Morphological and Histological Study of the Gonads Maturation Stages in the Chub Mackerel *Scomber japonicus* (Houttuyn, 1782) in the Coastal Water of Latakia

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Abstract

This study was carried out on /516/ fish individuals of Chub Mackerel *Scomber japonicus* (Houttuyn, 1782), which were caught from the Coastal water of Latakia province (Levantine basin) from December 2014 to November 2015, to identify the evolution stages of sexual maturity (by morphological and histological methods) and determine the spawning period of this important economic species. The results showed that *Scomber japonicus* begin with sexual maturity from the beginning of February and extend until mid-May, with a single peak in Mars. The average value of the gonado-somatic index (GSI) was (12.46 ± 1.52)% for males and (13.21 ± 3.9)% for female in Mars. And the total body length at sexual maturity was (21.5) cm for males, and was (23.5) cm for females. The development stages and gonad maturation in this specie, are similar with regard to the tissue and the form of gonads and according to the six gonad maturation steps.

Key words: *Scomber japonicus*, morphological, Histological, Maturation sexual, Latakia Coastal water.

Introduction:

Chub mackerel *Scomber japonicus* (Houttuyn, 1782) is a geographically widespread coastal pelagic fish species, which inhabits moderate and warm waters of the Atlantic, Pacific and Indian oceans, as well as the Mediterranean and its adjacent seas (the Black Sea and Adriatic Sea) (Whitehead *et al*., 1986). This species is one of the most important commercial fish throughout its habitat (F.A.O, 2010). Because of its wide world distribution and important commercial exploitation, it is necessary to get more information on its reproductive biology for effective fish stock management.

The biology of reproduction of chub mackerel has been thoroughly investigated in the Atlantic and Pacific oceans (Parrish and Knaggs, 1971; Knaggs and Parrish, 1973; Dickerson *et al*., 1992; Ermakov, 1996; Martins, 1996; Yamada *et al*., 1996; Gluyas-Millan and Quinonez-Velazquez, 1997; Watanabe and Yatsu, 2004; Caramantin-Soriano *et al*., 2009; Shiraishi *et al*., 2009); while, few information are available for the Mediterranean (Tuggac, 1957; Demir, 1961; Baird, 1977; Kiparissis *et al*., 2000). Despite the wide distribution and commercial value in the Eastern Mediterranean Sea, few studies have focused on the reproductive biology in the Levantine Basin population. Ben- Tuvia (1957) has recorded the spawning period of chub mackerel during spring and summer in the South-Eastern Mediterranean.

Knowledge of the reproductive biology and spawning period of chub mackerel is essential for a comprehensive understanding of their population dynamics (Hilborn and Walters, 1992; Rinchard and Kestenmont, 2003). In addition, reliable indicators of reproductive status, such as size at the first maturity, and spawning season, are fundamental elements required for the proper assessment and management of chub mackerel fish stocks.

The main objective of this study is to test the following hypotheses (i) chub mackerel lay eggs during the warmer part of the year; and (ii) it is a batch spawner. Results from this study should provide fishery managers with essential information for the development of science-based management.

Taxonomic position:

Scomber japonicus is a teleost species, belonging to order *Perciformes* and Family *Scombridae*.

Fig. 1. *Scomber japonicus*

Largely distributed in all the shores of the Mediterranean Coastal waters and the southern shores of the Black Sea as well as the east coast of the Atlantic Ocean.

Materials and methods:

The specimens of chub mackerel were collected randomly from commercial landings. Samples were collected during the night, with artificial light, using a purse seine net with a mesh size of 10 mm (Fig. 2). The use of a purse seine with artificial light is preferred in the Mediterranean Sea to catch individuals aggregating close to the surface, like sardines, mackerels, anchovies, herring and some species of tuna.

A total of 516 specimens were sampled between December 2014 and November 2015 in Latakia area (35º 39’ 47’’ E - 35º 53’ 17’’ N). Samples were caught once a month, except when prevented by logistical problems or bad weather (Fig. 3).

After the arrival of fresh fish samples to the laboratory, the following measurements are taken for every fish specimen, total length (Tl) cm, standard length (Sl) cm and total weight (Tw)g.

Fig. 2. Catch and sampling of chub mackerel by purse seine net in the Coastal waters of Latakia

Fig .3. Fishing site of Latakia Syrian Coast.

During the dissection of fish samples, the liver and gonads are separated for the measurements of liver weight (Lw) g and weight of gonads (Gw) g.

Preparation of samples for histological studies:

After the gonads removal, the fish samples were examined with the naked eye and stored in formalin concentration 10% formaldehyde pending tissue sections later.
The sex of each individual specimen was determined according to the shape of the gonad, external appearance and structure of the gonad. The analyzed specimens clarified that 256 were male and 138 were female; whereas 122 specimens the sex was not determined because either the specimens were immature; or they were in the resting phase of reproduction or specimens were not well preserved.
Maturity stages were determined according to the empiric scale which described by Sinovčić. (1978), then modified to include immature stages I and II, mature stages III and IV, ripe and spawning stages V and VI.
Additional information on chub mackerel spawning period was determined by measuring monthly changes in gonad-somatic indices, gonad weight and maturity stage fluctuations. The gonad somatic index (GSI) was calculated by expressing gonad weight (Gw) as a percentage of total body weight (T*w*): Gw ×100 / Tw.

Results:

Size at the first maturity:
The smallest analyzed sexually mature male was 19 cm, while the smallest female length of 20.5 cm. The estimated mean length at first maturity ($LT_{50\%}$) was 21.5 cm for males and 23.5 cm for females.

Spawning period:
Monthly variations in maturity stages (Fig. 5, 6, and 7), gonad weight and GSI (Fig. 4) displayed synchronicity. Based on these three parameters, *S. japonicus* spawn from February to May, with peak spawning period occurring simultaneously for both sexes in Mars. Subsequently, a sharp decline in GSI and gonad weight were observed after peak spawning, which lasted until October, when both parameters had very low values and the majority of gonads been in the spent and resting phase. In colder months of the year (until Feb.), the observed parameters indicate either absence or low sexual activity.

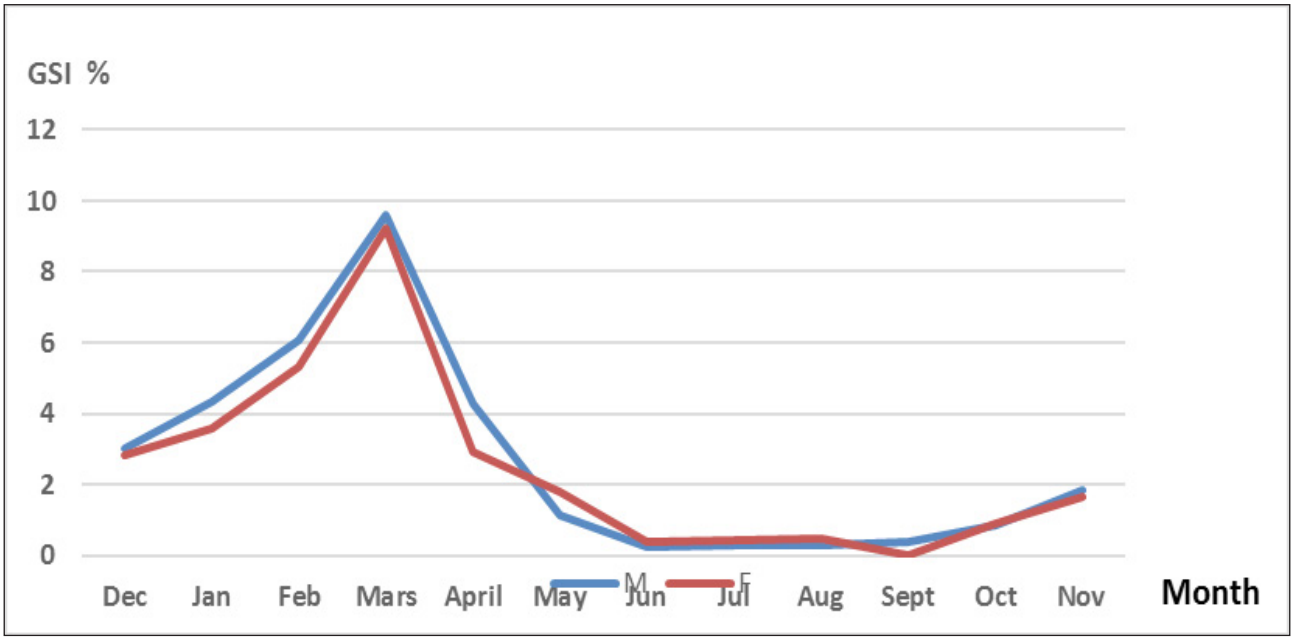


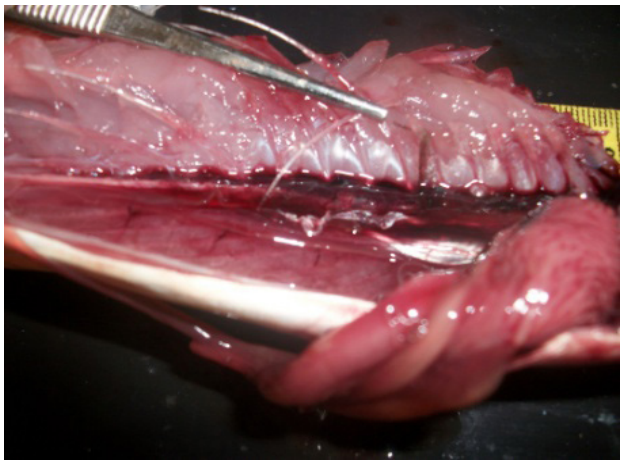
Fig .4. Monthly fluctuations of GSI with mean for Males and Females of *S. japonicus*.

Different stages in the morphological and histological evolution of ovary and testis in *Scomber japonicus* are exhibited in Tables (1, 2, and 3) and Fig. (5, 6, and 7).

Table. 1. Characteristic features of different maturity stages of gonads as found in *S. japonicus*

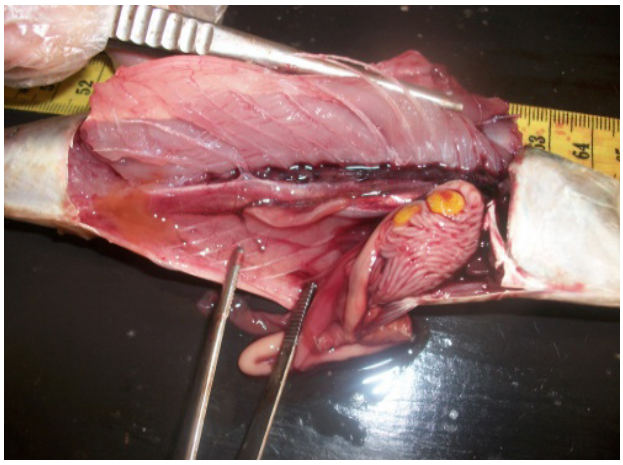
stage	Female (♀)	Male (♂)
Juvenile	Pinkish, occupying 1/4th to 1/2 body cavity; ova irregular and transparent.	Whitish, ribbon- shaped, occupying 1/2 body cavity
Beginning of sexual maturity	Yellowish, occupying 1/2 to 2/3rd body cavity; ova round and completely filled with yolk.	Whitish, occupying 2/3 body cavity
before sexual maturity	Yellowish, occupying 2/3rd to3/4 body cavity; ova round and completely filled with yolk.	Whitish, occupying 2/3rd to 3/4 body cavity
Sexual Maturity	Yellowish, occupying nearly entire body with some ova visible outside; yolk vacuolated; perivitelline space present.	Creamy white, occupying the entire body cavity
Spawning, laying eggs, laying gametes	In the oozing stage	In the oozing stage
Suction	Flaccid, with blood vessels prominent all over surface - occupying not more than 1/2 body cavity	Flaccid, occupying about ½ body cavity.

1♀



1♂

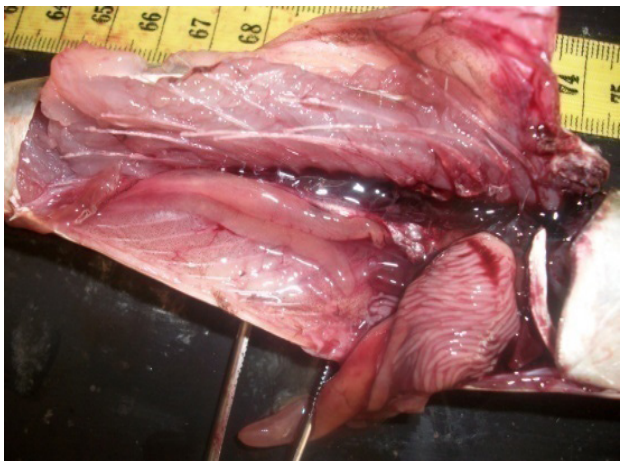
Stage I. Juvenile



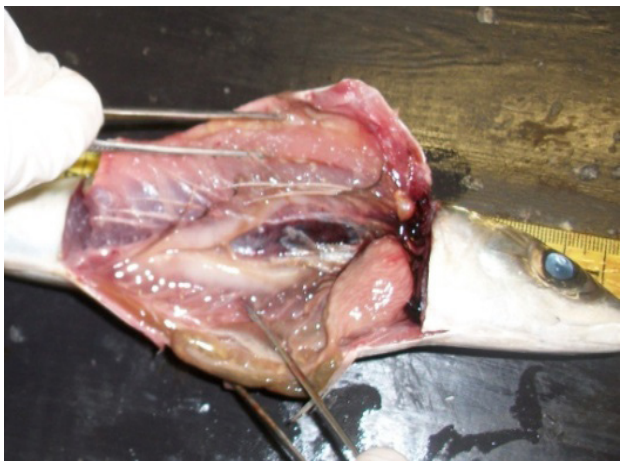
2♀

2♂

Stage II. Beginning of sexual maturity



3♀

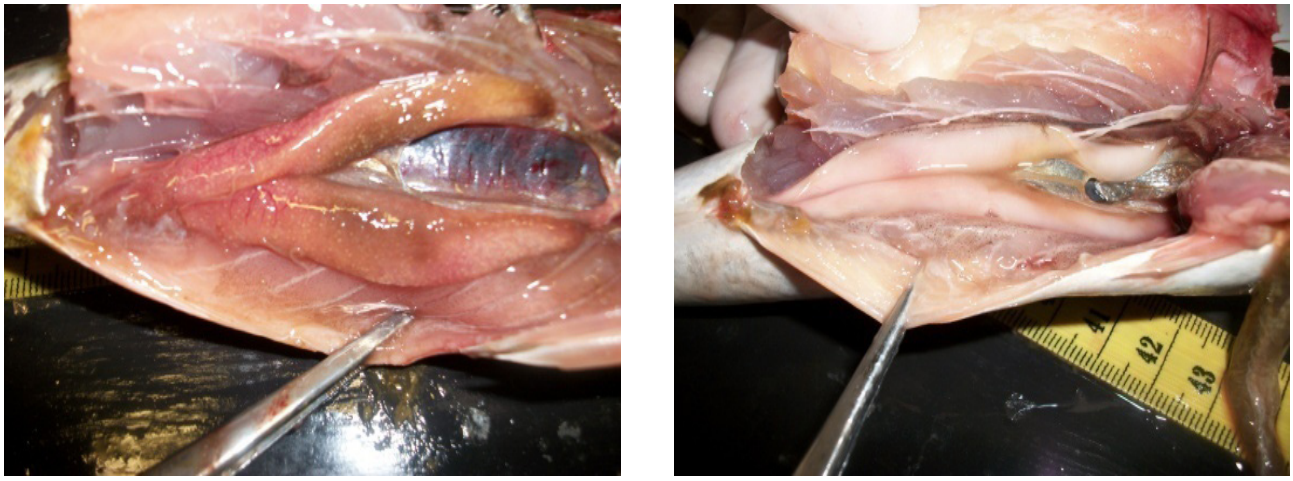


3♂

Stage III. Before sexual maturity

4♀ **Stage IV. Sexual Maturity** 4♂

5 ♀ **Stage V. Spawning, laying eggs, laying gametes** 5 ♂

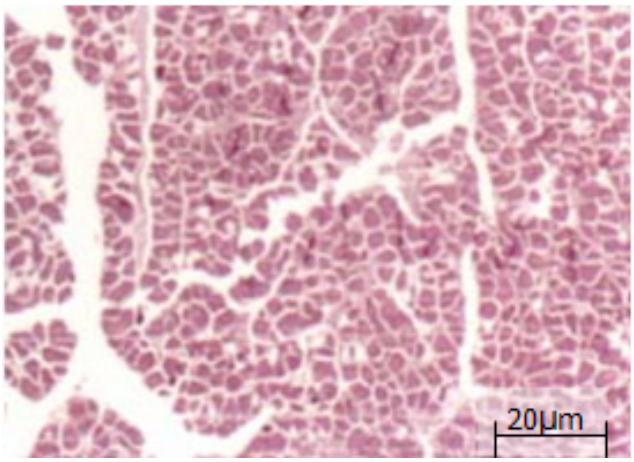


6 ♀ **Stage VI. Suction** 6 ♂

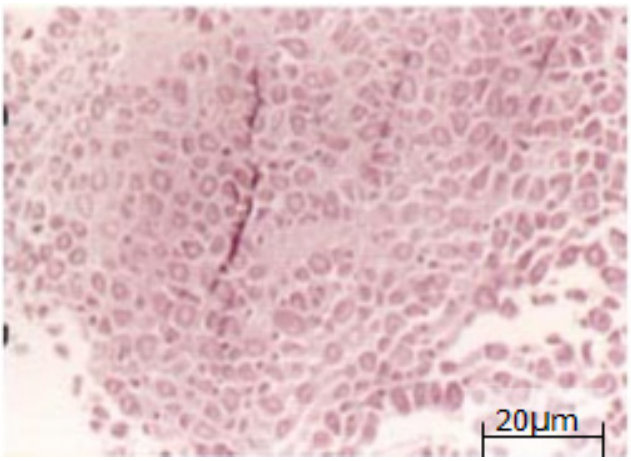
Fig. 5. Evolution of gonad morphology during the reproductive cycle of chub mackerel in the Coastal waters of latakia.

Table. 2. Histological description of microscopic ovarian phases of the gonads of *S. japonicus*

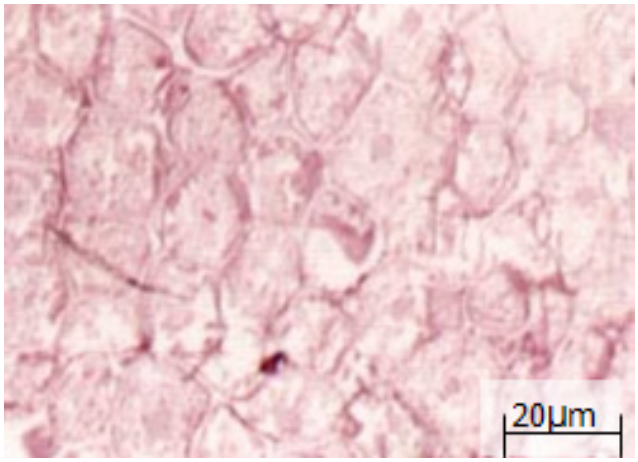
stage	Histological
Sexual resting	Small ovarian cavity, chromatin- nucleolus stage and peri nucleolar oocytes. Some oocytes (but scarce) at lipid globule stage during the entire year
Beginning of sexual maturation	Numerous primary oocytes, together with secondary oocytes
Oocytes with fatty vacuoles	Oocytes at all stages of developing, including batches of secondary vitellogenic oocytes at yolk granule stages 1, 2 and 3. Very few, mainly of advanced vitellogenic oocytes (VO).
Oocytes full with vitelline	Oocytes at final maturation. Oocytes in all stages development. Few (or none) O. A large population of oocytes remains in the PG phase. Ovarian cavity increases in size as spawning proceeds.
Sexual Maturity	Wide ovarian cavity. Vascularized, empty and irregular ovigerous lamellae, together with residual healthy, yolked oocytes. A large population of primary oocytes present at the periphery of the ovigerous folds
Suction	Wide ovarian cavity and thick ovarian wall. primary oocytes numerous. No vitellogenic oocytes. Abundant stroma in the inner of bloodshot ovigerous folds. No vitellogenic oocytes



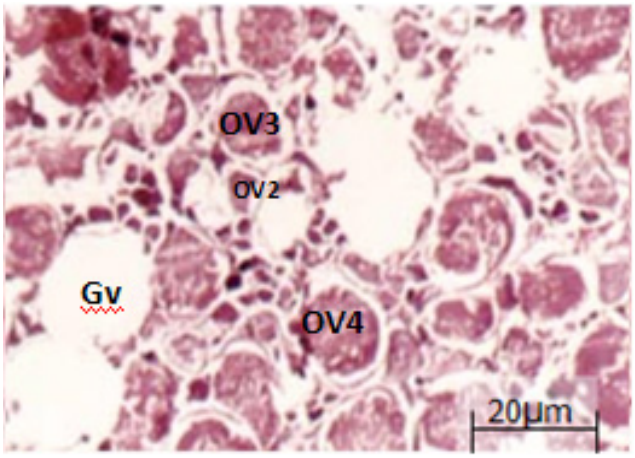
1♀ Sexual resting



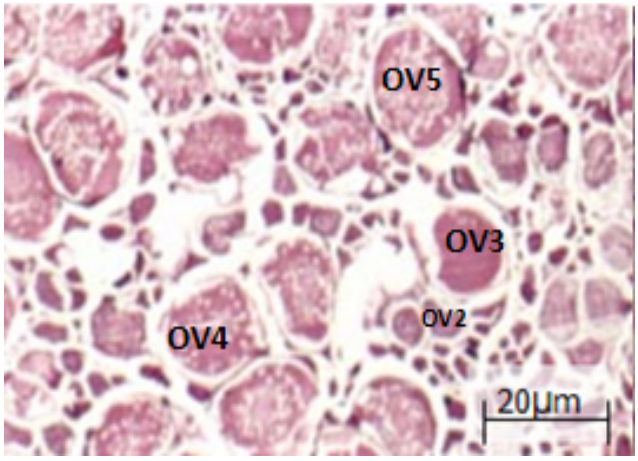
2♀ Beginning of sexual maturation



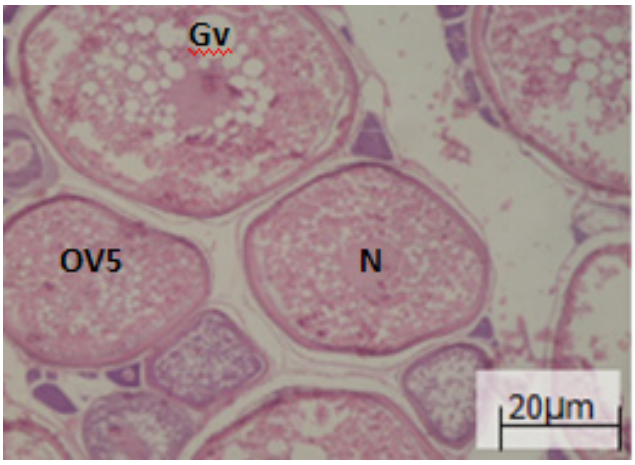
3♀ Oocytes with fatty vacuoles



4♀ Oocytes full with vitelline



5♀ Sexual Maturity

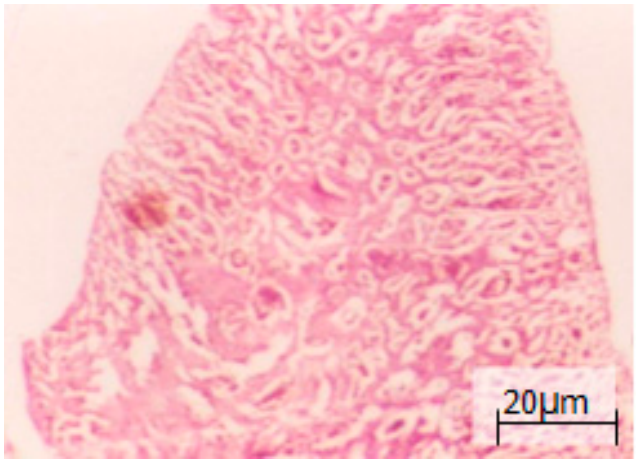


6♀ Suction

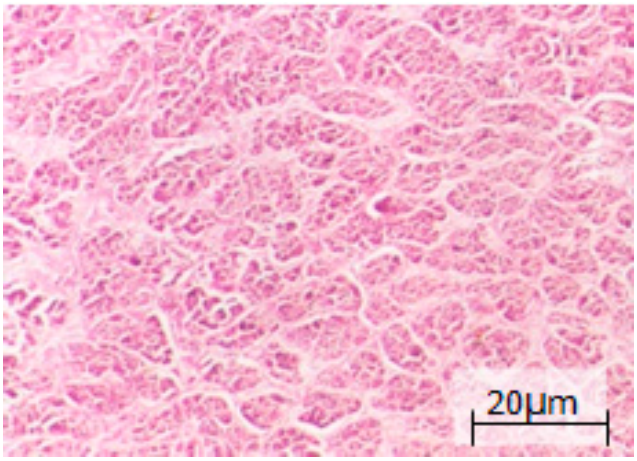
Fig. 6. Histological variation of ovaries during the reproductive cycle of chub mackerel in the Coastal waters of Latakia

Table .3. Histological description of microscopic testes phases of the gonads of *S. japonicus*

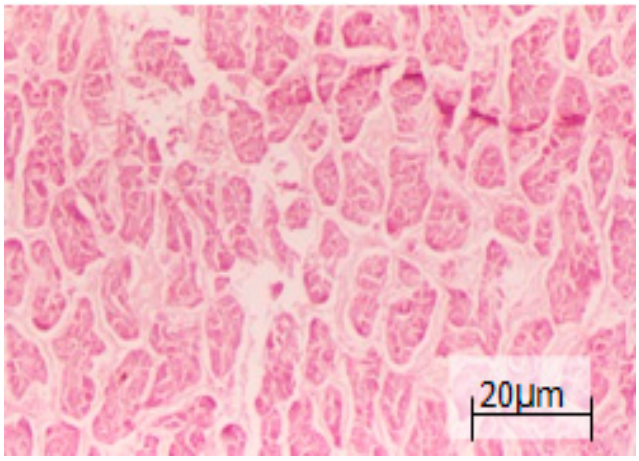
Stage	Histological
Spermatogonie	Very mall gonads with well-developed tubules. Abundant spermatogonia. Spermatogenic activity during all year, more intense in the reproductive season. Spermatozoa are present in the lumen of tubules and vas deferens during the reproductive season.
Spermatocytes I	Spermatogenic activity is generalized in testes, with abundant spermatocytes. Spermatozoa can be observed in tubules but not in all of them
Spermatocytes II	Intense spermatogenic activity. Abundant spermatids. Spermatozoa are present in the tubules but do not fill all the lumen.
Spermatides	Intense spermatogenic activity dilated tubules and vas deferens fully filled with spermatozoa
Laying gametes	No spermatogenic activity or very limited. Tubules and vas deferens continue full of residual spermatozoa.
Suction	Wall of spermatogenic tubules is full of spermatogonia. Residual spermatogenic activity and scattered residual spermatozoa are still present in the tubule and vas deferens abundant stroma in the testes.



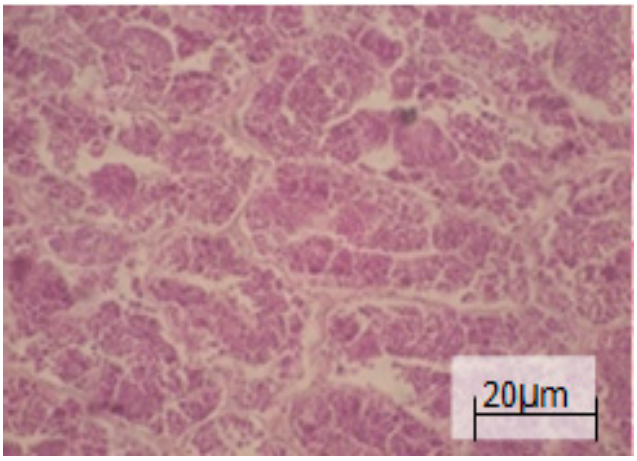
1♂ Spermatogonie



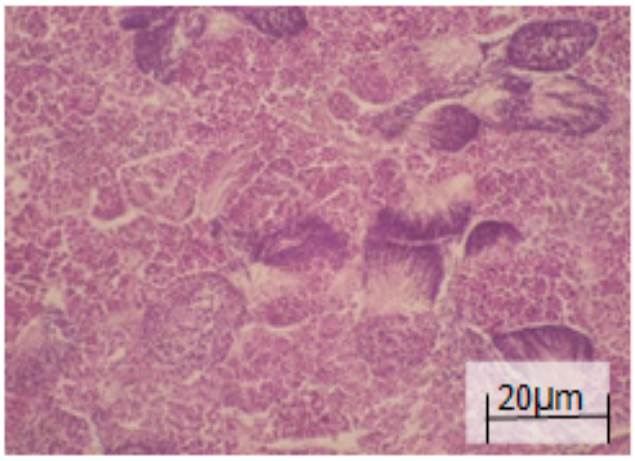
2♂ Spermatocytes I



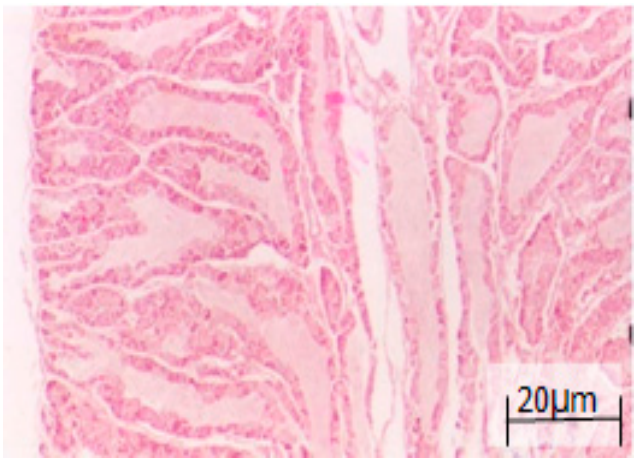
3♂ Spermatocytes II



4♂ Spermatides



5♂ Laying gametes



6♀ Suction

Fig. 7. Histological variation of testis during the reproductive cycle of chub mackerel in the Coastal waters of Latakia

Discussion:

Size at the first maturity:

In addition to mortality, length at first sexual maturity directly influences the reproductive efficiency of a species, partially determining the duration of the spawning period for each individual as well as influencing the quantity of the spawning stock.

Studies investigating the size of chub mackerel at maturity are rather scarce, especially in the Mediterranean and Adriatic regions. In the present study, *S. japonicus* size at maturity was found to be much lower (Tl:19 cm for males; and 20.5 cm for females) than those previously reported. For example, Mužinić (1979) described chub mackerel specimens 26.0 cm as sexually mature, while Rodriguez-Roda (1982) established that 30.6 cm specimens in the NW Mediterranean Sea had reached their first sexual maturity. These differences are probably due to the fact that size/age of first maturity depends on environmental factors, such as food availability, seawater temperature (Nikolsky, 1963; Hempel, 1965; Blaxter, 1969), and genetic factors (Wootton, 1998), as well as other parameters such as long-term fishing pressure and selectivity (Jørgensen, 1990; Trippel, 1995; Helser and Almeida, 1997; O' Brien, 1999; Jennings *et al*., 2001).

Spawning period:

In general, pelagic fish such as *S. japonicus* spawn in areas with substantial biological production, to ensure adequate adult and larval feeding (Blaxter and Hunter, 1982; Caramantin-Soriano *et al*., 2009). Furthermore, one of the main triggers of spawning activities in chub mackerel is the water temperature (15–20°C) (Collete and Nauen, 1983). The specimens analyzed in this study tended to spawn from spring to summer, with peak spawning in June. This was also established for the same Adriatic Sea population by Mužinić (1978), who found specimens with ripe gonads from April to September. The few papers that examined chub mackerel spawning patterns in the Mediterranean Sea reported almost the same spawning season duration. Thus, Tuggac (1957) noted that peak spawning for this species occurs in June and July in the Marmora Sea; whereas Ben-Tuvia (1957) established intense spawning from April to August along the South-East Mediterranean coast and Atli (1960) reported peak spawning in July and August in the Black and Marmora seas. Based on these and the present results, it seems that mass spawning is favored by sudden spring warming, causing slight discrepancies in the duration/peak of spawning in different.

The reproduction period of *Scomber japonicus* in the East Mediterranean (Feb – May) between Palestinian and the Syrian Coasts is different. During 1957 the reproduction of this species occurred in April-May, whereas in our actual survey and after 55 years, it was noticed between February and May. This difference in the timing and the shifting to the cold months is probably due to the global warming, inducing an increase of the seawater temperature, that became close to the summer season. Because of this climate change the spawning, and reproduction period occur now earlier in winter and early spring in Levantine Basin water.

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دراسة مراحل نضج المناسل شكلياً ونسيجياً عند سمك السقمبري *Scomber japonicus* (Houttuyn, 1782) في المياه الشاطئية لمحافظة اللاذقية

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الملخص

نُفّذت هذه الدّراسة على 516 فرداً سمكياً من النوع *Scomber japonicus* (Houttuyn, 1782) تمّ اصطيادها من المياه الشاطئية لمحافظة اللاذقية (الحوض الشرقي للمتوسط)، للتعرّف على تطوّر مراحل نضج المناسل شكلياً ونسيجياً، وتحديد فترة النضج الجنسي لهذا النوع السمكي، خلال الفترة الممتدة من شهر كانون الأول/ديسيمبر 2014 وحتى شهر تشرين الثاني/نوفمبر 2015، حيث يُعدّ هذا النوع من الأنواع الهامّة اقتصادياً. أظهرت النتائج أنّ أفراد النوع السمكي *S. japonicus* تبدأ بالنضج الجنسي من بداية شهر شباط/فبراير وتمتد حتى منتصف شهر أيار/مايو، مع وجود ذروة وحيدة في شهر أذار/مارس. وكان متوسط أعلى قيمة لمعامل النضج الجنسي GSI% (12.46 ± 1.52)% للذكور، و(13.21 ± 3.9)% للإناث في شهر أذار. وبلغ الطول الكلي عند أول نضج جنسي (21.5) سم للذكور، و(23.5) سم للإناث. توافقت مراحل نضج المناسل (شكليّاً ونسيجيّاً) لدى النوع السمكي المدروس مع السلم السداسي لنضج المناسل.

الكلمات المفتاحية: *Scomber japonicus*، شكلي، نسيجي، نضج جنسي، شاطئ اللاذقية.