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Fisheries biology assessment of the European hake, *Merluccius merluccius* (Linnaeus, 1758), from Egyptian Mediterranean deep sea waters

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ABSTRACT

843 specimens of *Merluccius merluccius* fish were collected seasonally and randomly from the northeastern Egyptian Mediterranean deep-sea waters, during 2017-2019, from the commercial boats. Izbet El borg fishing port is the main deep-sea landing site forming more than 99% of the total deep-sea catch. The length ranged from 12.3 cm to 63.9 cm. The length-weight relationship was: $W = 0.0041\ L^{3.2906}$, $W = 0.0038\ L^{3.1711}$, $W = 0.0039\ L^{3.1752}$ and $W = 0.0044\ L^{3.1364}$ for thread, males, females and total sample, respectively. The estimated age groups ranged from 1 to 8 years. The von Bertalanffy growth parameters were {(L_∞= 62.63cm, k= 0.22 y^{-1}, W_∞= 1669.43g); (L_∞= 66.84cm, k= 0.24 y^{-1}, W_∞= 2370.22g); L_∞= 67.26cm, k= 0.19 y^{-1}, W_∞= 2420.62g)} for males, female and total samples, respectively. The growth performance (ø) was= 2.93, 2.99, and 2.97 for males, females and total samples, respectively. The overall growth performance OGP=4.76. The gonado-somatic index and the maturity stages variations evidenced that the spawning period starts in autumn and extends to winter. Males' and females' lengths at first maturity (L_m) were 32.15 and 32.3cm, respectively. The total, natural and fishing mortality rates were 1.33, 0.34, and 0.99, respectively. The exploitation rate (E) was 0.74. Length and age at first capture were L_c= 26.4 cm and t_c= 2.6 years. Results revealed that the deep sea *M. merluccius* stock is suffering from overexploitation; some management regulation must be involved.

INTRODUCTION

The European hake fish *Merluccius merluccius* (Linnaeus, 1758) is belonging to family Merluccidae of genus Merluccius, widely distributed in the Eastern Atlantic, the Mediterranean Sea and the southern coast of the Black Sea **(Froese and Pauly, 2016)**.

The European hake is one of the most important target species for trawlers of a highly commercial value and elevated price; therefore it is intensively exploited in both the Atlantic and Mediterranean basins **(Oliver and Massutí, 1995; Boudjadi and Rachedi, 2021)**.

The European hake is found in a wide depth range from the coastline to 1000 m depth **(Cohen *et al.*, 1990; Philips, 2012)** and also on the muddy bottoms **(Froese and Pauly, 2016)**. In the Egyptian Mediterranean deep sea, European hake was caught at depth between 200 m and 500 m **(Sabrah *et al.*, 2017)**. Usually, the large lengths of European hake are distribution in water deeper than 200 m, while the small lengths are present in the coastal shelves **(Meiners, 2007; Belcaid and Ahmed, 2011; Boudjadi and Rachedi, 2021)**. Hake fishes move vertically to higher at night in addition to horizontal migrations for searching of food **(Jardas, 1996)**. European hake is a carnivorous predator, feeds on fish, crustaceans, algae, and plant detritus **(Carpentieri *et al.*, 2005; Philips, 2012)**.

Age, growth, reproduction and feeding habit of European hake is included in several scientific papers from, Izmir Bay in Aegean Sea **(Uçkun *et al.*, 2000)**; Moroccan Mediterranean **(Belcaid and Ahmed, 2011)**; Spanish Mediterranean Sea **(Garcia-Rodriquez and Esteban, 2002)**; from the Western Pacific **(Randall, 2003)**; the Bay of Biscay **(De Pontual *et al.*, 2006; Murua and Motos, 2006)**; the Balearic Islands **(Cartes *et al.*, 2009)**. Edremit Gulf in the Aegean region of Turkey **(Akalin, 2014)**; the Gulf of Lions **(Mellon-Duval *et al.*, 2010)**; the Tunisian coast **(Khoufi *et al.*, 2014)**; the central Aegean Sea in Turkey **(Soykan *et al.*, 2015)**; the Sea of Marmara, Turkey **(Kahraman *et al.*, 2017)**; the Northern Aegean Sea, Turkey **(Uzer *et al.*, 2019)**; northeastern Mediterranean **(Girgin *et al.*, 2020)**; and El-Kala Coastline, Algeria **(Boudjadi and Rachedi, 2021)**.

Furthermore, stock distribution and assessment of hake were reported by other studies: in the northern Tyrrhenian Sea (NW Mediterranean) **(Belcari *et al.*, 2006)**; in the northeastern Mediterranean Sea **(Gücü and Bingel, 2011);** in Izmir Bay, Aegean Sea **(Yalçin and Gurbet, 2016)** and in the Marmara Sea **(Demirel *et al.*, 2017)**.

Despite the intensive investigations of age composition and growth of *M. merluccius* in many countries of the world, very little works have been carried out in the Egyptian Mediterranean hake for example; **(Soliman, 1992; Philips, 2012, 2014)** at the Egyptian Mediterranean coast off Alexandria and there are no studies have been carried out on the Egyptian hake deep sea fishery.

The present work aimed to study and address the deficiency in deep sea European hake fishery as the age, growth, reproduction, and exploitation ratio for the first time in the Egyptian Mediterranean deep sea fishery. In addition to, indicate the variation in the *Merluccius merluccius* deep sea catch trend during the last few years.

MATERIALS AND METHODS

Sampling area

There are seven deep sea fishery landing sites at northeastern Egyptian Mediterranean sea, (Ezbt El Borg, El Maadia, Borg Megeizel, Abu Qir, El Anfoshy, Rashid, and El Gazira El Khadra) **(Fig. 1)**. More than 95% of the total trawl deep sea catch comes from Izbet El borg fishing port. 843 specimens of *M. merluccius* were sampled seasonally from the commercial fishing boats operating in northeastern

Mediterranean deep sea, and landed their catch at Ezbt El Borg fishing port. Deep sea fishing boats use bottom trawl net with cod end mesh size ranged from 2.5 to 6.0 cm with an average of 4.0 cm. Samples of *M. merluccius* were caught at depth ranged from 200 to 400 m.

Sampling strategy

1) Monthly and annual catches statistical data of *M. merluccius* as well as the total deep sea trawl catch for the Mediterranean Sea were obtained from the statistical records by the General Authority for Fish Resources Development (GAFRD) during the period from 2017 to 2019 (GAFRD started to record and reported the total trawl deep sea catch on its annual statistical book since 2017 only). By using these data we can investigate the seasonal variation in the catch trending and the percentage of *M. merluccius* catch to the total deep Sea catch.
2) For each specimen, the total length (TL) was measured to the nearest 0.1 cm. As *M. merluccius* has a relatively large species, lengths of the individuals were classified into 5cm length group intervals. The number for each length group interval was recorded and the pooled data was used to draw the seasonally length frequency diagrams. The total weight (W) and gonad weight (W. g.) were measured to the nearest 0.01 g, and the sex was recorded by dissection.

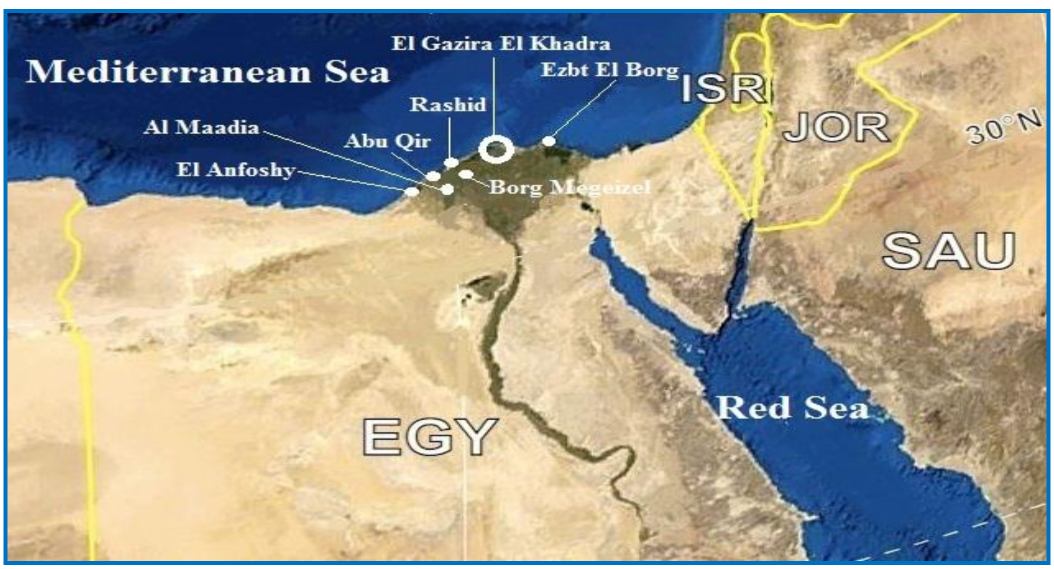

Fig.1. Sampling area

3) The length–weight relationship (LWR) was calculated using the equation W =a L^b, where W is the total weight, L is the total length (TL), and "a" is the intercept, and "b" is the growth type exponent or slope of the equation **(Ricker, 1973)**. The degree of association between variables was calculated by the correlation coefficient (R^2). The

condition factor (K) was estimated by **Bagenal and Tesch (1978)** as K= 100* W/L^3, where W is the total weight, and L is the total length (TL).

4) For age determination, otoliths reading were used. ELEFAN I method in the FiSAT II software program was used for estimating the growth parameters [asymptotic length ($L\infty$) and the growth rate (K)] of the **Von Bertalanffy (1938**) Growth Function (VBGF) according to **Gayanilo *et al*. (2002)**. The growth performance index (*Φ′*) was estimated as [$Ǿ= \log_{10}K + 2\log_{10}L_\infty$] according to **Pauly and Munro (1984)** and overall growth performance was OGP = log [K $(L\infty)^3$]. The total mortality (Z) was calculated from the age-structured catch curve formulated by **Pauly *et al.* (1995)**. The natural mortality was estimated using empirical equation described by **Pauly (1980)**: Log M= -0.0066 – 0.2790 Log L∞+ 0.6543 Log K + 0.4634 Log T. The annual average Mediterranean temperature was 13.3-13.5°C according to **Said *et al.* (2007)**. Fishing mortality (F) was calculated as F= Z - M **(Beverton and Holt, 1957)**. The exploitation rate (E) was computed by F / Z **(Pauly, 1983)**.

5) Reproductive parameters: Males to females (M: F) sex ratio was calculated using all individuals except the thread samples were excluded. The significance of male to female ratio was determined by using the Chi-square (χ2) test.

The spawning period was established based on:

- ❖ The seasonal gonado- somatic index (GSI, %) using the equation GSI= [Wg. / (W)] × 100, where Wg. is the gonad weight (g) and W is the total weight (g) of the fish **(Ricker, 1975)**.
- ❖ The seasonal variation in maturity stages was evaluated according to their development based on **King (1982)** into 6-stages, I immature, II developing/ recovery, III maturing, IV ripe, V running/ spawning and VI spent.

6) Length at sexual maturity (L_m or L_{50}) was estimated by fitting the percentage maturity against mid-lengths **(king, 1995)** or the length at which 50% of the fish reach their sexual maturity **(I˙lkyaz *et al.*, 1998)**. L_m is represented at the point on X-axis corresponding to 50% point on Y-axis. The reproductive load was estimated as [L_m/L_∞] according to **Froese and Binohlan (2000)**, L_m is the length at first maturity (cm), and L_∞ is the asymptotic length (cm).

7) The length at first capture (L_c) was estimated using the formula [$Lc= L` - k (L_\infty - L`)/Z$] as given by **Beverton and Holt (1957)**. The corresponding age (t_c) was obtained by converting L_c using the von Bertalanffy growth equation $T_c = -1/k * \ln (1 - L_c/ L_\infty) + t_0$). The maximum age ($t_{max}$) was determined as $t_{max}= 3/ K$ **(Beverton, 1963)**.

RESULTS

1. Seasonal and annual catch variation

Seasonal study of the total trawl and *M. merluccius* catches were performed from 2017 to 2019. Total trawl and *M. merluccius* catches took the same trend variation during the different seasons. Results revealed that the minimum of the total trawl and *M.*

merluccius catches appeared in winter, then increased gradually in spring and reached their maximum peak in summer. Seasonal catch slightly began to decrease again in autumn **(Fig. 2)**.

The annual deep sea total trawl catch ranged from about 50000 to 60000 tons during the fishing years from 2017 to 2019 **(Fig. 3)**. *M. merluccius* deep sea fishery become under focus starting from 2017 and its percentage to the total catch increased from about 0.46 % during 2017 to 1.19 % in 2018 then decreased to be 0.96 in 2019.

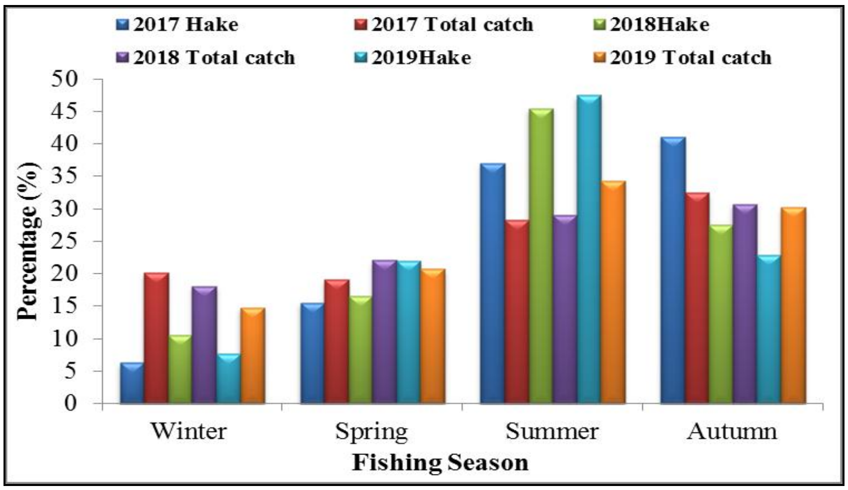

Fig. 2. Seasonal catch trend of total trawls and *M. merluccius* in different fishing seasons from 2017 to 2019

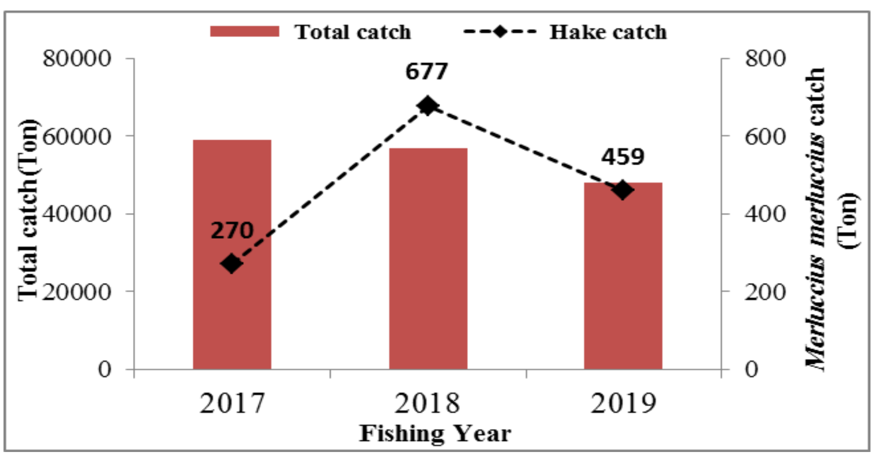

Fig. 3. Annual catch trend of total trawls and *M. merluccius* from 2017 to 2019

Deep Sea trawling fishing operation in the Egyptian Mediterranean Sea was mainly targeting the red shrimp since 2008. Izbet El borg fishing port forming about 99.63, 98.97 and 99.13 % of the total Egyptian Mediterranean deep sea *M. merluccius* catch in 2017, 2018 and 2019, respectively.

2. Length weight relationship

843 European hake were sampled in the present study including 283 males, 352 females and 208 unidentified individuals (thread gonad).

The total samples lengths were ranged from 12.3 cm to 63.90 cm, with mean length of 30.1± 11.09cm and the total weight was ranged from 10.4 to 1909.50 g with mean weight of 289.10± 319.37 g. In males, the total lengths were ranged from 12.30 cm to 59.50 cm with mean length of 27.51± 8.68cm and the total weights were ranged from 19.30 to 1767.80 g with mean weight of 199.16± 257.22 g. In females, the total lengths were ranged from 14.20 cm to 63.90 cm with mean length of 33.18± 11.65 cm and the total weights were ranged from 10.40 to 1909.50 g with mean weight of 375.02±343.69 g. It is clear that males are smaller than females in the whole sample, but females are dominant at the small length groups.

Length–weight relationships study were declared a positive allometric growth pattern, where p> 3 for thread, males, females and total sample **(Fig. 4** and **Table 1)**. It is clear from the results that the constants of the length weight relationship are nearly the same in threads, males, females and total samples, where **a** is in the average of 0.004 and **b** is in the average of 3.2.

Table 1. Length- Weight relationship of deep sea *Merluccius merluccius* (thread-males-females- total samples)

Parameter / Sex	No.	a	b	R^2
Males	283	0.0038	3.17	0.98
Females	352	0.0039	3.18	0.99
Thread	208	0.0040	3.29	0.98
Total samples	843	0.0044	3.14	0.99

3. Seasonal length frequency distribution

The Length frequency distribution was varied from season to another i.e. in winter and spring the smallest lengths were recorded whereas the larger lengths were reported in autumn and summer **(Fig. 5)**. About 58% of the samples were caught in the spring with length range from 17- 34cm followed by winter by 25% with length range from 12-36cm. The largest length groups in the catch were recorded in summer and autumn where, the length range in summer was from 29- 63cm and in autumn was from 31-59cm.

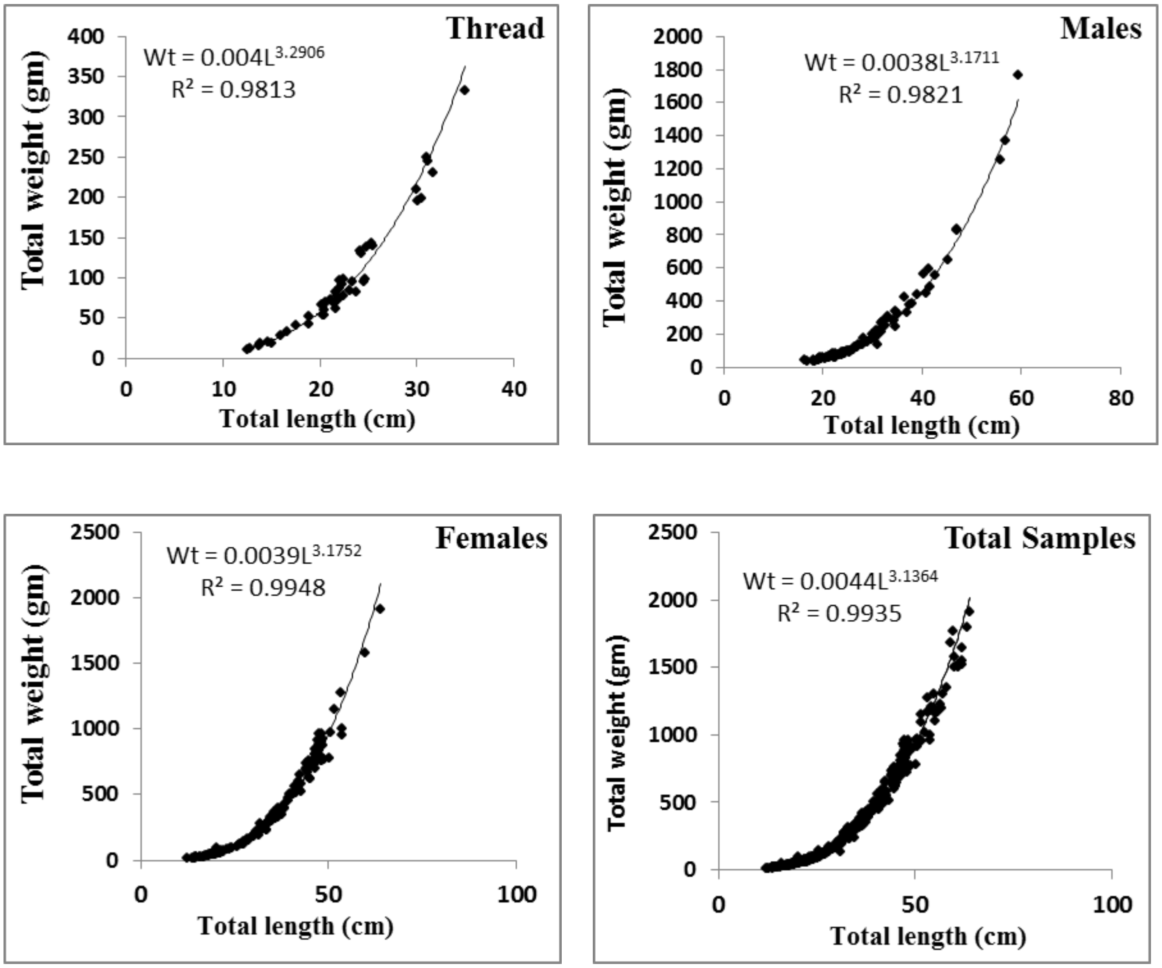

Fig. 4. Length- weight relationship for the deep sea *M. merluccius* (thread-males- females-total samples)

4. Seasonal variation of condition factor (Kn)

Results in **Table 2** and **Fig. 6** showed that the seasonal condition factor of the deep Sea *M. merluccius* (males- females- total samples). It is noticed that the condition factor increased in summer, reaching its highest value in autumn which coincides with the spawning time and gonad ripeness for males, females and total samples. Then it decreased by a slightly value in winter (the completion of the spawning time).

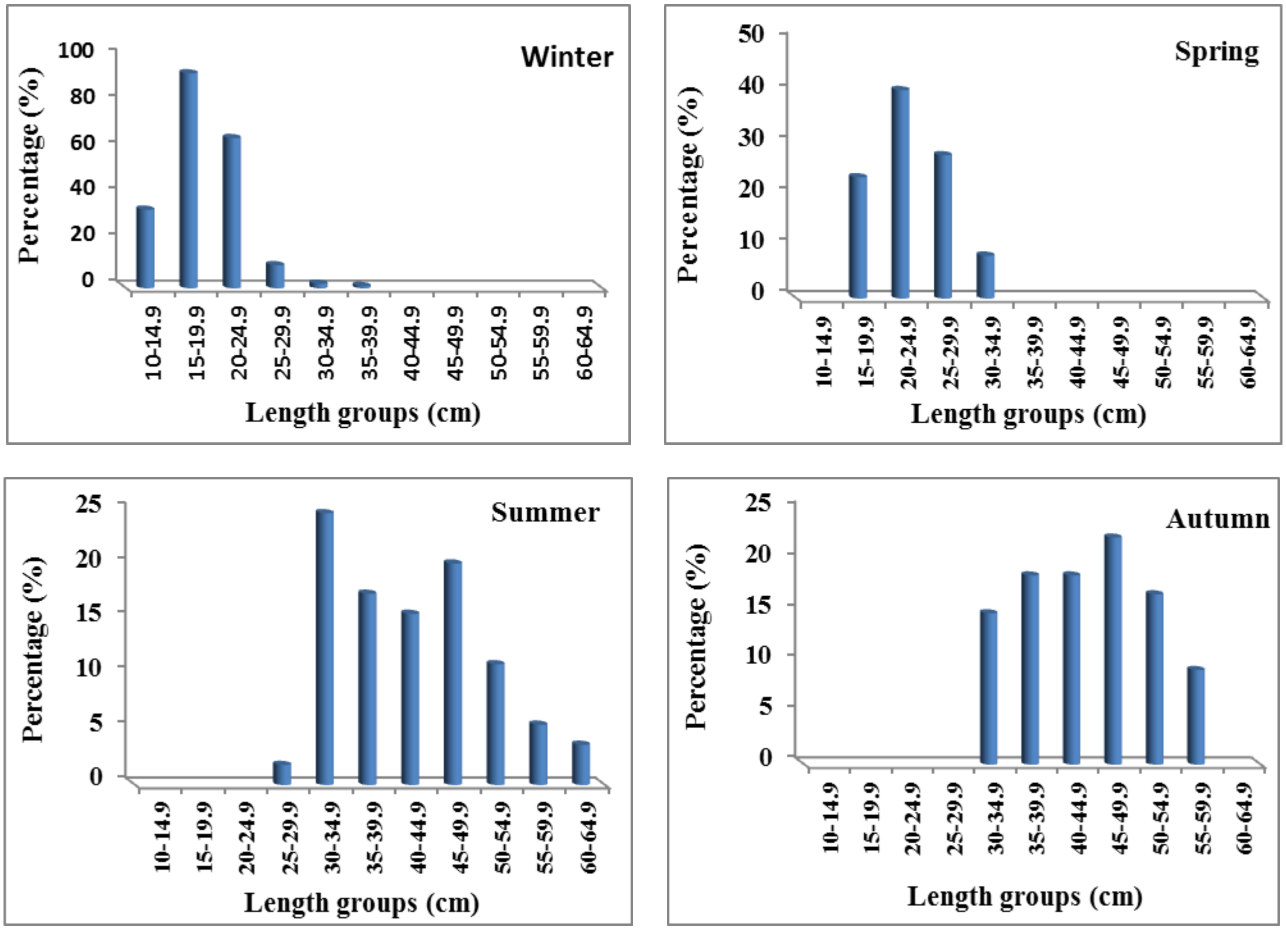

Fig. 5. seasonal variation in the length frequency seasonal of the deep sea *Merluccius merluccius*

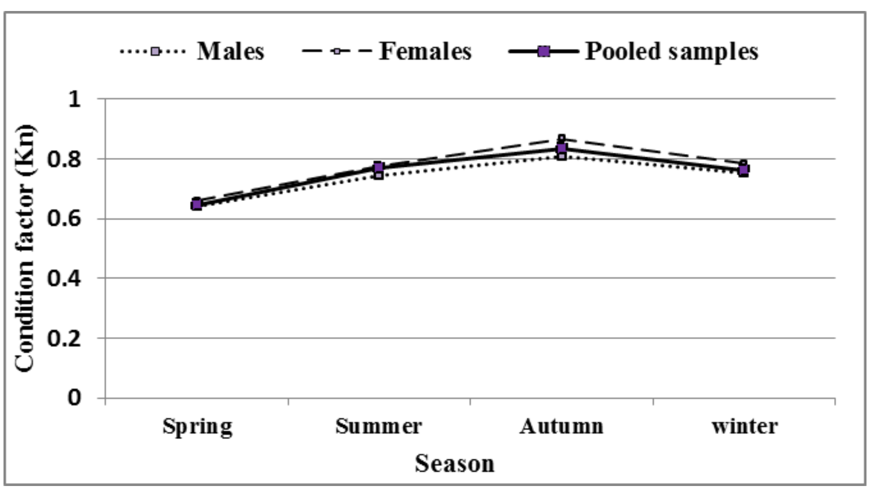

Fig. 6. Seasonal variation in condition factor of the deep sea *M. merluccius* (males- females- total samples)

Table 2. Seasonal variation in condition factor of deep sea *M. merluccius* (males- females- total samples)

Groups / Seasons	Male± SD	Female± SD	Total samples± SD
Spring	0.640± 0.08	0.659± 0.09	0.647± 0.08
Summer	0.742± 0.07	0.774± 0.10	0.768± 0.09
Autumn	0.809± 0.08	0.867± 0.06	0.835± 0.07
Winter	0.754± 0.06	0.783± 0.06	0.763± 0.06

5. Age and growth studies

Otolith reading revealed that age was ranged from 0 to 8 years. The mean lengths and growth increments at each age group were illustrated at **Table 3**. The age group one was the most dominant age group in the samples and the growth increment decrease as the fish age increase. The mean length at each age group was a little bit different in males and females.

Table 3. Age groups with their corresponding lengths and growth increment of *Merluccius merluccius* from the deep sea fishery

Sex / Age group	Males			Females			Total samples		
	No.	**Mean ±S.D.**	**Increment**	**No.**	**Mean± S.D.**	**Increment**	**No.**	**Mean± S.D.**	**Increment**
0	13	14.19± 0.71	14.19	17	14.19	14.19	83	14.5	14.5
1	105	23.97± 1.92	9.78	112	24.24± 1.92	10.05	318	23.10± 1.45	8.6
2	66	32.09± 1.59	8.12	78	32.67± 1.59	8.43	174	30.60± 1.56	7.5
3	54	40.04± 1.04	7.95	71	40.14± 2.17	7.47	151	37.70± 2.18	7.1
4	9	45.70± 1.04	5.66	24	46.80± 1.84	6.66	33	44.50± 0.82	6.8
5	11	50.50± 1.59	4.8	13	52.12± 0.78	5.32	24	50.60± 0.88	6.1
6	10	53.80± 0.88	3.3	12	56.49± 1.06	4.37	22	55.65± 1.05	5.05
7	13	56.61± 1.05	2.81	21	59.90± 1.15	3.41	34	59.15± 1.15	3.5
8	2	58.91± 1.07	2.3	2	62.72± 1.3	2.82	4	62.02± 1.3	2.87

The asymptotic length and weight were calculated as (L_∞= 62.63cm, W_∞= 1669.43g- L_∞= 66.84cm, W_∞= 2370.22g- L_∞= 67.26cm, W_∞= 2420.62g) for males, female and total samples, respectively. Moreover, the growth rate coefficient was found to be k= 0.22, 0.24, and 0.19 y^{-1} for males, female and total samples, respectively. The growth performance index was ø´ = 2.93, 2.99, and 2.97 for males, female and total samples, respectively. The overall growth performance OGP =4.76.

6. Reproductive studies

6.1. Sex ratio

Male: Female ratio was calculated as 1: 1.24. The overall and the seasonal sex ratio declared that the females were more dominant than of males. The highest percentage of females was in spring (57.98%) and the smallest percentage was observed in autumn (52.45%). The percentages were nearly equals in winter and summer (55.56& 55.08). The expected ratio (1:1) in *M. merluccius* occurred during autumn (1: 1.10). Chi-square analysis indicated that there is a significant difference in the number between males and females (χ^2, $P < 0.05$) **(Table 4** and **Fig. 7)**.

Table 4. Sex ratio seasonal variations in *M. merluccius* (males - females) from the deep sea

Parameters / Seasons	Total No. of fish	Males		Females		M/ F	χ^2
		NO.	%	NO.	%		
Autumn	143	68	47.55	75	52.45	1: 1.10	0.24
Winter	117	52	44.44	65	55.56	1: 1.25	1.23
Spring	188	79	42.02	109	57.98	1: 1.38	2.55
Summer	187	84	44.92	103	55.08	1: 1.23	1.03
Total samples	635	283	44.57	352	55.43	1: 1.24	1.18

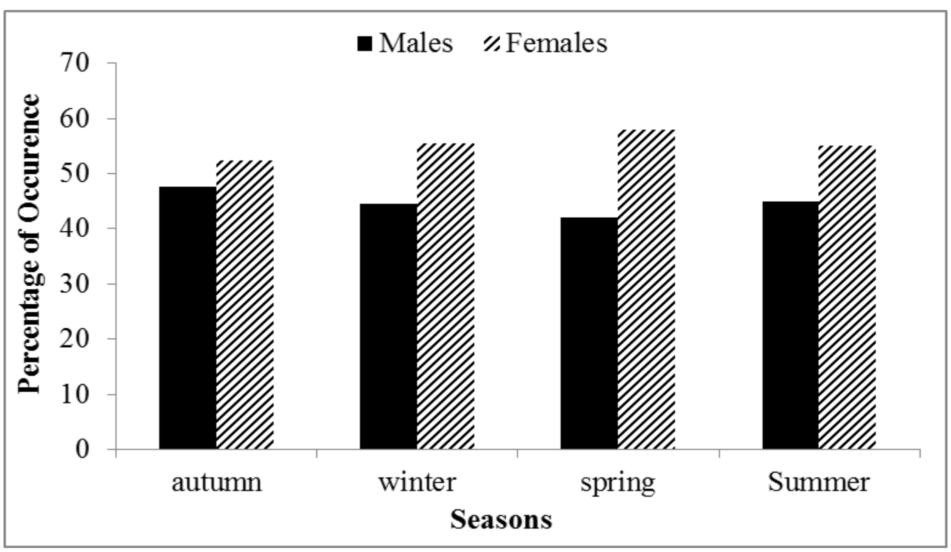

Fig. 7. Sex ratio seasonal variation in *M. merluccius* from the deep sea (males- females- total samples)

6.2. Gonado-somatic index (GSI)

Seasonal GSI of *M. merluccius* attained its maximum values in autumn (3.65 and 7.45) and in winter (2.8 and 6.55) for males and females respectively. On the other hand the minimum values of GSI were represented in spring then it begins to increase slightly in summer and reach its high peak in autumn, where *M. merluccius* become ready for the spawning period **(Fig. 8)**, where the data declared that *M. merluccius* spawning time takes place in autumn and extending to winter.

6.3. Seasonal variations in the maturity stages

Seasonal variation in the maturity stages of *M. merluccius* during the study period is represented in **(Fig. 9)**. Results show that the immature fish encountered by small percentage in winter (3.64%) and summer (5.84%). The developing/ recovery (stage II) was found in spring (40.45%), summer (26.90%) and autumn (23.26%). The maturing (stage III) peak ratio was in summer (43.08%) and spring (28.09%). The full rip fish (stage IV) shows the highest percentage in autumn (39.53%) and winter (23.64%). The running/ spawning fish (stage V) give the highest percentage in winter (65.46%), whereas the spent fish (stage VI) represented by a considerable ratio in spring (23.48%) and summer (23.0%). The seasonal variations in maturity stages evidenced that the spawning period of *M. merluccius* starts in autumn and extending to winter.

6.4. Percentage occurrence of maturity stages

Percentage occurrence of maturity stages for the deep sea *M. merluccius* according to the length group **(Fig. 10)** show that at length groups < 15.0 cm all individuals were the immature (stage I by 42.86% and stage II by 57. 14%). The mature individuals appears at the length groups >15.0 cm. The full rip fish (stage IV) started to occur at length group (20.0- 24.9) cm by 20%. At length group (30.0- 34.9) cm the immature stage was 46.7% and mature fish percentage was represented by 53.3%. All samples larger than 39.9cm in length are mature. The percentage occurrence of maturity stages evidenced that the length at maturity (L_{m50}) is found at the length range 30.0-34.9 cm.

6.5. Length at first maturity

Variation in mature and immature stages of *M. merluccius* by length groups were calculated for each 5 cm **(Fig. 11)**. The percentage of immature and mature distribution for each length group was used to determine the length at first sexual maturity. Figure 11 shows It is noticed that *M. merluccius* smaller than 15cm were all immature. The length at first maturity (L_m) appears at (30.0- 34.9) cm length group as the immature was 48% and mature fish percentage was 52%. Males and females lengths at first maturity (L_m) were computed as 32.15- 32.3 cm respectively with corresponding age's t_m= (3.00- 3.00) years **(Fig. 11)**. The reproductive load value for the present study was 0.5.

7. Mortality rate coefficient

The estimated total mortality Z= 1.33 y^{-1} and natural mortality M= 0.34 y^{-1}, that resulted an estimated of fishing mortality rate F= 0.99 y^{-1}. Finally, the exploitation rate was estimated as E= 0.74.

The estimated length at first capture was L_c= 26.4cm with corresponding ages t_c= 2.6 years and the maximum age (t_{max}) was (12.5- 13.64- 15.79) years for males, females and combined sex, respectively.

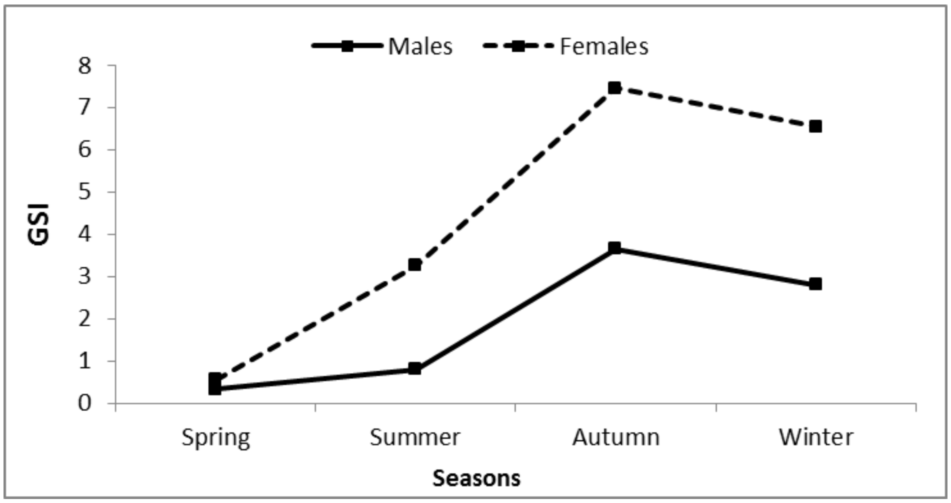

Fig. 8. Seasonal variation in Gonado-somatic index (GSI) of the deep sea *M. merluccius*

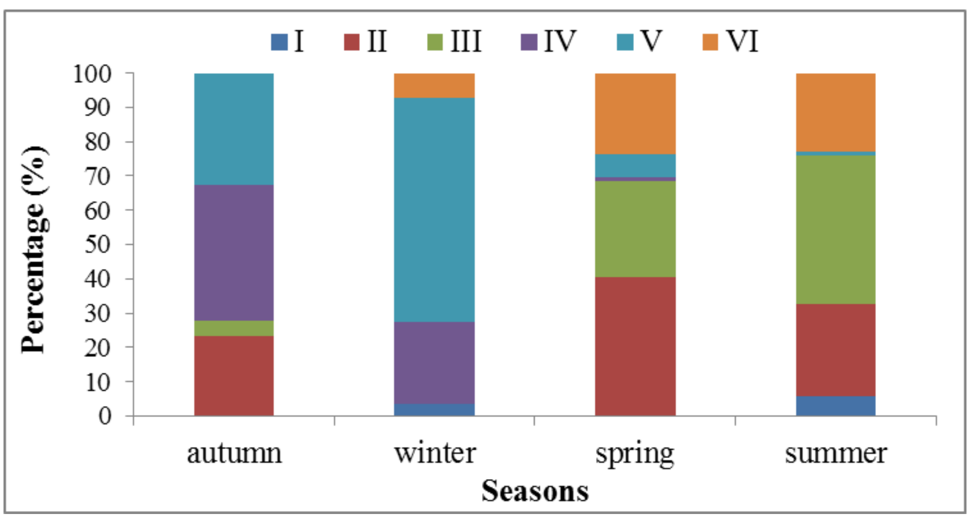

Fig. 9. Seasonal variation in maturity stages of the deep sea *M. merluccius*

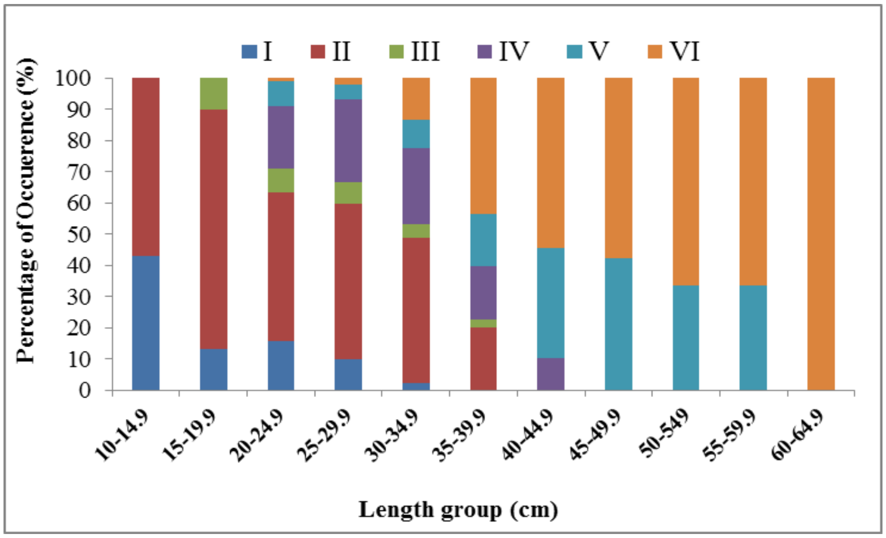

Fig. 10. Percentage occurrence of maturity stages in the deep sea *M. merluccius*

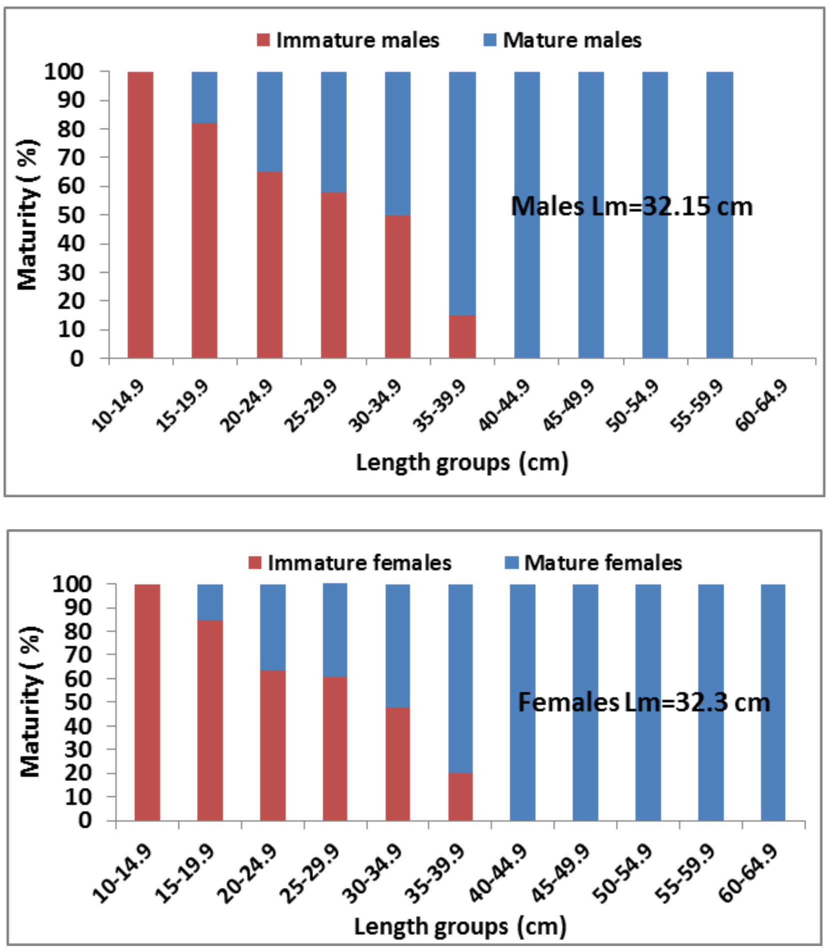

Fig. 11. Percentage of immature and mature deep sea *M. merluccius* (males and females) at different length groups

DISCUSSION

The fishing stress on the *M. merluccius* fishery in Egyptian Mediterranean deep sea increases from year to year. More than 95% of the Egyptian Mediterranean deep Sea *M. merluccius* catch comes from Izbet El borg fishing port. The sustainable stock management of European hake is based on the age, growth and reproduction which give this species ecological and commercial importance **(Soykan *et al.*, 2015)**.

843 of *M. merluccius* samples were examined during the study period, with minimum and maximum lengths of 12.30 cm and 63.90 cm, with mean length (33.18± 11.65cm), that is indicate an efficient, effective sampling which was wider in range than 14.2 and 43 cm reported by **Philips (2014)**, which caught from the coastal area off Alexandria, Egyptian Mediterranean. This variation may be related to the differeces in the fishing depth, as *M. merluccius* large lengths are distribution in water deeper than 200 m, while the small lengths are present in the coastal shelf **(Meiners, 2007; Belcaid and Ahmed, 2011; Boudjadi and Rachedi, 2021)**.

In our study, it was observed that female are larger than males and it is dominating the lengths > 60 cm, this may be due to the fact that female of *M. merluccius* reach larger size and grow older than males, as well as, differences in metabolism and oxygen consumption between sexes as reported by **(Pauly, 1980; Pineiro and Sainza, 2003; De pontual *et al.*, 2006; Philips, 2014)**.

The present result is in accordance with **Gurbet *et al.* (2013)** that *M. merluccius* exhibit high abundance during summer season which may be attributed to many considerations as environmental factors or migration and aggregation of the fish to the nursery ground areas during spawning periods (autumn-winter).

The length–weight relationship and condition factor are important biological parameters for indicating the population growth and studying fishery management **(Simon and Mazlan, 2008)**. In the present study, Length–weight relationship exponent "b" of both sexes separately and combined was more than "3" reflecting positive allometric growth, which was in agreement with **(Soliman, 1992; Philips, 2014)**. The minor variations in the length–weight could be related to study area, sampling period, physical and environmental conditions faced by the different stocks such as food availability and temperature prevailing in these areas where, the water temperature may affect fish growth directly by affecting the physiology of the fish **(Weatherly and Gills, 1987; Bruton, 1990)**.

The condition factor reflects the fitness and the health of the fishery. **Bennet (1970)** stated that the well-being bench mark values of the fish condition factor ≥0.56. *M. merluccius* stock considered to be in a good condition hence the condition factor values in the present study were above the well-being bench mark values.

The condition factor value increases in summer for males, females and total samples i.e. before spawning season which starts in autumn and extend to winter. The spawning season in the present study for the deep sea *M. merluccius* begin after which reported by **Philip (2014)**, this may be due to the fact observed by **Ross (1988)** that the cold and deeper waters is characterized by longer fish, older fish and late maturing time of the fish than it in warm and coastal waters.

In the current study the maximum age reported was 8 years old. The age group one was the most dominant age group in the samples so; the net mesh size must be increase to prevent catch of the small size fish. In compare with 9 years old recorded by **Lucio *et al.* (2000)** in Bay of Biscay; 10 years old by **Godinho *et al.* (2001)** in Northeast Atlantic; 10 years old by **Piñeiro and Sainza (2003)** in Iberian waters, Spain; 10 years old by **Belcaid and Ahmed (2011)** in Moroccan North Atlantic Sea; 6 years old by **Philips (2014)** in Egypt Mediterranean waters; 5 years old by **Akalın (2014)** in Edremit Bay (North Aegean); 5 years old by **Soykan (2015)** in the Central Aegean Sea, 6 years old by **Kahraman *et al.* (2017)** in the Sea of Marmara, 6 years old by **Uzer *et al.* (2019)** in Gökçeada Island northern Aegean Sea; 7 years old **Girgin and Başusta (2020)** in Turkey (Northeast Mediterranean); 7 years old by **Boudjadi and Rachedi, (2021)** in El-Kala Coastline the extreme North -East of Algeria. The variation in the age determination from area to another could be regards to the difference in the length range or in the environmental condition, but it is not affected by sex as the reported by **García-Rodríguez and Esteban (2002)**.

Data in **Table 5** showed a comparison between the von Bertalanffy growth parameters and growth performance index values (Φ') of the present study and estimated by other authors worked on *M. merluccius* species. The differences in results are affected by the genetic diversity of different area, maximum length, samples length range, mortalities rates, maturity stages, fishing area, in addition to the environmental and the ecological factors **(Domínguez-Petit *et al.*, 2010; Mellon-Duval *et al.*, 2010; Soykan *et al.*, 2010; Burton *et al.*, 2012; Kahraman *et al.*, 2017)**.

Similarly, **O¨ Zaydın *et al.* (2007); Akalın (2014); Philip (2014); Soykan *et al.* (2015)** in the current work females were more dominated in the stock where male: female: ratio was 1: 1.24. **Mendonca *et al.* (2006)** explained that this phenomena regarding to the feeding behavior and the environmental factor.

Table (5): Von Bertalanffy growth parameters and growth performance index values (Φ') estimated by different authors and the present study for *M. merluccius*

Author	Study of area	Method	Sex	L∞	k	Φ′
Godinho *et al*. 2001	Atlantic, North-east	Otolith	**All**	110.6	0.089	2.99
García-Rodríguez and Esteban 2002	Mediterranean, Alicante Bay, Spain	FISAT (ELEFAN)	**Males** **Females** **All**	93.00 108.0 108.0	0.20 0.21 0.21	3.24 3.42 3.39
Piñeiro & Saínza 2003	Atlantic Coast of Iberian, Spain	Otolith	**Males** **Females** **All**	70 89 88	0.18 0.13 0.128	2.94 3.02 3.04
de Pontual *et al*. 2006	Atlantic, Bay of Biscay, Spain	Otolith	**Males** **Females** **All**	80 110 108	0.181 0.122 0.21	3.17 3.06 3.17
Belcaid and Ahmed 2011	Atlantic, North, Morocco	FISAT (ELEFAN)	**All**	72.45	0.280	3.63
Gurbet *et al*. 2013	Aegean Sea, northern, Turkey	Otolith	**All**	57.05	0.32	2.97
Philips 2014	Egyptian Mediterranean Sea waters	FISAT (ELEFAN)	**Males** **Females** **All**	58.97 69.21 74.19	0.158 0.133 0.119	2.74 2.80 2.82
Akalın 2014	Edremit Bay (North Aegean Sea)	Otolith	**Males** **Females** **All**	47.40 53.50 53.90	0.349 0.385 0.377	2.90 3.04 3.04
Soykan *et al*. 2015	central Aegean Sea, , Turkey	Otolith	**All**	54.53	0.32	-
Kahraman *et al*. 2017	Marmara Sea, Turkey	Otolith	**Males** **Females** **All**	102.43 106.36 103.9	0.09 0.08 0.08	2.83 2.96 -
Uzer *et al*. 2019	Northern Aegean, Turkey	Otolith	**Males** **Females** **All**	88.54 102.3 102.6	0.10 0.09 0.9	2.93 2.97 3.01
Gül *et al*. 2019	Marmara Sea, Turkey	FISAT (ELEFAN)	**Males** **Females** **All**	44.2 53.0 57.5	0.38 0.30 0.27	-
Girgin and Başusta 2020	Northeastern Mediterranean	Otolith	**Males** **Females** **All**	77.65 93.98 84.44	0.153 0.114 0.135	- - 2.98
Boudjadi and Rachedi 2021	Extreme North-East of Algeria	FISAT (ELEFAN)	**All**	44.08	0.29	2.75
Present study	Egyptian Mediterranean deep Sea waters	FISAT (ELEFAN)	**Males** **Females** **All**	62.63 66.84 67.26	0.22, 0.24, 0.19	2.93 2.99 2.97

The spawning period set according to the variation in maturity stages and gonado-somatic index values. In the present study seasonal variations in pattern of gonadal activity and the GSI of *M. merluccius* showed that spawning occurred and run from autumn to winter, while, it was from December to May **(Pineiro and Sainza, 2003)**, December to March **(Akalın, 2014)**, and from January to March **(Murua and Motos, 2006)**. Moreover, **Absawey *et al.* (2010)** mentioned that *M. merluccius* spawning period extending from January to early June. Furthermore, **Soykan *et al.* (2015); Khoufi *et al.* (2014)** observed that the spawning were mostly between December and May, peaking in April. On the other hand **(Philips, 2014)** demonstrated that the spawning season starts from April to June. The current work carried out in the Egyptian Mediterranean deep sea where the temperature is cooler, so the spawning time shifts to appear later than that of other studies. This is in accordance with the fact of the spawning season of fishes are correlated to environmental conditions especially the water temperature **(Coetzee, 1986; Garratt, 1986 and Mehanna *et al.*, 2019)**.

The seasonal length distribution revealed that the small fish were appeared during winter and spring seasons indicating the appearance of the new generations during these seasons which match with the spawning season beginning in autumn extend to winter. Indeed, the seasonal variation in maturity stages of *M. merluccius* during the period of study declared that the spawning time present in autumn and winter. Likewise the mature individuals appear at length group more than 15.0cm and increase to 50% at length 32.15- 32.3 cm which considered as L_m for males and females, respectively. According to **Absawey *et al*. (2010)** *M. merluccius* spawning period appears from January to early June and the length at maturity was 32.5 cm. The difference in the previous results may be attributed to the regional discrepancies and sampling fishing depth as well as the genetic variations, **(Table 6)**.

Table (6): Spawning period of *M. merluccius* in different study areas

Authors	Spawning period	Study area
Pineiro and Sainza, 2003	December to May	Atlantic–Med, Strait of Gibraltar, Spain
Akalın, 2014	December to March	Edremit Bay, Turkey
Murua and Motos, 2006	January to March	Bay of Biscay
Absawey *et al*., 2010	January to early June	Mediterranean, Egypt
soykan *et al*., 2015	December and May	Aegean Sea, central, Turkey
Philips, 2014	April to June	Mediterranean, Egypt
Present study	autumn and winter	Mediterranean deep sea water, Egypt

The observed value of the present study reproductive load was 0.5 which lies in the range of 0.3–0.8 and 0.4–0.9 gather by **Froese and Binohlan (2000)**; **Trindade-Santos and Freire (2015)**, respectively. The reproductive load is usually tended to be small in large fishes and it is bigger in smaller size fishes **(Froese and Binohlan, 2000; Froese and Pauly, 2000)**.

The size at first capture of deep sea *M. merluccius* was (26.40 cm), it was smaller than the size at first sexual maturity (32.15- 32.3 cm for males and females, respectively), The mesh size must be increased to prevent the catch of the small fish and enable the fish to add a new generation at least for once to fishery.

M. merluccius fishery is characterized by a total mortality of (1.33 y^{-1}), high fishing mortality rate (0.99y^{-1}), and low natural mortality rate (0.34y^{-1}). Results indicated that the fishing mortality is higher than the natural mortality by about 2/3 or by (66%). That is causing a high exploitation ratio (E = 0.74). The high exploitation ratio was good evidence that *M. merluccius* deep sea stock was under high fishing pressure or over-fishing. By comparing the present results with that carried out by **Philips (2014)** where E = 0.3987, we concluded that there was a clear increase in fishing pressure of the deep sea *M. merluccius* stocks in Egyptian Mediterranean waters

Accordingly, to **GFCM (2016)** *M. merluccius* stock in the Mediterranean was over exploited. **Fernandes *et al.* (2016)** set it as "vulnerable” species moreover, it add to IUCN Red List of Threatened Species, consequent to declines in abundance attributed to high fishing pressure.

CONCLUSION

In the last few years, fishing fleets in Egypt targeted this valuable species, especially in the Mediterranean deep Sea waters as it is an export commodity from the Egyptian market to the European markets. Therefore, more researches are required to enrich our knowledge on *M. merluccius* stock for better sustainable fisheries management.

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