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Reproductive biology of the Atlantic mackerel *Scomber scombrus* Linnaeus, 1758 in Mediterranean coast of Sinai, Egypt.

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ABSTRACT

This work aims to investigate reproductive biology of the Atlantic mackerel (*Scomber scombrus* L. 1758) to provide biological base for management of its fisheries in the Mediterranean coast of Sinai, Egypt. Monthly samples of *S. scombrus* were collected from the commercial catch in different landing sites of the Mediterranean coast of Sinai during 2019. The length-weight relation was found as $W= 0.0116\ L^{2.9556}$, $W= 0.0077\ L^{3.091}$ and $W= 0.0094\ L^{3.022715}$ for males, females and combined sexes respectively. Overall sex ratio (males: females) was 1: 1.4 during the period of study. Gonado- Somatic Index (GSI) of females showed that *S. scombrus* spawn during March, April and May, since GSI peaked in these months (6.5, 7.2 and 5.2 % respectively). The lowest value of GSI of females was recorded in October (0.05%). Lengths at first sexual maturity (L_m) were determined as 23.2 and 23.4 cm for males and females respectively. The absolute fecundity (F) was increasing with the fish length and described by a power equation: $F = 0.0014\ L^{5.6414}$. The relative fecundity gradually increased from 2481.8 to 7599.3 eggs per cm (average 4748.9 eggs / cm). To protect and maintain the stock of Atlantic mackerel in the Mediterranean coast of Sinai, it is recommended to ban using fishing nets of illegal mesh sizes and other destructive fishing methods which catch small fish sizes. Length at first capture should be larger than length at first sexual maturity (> 23.4 cm) and ban fishing nets targeting *S. scombrus* during its spawning season (from March to May).

INTRODUCTION

The Atlantic mackerel (*Scomber scombrus* Linnaeus, 1758) is one of the most widely distributed migratory fish species in the North Atlantic (ICES, 2011). It is a pelagic schooling species abundant in cold and temperate waters of the northern Atlantic Ocean and Mediterranean Sea (Froese and Pauly, 2012). *S. scombrus* is a beneficial commercial species, targeted by purse seines, midwater trawls and longlines (FAO-FIGIS, 2005). Mackerel, like most scombrids, are highly-streamlined, quick -swimming, pelagic fish, and they are diffused in shelf seas of the North Atlantic, usually at depths of

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less than 200 m. They are a classic shoaling fish, with shoals of up to 9 km long, 4 km wide, and 40 m deep being reported (Lockwood, 1988).

The catch of this species has been decrease in the Adriatic Sea at the beginning of the 1970s (Sinovcic, 2001; Azzurro *et al*., 2011; Barausse *et al*., 2011). It is an important food resource for larger pelagic predators, including sharks and marine mammals, and a variety of sea birds (Dahl and Kirkegaard, 1986) .

Descriptions of reproductive strategies and evaluation of fecundity are essential topics in the study of the biology and population dynamics of fish species and also for estimating the reproductive potential of individual fish species (Shalloof and Salama, 2008; Costache *et al*., 2011). Moreover, the availability of data concerned with reproductive parameters and environmental fluctuation could lead to a better understanding of observed variations in reproductive output and increase our ability to estimate recruitment (Kraus *et al*., 2002).

Egypt is considered the second top ten countries consuming Mackerel (*Scomber scombrus*) (El-Dengawy *et al*., 2017). The production of these fish from the Mediterranean coast of Sinai ranged from 4 tons to 75 tons with an average of 22.1 tons per year. There are fluctuations in the production of these fish (GAFRD, 2018).There are no recorded biological studies or any other studies concerning this species in Egypt. So, the present study, for the first time, provides information on Length- weight relationship, condition factor, sex ratio, gonadosomatic index, length at first maturity and fecundity of the Atlantic Mackerel (*S. scombrus*) in the Eastern Mediterranean of Egypt. These details are needed for increasing better rational exploitation, planning and management execution of this species.

MATERIALS AND METHODS

From the Eastern Mediterranean, El-Arish port, 1106 samples of Atlantic mackerel *S. scombrus* (Fig. 1) were collected during the period from January to December 201٩, from the catches by the Purse - seine nets.

Fig. 1: Atlantic mackerel *S. scombrus* from Mediterranean coast of Sinai, Egypt

The relationship between length and weight was described by the potential equation ($W = aL^{b}$, Ricker, 1975), where W is the total weight (g), and L is the total length (cm), a and b are constants. The condition factor (K) was calculated monthly by the formula $K = (W * 100) / L^3$ as cited by Azab *et al*., (2019) Where: K = condition factor W = weight in gram, and L = length in centimeter.

The Gonado-Somatic Index (GSI) was calculated by equation of Albertine-Berhaut (1973) as follows: GSI = (Gonad Weight / Body Weight) *100.

Probability of capture against mid-length a resultant curve was used to compute the length at first capture (L_{c50}) as recorded by Olopade *et al*., (2019) .The length at first capture L_{c50} (the length at which 50% of fish retained in fishing gear) was estimated by fitting the capture curve between the observed points of mid-class interval and the percentage of capture probability of fish corresponding to each length interval. Then L_{c50} was estimated as the point on the X-axis corresponding to the 50% point on the Y-axis.

To estimate the length at first maturity, the total body length was plotted against the frequency percentage of mature individuals during the spawning season, and then the length at 50% consider as the length at first maturity (Sendecor, 1956).

The absolute fecundity ($F_{abs.}$) is defined as the number of mature eggs in the ovaries during the spawning season. 61 mature ovaries were used to determine fish fecundity. Mature ovaries were taken, washed, dried and weighted. Then the ovarian tissue was removed and the net eggs weight was obtained. Eggs were well mixed, and three subsamples were weighted and counted under the microscope. Total fecundity was calculated according to Yeldan and Avsar (2000) as:

F_{abs}. = [(Gonad weight* Egg number in the subsample)/ Weight of subsample].

The relative fecundity ($F_{rel.}$) was calculated as:

F_{rel}. = F_{abs}. / (Total length or Body weight).

RESULTS

A total of 1106 Atlantic mackerel *S. scombrus* from the Eastern Mediterranean, ranged from 12.3 to 30.9 cm, and the observed total weight from 15 to 261 g were collected. The length – weight relationship was described by the power equation as: $W= 0.0116 L^{2.9556}$ ($R^2 = 0.8924$), $W= 0.0077 L^{3.091}$ ($R^2 = 08826$) and $W= 0.0094 L^{3.0227}$ ($R^2 = 0.8869$) for males, females and combined sexes respectively (Figs.2, 3 and 4).

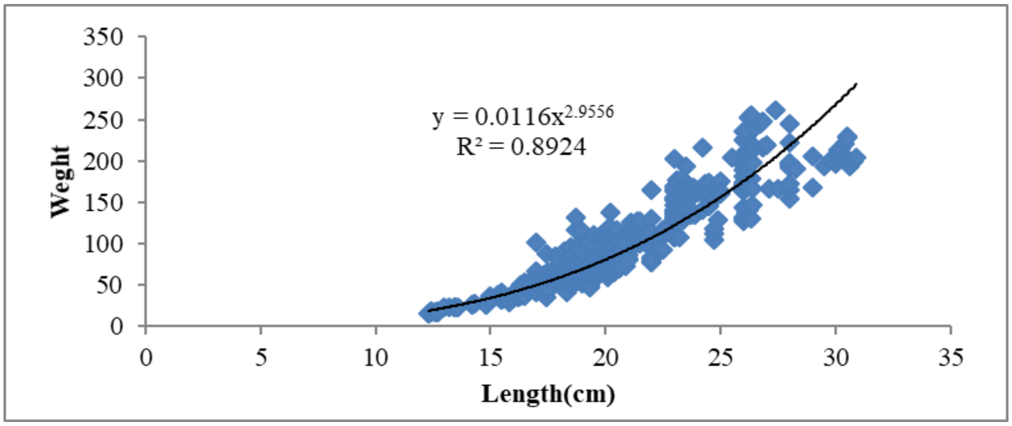

Fig. 2: Length weight relationship of males for *S. scombrus* from the Eastern Mediterranean 2019

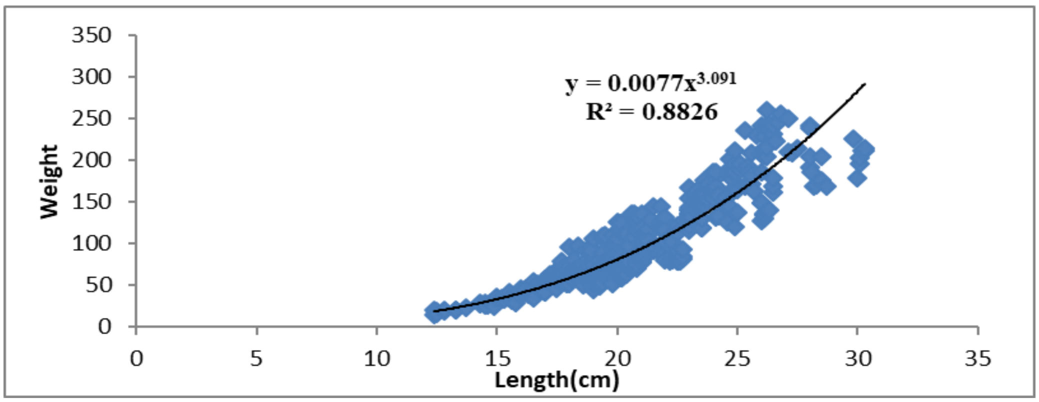

Fig. 3: Length weight relationship of females for *S. scombrus* from the Eastern Mediterranean 2019

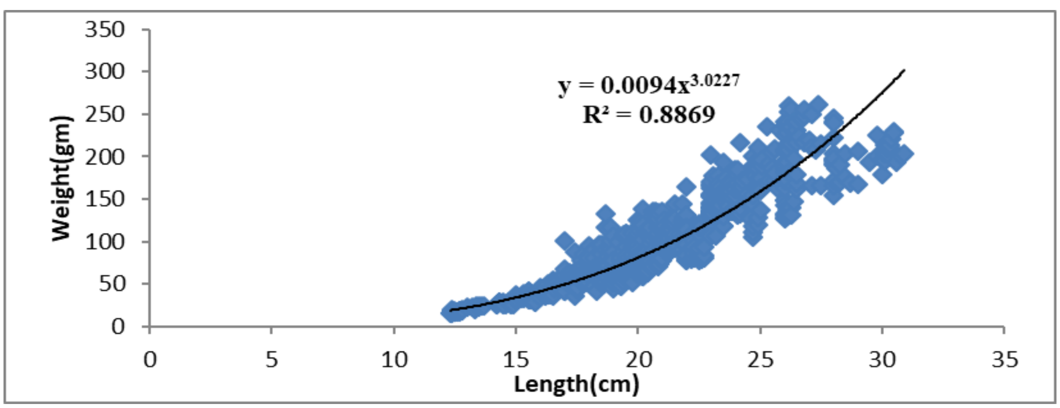

Fig. 4: Length weight relationship of combined sexes for *S. scombrus* from the Eastern Mediterranean 2019

Condition Factor:

The mean condition factors for males, females and combined sexes were nearly similar. Lower condition factor values (K) were recorded in December while the highest values were observed in March (Fig. 5).

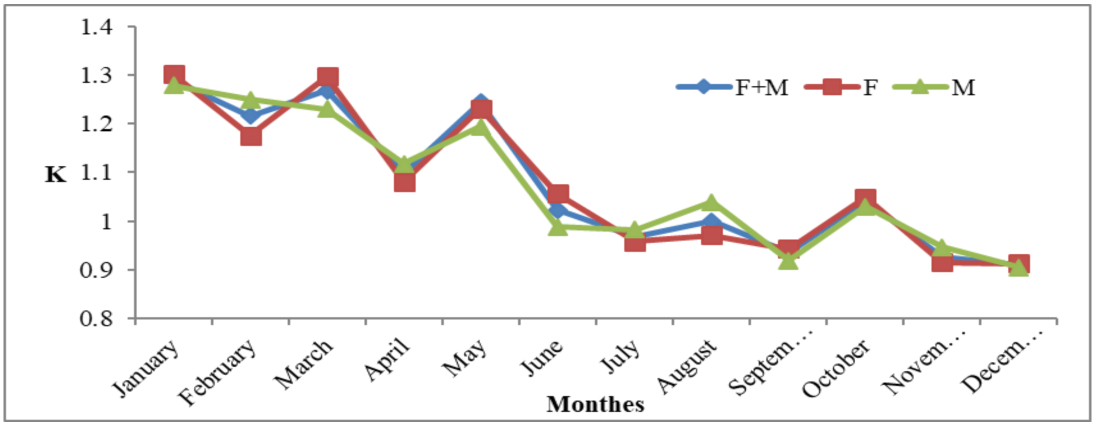

Fig. 5: Monthly variation in condition factor (K) of combined sexes (F&M), females (F) and males (M) of *S. scombrus* during 201٩.

Sex ratio:

It was seen from sex distribution in Table (1) that the two sexes did not occur in the same proportion, since females predominated during all months except in May and June, since it has constituted more than 50 % of the collected sample during the period of study. The overall ratio of males to females (M: F) was 1: 1.4. This means that the existed number of females was relatively higher than males.

Table 1: Monthly variations in sex ratio of *S. scombrus* from the Eastern Mediterranean 2019

Month		Females		Males		Sex ratio
	No. of fish	No.	%	No.	%	M/F
January	46	24	52.2	22	47.8	1-1.1
February	63	35	55.6	28	44.4	1-1.3
March	145	84	57.9	61	42.1	1-1.4
April	98	56	57.1	42	42.9	1-1.3
May	65	25	38.5	40	61.5	1-0.6
June	109	50	45.9	59	54.1	1-0.8
July	93	57`	61.3	36	38.7	1-1.6
Aug.	74	43	58.1	31	41.9	1-1.4
Sep.	89	56	62.9	33	37.1	1-1.7
Oct.	100	62	62.0	38	38.0	1-1.6
Nov.	154	103	66.9	51	33.1	1-2.0
Dec.	70	41	58.6	29	41.4	1-1.4
Total	1106	636	57.5	470	42.5	1-1.4

Regarding to fish length, it was noticed that female's individuals were outnumbered males for all length groups except in the length groups 12, 13, 26, 29 and 30 cm, where the males outnumbered females (Fig. 6).

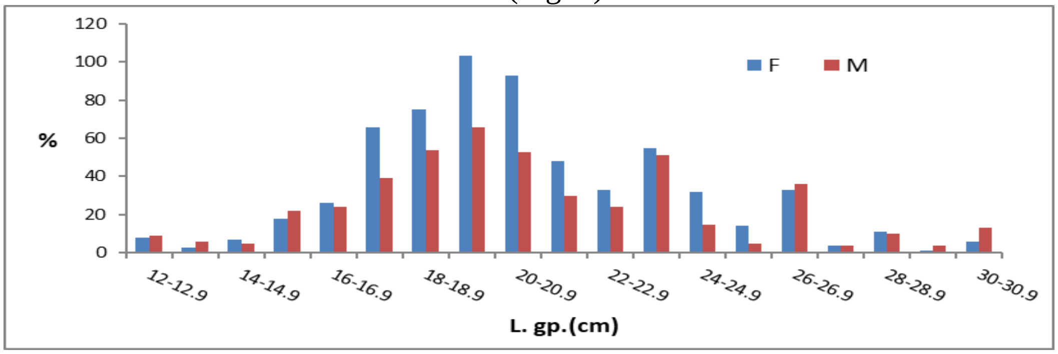

Fig. 6: Sex ratio according to length groups of *S. scombrus* from the Eastern Mediterranean 2019.

Gonado- Somatic Index (GSI):

Gonad development was followed using the GSI. The reproduction period (expressed by GSI) of *S. scombrus* was determined to be in March, April and May. The monthly changes in males and females GSI of *S. scombrus* were represented in Fig. (7). GSI values of males were lower than females, and the lowest value of GSI of males (0.06) was recorded in October, and then started to increase slightly from November. On the other hand, highest value of GSI (7.2 and 5.2) was recorded in April of females and males respectively. Values of GSI of females showed a similar pattern that of males. It attained the lowest value (0.05) in October.

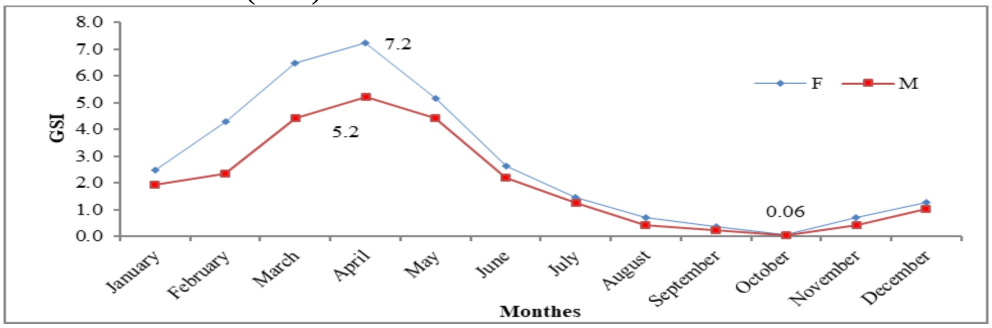

Fig. 7: Monthly variations in GSI of *S. scombrus* from the Eastern Mediterranean 2019

The length at first maturity (L_m) was determined as 23.2 and 23.4 cm for males and females respectively (Fig. 8). The length at first capture (L_c) was determined as 20.0 cm for males, females and combined sexes (Fig. 9).

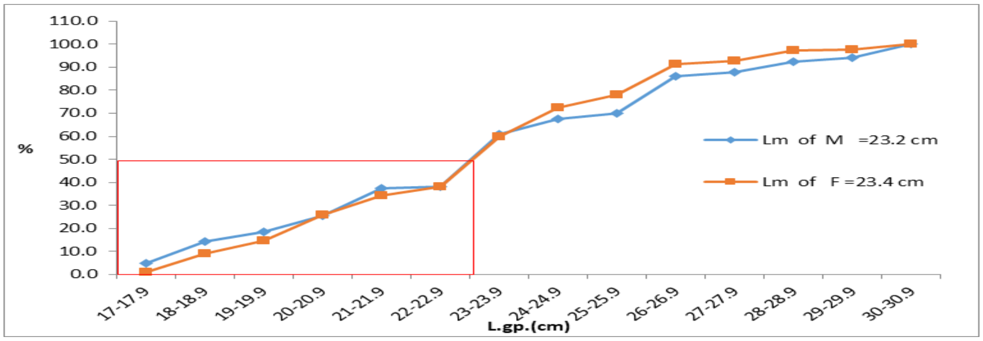

Fig. 8: Length at first sexual maturity (L_m) of males, females and combined sexes of *S. scombrus* from the Eastern Mediterranean 2019

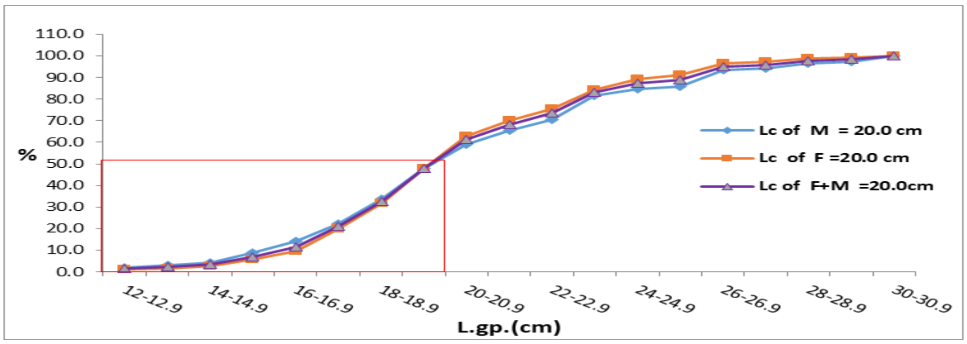

Fig. 9: Length at first capture (Lc) of males, females and combined sexes of *S. scombrus* from the Eastern Mediterranean 2019

Fecundity:

The relation between fecundity (absolute and relative) with body size (total length) and body weight of *S. scombrus* were calculated. The results showed that the number of eggs gradually increased by increasing fish length or weight, since fish of 22 cm (131.5 g) bears about 54600 eggs, reaching maximum of about 229500 eggs for a fish of length 30.2 cm, (212 g.). The relationship between absolute fecundity and total length in (Fig. 10) was represented by power equation of the form: $F= 0.0014 L^{5.6414}$ ($R^2 = 0.8822$).

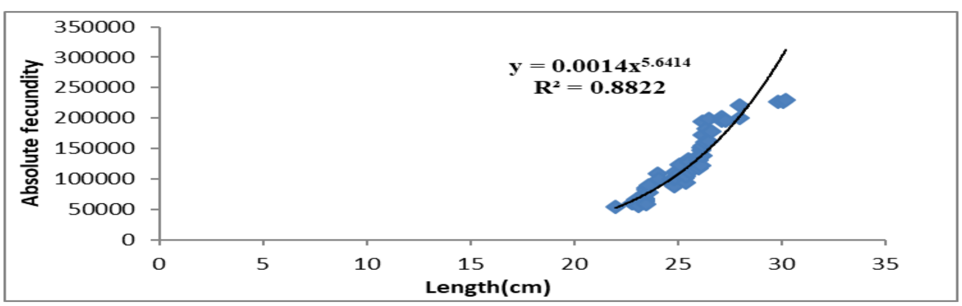

Fig. 10: Relationship between total length and absolute fecundity of *S. scombrus* from the Eastern Mediterranean

Also the relationship between absolute fecundity and the body weight of *S. scombrus* (Fig. 11) was represented by the following linear regression: F= 1176.9 W - 97733 (R^2= 0.7429).

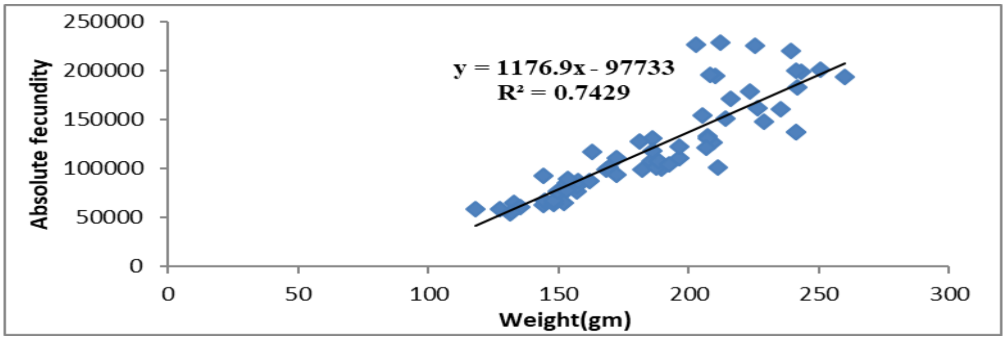

Fig. 11: Relationship between total weight and absolute fecundity of *S. scombrus* from the Eastern Mediterranean

The relative fecundity gradually increased from 2481.8 to 7599.3 eggs per cm (average 4748.9 eggs/ cm).

DISCUSSION

Mackerel fish are important fishery resources, extremely distributed in the Pacific coast of Japan, East China Sea, and zones of Indian (Zhang and Deng, 2012). The total length distribution of the samples in the present study varied between12.3 to 30.9 cm. These lengths were 12.0-27.0 cm in the Sea of Marmara as recorded by Bal and Türker (2019).

The "b" values of length- weight relationship in fish is specific and varies with sex, age, seasons, physiological conditions, growth increment and nutritional status of fish, health, habitat, nutrition, environmental conditions (such as temperature and salinity), area, degree of stomach fullness, differences in the length range of the caught specimen, maturity stage and techniques of sampling fishing gear (Le Cren, 1951; Tesch, 1968; Bagenal and Tesch, 1978). In the present study, the calculated value of 'b' for length and weight relationship of *S. scombrus* was 3.0227 for combined sexes. The correlation coefficient was close to one suggesting a good adjustment between length and weight of Atlantic mackerel *S. scombrus* which were of expected range. These results were nearly equal with results obtained by Santos *et al. (*2002) and Froese and Pauly (2003), where the (b) values were 3.079 and 3.084 respectively. Our results are lower than which obtained by Mendes and Campos, (2004) and Morse (1980) since the b values were 3.258 and 3.275 respectively, but much lower than that the obtained by Sinovicic (2001). The latest author reported that, the b value of *S. scombrus* in the Adriatic Sea was 3.7685. Costa *et al.* (2017) mentioned that the (b) value of length weight relationship of Atlantic mackerel (*S. scombrus*) from 2009 to 2013 in west coast of Portugal ranged from 3.313 to 3.903 and 3.00 to 3.626 of males and females respectively .These differences in b values may be due to changes in ecological conditions , feeding habits, mesh sizes and sizes of collected samples.

The mean condition factors of males, females and combined sexes in the present study were likely the same. Lower condition factor values (K) were recorded in December (0.9052) while the highest values were in March (1.2973). In the present study, spawning period of the studied species recorded from March to May. This means that, elevation in condition factor of *S. scombrus* coincide with spawning season. Condition factor (K) of *S. scombrus* in Sea of Marmara, Turkey was calculated as 0.938, 0.909 and 0.947 for females, males and all samples respectively (Bal and Türker, 2019).

The sex ratio of *S. scombrus* was not present in the same proportion throughout the different months of the year. The females are dominant during most of the year, except in May and June. Also, the overall of sex ratio of *S. scombrus* was about 1.0:1.4. Our results different than the result by MacKay (1979), since sex ratio of *S. scombrus* in North Sea coast (1.0: 1.06). Our results are fairly close to the results obtained by Moores *et al*. (1975) from the Newfoundland area (1.0: 1.25). The sex ratio (F: M) of *S. scombrus* in the Sea of Marmara, Turkey of the population was found to be 1:0.94. (Bal and Türker, 2019). Shafi and Quddus (1974) reported that the number of male and female varied greatly from month to month and the difference may largely be due the selective gear used. However, it is not clear which factors might be responsible in the variation of male and female population distribution. Also according to Beevi and Ramachandran (2005), a rising temperature and moderate water velocity, vulnerability of female to their predators and other natural hazards, migratory phase in brooder population are some of the causes for the change in the sex ratio in fishes. The presence of more female in most of the months may be due to vulnerability of female (Bhatnagar, 1972).

The analysis of gonado somatic index values provides fundamental -information regarding to the measure of gonad size relative to body weight (Wootton, 1990) and also the studying of the spawning season (Ahirrao, 2002).

The monthly changes in GSI suggest that this species have spawning period extends from March to May. The pattern of changes in GSI of males is almost similar to that of females. The gonads were in the resting stage of maturity during September, October and November. In the present study, Gonado-Somatic Index (GSI) of Atlantic mackerel *S. scombrus* in the Mediterranean coast of Sinai ranged from 0.05 to 7.2 in females and from 0.06 to 5.2 in males of. These results lower than that obtained by Meneghesso *et al*., (2013) in northern-central Adriatic Sea, since GSI ranged from 0.01 to 9.20 in females and from < 0.01 to 8.58 in males.

Mackerel (*Scomber scombrus*) is a migrant type. Spawning followed by migration of adults belongs to the southern and western areas to feed zones in the Norwegian Sea and the North Sea, El- Dengawy *et al*., 2017.There are two spawning contingents; a southern group that spawns primarily in the Mid-Atlantic Bight and Gulf of Maine from mid-April to June and a northern contingent that spawns in the southern Gulf of St. Lawrence from the end of May to mid-August .The southern contingent begins the spring spawning migration by moving inshore between Delaware Bay and Cape Hatteras, usually between mid-March and mid-April depending to some extent on water temperature (Berrien, 1982).

L_{m50} is an important characteristic of life history essential for prosperity of fishery management, fundamental to establishment of the means that avoid exploitation of young specimens and consequential reduction of spawning stock (Penha and Mateus, 2007). In the present study, the length at first maturity L_{m50} of *S. scombrus* in the Mediterranean coast of Sinai during 2019 was 23.2 and 23.4 cm for males and females respectively. These results differ from the results obtained by DFO Science (1997) in the northwest Atlantic (L_{m50} = 28.2 cm)

In the present study, the fecundity of Atlantic mackerel *S. scombrus* ranged from 54600 to 229500 eggs in fishes sized between 22.0 -30.2 cm. These results nearly agree with the results obtained by Meneghesso *et al*., (2013), since fecundity ranged between 40 000 and 190 000 eggs. The fecundity (F) of *S. scombrus* in the North sea range from 130,000 to 1,100,000 eggs in fishes between 28.5-46.0 cm Total length (TL) (Macer,1976) , in northwest Atlantic from 285,000 to 1,980,000 eggs for fish between 307 and 438 mm FL (Morse,1980). Siddiqui *et al*. (1997) pointed out that, fecundity increased with increased feeding levels. Increased food availability improved body condition and by extension enhanced reproduction (Fagade *et al*., 1984; Offem *et al*., 2007; Olele, 2010). In addition, marked variations in fecundity among species often reflect different reproductive strategies (Murua and Saborido-Rey, 2003; Shalloof and Salama, 2008).

The absolute fecundity was increased with ~~a~~ total length and described by power equation $F = a L^b$ as $F = 0.0014 L^{5.6414}$. Values of the constants (a and b) may vary according to the studied population and to environmental variations (Kartas and Quignard, 1984). Also, they recorded that the fish condition, varies with region or year. In the present study, the relationship of absolute fecundity and weight was found to be linear, indicating that the number of ova increased generally with increase in weight of fish. Griswold and Silverman, (1992) found that the relationship between total length and fecundity of Atlantic mackerel (*S. scombrus*) by equation $F = 0.00311 * TL^{3.169}$.

The principal methods for optimizing yield and preventing overfishing include regulation of length at first capture and regulation of effort or catch. This involves establishing the optimum size at capture in order to permit a cohort of fish to grow to its optimum biomass and to reproduce. One can define (L_c) to be the size of full vulnerability to the commercial gear and compute the mean length of fish larger than L_c. However, this means that fish smaller than L_c will faced some fishing mortality, and thus changes in fishing effort may influence the number of fish reaching the size L_c. As a practical case, this will be important. The length at first capture L_c of of Atlantic mackerel (*S. scombrus*) was estimated as 20.0 cm for combined sexes, females and males. From this study, it was found that, most of the fishing operation in the area of study target *S. scombrus* at sizes lower than the length at first sexual maturity (L_{m50}). Hence, there is jeopardy to the Atlantic mackerel stock (*S. scombrus*) later.

CONCLUSION

The results showed that the spawning season of the studied species was from March to June, and the most of studied species is caught before its sexual maturity, so there is a high risk imposed on this species. To reserve *S. scombrus*, some regulations should be applied as:

1- Stop fishing during the reproduction period of these fish from March to June.

2- Enlarge the mesh size of the Chanchula nets purse seines that catch these fish to allow the passage of fish whose length is less than the length at maturity 23.4 cm.

REFERENCES

Ahirrao, S.D. (2002). Status of gonads in relation to total length (TL) and gonado somatic index (GSI) in freshwater spiny eel (pisces) *Mastacembelus armatus* (Lacepede) from Marathwada region Maharashtra. J, Aqua. Biol., 17(2): 55-57.

Albertine-Berhaut, J. (1973). Biologie de stades juveniles de téleostéens mugilidae *Mugil auratus* Risso 1810, *Mugil capito* Cuvier 1829, et *Mugil salines* Risso 1810: I. Régime alimentaire. Aquaculture 2: 251–266. DOI: 10.1016/0044-8486(73)90158-0.

Azab, A. M.; El-Far; A. M. and El-Sayed, A. M. (2019). Age, growth and population structure of bogue, *Boops boops*, in the mediterranean waters front Alexandria, Egypt. Egyptian Journal of Aquatic Biology and Fisheries, 23(3): 69-81.

Azzurro, E.; Moschella, P., and Maynou, F. (2011). Tracking signals of change in Mediterranean fish diversity based on local ecological knowledge. PLoS One 6, e24885. doi: 10.1371/journal.pone.0024885.

Bagenal, T. B. and Tesch, F. W (1978). Age and growth In: T. Bagenal, editor, methods for assessment of fish production in fresh waters. IBp handbook No.3 (3rd ed) Black well scientific publications, Oxford. Pp. 101-136(chapter 5).

Bal, H. and Türker, D. (2019). Investigation Some Biological Properties of Atlantic Mackerel *Scomber scombrus* Linnaeus, 1758 in the Sea of Marmara. NESciences, 4(2): 133-140.

Barausse, A.; Michieli, A. ; Riginella, E.; Palmeri, L.; and Mazzoldi, C. (2011). Long-term changes in community composition and life-history traits in a highly exploited basin (northern Adriatic Sea): the role of environment and anthropogenic pressures. Journal of Fish Biology 79: 1453–1486. doi: 10.1111/j.1095-8649.2011.03139.x

Beevi, J. K. S. and Ramachandran , A. (2005). Sex ratio in *Puntius vittatus* (Day) in the fresh water bodies of Ernakulam district, Kerala. Zoos' Print J. 20(9):1989-1990.

Berrien, P. (1982). Atlantic mackerel, *Scomber scombrus*. In M.D. Grosslein and T.R. Azarovitz eds. Fish distribution. p. 99-102. MESA New York Bight Atlas Monograph 15. N.Y. Sea Grant Institute, Albany, NY.

Bhatnagar, G.K. (1972). Maturity, fecundity, spawning season and certain related aspects of *Labeo fimbriata* (Bloch) of river Narmada near Hoshangabad (M.P.), Journal of Inland Fish Society of India; 4: 26-37.

Costa, A. M.; Gordo, L. and Martins, M. M. (2017). Growth and distribution of mackerel *Scomber scombrus* Linnaeus, 1758 from the west coast of Portugal. Cah. Biol. Mar. (2017) 58: 409-421. DOI: 10.21411/CBM.A.FCACD9B0.

Costache, M.; Oprea, D. ; Radu, D. and Bucur, C. (2011). Testing the reproductive potential of Nile Tilapia (*Oreochromis niloticus*) under eco technological conditions from Nucet. Bull. UASVM Anim. Sci. Biotechnol., 68: 118-124.

Dahl, K., and Kirkegaard, E. (1986). Stomach contents of mackerel, horse mackerel and whiting in the eastern part of the North Sea in July 1985. ICES-CM-1986/H: 68, 17 pp.

DFO Science (1997). Stock status report of Atlantic mackerel of Laurentian region Canada July 1997 published by Regional stock assessment office Maurice Lamontagne institute . P.O Box 1000 Mont-Jo .Quebec , Canda . G.S.H. 3Z4.

El-Dengawy, R.A.; Sharaf, A.M.; El-Kadi, S.M.; Mahmoud, E. A. and Baidoon, E.S. (2017). Effect of Frozen Storage on the Chemical, Physical and Microbiological Quality of Imported Mackerel (*Scomber scombrus*). J. Food and Dairy Sci., Mansoura Univ., 8 (7): 287 - 293.

Fagade, S.O.; Adebisi, A.A. and Atanda, A.N. (1984). The breeding cycle of *Sarotherodon galilaeus* in the IIta lake, Ibadan, Nigeria. Arch. Hydrobiol., 100: 493-500.

FAO-FIGIS (2005). A world overview of species of interest to fisheries. Chapter: *Thunnus maccoyii*. Retrieved on 12 July 2005, from www.fao.org /figis /servlet /species?fid=3298. 3p. FIGIS Species Fact Sheets. Species Identification and Data Programme-SIDP, FAO-FIGIS.

Froese, R. and Pauly, D. (2003): FishBase (WWW Database). World Wide Web Electronic Publication. URL: http://www.fishbase.org, Version 5, January 2004.

Froese, R .and Pauly , D. (2012). FishBase. FishBase. http://www.fishbase.org.

GAFRD, General Authority for Fish Resources Development (2018). Annual reports of fish statistics, Cairo, Egypt.

Griswold, C.A. and Silverman, M. J. (1992). Fecundity of the Atlantic Mackerel (*Scomber scombrus*) in the Northwest Atalntic in 1987. Journal of Northwest Atlantic Fishery Science, 12: 35-40.

ICES. (2011). Report of the Working Group on Widely Distributed Stocks (WGWIDE). ICES CM 2011/ACOM: 15.

Kartas, F. and Quignard, J.P. (1984). La fécondité des poisons téléostéens. Collection de Biologie des Milieux Marins 5. Masson, Paris.

Kraus, G. ; Tomkiewicz, J. and. Koster, F.W (2002). Egg production of Baltic cod in Gadus morhua) relation to variable sex ratio, maturity and fecundity. Can. J. Fish. Aquat. Sci., 59: 1908-1920.

Le Cren, E.D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the Perch (*Perca fluviatilis*). J. Anim. Ecol., 20: 201-219.

Lockwood, S.J. (1988). The mackerel. Its biology, assessment and the management of a fishery. Fishing News Books, Farnham, Surrey, England. 181 pp.

Macer, C.T. (1976). Observations on the maturity and fecundity of mackerel (*Scomber Bcombru*B L.) Int. Counc. Explor. Sea, CM 19761H: 6, 7 p.

MacKay, K.T. (1979). Synopsis of biological data of the northern population of Atlantic mackerel (*Scomber scombrus*). Can. Fish. Mar. Serv. Tech. Rep. 885. 26 p.

Mendes, P.F. and Campos , A. (2004). Weight–length relationships for 46 fish species of the Portuguese west coast. J. Appl. Ichthyol. 20: 355–361. Blackwell Verlag, Berlin. ISSN 0175–8659.

Meneghesso, C.; Riginella, E.; La Mesa, M.; Donato, F. and Mazzoldi, C. (2013). Life-history traits and population decline of the Atlantic mackerel *Scomber scombrusin* the Adriatic Sea. Journal of Fish Biology (2013) 83:1249–1267

Moores, J.A.; Winters, G.H. and Parsons, L.S. (1975). Migrations and biological characteristics of Atlantic mackerel (*Scomber scombrus*) occurring in Newfoundland waters. J. Fish. Res. Board Can. 32: 1347-1357.

Morse, W.W. (1980). Spawning and fecundity of Atlantic mackerel, *Scomber scombrus*, in the middle Atlantic Bight. Fishery Bulletin: 78(1): 103- 108.

Murua, H. and Saborido-Rey, F. (2003). Female reproductive strategies of marine fish and their classification in the North Atlantic. Journal of Northwest Atlantic Fishery Science, 33: 23-31.

Offem, B.O.; Akegbejo-Samsons , Y. and I.T. Omoniyi (2007). Biological assessment of *Oreochromis niloticus* (Pisces: Cichlidae; Linne; 1958) in a tropical floodplain river. Afr. J. Biotechnol., 6: 1966-1971.

Olele, N.F. (2010). Reproductive biology of *Sarotherodon galilaeus* (Artedi, 1757) in Onah Lake, Delta State, Nigeria. J. Applied Sci. Res., 6: 1981-1987.

Olopade, O.A.; Dienye, H.E.; and Bamidele, N.A. (2019). Some population parameters of the *Sardinella maderensis*(Lowe, 1838) in the Sombreiro River of Niger Delta, Nigeria. Acta Aquatica Turcica, 15(3): 354-364.

Penha, J.M.F. and Mateus, L.A.F. (2007). Sustainable harvest of two large predatory Catfish in the Cuiabá river basin, northern Pantanal, Brazil. Brazilian Journal of Biology; 67(1):81-89.

Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Canada, 191:382 p

Santos, M.N.; Gaspar, M.B.; Vasconcelos, P. and Monteiro, C.C. (2002): Weight-length relationships for 50 selected fish species of the Algarve (southern Portugal). Fish. Res. 59: 289–295.

Sendecor, G. W. (1956): Statistical methods. Iowa State College Press, 5th ed. 534p.

Shafi, M. and Quddus, M.M.A. (1974). The length-weight relationship and condition factor in *Hilsa ilisha* (Hamilton) (Clupeiformes: Clupeidae). Bangladesh J. Zool. 2(2): 179-185.

Shalloof, K. A. Sh. and Salama, H. M. (2008): Investigations on some aspects of reproductive biology in *Oreochromis niloticus* Linn. 1757 inhabited Abu-Zaabal Lake, Egypt. Global Veterinaria, 2: 351- 359.

Siddiqui, A.Q. ; Al-Harbi, A. H. and Al-Hafedh, Y.S. (1997). Effects of food supply on size at first maturity, fecundity and growth of hybrid tilapia, *Oreochromis niloticus* (L.) x *Oreochromis aureus* (Steindachner), in outdoor concrete tanks in Saudi Arabia. Aquacult. Res., 28: 341-349.

Sinovcic .G. (2001). Population structure, reproduction, age and growth of Atlantic mackerel, *Scomber scombrus* (L.) in the Adriatic Sea. *Acta Adriat*. (00015113) 2 (42): 85-92.

Sinovcic, G.; Franicevic, M.; Zorica, B. and Cikes-Kec, V. (2004). Length-weight and length-length relationships for 10 pelagic fish species from the Adriatic Sea (Croatia). Journal of Applied Ichthyology 20(2): 156-158.

Tesch, F.W. (1968). Age and Growth in Methods for Assessment of Fishes Production. In: W.E. Ricer (Ed.), in methods for assessment of fish production in Freshwater, IBP Handbook, Blackwell Science Publication, London: 93-123.

Wootton, R.J. (1990). Ecology of Teleost Fishes. 1st Edition, Chapman and Hall, London, UK., ISBN-13: 9780412317200, Pages: 404.

Yeldan, H. and Avşar , D. (2000). A preliminary study on the reproduction of rabbit fish, *Siganus rivulatus* (Forsskål, 1775), in the northeastern Mediterranean. Turk. J. Zool. 24: 173-182.

Zhang, B. and Deng, S. G. (2012). Quality assessment of *Scomber japonicus* during different temperature storage: biochemical, textural and volatile flavor properties. ICAISC. Lecture Notes in Information Technology. 12: 301-307.