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Growth Characteristics of the Thick-Lipped Grey Mullet *Chelon labrosus* (Risso, 1827) from Bardawil Lagoon, Southeastern Mediterranean, Egypt

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ABSTRACT

The IUCN Red List classifies *Chelon labrosus* as Near Threatened. It is a species that has economic importance in the southeast Mediterranean. Thus, to support sustainable management of its stock in Bardawil Lagoon, this study provides baseline biological and fisheries data. A total of 472 specimens, ranging from 14.3– 43.1cm in total length and 40.0– 765.3g in body weight, were collected during the 2023 fishing season. The length–weight relationship followed the equation $W=0.0105L^{3.02}$, suggesting that the species exhibits isometric growth. Age determination from scales revealed seven age classes, with mean lengths at the end of each year estimated at 15.3, 19.6, 23.4, 27.1, 30.4, 32.9, and 34.5cm for ages one through seven, respectively. According to the von Bertalanffy growth model, the estimated growth parameters were L_∞ =47.4cm, K=0.152yr $^{-1}$, and t_0=−1.508 yr, while the growth performance index (ϕ′) was calculated as 2.535. Mortality rates were estimated as Z = 0.848 yr^{-1} (total), M = 0.419 yr^{-1} (natural), and F = 0.429 yr^{-1} (fishing), yielding an exploitation rate (E) of 0.51. The estimated length at first capture was 21.9cm, corresponding to an age of 2.56 years. The results suggest that the stock is experiencing moderate overexploitation. Therefore, a reduction in fishing mortality of approximately 29–30% is advised to secure the long-term sustainability of *C. labrosus* in Bardawil Lagoon. These findings provide the first comprehensive biological and fishery insights for this species in the region and highlight the urgent need for science-based management measures.

INTRODUCTION

Members of the family Mugilidae are widely distributed in tropical, subtropical, and temperate waters. The grey mullet is a euryhaline species that inhabits coastal areas, estuaries, and freshwater environments **(Nelson, 2006)**. The family Mugilidae has global economic value due to the high quality of its flesh and caviar **(Turan, 2016)**. On a global scale, the family Mugilidae consists of 17 genera and 72 recognized species **(Harrison & Senou, 1999; Nelson, 2006)**. Furthermore, according to **Ayo-Olalusi *et al.* (2010)**, eight species of Mugilidae—originally grouped under the same genus (*Mugil*)—live in the

Mediterranean Sea. They go by various names, including *Mugil ramada, Mugil cephalus*, *Chelon labrosus*, *Mugil labeo*, *Mugil aurata*, *Mugil abu*, *Mugil saliens*, and *Mugil carinata*. In the Mediterranean, eight species of the family Mugilidae have been recorded, all confined to the eastern basin. Notably, some mullet species occasionally expand their distribution and appear in new areas **(Nehring, 2002)**. These species account for the largest share of fish production in El Mellah **(Chaoui *et al*., 2006)**. Among the family Mugilidae, the thick-lipped grey mullet *Chelon labrosus* (Risso, 1827) is distributed in the North Atlantic, extending southward to the coast of West Africa **(Ben-Tuvia, 1986)**, and is also present in the Mediterranean and western Black Sea **(Keit & Allardi, 2002)**.

Chelon labrosus (thick-lipped grey mullet) is a euryhaline teleost commonly found in coastal lagoons, estuaries, intertidal marshes, and earth ponds along the Mediterranean coasts and northeastern Atlantic **(Sarasquete *et al.*, 2014)**. This species is listed in IUCN Red List Status as nearly threatened fish species **(IUCN, 2025)**. As shown in Fig. (1). *C. labrosus* is morphologically characterized by a relatively large pupil diameter, four spines in the first dorsal fin, one spine and eight rays in the second dorsal fin, a thick upper lip, and nine rays in the anal fin **(Nelson, 2006)**. Overall, morphological and meristic analyses continue to represent the most straightforward and widely applied techniques for identifying fish species **(Abdrabba, 2009)**. According to **Talwar and Jhingran (1992)**, descriptive traits are morphological features of the body that are neither measurable nor countable, and they often exhibit clinal variation across geographical gradients **(Lindsey, 1988)**. Morphometric measurements describe the external dimensions of an organism, while meristic measurements refer to serial counts of body structures.

Fig. 1. *Chelon labrosus* from Bardawil Lagoon, Egypt

Mullets' species are of significant economic importance, which has led to numerous biological studies across different aquatic habitats **(El-Ganainy *et al*., 2002; Fazli *et al*., 2008; Kraljević *et al*., 2011; Saoudi & Aoun, 2014; Tulkani, 2017; Panda *et al*., 2018)**. In Bardawil Lagoon, mullets are mainly harvested using two traditional fishing gears: the Veranda (Bouss) and the Dabba, which employ trammel nets **(El-Ganainy *et al*., 2002)**. Despite their economic and ecological value, research on mullet species in Egypt—and particularly in Bardawil Lagoon—remains scarce. This study represents the first attempt to characterize the fishery of *Chelon labrosus* in the lagoon and provides essential baseline information to support sustainable management and conservation of its stock.

MATERIALS AND METHODS

Bardawil Lagoon (Fig. 2) is located between latitudes 31°03′ and 31°14′ N and longitudes 32°40′ and 33°30′ E in the northern part of the Sinai Peninsula, Egypt. It is separated from the Mediterranean Sea by a sandy bar with two narrow inlets. The lagoon represents a natural depression with an average depth of about 1.5m **(El-Ganainy *et al.*, 2002)**. Surface water temperature in Bardawil Lagoon fluctuates between 14.8°C in January and 29.4°C in August, with an annual average of 22.7°C **(Mehanna, 2014)**. Salinity levels range from 38.46ppt in March to 51.86ppt in September **(Khalil *et al.*, 2016)**.

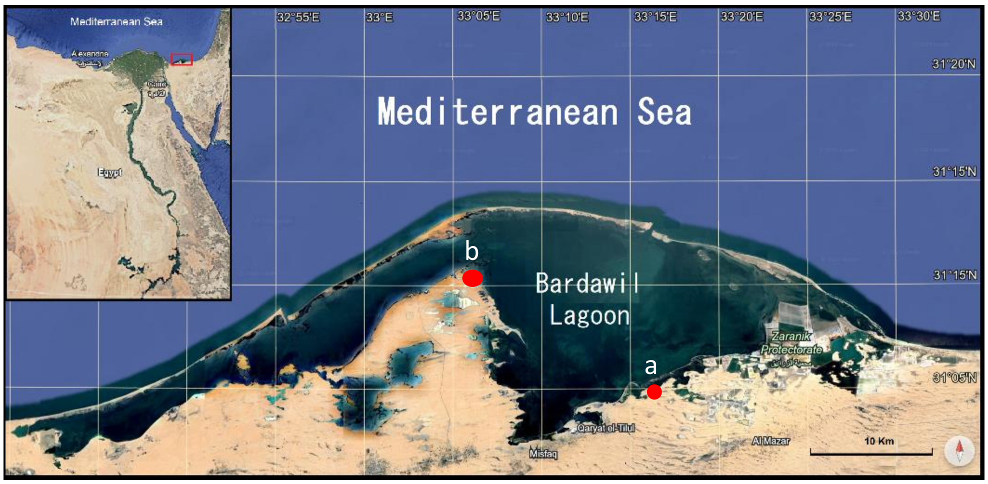

Fig. 2. Map of Egypt showing the location and map of Bardawil Lagoon, Teloul (a) and Oghzoan (b) landing site

During the 2023 fishing season, monthly samples of *C. labrosus* were collected from the commercial landings at the two main sites in Bardawil Lagoon (Teloul and Oghzoan). The specimens were obtained from catches taken by the primary fishing gears used in the lagoon, Veranda and Dabba.

A total of 472 *C. labrosus* specimens were sampled monthly. Total length (mm) and weight (0.1 g) were recorded. The length–weight relationship was estimated as $W=aL^b$ **(Ricker, 1975)**, where W is total weight (g); L stands for total length in cm; a and b are constants. The condition factor (K_c) was calculated as $K_c = (W\times100)/L^3$ **(Hile, 1936)**, Where W = weight in gram, and L = length in centimeter. The relative condition factor (K_n) accounts for the actual weight–length relationship of the studied population and is calculated as: $K_n = W/W'$, where W is the observed weight, W′= is the expected weight from the length–weight regression, Thus, while K_c is useful as a general condition index, K_n is considered more reliable for precise comparisons across varying growth patterns **(Le Cren, 1951; Froese, 2006)**. Values of K_n greater than 1 indicate fish in better condition than expected, whereas values below 1 indicate poorer condition. Data were analyzed and processed using MS Excel 2016.

Scales were cleaned and examined under reflected light at 33× magnification to determine age. Back-calculated lengths at the end of each year were obtained using **Lee**'s **(1920)** equation: $L_n = (L - a) S_n / S + a$, where L_n is the fish length at age n; L the length at capture; S_n the scale radius at age n; S the total scale radius; and a is constant. Annual weights were then estimated from the length–weight relationship.

The total mortality coefficient (Z) was estimated using the Powell–Wetherall plot **(Powell, 1979; Wetherall *et al.*, 1987)**, where Z=1−K. Natural mortality (M) was calculated following **Pauly**'s **(1983)** empirical formula: $\log M = [-0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T]$, where L_∞ is the asymptotic length, K is the growth coefficient, and T is the mean annual temperature (°C). Fishing mortality (F) was derived as: F=Z−M.

The exploitation rate (E) was calculated according to **Gulland (1971)**: E= F/(F+M). For yield prediction, relative yield-per-recruit, biomass, and relative biomass-per-recruit were estimated using the knife-edge selection model of **Beverton and Holt (1966**). Yield-per-recruit was further calculated using the **Gulland (1969)** model:

$Y`/R = F e^{-M (T_c - T_r)} W_\infty [(1/Z) - (3S/Z+K) + (3S^2/Z+ZK) - (S^3/Z+3K)]$, where $S=e^{-k(T_c-T_o)}$ and W_∞= asymptotic body weight.

RESULTS

Frequency distribution of length

472 samples of *C. labrosus* were collected during the 2023 fishing season from the commercial catch at two landing sites in Bardawil Lagoon. The lengths of the collected samples lie between 14.3 and 43.1cm (Fig. 3) with an average of 23.25 cm ± 5.92 SD, and the lengths between 17 and 27cm were the most common in the catch. The average weights (±SD) were 174.01gm ± 154.89.

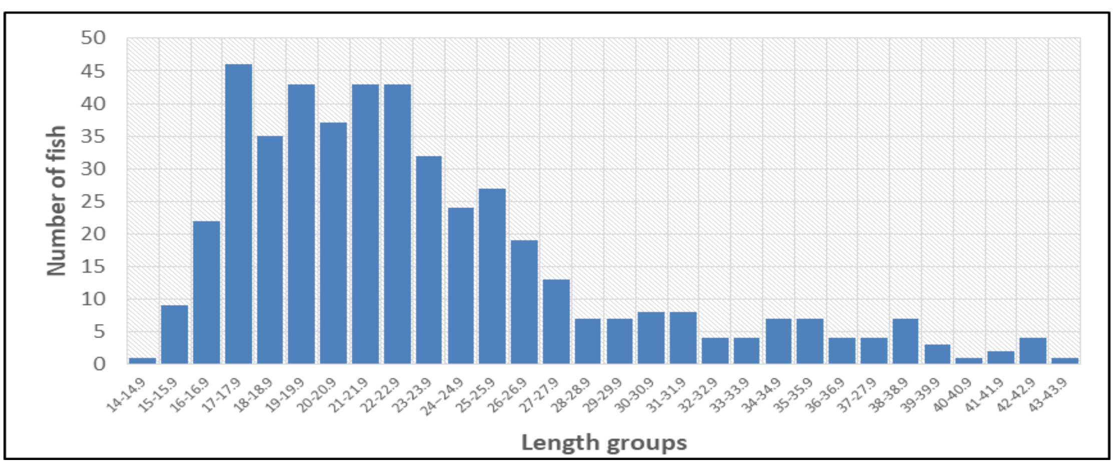

Fig. 3. Length frequancy distrubition of *C. labrosus* in Bardawil Lagoon during the period of study

Relationship between length and weigh:

The length – weight relationship of 472 specimens of *C. labrosus* fish is presented graphically in Fig. (4). The lengths of combined sexes fluctuated between 14.3 and 43.1cm (mean= 23.3cm), and the overall weight ranged from 40 to 765.3g and averaged 174.01g. The resulting power equation was used to show the length-weight relationship: $W = 0.0105 \times L^{3.0221}$.

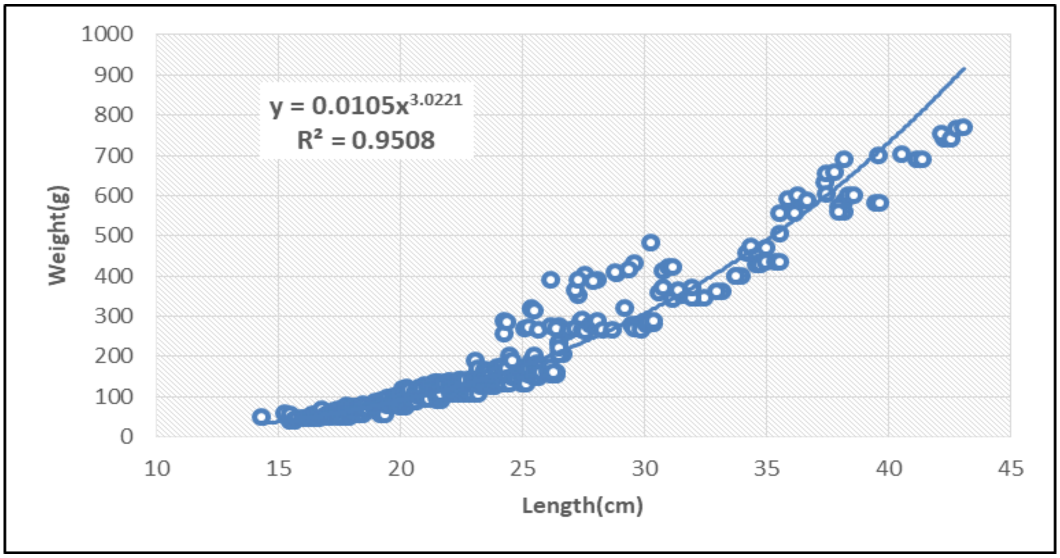

Fig. 4. Length weight relationship of *C. labrosus* combined sexes from Bardawil Lagoon during the period of study

Condition factor (K)

Condition factor (K_c) of the combined sexes of of *C. labrosus* in Bardawil Lagoon related to lengths groups is graphically represented in Fig. (5). The lowest value of K_c for combined sexes of *C. labrosus* was observed in size class 32 , 38 , 41, 42, and 43cm and the highest one was recorded in size class of 14 to 31cm , and 33 to 37cm (K= 1.1).

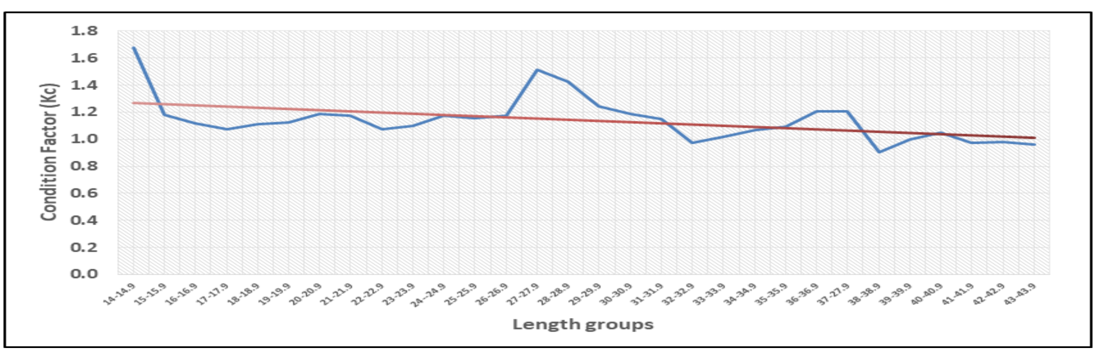

Fig. 5. Condition factor (Kc) variation according to length group of *C. labrosus* combined sexes from Bardawil Lagoon during the period of study

The relative condition factor (K_n) is represented in Fig. (6). The lowest value of relative condition factor (K_n) of combined sexes of of *C. labrosus* was observed in size class 17, 18, 22, 23, 32, 33, 34, 38, 39, 40, 41, 42, 43 and 44.9 cm and the highest one was recorded in size class of 14, 15, 16, 19, 20, 21, 24 to 31 and 35, 36, 37cm (K_n= 1.0). For sexes combined, K_c and K_n ranged from 0.9 to 1.7, and 0.8 to 1.5, respectively.

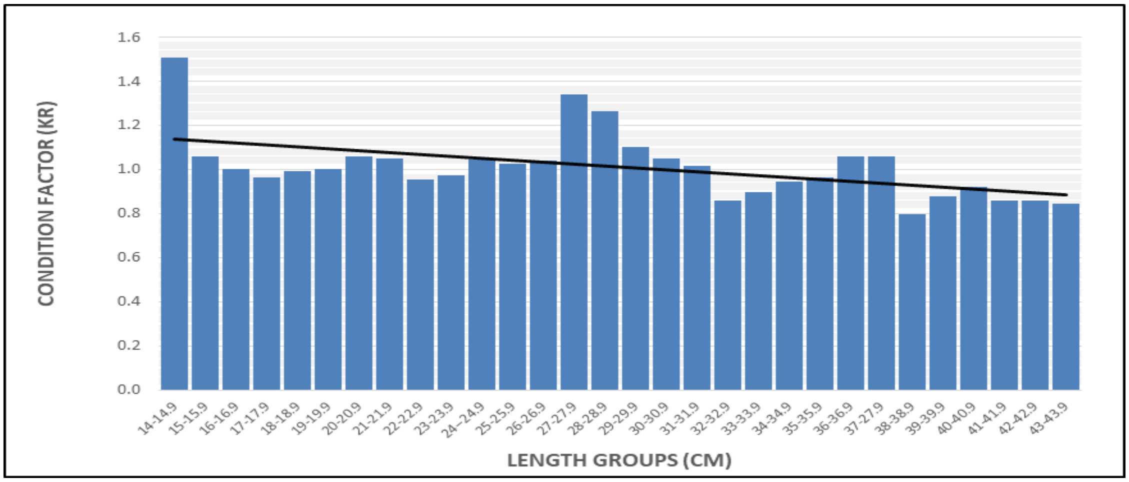

Fig. 6. Relative condition factor (Kr) variation according to length group of *C. labrosus* combined sexes from Bardawil Lagoon during the period of study

Age determination

The scales of all samples were used for determination of age. The longevity of *C. labrosus* was estimated to be 7 years by counting the scales annual growth rings. Back-calculated lengths and weights were estimated from 472 individual fish scale. Lengths at the end of each year of life were 15.3, 19.6, 23.4, 27.1, 30.4, 32.9 and 34.5cm from one to seven years (Fig. 7). Calculating the weight at the end of years was performed from the equation of length weight relationship. Weights at the end of years were 38.9, 79.4, 135.2, 207.5, 290.2, 384.4, and 465.9 g, from one to seven years (Fig. 8).

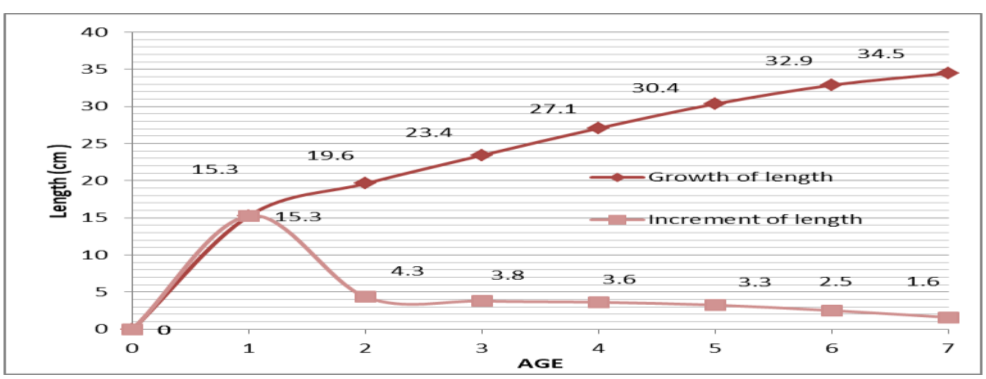

Fig. 7. Length at the end of each age group of *C. labrosus* during the period of study

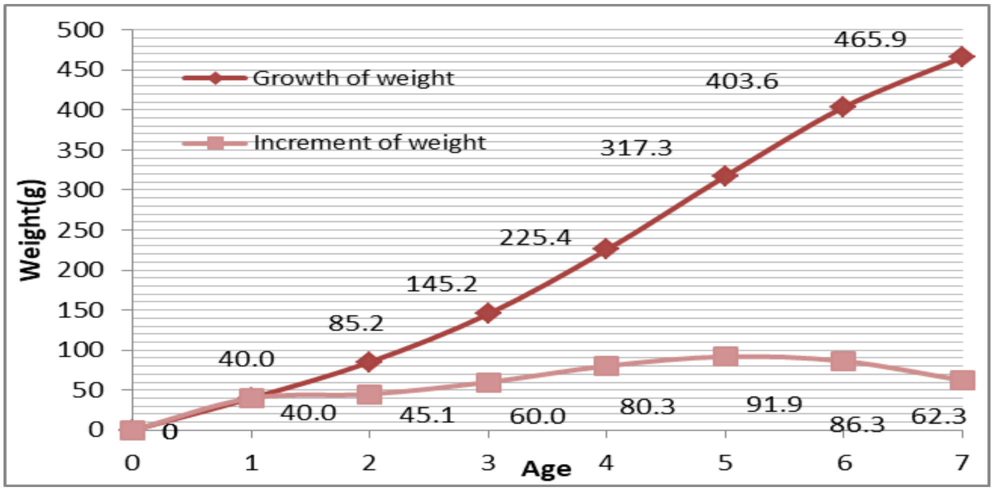

Fig. 8. Weight at the end of each age group of *C. labrosus* during 2023

Growth parameters

According to the findings, the von Bertalanffy growth parameters for L_∞, K, and t_o were estimated to be 47.43 cm, 0.1523 year^{-1}, and – 1.5081 year, respectively. W_∞ was calculated using the length-weight relationship equation (=1219.9 g). A growth performance of 2.535 was determined. Equations that show growth in weight (W_t) and length (L_t) are as follows:

$L_t = 47.43\ [1\text{-}e^{-0.1523(t+1.508)}]$ … growth in length, and

$W_t = 1219.9\ [1\text{-}e^{-0.1523\ (t+1.508)}]^{3.022}$ … growth in weight.

The length at first capture (L_c) of *C. labrosus* from Bardawil Lagoon during 2023 fishing season was estimated to be 21.9cm (Fig. 9) corresponding to age ($T_r = 2.558$ yrs).

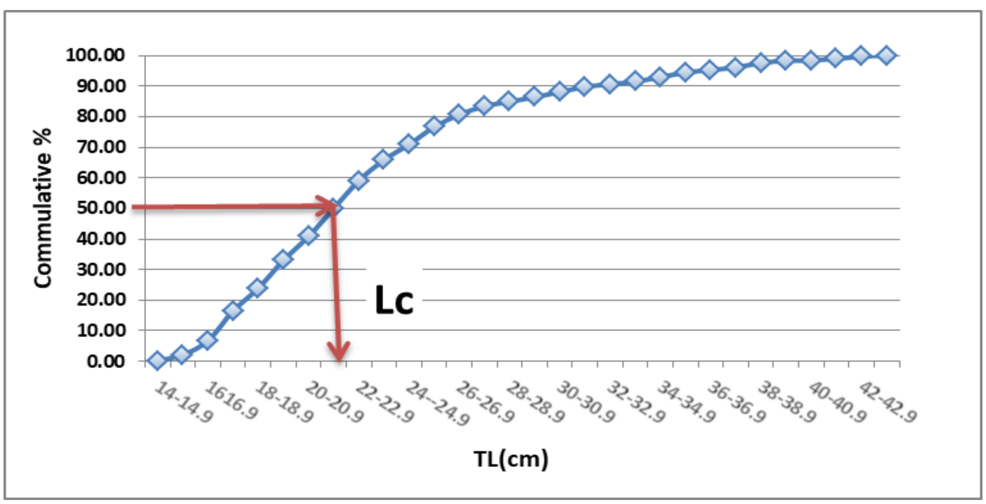

Fig. 9. Length at first capture (Lc) of *C. labrosus* from Bardawil Lagoon during the period of study

Mortalities and exploitation rates

From the length freqency distrubution and estimated growth parameters, natural mortality (M= 0.419 yr^{-1}) and fishing mortality (F= 0.429 yr^{-1}) were computed, and the overall mortality (Z= 0.848 yr^{-1}) was calculated. Using estimated values of the total (Z) and the fishing mortalites (F), the exploitation rate (E) was calculated to be 0.51 $year^{-1}$

Biomass per recruit (B/R) and Yield per recruit (Y/R) :

The biomass per recruit (B/R) and yield per recruit (Y/R) were found to be 59.969 and 51.01gm at the actual fishing mortality 0.43 and 2.3 $year^{-1}$, respectively (Fig. 10). Biomass per recruit decreased with increasing fishing mortality, reaching its maximum value (343 g) at F= 0.0.

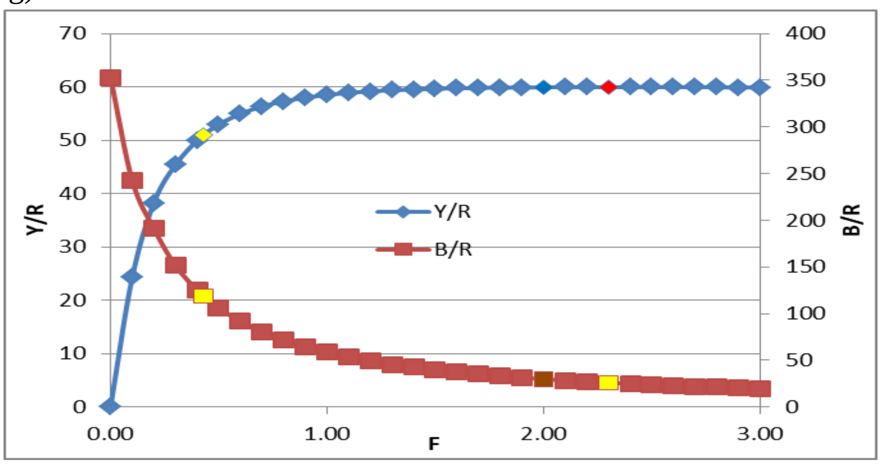

Fig. 10. Yield per recruit (Y/R) and biomass per recruit (B/R) of *C. labrosus* from Bardawil Lagoon during the period of study

Assuming a constant fishery mortality rate (F) and varying the length at first capture, the yield per recruit was found to be low at 14.3cm (48.8 g). The yield increased with increasing length at first capture, reaching a maximum at 19.3cm (52.14 g). Beyond this point, the yield per recruit declined with further increases in length at first capture (Fig. 11).

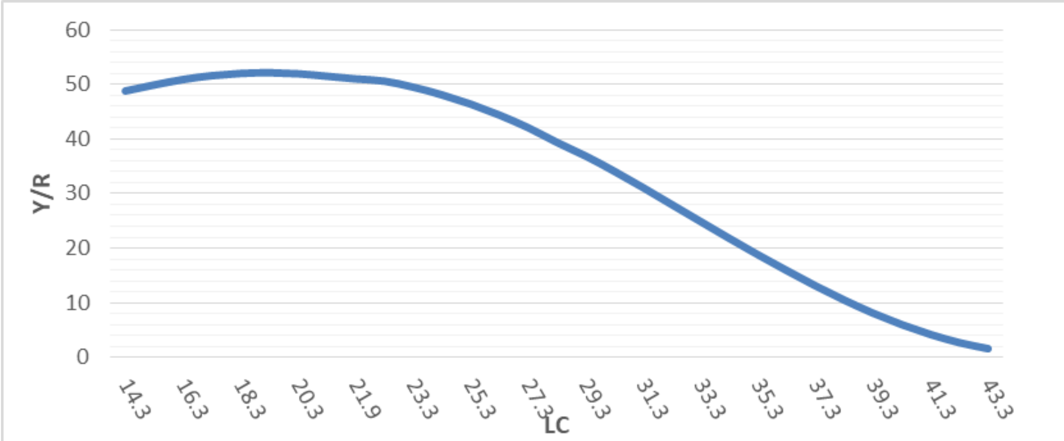

Fig. 11. The yield per recruit (Y/R) in defferent age groups at constant F value of *C.labrosus* from Bardawil Lagoon during the period of study

Relative yield per recruit (Fig. 12), the maximum yield per recruit (E_{max}), representing the highest level of exploitation that generates the maximum sustainable yield, was 0.849. The level of exploitation at which 50% of the fish's biomass would be maintained ($E_{0.5}$) was 0.361, and the level of exploitation for economic yield ($E_{0.1}$) was 0.716. Table (1) provides the data necessary to calculate the maximum, optimal, and economic exploitation levels.

Table 1. Natural mortality, growth parameters and yield per recruit at different levels of exploitation of *C. labrosus* from Bardawil Lagoon

Parameters	**M**	L_c	L_∞	**K**	**M/K**	L_c/L_∞	$E_{0.1}$	$E_{0.5}$	E_{max}
Value	0.419	21.9	47.43	0.1523	2.7499	0.4617	0.716	0.361	0.849

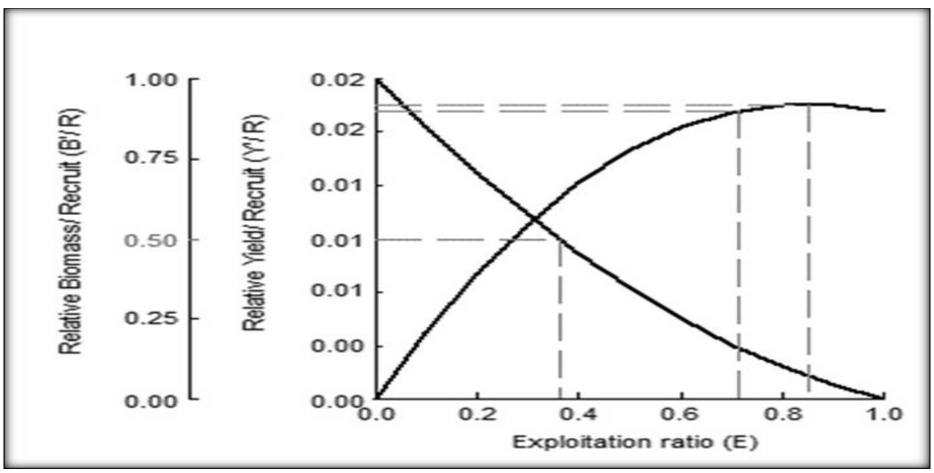

Fig. 12. Relative yield per recruit (Y'/R) and relative Biomass per recruit (B'/R) of *C. labrosus* from Bardawil Lagoon during the fishing season of 2023

DISCUSSION

In this study, the sizes of all individuals ranged from 11.3 to 43.3cm total length and 40 to 770g total weight. Our results largely agree with those of previous studies, with slight variations in size range. **Reis and Ateş (2020)** reported sizes ranging from 10.18 to 45.2cm and weights from 7.5 to 470g in Köyceğiz Lagoon, Turkey. **Moura and Gordo (2000)** documented sizes between 5 and 33cm in Óbidos Lagoon, Portugal. **El-Mor *et al.* (2020)** reported sizes ranging from 11.1 to 25.9cm and weights from 25.6 to 166.6g in Um-Hufayan Lagoon, Libya. Similarly, **Verdiell-Cubedo *et al*. (2006)** reported sizes between 17 and 43cm in the Mar Menor coastal lagoon (western Mediterranean Sea).

The length-weight relationship represents a key biological characteristic of fish, indicating that weight increases proportionally with length. In the present study, the estimated length-weight equation for both sexes combined was: $W = 0.0105\ L^{3.0221}$. The value of 'b' in the present study of *C. labrosus* from Bardawil Lagoon during 2023 was approximately equal to 3. These results show that the relationship is isometric. The differences in the 'b' values presented in Table (2) may be attributed to variations in the sample size, the season of collection, and the sampling method. Variations in the exponent "b" values observed in fish across different localities can be attributed to differences in environmental conditions and geographic settings **(Andreu-Soler *et al.*, 2006)**. These parameters are influenced by a range of factors, including seasonal changes, habitat characteristics, reproductive maturity, sex, dietary habits, stomach content, overall health, and methods of preservation **(Bagenal & Tesch, 1978; Hossain *et al*., 2006)**.

Table 2. Variations of 'b' values in LWR of *C.labrosus* from diferent locations

Location	b- value	Reference
Bardawil Lagoon, Egypt	3.022	Present study
Köyceğiz Lagoon, Turkey	3.06	**Reis and Ate (2019)**
North West Wales	3.32	**Tulkani (2017)**
Agean Sea	3.09	**Kara *et al.* (2017)**
Agean Sea	3.061	**Acarlı *et al.* (2014)**
Greece	2.993	**Koutrakis and Tsikliras (2003)**
Óbidos Lagoon, Portugal	3.048	**Moura and Gordo (2000)**
Agean Sea	3.084	**Egemen *et al.* (1999))**
	2.931	**Buhan (1998)**
Greece	3.04	**Koutrakis, and Sinis (1994)**
France	3.10	**Cassifour (1975)**
Tunisia	3.04	**Farrugio (1975)**
Tunisia	3.21	**Farrugio, and Quinard (1974)**
Ireland	3.05	**Kennedy and Fitzmaurice (1969)**
Brittany and France	3.02	**Thong (1969)**

According to **Nehemia *et al*. (2012)**, the length-weight relationship plays a crucial role in fisheries science by: (a) facilitating the integration of fishery and growth models, (b) enabling the estimation of fish weight from length measurements for yield assessments. In addition, it plays a substantial role in (c) serving as an indicator of the fish's condition and overall well-being **(Beyer, 1987)**.

The condition factor in fish provides valuable insights into their life cycle and supports effective management strategies, thereby contributing to the maintenance of ecological balance **(Imam *et al*., 2010)**.

In the present study, the back-calculated lengths at successive ages were 15.3, 19.6, 23.4, 27.1, 30.4, 32.9, and 34.5cm for age groups one to seven, respectively. Table (3) compares the back-calculated lengths at different ages in the present study with those reported from other water bodies. The results reveal considerable variation among studies. These differences may be attributed to ecological conditions, fishing gears and methods employed, as well as differences in food availability.

Table 3. Back calculated lengths at different years of life of *C. labrosus* from Bardawil Lagoon and other locations in the world

Area	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Reference
Bardawil Lagoon Egypt	15.3	19.6	23.4	27.1	30.4	32.9	34.5				**Present study**
Turkey	13.9	20.2	25.8	29.4	32.9	36.2	-	-	-	-	**Reis and Ateş (2020)**
North West Wales	13.3	15.5	17	22.8	33.8	37.3	40.4	42.5	46.4	49	**Tulkani (2017)**
Güllük Lagoon		22	23.9	26.5	30.3	35	-	-	-	-	**Hossucu (2001b)**
Portugal	16.1	20.8	23.2	25.5	27.4	31.5	-	-	-	-	**Moura and Gordo (2000)**
Greece	11.6	17.7	22.1	25.3	2.3	29.3	31.3	32.9	-	-	**Koutrakis and Sinis (1994)**
Irland	12.6	17.2	22.8	2.4	30.8	34.2	37.6	41	43.3	45.6	**Walsh (1994)**
Köyceğiz Lagoon	15.8	20.4	23.4	25.6	27.5	-	-	-	-	-	**Yerli (1991)**
Izmir Bay	20.9	23.2	26.5	30.3	35	-	-	-	-	-	**Temelli (1987)**
France	9.3	18.5	26.2	30.7	34.4	37.6	40.2	43.7	46.7	-	**Cassifour (1975)**
Tunisia	15.6	23.3	32.4	37.3	43.5	47.8	-	-	-	-	**Farrugio (1975)**
Coroatia	9.4	16.6	23.7	31.2	36.1	39.9	42.5	-	-	-	**Morovic (19640**
Coroatia	9.5	15.5	23.3	32.4	38.3	44.5	48.	52.3	-	-	**Morovic (1960)**
Morroco	10.2	21	26	35.9	38.6	47.3	51.9	55.0	61.0	-	**Rossignol (1951)**

In the present study, the length at first capture (L_c) of *Chelon labrosus* individuals from Bardawil Lagoon during 2023 was recorded at 21.9cm. This value is notably smaller than the length at first sexual maturation (L_m), which is 29.5cm, as reported by **Froese and Pauly (2019)**. Capturing fish before they reach sexual maturity may lead to a decline in stock abundance in the near future. For sustainable management of grey mullet fisheries, it is essential to allow each fish the opportunity to reproduce at least once in its life cycle. Therefore, the length at first capture (Lc) should exceed the length at first maturity (L_m).

In the present study, the L_∞ value (47.43cm) is close to the results recorded in previous studies, for instance **Farrigio and Quinard (1974)** and **Reis and Ates (2020)**, and highly lower than values determined (Table 4) for *C. labrosus* in other areas. In addition, K value (0.1523) is similar in other areas **(Thong, 1969)** and profoundly lower in the other regions for the same species (Table 4). In the present study, the index of growth performance (φ′) agrees with the results obtained by different authors for the same species, as shown in Table (4).

Table 4. Growth parameters (L_∞, K, t_0) and Growth perfermence index of *C. labrosus* from bardawil lagoon and other locations in the world

Area	L_∞	K	T_0	φ	Reference
Bardawil lagoon	47.43	0.1523	-1.508	2.535	**Present** study
Köyceğiz Lagoon	49.8	0.193	0.293	2.679	**Reis and Ates (2020)**
NW Wales	83.9	0.081	-0.79	2.76	**Tulkani,(2017)**
Obidos Lagoon	30.1	0.391	-0.924	2.548	**Moura and Gordo (2000)**
Köyceğiz Lagoon	39.0	0.523	-0.239	2.9	**Buhan (1998)**
Strangford Lough	60.9	0.119	-0.416	2.645	**Richter (1995)**
Northeastern Greece	35.8	0.287	-0.406	2.565	**Koutrakis and Sinis (1994)**
SE Ireland	68.4	0.100	0.01	2.67	**Walsh et al. (1994)**
S Ireland	65.8	0.129	-0.45	2.75	**Grove (1980)**
Arcachon, SW France	53.9	0.219	0.12	2.80	**Cassifour (1975)**
Lac du Tunis,	64.2	0.206	-0.35	2.93	**Farrigio (1975)**
Lac du Tunis, Tunisia	42.7	0.498	0.14	2.96	**Farrigio and Quinard (1974)**
England and Wales	62.3	0.132	-0.70	2.67	**Hickling (1970)**
Brittany, France	62.4	0.157	-0.41	2.79	**Thong (1969)**
Ireland	67.2	0.105	0.04	2.68	**Kennedy and Fitzmaurice (1969)**
E. Mediterranean	78.7	0.168	-0.29	3.02	**Ermen (1961)**
Morocco	108.2	0.096	0.13	3.05	**Rossignol (1951)**

During the 2023 fishing season, the total mortality (Z) of *C. labrosus* from Bardawil Lagoon was estimated at 0.848 yr^{-1}. Natural mortality (M) was calculated at 0.419 yr^{-1}, while fishing mortality (F) was 0.429 yr^{-1}. Based on these values, the current exploitation rate (E) was determined to be 0.51. This level of fishing mortality and exploitation rate suggests a relatively high degree of exploitation. It is important to note that total mortality (Z) is the sum of natural mortality (M) and fishing mortality (F). **Barry and Tegner (1990)** proposed that the ratio of total mortality (Z) to growth coefficient (K) serves as an indicator of stock status. A Z/K ratio below 1 suggests that growth predominates over mortality, indicating a healthy stock. A ratio equal to 1 reflects a population in equilibrium, while values exceeding 1 imply stock decline. Notably, a Z/K ratio significantly greater than 2 is indicative of overexploitation. In the present study, the Z/K ratio for *C.labrosus* from Bardawil Lagoon in 2023 was calculated at 5.57 (0.848/0.1523), clearly signaling that the species is experiencing overexploitation in this region. The exploitation rates calculated in the present study are consistent with findings from prior research **(Buhan, 1998; Hotos *et al*., 2019; Reis & Ateş, 2020)**. According to **Gulland (1971)**, an optimal exploitation rate for fish stocks is 0.5, where fishing mortality (F) equals natural mortality (M). Based on this benchmark, the current exploitation pressure on fish stocks in Bardawil Lagoon suggests a trajectory toward depletion. To ensure the sustainable management of grey mullet (*C.labrosus*) in this region, it is essential that a portion of mature individuals entering the fish barriers be released back into the lagoon to allow for reproduction and stock replenishment.

In the present study, the yield per recruit (Y/R) and biomass per recruit (B/R) for *C. labrosus* were estimated at 51.01 and 59.969g, respectively, with an actual fishing mortality rate of 0.43 yr^{-1} and 2.3 yr^{-1}. The analysis revealed a clear inverse relationship between fishing mortality and biomass per recruit, with B/R reaching its maximum value of 343g when fishing mortality (F) was zero. This trend underscores the impact of fishing pressure on stock productivity and highlights the importance of regulating fishing mortality to sustain biomass levels

Based on the findings of the present study, it is evident that *C. labrosus* stocks in Bardawil Lagoon are subject to considerable exploitation. The analyses of yield-per-recruit and biomass-per-recruit indicate that further increases in fishing effort would not yield significant economic benefits and would instead contribute to stock depletion. For sustainable management, it is crucial to regulate fishing pressure and ensure that mature individuals are allowed to reproduce at least once in their life cycle. Therefore, it is recommended that part of the mature *C. labrosus* entering the fish barriers be released back into the lagoon to support stock regeneration and maintain ecological balance.

- **Adjust exploitation rate**

Based on the relative recruitment supply analysis, the optimal exploitation rate (E) to sustain *C. labrosus* stocks should be 0.361. This requires a reduction from the current rate of 0.51, representing a 29.2% decrease. Implementing this adjustment will help maintain sufficient spawning biomass and support long-term stock viability.

- **Increase length at first capture**

The current length at first capture (L_c) recorded in this study is 21.9cm, while previous studies reported the length at first maturity (L_m) as 29.9cm **(Froese & Pauly, 2019)**. To ensure that individuals have the opportunity to spawn at least once before being harvested, L_c should be increased to match or exceed Lm. This can be achieved by increasing the mesh size of fishing nets, allowing smaller, immature fish to escape and continue their growth and reproductive cycle.

CONCLUSION

This study provides essential insights into the age structure, growth dynamics, mortality rates, and exploitation levels of *C. labrosus* in Bardawil Lagoon. The findings contribute valuable data for fisheries research, resource management, and conservation planning in the region. To ensure optimal and sustainable utilization of Bardawil Lagoon as a productive source of capture fisheries, the following management measures should be considered:

1. **Reduce Exploitation Pressure**
    - Lower the current exploitation rate to maintain adequate spawning biomass.
    - Align the length at first capture (L_c) with or above the length at first maturity (L_m) to allow reproduction.
2. **Regulate Fishing Effort**
    - Limit the number of fishing days per season.
    - Reduce the number of active fishermen.
    - Release a portion of mature fish from barriers to support natural spawning.
3. **Modify Fishing Gear**
    - Increase the mesh size of nets to prevent the capture of immature individuals.
    - Shorten net lengths to reduce catch volume.

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