has recently been described for Atlantic hake populations (Murua and Motos, 2006), so this protracted spawning period is a specific characteristic for *M. merluccius*. This pattern has been observed in other *Merluccius* species like *M. capensis* (Kainge *et al.*, 2007) but for other ones like *M. hubbsi* (Macchi *et al.*, 2004) the spawning season lasted fewer months. In our results, advanced mature females (pre-spawning, III; spawning, IV and partial postspawning, II+) were present during all the sampled months in both study areas, confirming that hake spawn continuously throughout the year. In fact, juvenile recruitment has also been observed throughout the year (Recasens *et al.*, 1998; Belcari *et al.*, 2001; Morales-Nin and Moranta, 2004; Belcari *et al.*, 2006).

The gonadosomatic index by maturity stages showed similar numeric values in the two areas and these values are not dependent of hake size. Thus, we can assume that hake gonads have a similar development in the Catalan and northern Tyrrhenian Seas.

The reproductive pattern shows the alternation of a period of 4-6 months of high activity followed by a period of low activity. Nevertheless, there is a temporal displacement of the spawning season, with spawning peaks occurring earlier in the northern Tyrrhenian Sea (winter and spring) than in the Catalan Sea (summer and autumn). The occurrence of these spawning peaks was confirmed by the finding of eggs and larvae in the study areas (Sartini *et al.*, 2002; Olivar *et al.*, 2003). There is also a correspondence with an autumn recruitment peak in the northern Tyrrhenian Sea (Belcari *et al.*, 2001) and a spring-summer recruitment peak in the Catalan Sea (Recasens *et al.*, 1998; Maynou *et al.*, 2003).

In Atlantic populations, the main spawning peak is centred in winter and early spring (Pérez and Pereiro, 1985; Lucio *et al.*, 2000; Piñeiro and Saínz, 2003; Murua and Motos, 2006), which coincide with the spawning peak in the northern Tyrrhenian.

The influence of temperature does not seem to a key factor for the determination of spawning peaks of European hake. In the northern Atlantic and western Mediterranean areas sea surface temperature (SST) seasonal variation follows the same trend.
tained from the Levitus Atlas (Levitus and Boyer, 1994) show slightly lower temperatures in the Atlantic zone (Biscayan Gulf), but the same trend as in the Catalan and northern Tyrrhenian Seas, with a high correlation between the three series (0.98) (Table 6).

The particular oceanographic conditions of the Catalan Sea may be responsible for the different spawning patterns observed. The phenomenon of surface dense water formation and later cascading events, which occur during the coldest and windiest winters in the Gulf of Lions from January until mid-April, with a current speed that reaches more than 80 cm s\(^{-1}\) (Font et al., 2007), can cause unfavourable conditions for hake spawning. These events have been proven to influence recruitment and abundance of deeper species like red shrimp (Aristeus antennatus) (Company et al., 2008). In cascading events displacements of shelf water to deeper areas through submarine canyons (Canals et al., 2006) can extend to whole Catalan Sea (Salat et al., 2006). This geographical feature is common in the Gulf of Lions and in the Catalan Sea up to 41°N and 2°E, where the shelf becomes wider due to the effect of the Ebro river delta. Bearing in mind that hake spawners concentrate at the end of the shelf near submarine canyons (Recasens et al., 1998), these strong currents may diminish hake spawning concentration in winter. Therefore, hake population in the Catalan Sea and in the Gulf of Lions develops its spawning peak previously (summer-autumn) (Recasens et al., 1998) when these cascading events do not occur.

Values of length at first maturity for females are in agreement with previous studies performed in the Iberian Mediterranean area (Larraneta, 1970; Sánchez and Martin, 1985; Oliver, 1991; Recasens, 1992; Recasens et al., 1998). A slightly greater length at first maturity of about 42-45 cm TL is also reported in the Mediterranean (Aldebert and Carries, 1989; Biagi et al., 1995) and about 45 cm TL in Atlantic areas (Lucio et al., 2000; Piñeiro and Sainza, 2003).

The fecundity results presented in this study represent the first estimation of reproductive potential of the Mediterranean hake population. Relative batch fecundity shows similar values in the two zones: around 200 eggs g\(^{-1}\) (gonad-free weight). These values, which are not significantly different from those obtained in Atlantic populations (165 eggs g\(^{-1}\)) (Murua et al., 1998; Murua et al., 2006), represent medium values in comparison with other Merluccius species, are higher than those of *M. capensis* (160 eggs g\(^{-1}\)) (Osborne et al., 1999) and are lower than those of *M. hubbsi* (551 eggs g\(^{-1}\)) (Macchi et al., 2004). Relationships between fecundity estimations and hake size indicate that the total of eggs number per female increases with size, but in relative terms the egg production per gram of female is similar.

In conclusion, the reproductive parameters of Mediterranean hake populations—size at maturity, oocyte development, reproductive modality and fecundity—have similar biological characteristics in the Catalan and northern Tyrrhenian seas. Furthermore, the results can be included in the normal range for this species in Atlantic waters. However, differences in the occurrence of the spawning peak in the Catalan Sea suggest that environmental factors such as strong winter currents can affect the synchronisation of the hake spawning cycle. These winter events, which originate in the surface water of the Gulf of Lions, can affect biological and ecological characteristics of marine populations, especially those of deeper species but also those of species that spawn or recruit in the shelf-break area.

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