CHARACTERIZATION OF THE REPRODUCTION OF EUROPEAN HAKE (*MERLUCCIUS MERLUCCIUS*, LINNAEUS, 1758) IN ORAN BAY

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Abstract. We have studied the European hake (*Merluccius merluccius*, Linnaeus, 1758) in Oran bay, obtained from fishermen coming to sell their catch at the local markets, in order to characterize the reproduction of this fish and to estimate the impact of local fishing on its population. Males are predominant in catches throughout most of the year, and, on average, males are smaller than females. *Merluccius merluccius* spawns in a partial manner, with asynchronous oocyte maturation, and breeds throughout the year. Determination of length at first sexual maturity (smaller for males) demonstrates earlier puberty in males compared to females. An essential item of information for achieving sustainable fishing is the demonstration that a large part (46%) of caught European hakes has a length below the length at first sexual maturity: they are juveniles. These juveniles are killed before being able to breed, which represents a danger for future fish stocks.
Keywords: *Algeria, reproduction, sexual maturity, sustainable fishing, fish stock*

Introduction

European hake (*Merluccius merluccius*. L) is a species widely present and exploited both in the Atlantic and Mediterranean (Aldebert and Carriès, 1988; Martin, 1991; Oliver and Massutí, 1995**)**. It has been the subject of studies about ecology (Abella et al., 1995; Bouaziz et al., 1998; Murua, 2010; Mellon-Duval et al., 2017; Carrozzi et al., 2019), biology (Pauly, 1980; Aldebert and Recansens, 1995; Murua, 2010; Dominguez, 2007; El Habouz, 2011; Khoufi et al., 2014a; Soykan et al., 2015; Kahraman et al., 2017; Candelma et al., 2018; Uzer et al., 2019; Gül et al., 2019; Carbonara et al., 2019; Girgin et al., 2020), economic interest (Perez-Agundez, 2002) and fishing activity (Gaynilo and Pauly, 1997; Yalçın and Gurbet, 2016; Demirel et al., 2017; Deniz et al., 2020). Its economic value makes it the target of a complex fishing activity composed of several fleets using the most diverse fishing gear (Recasens et al., 1998; Lloret et al., 2001; Lloret and Lleonart, 2002). This represents about 150,000 tonnes of fishes caught by year (FAO, 2007). In Algeria, fishing has been developed in more than 30 ports, with the support of the Algerian government, and the fisheries and fish resources sector have significant potential to contribute to the country’s food security, job creation and economic consolidation. The fishing ports of Oran have produced, for example, about 66.5 tonnes of hake in 2010 (Direction des Pêches et des Ressources Halieutiques, personal communication). Hake fishing in Algeria is mainly directed towards the white

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hake (*Merluccius merluccius*), and its minimum market size has been set at 20 cm for Algerian waters according to the Ministry of Fisheries and Fishery Resources of the Republic of Algeria (M.P.R.H, 2016).

Understanding the life cycles of fishes is necessary to achieve sustainable fishing. In order to allow the replenishment of stocks, it is necessary not to catch too many fishes before they have been able to breed. For example, according to Bouaziz et al. (1998), the analysis of hake supplies in Bou-lsmaïl bay has shown that more than 70% of individuals were less than 30 cm in size, with a length at first sexual maturity for females of 30.6 cm. This is alarming because this means that a large quantity of these hakes are young fish caught before they are able to reproduce. To our knowledge, the data on the reproduction of hake in Algeria are limited to those of Bouaziz et al. (Bouaziz, 1992; Bouaziz et al., 1998). Today, our knowledge of the biology of *Merluccius merluccius* (growth and reproduction) is not a sufficient basis for a proper assessment of fish stocks (Morales-Nin et al., 2005), even though studies on the characterization of its reproduction have been carried out in several Atlantic or Mediterranean areas, for example by Bouaziz (1992) or Lahaye (1972). Nevertheless, it is well known that this species is gonochoric and that mature males and females eject gametes in the environmental water where fecundation takes place (Belloc, 1929). Hake has oocytes that do not develop simultaneously (Pérez and Pereiro, 1985; Sarano, 1986; Murua et al., 1998; Murua and Saborido-Rey, 2003; Murua and Motos, 2006), and its spawning activity continues until the death of the fish (Bouhlal, 1973). Note that, as an exception, we have characterized in a previous study a case of hermaphrodism (Belhoucine et al., 2012). Finally, depending on previous studies, this species has been shown to have a spawning period either all year round or discontinuous, and the length at first sexual maturity for females and males greatly varied between studies (as it will be covered in the discussion of the present paper). Hence, in the present study, we have studied the European hake (*Merluccius merluccius*, Linnaeus, 1758), collected from fishermen who came to sell their catch at the local markets of Oran, in order to estimate the impact of local fishing on the European hake population.

Usually, reproduction is characterized by at least two of the following parameters. One of these parameters is the sex ratio which may or may not be close to optimum. Another possibility is to evaluate the physical condition of the animals by classical indexes: hepatosomatic index (useful to estimate whether lipids are accumulated in the liver before being used for gamete production), gonadosomatic index (as it is well known that progression of the weight of gonads during the year allowed assessment of the reproduction period for a given species: gonad weight is at a minimum during biological rest periods, increases during gamete maturation, then decreases for spawning), and the Fulton condition factor (K factor, determined from the relationship between weight and length, which reflects the general state of a fish in function of its physiological activities, is an indicator of fitness). Finally, spawning frequency and fecundity parameters, such as the quantity of mature oocytes in ovaries, age or length at sexual maturity, may be studied.

The present paper presents the estimation of the sex ratio of the European hake caught in Oran bay and the physical condition of these fish. We also focus on results of the characterization of their sexual maturity, by macroscopic and microscopic observations, allowing assessment of length at sexual maturity. For the purposes of environmental management, to achieve sustainable fishing, length at sexual maturity

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should inform on the minimum length for fish catches necessary to avoid a negative impact on fish stocks.

Material and methods

European hake from the Mediterranean Sea were collected monthly for a full year (2017-2018), in Oran bay. Hake fishing is mainly carried out by trawlers, but also by small trades (set nets and bottom longlines) (FAO, 2007), in coastal zones, zones with maximal depth of 500 m. Each month, random sampling was carried out for fish of sizes ranging from 13.6 to 56 cm, when fishermen came to sell their catch at the local markets. A total of 831 specimens were sampled.

Overall measurements

Samples were treated very soon after being caught. All organs were removed by evisceration of the fish. Sex was determined. For each fish, we measured the following parameters:

- Total length (Lt), from the tip of the upper jawbone, adjusted to the lower 1 cm
- Total weight (Wt) and weight of eviscerated fish (We), adjusted to 0.01 g
- Liver weight (Wl, when fresh), adjusted to 0.01 g
- Gonads weight (Wg, when fresh), adjusted to 0.01 g
- Sex determination, observing gonads
- Control of macroscopic stage of sexual maturity and gonad description.

Sex ratio

We have separated the European hake into three categories: immature/undefined sex (immature European hake have gonads similar to thin cords; when mature, gonad volume increases and represents half of the abdominal part), male, or female. Males and females were identified by macroscopic gonad observation in our fish population. Then we have directly calculated the sex ratio as the number of males divided by the number of females. We studied the sex distribution in parallel with the length of each fish. Then the sex ratio was calculated each month of the year from caught fish, in order to follow the dynamic of sex ratio. Significance was statistically assessed with Statistica software (StatSoft Inc 2007), by chi-two, X^2, test of heterogeneity ($p < 0.05$).

Comparison of mean sizes for males or females

To compare these means, we have used Wilcoxon test with R software (R-3.6.1-win, RStudio-1.2.1335).

Hepatosomatic index

In the present paper, for the hepatosomatic and gonadosomatic indexes, we have chosen weight of eviscerated fish as reference to avoid bias due to either the large quantity of fat in the abdominal cavity during some annual periods or gonads/liver weight variations or more or less full digestive tract. Hepatosomatic index was calculated as: weight of liver (g) divided by weight of eviscerated fish (g), multiplied by 100. Then, for each sex, a mean was calculated for each month.

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Gonadosomatic index

This index was calculated as: weight of gonads (g) divided by weight of eviscerated fish (g), multiplied by 100. It was determined separately for males and for females. Then a mean for each month was calculated for each group.

Fulton condition factor (K)

This corresponds to the weight of eviscerated fish (g) divided by the total length (cm) to the power 3, multiplied by 100.

Microscopic observations

Each month, a random sample of females (immature, or mature and at different stages of maturity) was treated for microscopy. Pieces of 50 gonads were fixed in alcoholic Bouin solution just after dissection. Histological sections were done as previously described by Martoja and Martoja-Pierson (1967), with the following protocol:

- Fixation in alcoholic Bouin solution for 4 to 6 days
- Dehydration by alcoholic solutions (ethanol, butanol)
- Inclusion in paraffin wax
- Cutting of 5 micrometer blocks, on a microtome, before displaying on microscopy glass slides (3 per block)
- Staining by green light and hematoxylin
- Observation with a photonic microscope with camera (Leica DM 2000 Wild M 20 and Olympus BH 2, Germany).

Interpretation of these observations was done using the scale of maturity established by Holden and Raitt (1974), maturation starting from stage III for males and females (*Table 1*).

Table 1. *Maturation stages for partial breeders (Holden and Raitt, 1974)*

Stage	State	Description
I	Immature	Ovaries volume is about 1/3 of length of abdominal cavity. Ovaries are pinkish and translucent. Eggs are not visible to the naked eye
II	Virgin during maturation and recovery	Ovaries volume is about 1/2 of length of abdominal cavity. Ovaries are pinkish and translucent. Eggs are not visible to the naked eye
III	Becoming mature	Ovaries volume is about 2/3 of length of abdominal cavity. Ovaries are yellow-pinkish and look rough. Neither transparent nor translucent eggs are visible
IV	Mature	Ovaries volume is about 2/3 of length to total length of abdominal cavity. Ovaries are pinkish orange, with superficial blood vessels visible. Mature and transparent eggs are present
V	After spawning	Ovaries retract to about 1/2 of length of abdominal cavity. Walls are loose. Ovaries may contain remaining eggs which are mature, opaque, disintegrating

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Macroscopic study of sexual maturity

With regard to sexual maturity, determination of stages of maturity was done by macroscopic observations of a large number of male or female gonads. Observed changing characteristics during maturation were color, firmness, quantity of vascularization, volume of gonads in the abdominal cavity, thickness and transparency of the gonad wall. This study was difficult for males, and they were only separated into immature and mature animals. For females, we determined, each month, percentages of stages of maturity. Combined with microscopic observations, there are 5 maturation stages for females.

Length at first sexual maturity

The definition retained for our work was the length at which 50% of the population is mature (Batts, 1972; Conand, 1977; Shung, 1973).

Results

As stated above, we sampled 831 fish (between 12 and 80 fish per month), but 175 were considered as of undefined sex and discarded (21.06%). Among the 656 remaining European hake, 391 were identified as males and 265 as females. Details of the fish catches each month are presented in *Table 2*.

Table 2. *Number of European hake (Merluccius merluccius L., 1758) considered in the present study, and numbers of females or males, caught each month in Oran bay*

Month	Number of considered fish i.e. females + males (total = 656 fish)	Number of females (total = 265)	Number of males (total = 391)
January	67	24	43
February	92	37	55
March	68	39	29
April	68	29	39
May	39	11	28
June	43	19	24
July	37	15	22
August	40	22	18
September	33	10	23
October	31	12	19
November	48	14	34
December	90	33	57

The monthly distribution of caught females or males of European hake shows that the number of females were lower almost all the time (except in March and August), during the year of the study.

The calculated ratio of total number of males divided by total number of females was about 1.47. So, the overall sex ratio compared to the balanced sex ratio of 1 (1 male for 1 female) was significantly different (chi-two test, threshold 95%), with more males than females.

The overall sex ratio is not precise enough to determine sex distribution in the studied population. It has to be completed by study of sex ratio variations in parallel with animal length.

In order to highlight potential variations of sex ratio as a function of fish length, we grouped our 656 European hake together in 2 cm length classes. Maximum length for females was 56 cm and maximum for males was 48.5 cm, thus females were bigger. Percentages of females or males are displayed by length classes in *Figure 1*.

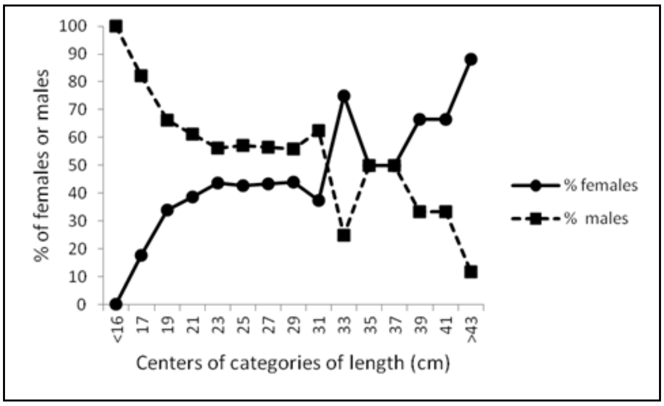

Figure 1. *Percentages of females or males as a function of European hake length, for Oran coasts*

We can see in *Figure 1* that males were more frequent than females for the smallest lengths, from < 16 cm to 30-32 cm. For the largest lengths, from 38-40 cm to maximum size, females were more frequent than males. For length > 49 cm, only females were found in catches.

For our samples, we determined mean size ± SE (standard error) for females of European hake as 28.55 ± 0.55 cm (number of fish = n = 265). Mean size for males was equal to 23.85 ± 0.27 cm (n = 391). Statistical comparison of female and male mean sizes with Wilcoxon test gave a highly significant result (p-value = 3.296 e^{-11}). In other words, females were on average bigger than males along the coasts of Oran.

Mean values of hepatosomatic index (HI) for females or males are presented as a function of month in *Figure 2*. No clear tendency appeared along the year, except that values for females seemed higher than those for males.

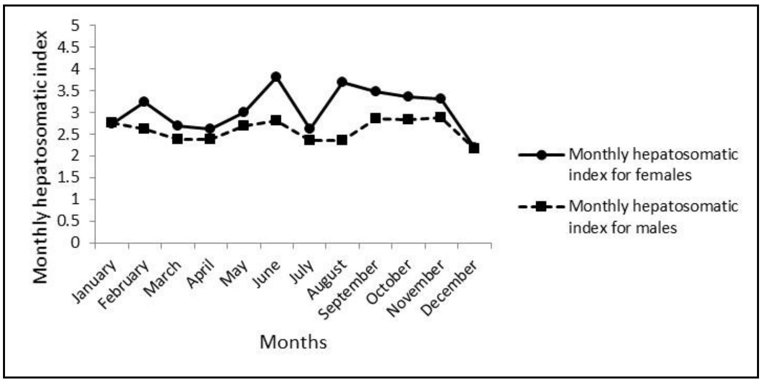

Figure 2. *Monthly progression of hepatosomatic index for female or male European hake, for Oran coasts*

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Mean values of gonadosomatic index (GI) for females or males are presented as a function of month in *Figure 3*. No clear tendency appeared along the year.

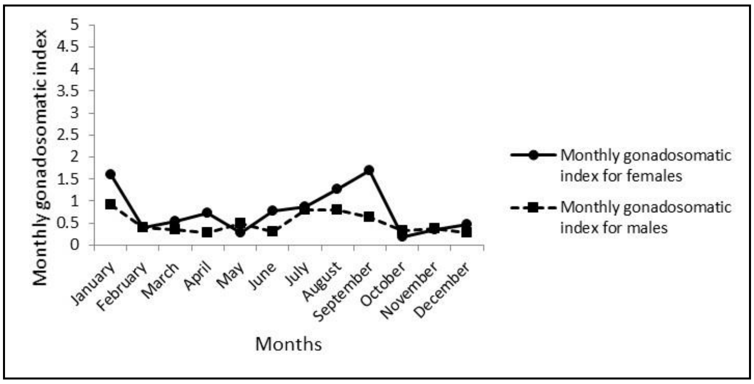

Figure 3. *Monthly progression of gonadosomatic index for female or male European hake, for Oran coasts*

Mean values of Fulton condition factor (K) for females or males are presented as a function of month in *Table 3*. No clear change appeared along the year.

Table 3. *Monthly progression of Fulton condition factor for female or male European hake, for Oran coasts*

Month	Monthly K for females	Monthly K for males
January	0.65	0.66
February	0.69	0.68
March	0.68	0.69
April	0.68	0.67
May	0.69	0.69
June	0.68	0.69
July	0.66	0.67
August	0.67	0.69
September	0.63	0.66
October	0.71	0.68
November	0.74	0.69
December	0.70	0.69

Ovarian dynamics were studied during the sexual cycle of female European hake. The ovary was constituted of conjunctive tissue and follicles. It contained oogonies spread between follicular cells, oocytes in previtellogenesis and oocytes at various stages of vitellogenesis. So, oocyte growth occurred in two phases: the first was previtellogenesis, consisting in organizing the metabolic processes needed for development of germinal cells; the second was vitellogenesis, needed for vitellus accumulation. Each observed ovary contained a set of gametes at different maturation stages. In *Figure 4*, we present photographs of microscopic ovary transverse cross-sections.

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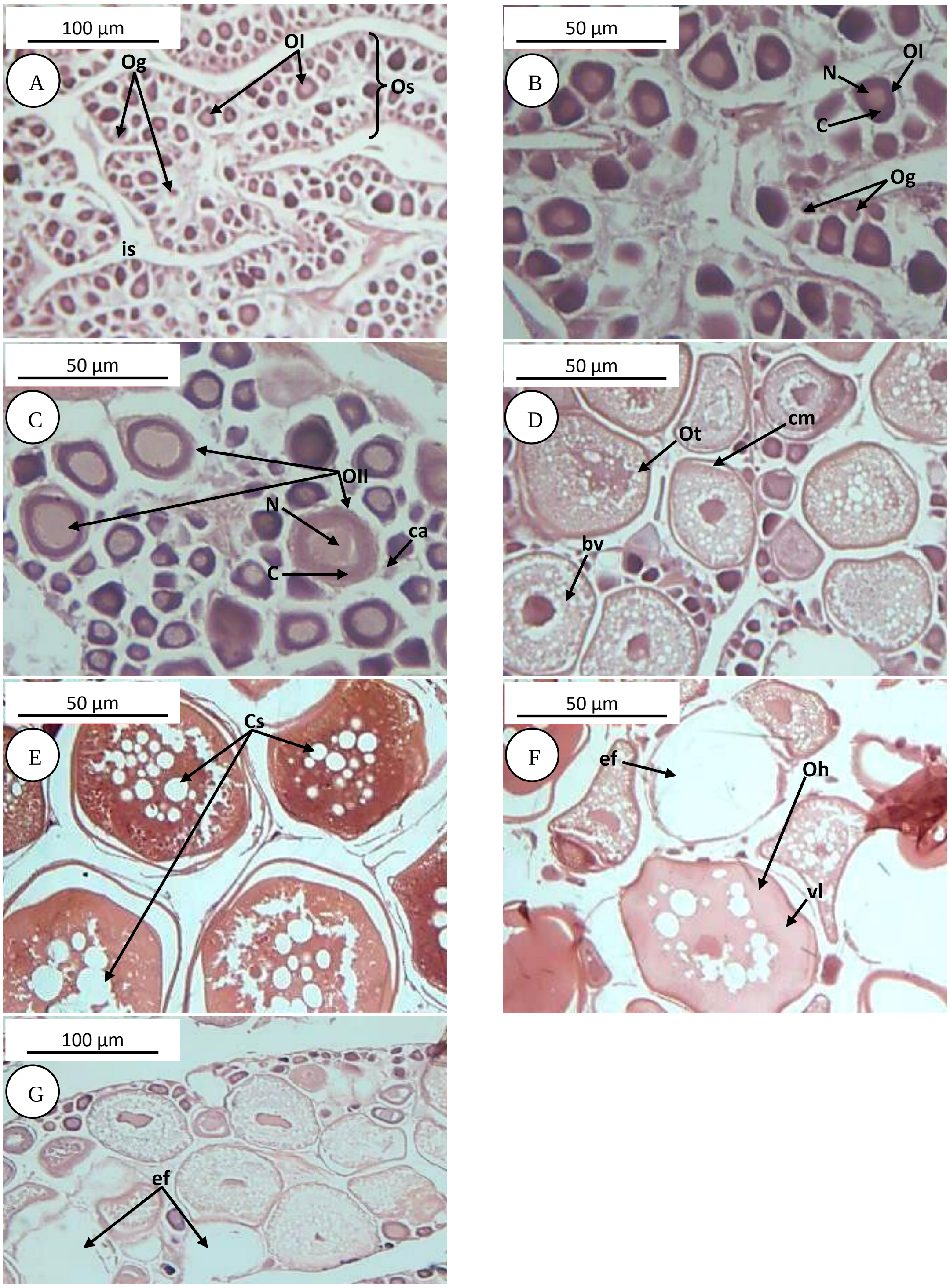

Figure 4. *Histological cross-sections of ovaries of European hake females from the coasts of Oran, for determining the different stages of reproduction. (A) Immature stage I (x0.5); (B) Immature stage I; (C) Beginning of vitellogenesis during stage II; (D) Maturation during stage III; (E) Before spawning period, stage IV; (F) Spawning, stage V; (G) After spawning, stage V. Stage I: ovarian strips (os), interlamellary spaces (is), oogony (Og), nucleus (N), cytoplasm (C), oocyte in previtellogenesis I (OI). Stage II: oocyte II (OII), nucleus (N), cytoplasm (C), cortical alveolus (ca). Stage III: ootide (Ot), cytoplasmic membrane (cm), bladder of vitellus (bv). Stage IV: corpuscles (Cs). Stage V: ootide almost totally hydrated (Oh), vitellus liquefaction (vl), empty follicles (ef)*

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Observations of these microscopic ovary cross-sections, matching the 5 previously described maturation stages, provide a basis for description of these stages as follows:

- Stage I: in *Figure 4A*, we observed piles of spread cells between conjunctive tissues and well-implanted in the epithelium of ovarian strips, separated by interlamellary spaces. Sexual cells were either oogonies (small cells due to mitosis of germ cells) or oogonies developed in oocytes I (in previtellogenesis, of larger size). Magnification of part of this cross-section in *Figure 4B* showed that oogonies have homogeneous, little abundant cytoplasm, oocytes I have large central nucleus and homogeneous and highly stained cytoplasm.
- Stage II: oocytes were starting vitellogenesis, increasing volume and becoming oocytes II (*Fig. 4C*). Cytoplasm became heterogeneous, with traces of lipids in cortical alveolus all around the border.
- Stage III: vitellogenesis continued and oocytes II became higher ootides (*Fig. 4D*). Cytoplasmic membrane was easy to see and cytoplasm was full of small bladders of vitellus. Oogonies, oocytes I and oocytes during vitellogenesis were present.
- Stage IV: ovary was in pre-spawning period (*Fig. 4E*). Bladders of vitellus merged to form corpuscles, starting in the center of the cell. Nucleus was ready for border migration.
- Stage V: *Figure 4F* showed the last maturation stage for gametes, the spawning. Merging of corpuscles full of vitellus went with high hydration, corresponding to vitellus liquefaction just before ovulation, in ootides which became hydrated mature ootides, also called ovums. Overall the gamete grows more than ten times. After ovulation, follicles appeared empty. After spawning, empty follicles degenerated, but we still observed oocytes during the maturation process (*Fig. 4G*).

Results of the macroscopic study completed by microscopic observations, according to the five previously defined maturation stages, are presented in *Figure 5*.

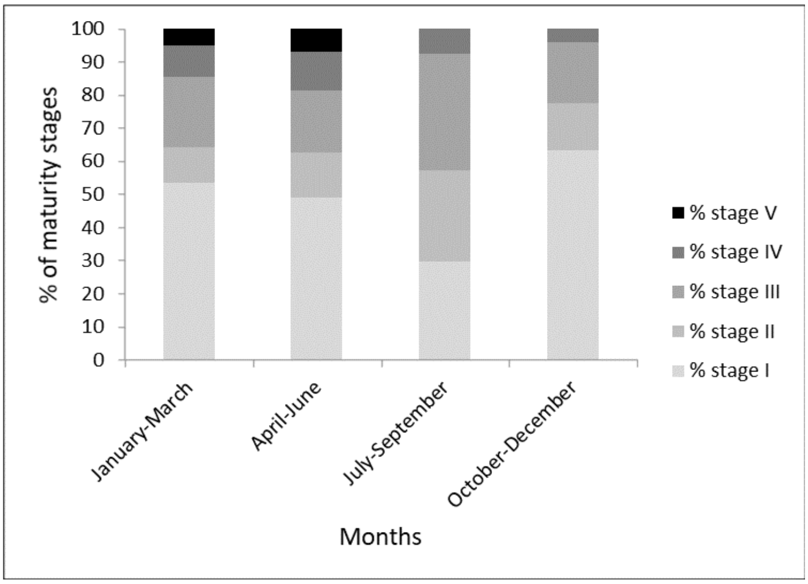

Figure 5. *Progression of sexual maturity stages during the year for female European hake, for Oran coasts*

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Fish of at least four of the five defined maturation stages were present throughout the year, with varying percentages. Note that during July-September and October-December, no females were at stage V. Total (stage III + stage IV) represented females capable of reproduction. We can notice that this total was higher during July-September (42.58%), lower during January-March (31.05%) and April-June (30.5%), and the lowest during October-December (22.44%). So, values are not zero for any time of the year.

Then, the length at first sexual maturity has been estimated by determining percentages of mature fish for each category of animal length, first for females (*Fig. 6*) and secondly for males (*Fig. 7*).

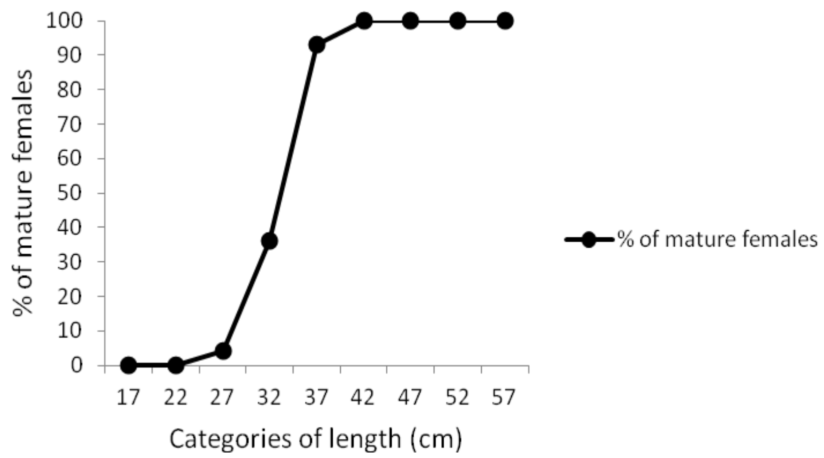

Figure 6. *Determination of length at first sexual maturity for females of European hake, for Oran coasts*

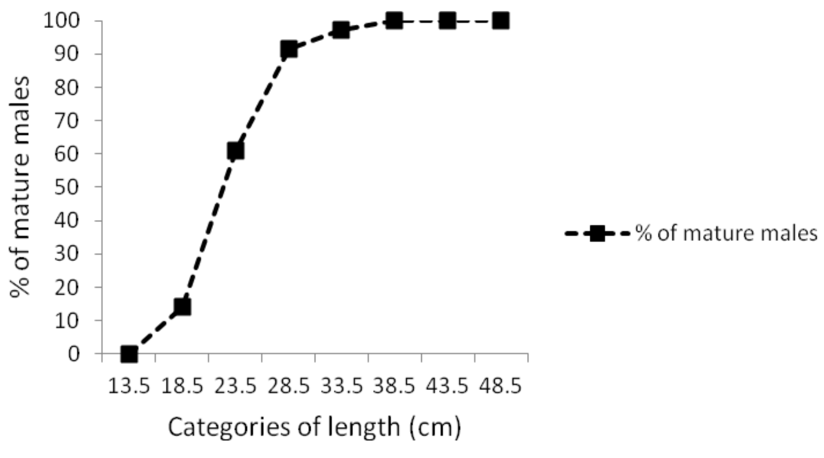

Figure 7. *Determination of length at first sexual maturity for males of European hake, for Oran coasts*

Note that percentages of maturity for females started from 27 cm to reach maximum value at more than 37 cm, and that they increased from 18.5 cm to maximum at more than 33.5 cm for males. Length at first sexual maturity was higher for females, i.e. 33.5 cm, than for males, i.e. 20.5 cm. This 13 cm gap between the two genders revealed the earliness of puberty for males compared to females.

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The most important information provided by determining length at first sexual maturity was that a large part of fish caught along the coasts of Oran were below these length values. Indeed, during this work, we have calculated the number of females, males, or females and males together, having a length below the length at first sexual maturity (*Table 4*).

Table 4. *Numbers of fish of each sex, numbers and percentages of fish smaller than length at first sexual maturity for each sex, for European hake from Oran coasts*

	Females	**Males**	**Total**
Number of fish	265	391	656
Number of fish with length < length at first sexual maturity	191	112	303
Percent of fish with length < length at first sexual maturity (%)	72.08	28.64	46.19

Taken altogether, fish smaller than length at first sexual maturity represented about 46%. This value was dramatically higher dealing only with females (about 72%) and was not negligible dealing only with males (about 29%).

Discussion

In the present study, we have characterized the reproduction of the European hake (*Merluccius merluccius*, Linnaeus, 1758) in Oran bay, from fish collected by fishermen over the course of a year. This was done by assessing the sex ratio, by calculating parameters such as the hepatosomatic and gonadosomatic indexes and Fulton condition factor, by means of macroscopic and microscopic studies of sexual maturity for females, and by measuring length at first sexual maturity.

First of all, sex-ratio is not optimum as it shows that males are predominant throughout most of the year in fishermen’s catches. Sex ratio as a function of fish length reveals a majority of males up to 30-32 cm, a majority of females at 38-40 cm or more, and only females are found at lengths > 49 cm. Similar results were obtained by other authors in the Mediterranean Sea, north coast of Tunisia (Khoufi et al., 2012), in the Atlantic, central Morocco (El Habouz et al., 2011), in the Iberian Atlantic (Piñeiro and Sainza, 2003).

Classical indexes have been calculated to estimate fishes’ physical state. The hepatosomatic index was calculated because all the energy necessary to obtain gonad maturity and gamete production is thought to come from lipids from hepatic stocks. Authors have previously demonstrated that, for some female fishes, the liver is also responsible for vitellogenine (main protein in oocyte vitellus) synthesis (Nunez-Rogriguez, 1985). Hence, during ovaries development, maturation and when vitellus is accumulated, the HI decreases rapidly (Billard, 1979; Encina and Granado-Lorencio, 1997; Lahaye, 1972). As progression of the weight of gonads during the year allows assessment of the reproduction period for a given species, the gonadosomatic index was calculated. Indeed, it is well known that gonad weight is at a minimum during biological rest periods, increases during gamete maturation and decreases for spawning (Lahaye, 1972). Finally, Fulton condition factor was determined as an indicator of fitness (Bolger and Connolly, 1989). In fact, it is postulated that the heavier an animal is, for a given length, the better is its physical condition. In the present study, as a

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function of the months of the year, no clear change appears for hepatosomatic and gonadosomatic indexes or Fulton condition factor. Hence these indexes and factor do not suggest a specific reproductive period. We assume that some females may lay their eggs not all at the same time. Perhaps their ovaries do not rest after spawning and continue vitellogenesis for a later spawning. For males, storage in the liver may not take place during spermatozoon maturation. Finally, fishes' physical condition seems not to vary in an important way, even during gamete formation or ejection, a result similar to that of Morgan who did not find any relationship between Fulton condition factor and male maturation for codfish (Morgan, 2004).

To investigate more precisely European hake reproduction, microscopic and macroscopic studies of sexual maturity were made. Microscopic study for females showed that each ovary contained a set of gametes at different maturation stages. In fish, two models of spawning have been observed. In the first model, total spawning consists in all oocytes maturing at the same time, see salmon and eel (West, 1990), or groups of oocytes developing in a simultaneous way, see herring, plaice and sole (Horwood, 1990; Le Duff, 1997), and spawned at the same time. In the second model, spawning is realized by series, oocyte maturation being asynchronous, see sardine, Brazilian menhaden, anchovy (Hunter and Goldberg, 1980; Macchi and Acha, 2000; Matsuura, 1998). Our microscopic observations led us to conclude that *Merluccius merluccius* spawns in a partial manner in Oran bay (spawning realized by series), oocyte maturation being asynchronous. This asynchronous oocyte maturation matches observations of other authors for the Mediterranean Sea (Biagi et al., 1995; Nannini et al., 2001; Carbonara et al., 2019) or the Atlantic Ocean (Murua et al., 1998; Murua and Motos, 2006; Murua and Saborido-Rey, 2003; Sarano, 1986). Our macroscopic study for females demonstrated that fish of at least four of the five defined maturation stages were present throughout the year. During July to December no females were at stage V, corresponding to sexual recovery after spawning, and during January to June, only a small percentage at stage V was observed. This might be explained by the fact that, after spawning, almost all female adults return to deep waters and were not caught by fishermen. We highlighted that females capable of reproduction (stages III and IV) were always present. Taken together, the microscopic and macroscopic observations allow us to conclude that females of *Merluccius merluccius* breed throughout the year on the coasts of Oran. Unlike our present results, some studies lead to the conclusion that there is a discontinuous reproductive period, less for the Mediterranean Sea and mainly for the Atlantic Ocean (see references in *Table 5*). But, like us, other authors have concluded that spawning occurs during the whole year (with or without one, two or three more intensive phases), as described mainly for the Mediterranean Sea and less for the Atlantic Ocean (see references in *Table 5*). *Table 5* summarizes data for *Merluccius merluccius* spawning period in various areas.

Finally, length at first sexual maturity provides information on the part of the fish stock able to reproduce and consequently on the replenishment potential of the species. In the present study, it is higher for females (33.5 cm) than for males (20.5 cm). This 13-cm gap between the two genders reveals the earliness of male puberty compared to females. Our observation of length at first sexual maturity lower for males than for females fits well with results from other authors (see *Table 6*), either in Mediterranean Sea or in Atlantic Ocean. Data about length at first sexual maturity for *Merluccius merluccius* in various areas are summarized in *Table 6*.

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In the present work, the most important information provided by determining the length at first sexual maturity is that a large part of fish caught along the coasts of Oran are under the values of length at first sexual maturity. So these individuals are juveniles, responsible for stock sustainability, caught before being able to breed.

Table 5. *Spawning period for Merluccius merluccius in various areas (white: no spawning; grey: spread spawning; black: maximal spawning)*

Sea/Ocean	Area	References	Month											
			J	F	M	A	M	J	J	A	S	O	N	D
Mediterranean Sea	Algeria (Oran)	Present study												
	Algeria (Bou-Ismail)	Bouaziz, 1998												
	Tunisia	Heldt, 1952												
	Tunisia	Bouhlal, 1973												
	Tunisia	Khoufi et al., 2014b												
	Western Mediterranean Sea	Oliver, 1991												
	Western Mediterranean Sea	Morales-Nin and Moranta, 2004												
	France (Gulf of Lion)	Recasens et al., 1998												
	Italy (Adriatic Sea)	Zupanovic, 1968												
	Italy (Adriatic Sea)	Zupanovic and Jardas, 1986												
	Italy (Adriatic Sea)	Arneri and Morales-Nin, 2000												
	Italy (Sardinia)	Carbonara et al., 2019												
	Italy (Tyrrhenian Sea, Adriatic Sea, Ionian Sea)	Carbonara et al., 2019												
	Greece	Tsimenidis and Papaconstantinou, 1985												
	Greece	Mytilineou and Vassilopoulou, 1988												
	Turkey	Soykan et al., 2015												
Atlantic Ocean	Morocco	Maurin, 1954												
	Morocco	El Habouz et al., 2011												
	Spain	Alcázar et al., 1983												
	Spain	Perez and Pereiro, 1985												
	Spain	Piñeiro and Sainza, 2003												
	France	Belloc, 1923												
	France (Bay of Biscay)	Sarano, 1986												
	France (Bay of Biscay)	Alvarez et al., 2004												
	France (Bay of Biscay)	Murua and Motos, 2006												
	Celtic Sea	Fives et al., 2001												

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Table 6. *Length at first sexual maturity for Merluccius merluccius in various areas*

Sea/Ocean	Area	References	Length at first sexual maturity for females (cm)	Length at first sexual maturity for males (cm)
Mediterranean Sea	Algeria (Oran)	Present study	33.5	20.5
	Algeria (Bou-Ismail)	Bouaziz et al., 1998	30.6	21.5
	Tunisia	Khoufi et al., 2014b	29	-
	Eastern Mediterranean Sea	Alheit and Pitcher, 1995	29.5	26.5
	Western Mediterranean Sea	Oliver, 1991	36.3	27.6
	Western Mediterranean Sea	Alheit and Pitcher, 1995	34.5	27
	Spain (Catalonia)	Recasens et al., 2008	35.8	-
	Italy (Tyrrhenian Sea)	Biagi et al., 1995	42.5	27
	Italy (Tyrrhenian Sea)	Recasens et al., 2008	35.1	-
	Italy (Adriatic Sea)	Zupanovic, 1968	26	24
	Italy (Adriatic Sea)	Zupanovic and Jardas, 1986	28	24
	Italy (Sardinia, Tyrrhenian Sea, Adriatic Sea, Ionian Sea)	Carbonara et al., 2019	32	-
	France (Gulf of Lion)	Recasens et al., 1998	38	28.8
	Turkey	Soykan et al., 2015	21.5	25.6
Atlantic Ocean	Morocco	Maurin, 1954	40	40
	Morocco	El Habouz et al., 2011	33.8	28.6
	Spain	Larrañeta, 1970	32.2	24.3
	Spain	Alcázar et al., 1983	54	42
	Spain	Perez and Pereiro, 1985	52.5	38
	Spain	Piñeiro and Sainza, 2003	45.4	32.8
	Spain	Domínguez-Petit et al., 2008	46	-
	North Atlantic	Domínguez-Petit et al., 2008	41	-

Conclusion

To conclude, in Oran bay, our results, from the fishermen’s catches studied, show that *Merluccius merluccius* spawns in a partial manner (with asynchronous oocyte maturation) and breeds throughout the year. Determination of length at first sexual maturity (smaller for males) demonstrates the earliness of puberty in males compared to females. During this work, we have also estimated that 46% of caught European hake have a length below the length at first sexual maturity, and thus are juveniles. This information is of crucial importance. It represents a danger for future fish stocks to continue to catch such a large quantity of fish killed before being able to breed. If sustainable fishing is to be achieved, appropriate laws will have to be enacted and observed. We suggest that the minimum market size of 20 cm for Algerian waters according to the Ministry of Fisheries and Fishery Resources of the Republic of Algeria (M.P.R.H, 2016) will have to be reconsidered. Furthermore, reducing fishing effort and increasing mesh sizes in the region is recommended for sustainable exploitation of this fishery resource.

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REFERENCES

[1] Abella, A., Auteri, R., Serena, F. (1995): Some aspects of growth and recruitment of hake in the northern Tyrrenian sea. – Rapport de la 1ère réunion du groupe de travail DYNPOP du CIESM, Tunis 10: 27-28.

[2] Alcázar, J. L., Carrasco, F. J., Llera, E. M., Méndez de la Moz, M., Ortea, J. A., Vizcaino, A. (1983): Biología, dinámica y pesca de la merluza en Asturias. – Recursos Pesqueros de Astuarias 3: 134-150.

[3] Aldebert, Y., Carriès, C. (1988): Problèmes d’exploitation du merlu du golfe du Lion. – Fuengirola, C. G. P. M., 5ème Consultation technique sur l’évaluation des stocks Baléares et Golfe du Lion, pp. 87-91.

[4] Aldebert, Y., Recasens, L. (1995): Estimation de la croissance du merlu dans le golfe du Lion par l’analyse des fréquences de taille. – Rapport de la Commission Internationale sur la Mer Méditerranée 34: 236-236.

[5] Alheit, J., Pitcher, T. J. (1995): Hake: Fisheries, Ecology and Markets. Fish and Fisheries Series 15. – Chapman and Hall, London.

[6] Alvarez, P., Fives, J., Motos, L., Santos, M. (2004): Distribution and abundance of European hake *Merluccius merluccius* (L.), eggs and larvae in the North East Atlantic waters in 1995 and 1998 in relation to hydrographic conditions. – J. Plankton Res. 26: 811-826. https://doi.org/10.1093/plankt/fbh074.

[7] Arneri, E., Morales-Nin, B. (2000): Aspects of the early life history of European hake from the central Adriatic. – J. Fish Biol. 56: 1368-1380. https://doi.org/10.1111/j.1095-8649.2000.tb02149.x.

[8] Batts, B. S. (1972): Sexual Maturity, Fecundity, and Sex Ratios of the Skipjack Tuna, *Katsuwonus pelamis* (Linnaeus), in North Carolina Waters. – Trans. Am. Fish. Soc. 101: 626-637. https://doi.org/10.1577/1548-8659(1972)101<626:SMFASR>2.0.CO;2.

[9] Belhoucine, F., Bouderbala, M., Flower, R., Francour, P., Boutiba, Z. (2012): Hermaphrodism case observed on the hake (*Merluccius merluccius* Linné, 1758) fished in Oran bay (south west Mediterranean sea). – J. Sci. Halieut. Aquat. 5: 171-176.

[10] Belloc, G. (1923): Note sur la croissance du merlu - Variations ethniques et sexuelles. – Notes et Mémoires. Office scientifique et technique des pêches maritimes.

[11] Belloc, G. (1929): Poissons de chalut. Etude monographique du merlu (*Merluccius merluccius*). – Rev. Trav. Inst. Pêches Marit. 2: 154-288.

[12] Biagi, F., Cesarini, A., Sbrana, M., Viva, C. (1995): Reproductive biology and fecundity of *Merluccius merluccius* (L., 1758) in the northern Tyrrhenian Sea. – Cahiers Options Mediterraneennes (CIHEAM) 10: 47-48.

[13] Billard, R. (1979): La gamétogenèse, le cycle sexuel et le contrôle de la reproduction chez les poissons téléostéens. – Bull. Fr. Piscic. 117-136. https://doi.org/10.1051/kmae:1979008.
[14] Bolger, T., Connolly, P. L. (1989): The selection of suitable indices for the measurement and analysis of fish condition. – J. Fish Biol. 34: 171-182. https://doi.org/10.1111/j.1095-8649.1989.tb03300.x.
[15] Bouaziz, A. (1992): Le merlu (*Merluccius merluccius mediterraneus*, Cadenat 1950) de la baie de Bou‑Ismaïl: biologie et écologie. [The hake of the Gulf of Bou‑Ismaïl: biology and ecology]. – Thèse Magister Océanogr. Biol. ISMAL, Alger, Algérie.
[16] Bouaziz, A., Bennoui, A., Djabali, F., Maurin, C. (1998): Reproduction du merlu *Merluccius merluccius* (Linnaeus, 1758) dans la région de Bou-Ismail. – In: Lleonart J. (ed.). Dynamique des populations marines. Zaragoza : CIHEAM, (Cahiers Options Méditerranéennes; n. 35), 109-117.
[17] Bouhlal, M. (1973): Le merlu des côtes nord de la Tunisie: étude économique et biologique (Reproduction, sex-ratio et répartition bathymétrique). – Bull. Inst. Océanogr. Pêche Salambo 2: 579-603.
[18] Candelma, M., Valle, L. D., Colella, S., Santojanni, A., Carnevali, O. (2018): Cloning, characterization, and molecular expression of gonadotropin receptors in European hake (*Merluccius merluccius*), a multiple-spawning species. – Fish Physiol. Biochem.44: 895-910.
[19] Carbonara, P., Porcu, C., Donnaloia, M., Pesci, P., Sion, L., Spedicato, M. T., Zupa, W., Vitale, F., Follesa, M. C. (2019): The spawning strategy of European hake (*Merluccius merluccius*, L. 1758) across the Western and Central Mediterranean Sea. – Fish. Res. 219: 105333.
[20] Carrozzi, V., Di Lorenzo, M., Massi, D., Titone, A., Ardizzone, G., Colloca, F. (2019): Prey preferences and ontogenetic diet shift of European hake *Merluccius merluccius* (Linnaeus, 1758) in the central Mediterranean Sea. – Reg. Stud. Mar. Sci. 25: 100440.
[21] Conand, C. (1977): Contribution à l'étude du cycle sexuel et de la fécondité de la sardinelle ronde, *Sardinella aurita*: pêche sardinière dakaroise en 1975 et premier semestre 1976. – Cah. O.R.S.T.O.M. 15(4): 301-312.
[22] Demirel, N., Gül, G., Dalkara, E. M., Yüksek, A. (2017): Ecosystem approach to sustainability level of European hake stock in the Marmara Sea. – The Scientific and Technological Research Council of Turkey, Final Report, 04/2017.
[23] Deniz, T., Göktürk, D., Ates, C. (2020): Selectivity parameters of European hake gillnets for target and by-catch species with a perspective on small-scale fisheries management in the Sea of Marmara, Turkey. – Reg. Stud. Mar. Sci. 33: 100934.
[24] Dominguez-Petit, R. (2007): Study of reproductive potential of *Merluccius merluccius* on the Galician Shelf. – PhD thesis. University of Vigo, Spain.
[25] Domínguez-Petit, R., Korta, M., Saborido-Rey, F., Murua, H., Sainza, M., Piñeiro, C. (2008): Changes in size at maturity of European hake Atlantic populations in relation with stock structure and environmental regimes. – J. Mar. Syst. 71: 260-278. https://doi.org/10.1016/j.jmarsys.2007.04.004.
[26] El Habouz, H., Recasens, L., Kifani, S., Moukrim, A., Bouhaimi, A., El Ayoubi, S. (2011): Maturity and batch fecundity of the European hake (*Merluccius merluccius*, Linnaeus, 1758) in the eastern central Atlantic. – Sci. Mar. 75(3): 447-454. https://doi.org/10.3989/scimar.2011.75n3447.
[27] Encina, L., Granado-Lorencio, C. (1997): Seasonal changes in condition, nutrition, gonad maturation and energy content in barbel, *Barbus sclateri*, inhabiting a fluctuating river. – Environ. Biol. Fishes 50: 75-84. https://doi.org/10.1023/A:1007381414397.
[28] FAO (2007): Rapport N°856 sur les pêches: dixième session du comité scientifique consultatif Nicosie, Chypre. – Rapport sur les pêches No. 856.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_947965

[29] Fives, J. M., Acevedo, S., Lloves, M., Whitaker, A., Robinson, M., King, P. A. (2001): The distribution and abundance of larval mackerel, *Scomber scombrus* L., horse mackerel, *Trachurus trachurus* (L.), hake, *Merluccius merluccius* (L.), and blue whiting, *Micromesistius poutassou* (Risso, 1826) in the Celtic Sea and west of Ireland during the years 1986, 1989 and 1992. – Fish. Res. 50: 17-26. https://doi.org/10.1016/S0165-7836(00)00239-3.

[30] Gayanilo, F. C., Pauly, D. (1997): FAO-ICLARM stock assessment tools. FISAT. In: Gayanilo, F. C., Pauly, D. (eds.) Reference Manual. – FAO-Computerized Information Series (Fisheries). FAO 8, Rome.

[31] Girgin, H., Basusta, N. (2020): Growth characteristics of European hake, *Merluccius merluccius* (Linnaeus, 1758), inhabiting northeastern Mediterranean. – Acta Adriat. 61(1): 79-88.

[32] Gül, G., Murat-Dalkara, E., Yüksek, A., Demirel, N. (2019): Age and growth of European hake, *Merluccius merluccius* in the Sea of Marmara. – COMU J. Mar. Sci. Fish. 2(2): 147-154.

[33] Heldt, H. (1952): Note préliminaire sur le merlu des mers tunisiennes. – ICES J. Mar. Sci. 18(2): 234-235.

[34] Holden, M. J., Raitt, D. F. S. (1974): Manuel des sciences halieutiques. Deuxième partie. Méthodes et recherches sur les ressources et leur application. – FAO, Rome.

[35] Horwood, J. W. (1990): Fecundity and maturity of plaice (*Pleuronectes platessa*) from Cardigan Bay. – J. Mar. Biol. Assoc. U. K. 70: 515-529. https://doi.org/10.1017/S0025315400036559.

[36] Hunter, J. R., Goldberg, S. R. (1980): Spawning incidence and batch fecundity in northern anchovy *Engraulis mordax*. – Fish. Bull. 641-652.

[37] Kahraman, A. E., Yildiz, T., Uzer, U., Karakulak, F. S. (2017): Age composition, growth and mortality of European hake *Merluccius merluccius* (Linnaeus, 1758) (Actinopterygii: Merlucciidae) from the Sea of Marmara, Turkey. – Acta Zool. Bulg. 69(3): 377-384.

[38] Khoufi, W., Jaziri, H., Elfehri, S., Ben Meriem, S., Romdhane, M. S. (2012): Apport de données in situ pour la mise en place d'indicateurs biologiques dans le cadre de la gestion du stock Tunisien de *Merluccius merluccius* (Linnaeus, 1758). – J. Sci. Halieut. Aquat. 5: 161-170.

[39] Khoufi W., Dufour J. L., Jaziri H., Elfehri S., Elleboode R., Bellamy E., Ben Meriem S., Romdhane M. S., Mahé K. (2014a): Growth estimation of *Merluccius merluccius* off the northern coast of Tunisia. – Cybium 38(1): 53-59.

[40] Khoufi W., Ferreri R., Jaziri H., El Fehri S., Gargano A., Mangano S., Ben Meriem S., Romdhane M. S., Bonanno A., Aronica S., Genovese S., Mazzola S., Basilone G. (2014b): Reproductive traits and seasonal variability of *Merluccius merluccius* from the Tunisian coast. – J. Mar. Biol. Assoc. U. K. 94(7): 1545-1556. https://doi.org/10.1017/S0025315414000356.

[41] Lahaye, J. (1972): Cycles sexuels de quelques poissons plats des côtes bretonnes. – Rev. Trav. Inst. Pêches Marit. 36: 191-207.

[42] Larrañeta, M. G. (1970): Sobre la alimentación, la madurez sexual y talla de primera captura de *Merluccius merluccius* (L.). – Investigación Pesquera 34(2): 267-280.

[43] Le Duff, M. (1997): Cinétique de l'ovogenèse et stratégies de ponte chez les poissons Téléostéens en milieu tempéré. – Thèse de Doctorat, Bretagne Occidentale, France.

[44] Lloret, J., Lleonart, J. (2002): Recruitment dynamics of eight fishery species in the Northwestern Mediterranean Sea. – Sci. Mar. 66(1): 77-82.

[45] Lloret, J., Lleonart, J., Solé, I., Fromentin, J. M. (2001): Fluctuations of landings and environmental conditions in the NW Mediterranean Sea. – Fish. Oceanogr. 10(1): 33-50.

[46] Macchi, G. J., Acha, E. M. (2000): Spawning frequency and batch fecundity of Brazilian menhaden, *Brevoortia aurea*, in the Río de la Plata estuary of Argentina and Uruguay. – Fish. Bull. 98: 283-289.

[47] Martin, I. (1991): A preliminary analysis of some biological aspects of hake (*Merluccius merluccius* L. 1758) in the Bay of Biscay. – International Council for the Exploration of the Sea Document, CM/G, Copenhagen.
[48] Martoja, R., Martoja-Pierson, M. (1967): Initiation aux techniques de l’histologie animale. – Masson et Cie. ed. Paris, France.
[49] Matsuura, Y. (1998): Brazilian sardine (*Sardinella brasiliensis*) spawning in the southeast Brazilian Bight over the period 1976-1993. – Rev. Bras. Oceanogr. 46: 33-43.
[50] Maurin, C. (1954): Les merlus du Maroc et leur pêche. – Bull. Inst. Pêches Marit. 2: 7-65.
[51] Mellon-Duval, C., Harmelin-Vivien, M., Métral, L., Loizeau, V., Mortreux, S., Roos, D., Fromentin, J. M. (2017): Trophic ecology of the European hake in the Gulf of Lions, northwestern Mediterranean Sea. – Sci. Mar. 81(1): 7-18. https://doi.org/10.3989/scimar.04356.01A.
[52] Morales-Nin, B., Moranta, J. (2004): Recruitment and post-settlement growth of juvenile *Merluccius merluccius* on the western Mediterranean shelf. – Sci. Mar. 68(3): 399-409.
[53] Morales-Nin, B., Bjelland, R., Moksness, E. (2005): Otolith microstructure of a hatchery reared European hake (*Merluccius merluccius*). – Fish. Res. 74: 300-305. https://doi.org/10.1016/j.fishres.2005.03.001.
[54] Morgan, M. (2004): The relationship between fish condition and the probability of being mature in American plaice (*Hippoglossoides platessoides*). – ICES J. Mar. Sci. 61(1): 64-70. https://doi.org/10.1016/j.icesjms.2003.09.001.
[55] M. P. R. H. (2016): Ministère de la Pêche et des Ressources Halieutiques. Recueil de textes règlementaires, Pêche et Aquacultures, Tome1. – Imprimerie officielle, les vergers-Bir-Mourad Rais-Alger, Algérie.
[56] Murua, H. (2010): The biology and fisheries of European hake, *Merluccius merluccius*, in the north-east Atlantic. – Adv. Mar. Biol. 58: 97-154. https://doi.org/10.1016/B978-0-12-381015-1.00002-2.
[57] Murua, H., Saborido-Rey, F. (2003): Female Reproductive Strategies of Marine Fish Species of the North Atlantic. – J. Northwest Atl. Fish. Sci. 33: 23-31. https://doi.org/10.2960/J.v33.a2.
[58] Murua, H., Motos, L. (2006): Reproductive strategy and spawning activity of the European hake *Merluccius merluccius* (L.) in the Bay of Biscay. – J. Fish Biol. 69: 1288-1303. https://doi.org/10.1111/j.1095-8649.2006.01169.x.
[59] Murua, H., Motos, L., Lucio, P. (1998): Reproductive modality and batch fecundity of the European hake (*Merluccius merluccius* L.) in the Bay of Biscay. – CalCOFI Rep. 39: 196-203.
[60] Mytilineou, C., Vassilopoulou, V. (1988): The reproductive cycle and sex ratio of hake, *Merluccius merluccius*, in Patraikos and Korinthiakos gulfs and the Ionian Sea. – Proc. of the 4th Hellenic Congress of Ichthyologists, pp. 164-177.
[61] Nannini, N., Pinna, D., Chiericoni, V., Biagi, F., Belcari, P. (2001): Ciclo ovarico di *Merluccius merluccius* (Linnaeus, 1758) del mar Tirreno settentrionale. – Biol. Mar Medit. 8(1): 745-748.
[62] Nunez-Rogriguez, J. (1985): Contribution à l’étude de la biologie de la sole *Solea vulgaris* Quensel. Approche ultrastructurale et physiologique. – Thèse 3ème cycle. Bordeaux I, France.
[63] Oliver, P. (1991): Dinámica de la población de merluza (*Merluccius merluccius* L.) de Mallorca (Reclutamiento, Crecimiento y Mortalidad). – Doctoral thesis, University of Baleares, Palma de Mallorca, Spain.
[64] Oliver, P., Massuti, E. (1995): Biology and Fisheries of Western Mediterranean Hake (*M. merluccius*). – In: Alheit J., Pitcher T. (eds.) Hake: Biology, Fisheries and Markets. Chapman & Hall, London, pp. 181-202.
[65] Pauly, D. (1980): On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. – Journal du Conseil international pour l’Exploration de la Mer 39(2): 175-192.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_947965

[66] Perez, N., Pereiro, F. J. (1985): Aspecto de la reproduccion de la merluza (*Merluccius merluccius* L.) de la plataforma gallega y cantabrica. – Bol. Inst. Esp. Oceanog. 2(3): 39-47.
[67] Perez-Agundez, J. A. (2002): Défaillance du marché et des systèmes de gestion. La «taxation transfert» comme mode de régulation des ressources halieutiques. Application à l'exploitation du *Merluccius merluccius*. – Thèse Doctorat, ENSA-Rennes, France.
[68] Piñeiro, C., Sainza, M. (2003): Age estimation, growth and maturity of the European hake (*Merluccius merluccius* (Linnaeus, 1758)) from Iberian Atlantic waters. – ICES J. Mar. Sci. 60: 1086-1102. https://doi.org/10.1016/S1054-3139(03)00086-9.
[69] Recasens, L., Chiericoni, V., Belcari, P. (2008): Spawning pattern and batch fecundity of the European hake (*Merluccius merluccius*, Linnaeus, 1758) in the western Mediterranean Sea. – Sci. Mar. 72: 721-732. https://doi.org/10.3989/scimar.2008.72n4721.
[70] Recasens, L., Lombarte, A., Morales-Nin, B., Tores, G. J. (1998): Spatiotemporal variation in the population structure of the European hake in the NW Mediterranean. – J. Fish Biol. 53: 387-401. https://doi.org/10.1111/j.1095-8649.1998.tb00988.x.
[71] Sarano, F. (1986): Cycle ovarien du merlu *M. merluccius*, poisson à ponte fractionnée. – Rev. Travaux Inst. Pêches Maritimes 48: 65-76.
[72] Shung, S. H. (1973): The sexual activity of yellowfin tuna caught by the longline fishery in the Indian Ocean, based on the examination of ovaries. – Bull. Far Sea Fish. Lab. 9: 123-142.
[73] Soykan, O., İlkyaz, A. T., Metin, G., Kınacıgıl, H. T. (2015): Age, growth and reproduction of European hake (*Merluccius merluccius* (Linn., 1758)) in the Central Aegean Sea, Turkey. – J. Mar. Biol. Assoc. U. K. 95(4): 829-837. https://doi.org/10.1017/S002531541400201X.
[74] Tsimenidis, N., Papaconstantinou, C. (1985): A preliminary study of the fecundity of the hake (*Merluccius merluccius* L., 1758) in the Greek seas. – Investig. Pesq. 49: 55-59.
[75] Uzer, U., Öztürk, B., Yildiz, T. (2019): Age composition, growth, and mortality of European hake *Merluccius merluccius* (Actinopterygii: Gadiformes: merlucciidae) from the Northern Aegean Sea, Turkey. – Acta. Ichthyol. Piscat. 49(2): 109-117. https://doi.org/10.3750/AIEP/02465.
[76] West, G. (1990): Methods of assessing ovarian development in fishes: a review. – Mar. Freshw. Res. 41: 199-222. https://doi.org/10.1071/MF9900199.
[77] Yalçın, E., Gurbet, R. (2016): Environmental influences on the spatio-temporal distribution of European hake (*Merluccius merluccius*) in Izmir Bay, Aegean Sea. – Turkish Journal of Fisheries and Aquatic Sciences 16: 1-14.
[78] Zupanovic, S. (1968): Study of Hake (*Merluccius Merluccius* L.) Biology and Population Dynamics in the Central Adriatic. – General Fisheries Council for the Mediterranean, FAO, Rome.
[79] Zupanovic, S., Jardas, I. (1986): A contribution to the study of biology and population dynamics of the Adriatic hake, *Merluccius merluccius* (L). – Acta Adriat. 27(1-2): 97-146.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_947965