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Length-Weight relationships, Mortality and Relative Yield Per Recruit of Common Pandora, *Pagellus erythrinus* from the Mediterranean Coast, North Sinai, Egypt

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ABSTRACT
Due to the importance of fish biological measurements in managing fisheries along the Mediterranean coast of Sinai, this study was conducted on common pandora, *Pagellus erythrinus*, during the 2021 fishing season. Data were collected monthly from January to December 2021, comprising a total of 1,512 fish samples from commercial catches. The fish ranged in length from 11 to 27.9cm and in weight from 17.7 to 235.4g. The most important measurements include the length-weight relationship of *P. erythrinus*, described by the power equation: $W = 0.0106L^{3}.0416$ for combined sexes. The study identified four age groups, with the lengths at the end of each year being 15.84, 20.3, 23.5, and 25.5cm for the 1st, 2nd, 3rd, and 4th years of life, respectively. The estimated von Bertalanffy growth parameters were $L\infty = 29.98$cm and $k = 0.38$ year^{-1}. The growth performance index (Φ') was 2.538. The estimated length at first capture was 16.79 cm. The total, natural, and fishing mortalities were 1.92, 0.58, and 1.34 year^{-1}, respectively, for both sexes combined. The exploitation ratio was $E = 0.70$, indicating a high level of exploitation of *P. erythrinus*. The relative yield per recruit analysis (Y'/R) showed that the current exploitation level significantly exceeds the sustainable threshold ($E_{0.5} = 0.381$). To sustainably manage this resource, the current exploitation rate needs to be reduced by 45%, from 0.70 to 0.381.

INTRODUCTION

The fish resource of the Mediterranean coast of Sinai is exploited by three main fishing gears, the purse-seine nets, trammel nets, longline gear and trowel net **(EL- Aiatt, 2004)**. The North Sinai coast has a deep seabed and low biological productivity due to the low nutrient composition of the water. Over the last few decades, a significant number of Red Sea species have entered this area, increasing biodiversity and changing the fisheries status in Egypt. Small-scale and medium-sized vessels exploiting inshore grounds dominate the fleets of Cyprus, Lebanon, Syria, Egypt, and Turkey, with some larger trawlers and purse seines used in Syria and Egypt **(Papaconstantion & Farrugio, 2000)**.

The common pandora belongs to the family Sparidae and inhabits the Mediterranean Sea, the Black Sea, and the Atlantic Ocean. This species is valuable for both aquaculture and fisheries. The fish range in length from 10 to 30cm and can reach up to 60cm **(Bauchot & Hureau, 1986)**. Common Pandora fish are found at depths ranging from 10 to 100 meters and can be found at depths of up to 320 meters **(Bauchot *et al.*, 1987)**. The common pandora, *Pagellus erythrinus* (Linnaeus, 1758), is a seabream from the family Sparidae that inhabits the continental shelf waters of the northeastern and central-eastern Atlantic Ocean, from Norway **(Bauchot & Hureau, 1986)** to Guinea-Bissau **(Sanches, 1991)**. It is also found in the Mediterranean Sea **(Bauchot *et al.*, 1987)** and around the Madeira, Canary, and Cape Verde Islands **(Reiner, 1996)**. The common pandora, *Pagellus erythrinus* (Linnaeus, 1758) is widely distributed throughout the Mediterranean, common from south Brittany to Cape Verde, but rare in the Black Sea **(Bauchot & Hureau, 1986)**. In the Adriatic Sea, it is found over sandy-muddy bottoms, mostly up to 100m **(Jardas, 1996)**. The common pandora is predominantly a diurnal feeder **(Benli *et al.*, 2001)**. In the Tyrrhenian Sea and Greek waters, **Ardizzone and Messina (1983)** and **Caragitsou and Papaconstantinou (1985)** describe common pandora as a carnivorous fish. In the western Mediterranean and Egyptian Mediterranean waters, the diet of *Pagellus erythrinus* is primarily based on zoobenthic invertebrates **(Rosecchi, 1983; Rizzkala *et al.*, 1999)**.

The common pandora (*P. erythrinus*) is a demersal fish distributed in the Mediterranean Sea, the Black Sea, and along the western coasts of Europe and Africa in the Atlantic Ocean **(Papacons *et al*., 1988)**

From 1983 to 1985, studies were conducted on the common pandora fish along the western coast of Greece to investigate their behavior, growth, and survival rates. These studies also revealed that growth rings are formed annually between June and September during this period **(Papaconstantinou *et al.*, 2016)**.

In Tunisian waters, the common pandora fish has significant economic value and is abundant in local fisheries. In the Gulf of Gabes, it represents 15% of the bottom fish catch **(Ghorbel *et al.*, 1997)**, and in the Gulf of Tunis, it accounts for 11% of the bottom fish catch **(Zarrad *et al.*, 2010)**. Additionally, **Spedicato *et al.* (2002)** reported that the common pandora is widely distributed in the Atlantic Ocean along the European and African coasts **(Fischer *et al.*, 1987)**, as well as around São Tomé and Príncipe and the Canary Islands **(Pajuelo & Lorenzo, 1995)**.

MATERIALS AND METHODS

Samples were taken from the common pandora (*P. erythrinus*) as it is one of the fish commonly caught by trawl nets for biological studies, particularly because it is a popular and affordable species. The present study was conducted from January to

December 2021, with 1,512 samples of common pandora collected from fishing boats operating off the coast of Sinai in the Mediterranean Sea. The relationship between length and weight was calculated by using **Le Cren (1951)** equation and the age was calculated by analyzing the length frequency data by using **Bhattacharya (1967)** method integrated into the FISAT II program of **Gayanilo *et al.* (1997)**, which converts length frequency into age groups. The ELEFAN I program (Electronic Length Frequency Analysis of Pauly and David, 1981) was used to estimate the growth parameters L∞ and K for the pooled samples. The equation of **Pauly and Munro (1984)** was applied: $\varphi = \log K + 2 \log L\infty$. The growth performance index was then calculated, where K and L∞ are the constants of the von Bertalanffy growth equation. The Catch Curve method was used to calculate total mortality (Z) **(Pauly, 1984b)**. Natural mortality (M) was calculated using the equation M = 1.5K, where K is the growth factor **(Jensen, 1996)**. Fishing mortality (F) was estimated using the equation F = Z - M **(Gulland, 1971)**. The exploitation rate (E) was calculated using the formula E = F/Z **(Cushing, 1968)**. The knife-edge selection model **(Beverton & Holt, 1966)** was used to estimate the relative yield per recruit.

RESULTS

The Common pandora *(P. erythrinus)* were divided into length class intervals of 1cm size TL. 1512 Common pandora were measured as a total length (cm). The length frequencies of combined-sex common pandora (*P. erythrinus*) are illustrated in Fig. (1).

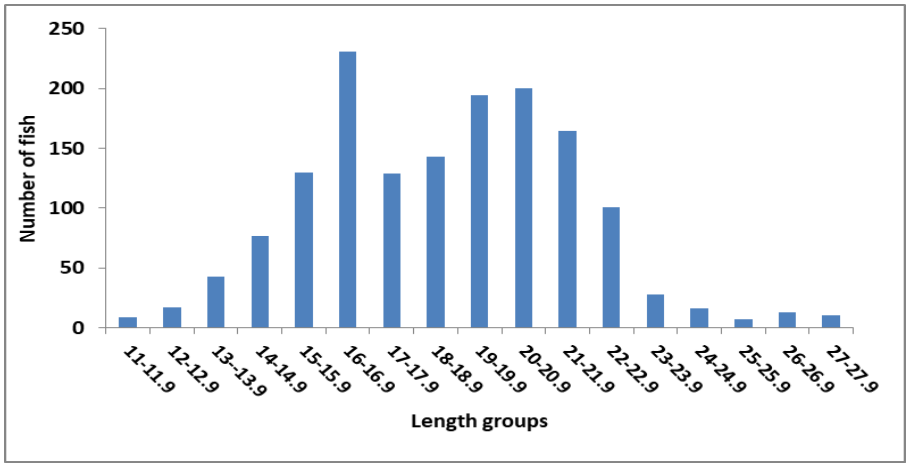

Fig. 1. Length frequency of combined sexes of (*P. erythrinus*) during 2021

The relationship between the length- and weight of Common pandora *(P. erythrinus)* is presented in Fig. (2). The equation used is as follows: $W = 0.0106\ L^{3.0416}$ ($r2 = 0.9374$).

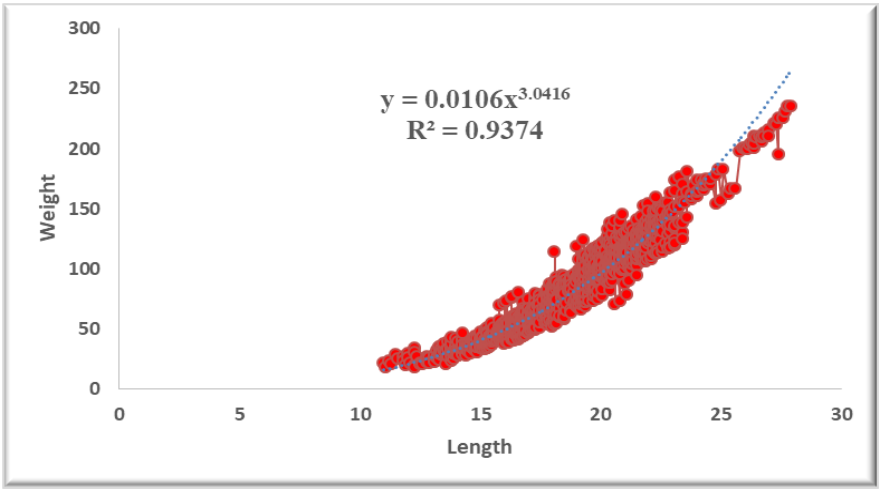

Fig. 2. Length-weight relationship of combined sexes of *Pagellus erythrinus* during 2021

Age determination

In this study, four age groups of *P. erythrinus* (common pandora) were determined from the length frequencies using the **Bhattacharya (1967)** method (Table 1). The average lengths at age for both sexes combined were 15.48cm (I+), 20.30cm (II+), 23.5cm (III+), and 25.5cm (IV+) (Fig. 3).

Table 1. Decomposition of composite distributions using Bhattacharya's method

Age groups	Computed mean length	S.D.	Population	S.I.
1	**15.84**	**1.820**	**759**	**n.a.**
2	**20.3**	**1450**	**701**	**2.730**
3	**23.5**	**1.980**	**33**	**1.870**
4	**25.5**	**2.270**	**19**	**0.940**

Growth in weight

In this study, the average weights of *P. erythrinus* (sexes combined) were 47.26, 100.50, 156.87, and 201.11g for age groups (I+), (II+), (III+), and (IV+), respectively (Fig. 4). Moreover, the annual weight increments from the first to the fourth year were 47.26, 53.25, 56.37, and 44.24 g, respectively (Fig. 4).

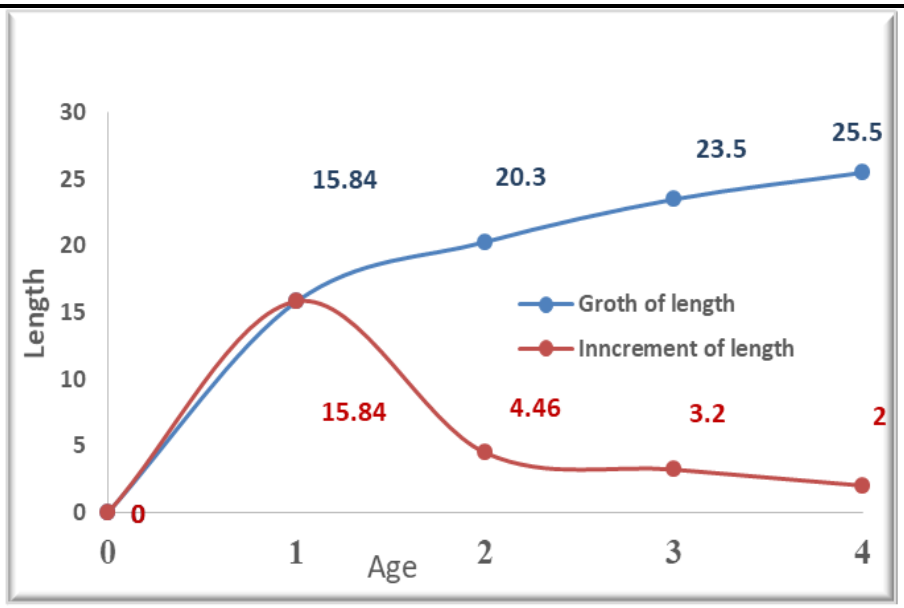

Fig. 3. Growth and annual increment in length of combined sexes of *P. erythrinus* during 2021

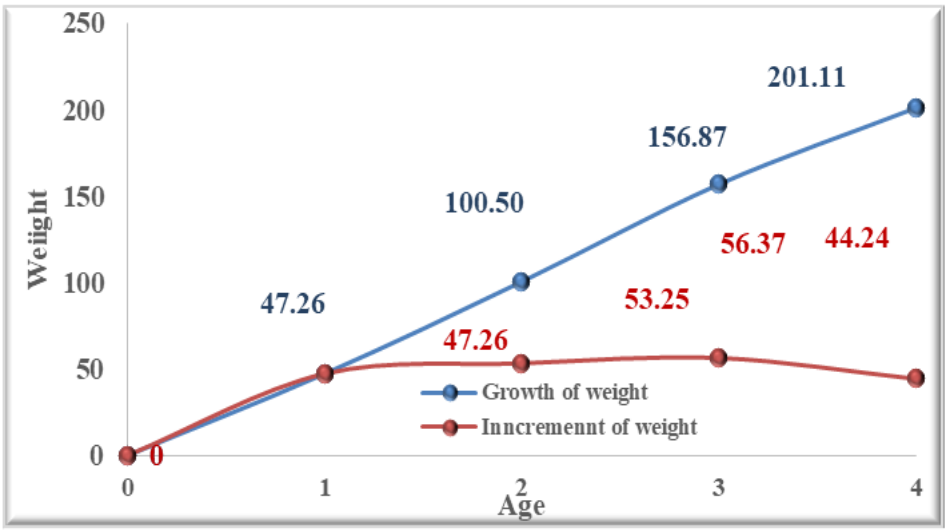

Fig. 4. Growth and annual increment of weight at the end of different years of life combined sexes of *P. erythrinus* during 2021

Growth parameters

The L∞, K, t0, and W∞ values obtained by Bhattacharya for *P. erythrinus* were 29.98cm, 0.3838, -0.9580, and 329.2g for combined sexes, respectively. The L∞, K, t0, and W∞ values obtained by ELEFAN for *P. erythrinus* were 28.35cm, 0.72, -0.13625, and 277.6g for combined sexes, respectively (Table 2).

Table 2. Constant of von Bertlanffy equation of combined sexes of *P. erythrinus* during 2021

Sexes	Constants of Von Bertlanffy	Bhattacharya Method	ELEFAN Method
Combined sexes	L∞	**29.98**	**28.35**
	K	**0.3838**	**0.72**
	To	**-0.9580**	**-0.13625**
	W∞	**329.2**	**277.6**

Growth performance index

The growth performance index was calculated from the data obtained using Bhattacharya's method. Based on length data, the index was 2.538, and based on weight data, it was 1.262. Similarly, the growth performance index was calculated from the data obtained using ELEFAN. Based on length data, the index was 2.762, and based on weight data, it was 1.486.

Mortality

Total mortality "Z"

In this study, the total mortality (Z) for combined sexes of *P. erythrinus* during the 2021 season was found to be 1.92 year^{-1}, natural mortality (M) was 0.58 year^{-1}, fishing mortality (F) was 1.34 year^{-1}, and the exploitation rate (E) was 0.70, based on the growth parameters obtained using the Bhattacharya method. Total mortality (Z), natural mortality (M), fishing mortality (F), and exploitation rate (E) are shown in Fig. (5).

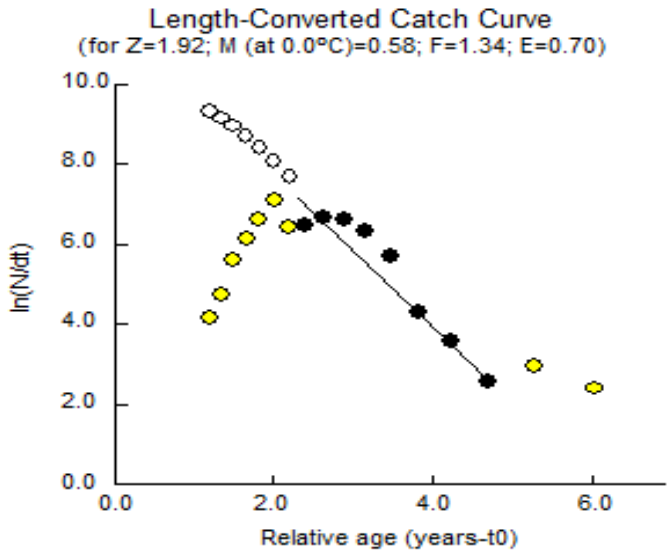

Fig. 5. Mortality rates and exploitation rate of *P. erythrinus* during 2021

Length at first capture (L_c)

The length at first capture (Lc) for combined sexes of *P. erythrinus*, based on the growth parameters obtained from the Bhattacharya method, was 16.79cm (Fig. 6 & Table 4).

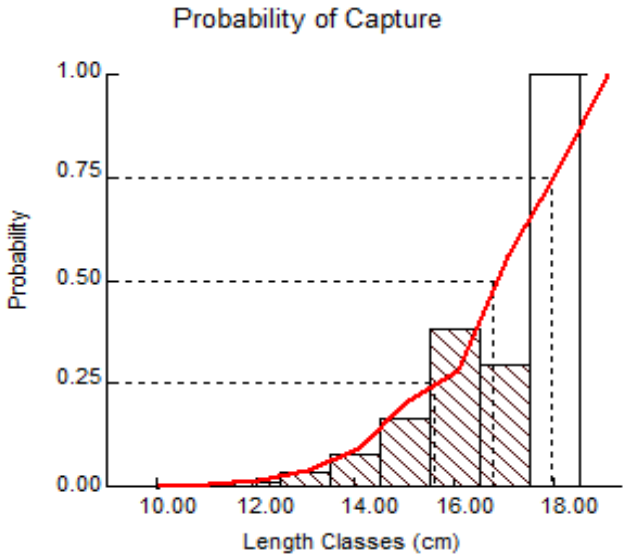

Fig. 6. Length at first capture (L_c) of combined sexes of *P. erythrinus*

Relative yield per recruit

In Fig. (7), the maximum yield per recruit (Emax), representing the highest level of exploitation that generates the maximum sustainable yield, was 0.802. The level of

exploitation at which 50% of the fish's biomass would be maintained (E0.5) was 0.381, and the level of exploitation for economic yield (E0.1) was 0.706. Table (3) provides the data necessary to calculate the maximum, optimal, and economic exploitation levels.

Table 3. LC, M, L∞, K , $E_{.5}$ LC/L∞ and M/K of *P. erythrinus*

Growth parameters	M	LC	L∞	K	M/K	Lc/L∞	E-10	E- 50	E-max
Bhattacharya	0.58	16.79	29.98	0.38	1.5	0.56	0.706	0.381	0.802

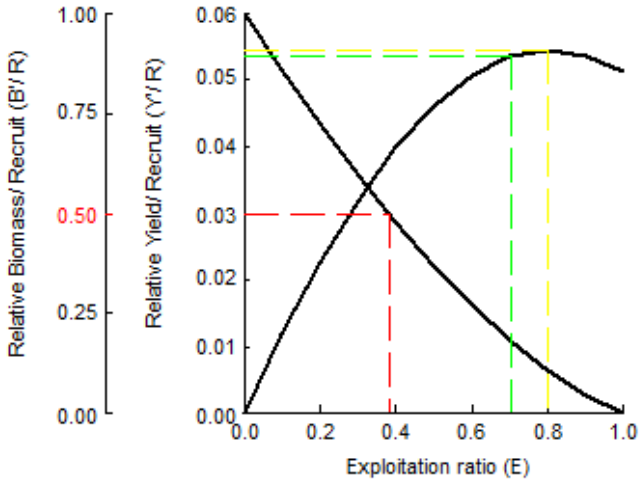

Fig. 7. Relative yield per recruit of *P. erythrinus* using the growth parameters obtained from Bhattachary method

DISCUSSION

In this study, the sizes of all individuals ranged from 11.0 to 27.9cm total length and 17.7 to 235.4g total weight. Our results largely agree with those of previous studies, with slight variations in size range. For example, **Lteif *et al.* (2021)** reported sizes from 7.5 to 40.0cm along the Lebanese coast in the Eastern Mediterranean, while **Taylan and Yapici (2021)** found sizes ranging from 10.2 to 28.5cm in Marmaris Bay. **Ayyidiz *et al.* (2019)** reported sizes from 18.5 to 34.5cm in the northern part of Gökçeada Island, Turkey, and **Fassatoui *et al.* (2019)** found sizes from 14.0 to 27.0cm in northern and southern Tunisia. **Mahdi *et al.* (2018)** observed sizes from 12 to 38.0cm in Oran Bay (Algerian West Coast), while **Saleh (2018)** recorded sizes from 16 to 28.0cm in Telmatha Coast, Eastern Benghazi, Libya. **Busalacchi *et al.* (2014)** reported sizes ranging from 5.5 to 48.0 cm in the Central Mediterranean, and **Metin *et al.* (2011)** found sizes from 4.1 to

27.8cm in the Aegean Sea. **Mehanna and Fattouh (2009)** observed sizes from 6 to 30.0cm in Mediterranean waters of Egypt, and **Coelho *et al.* (2010)** reported sizes from 12 to 44.8cm in coastal Southern Portugal. **Hoşsucu and Cakir (2003)** recorded sizes from 7.0 to 22.8cm in Edremit Bay, Turkey. The differences in these results are likely due to environmental factors, and small fish were rarely represented in the whole sample.

In this study, the length - weight relationship of combined sexes was W = 0.0106 L $^{3.0416}$ (r2 = 0.9374). The value of 'b' in the present study of the common pandora *P. erythrinus* was approximately equal to 3. These results show that the relationship is isometric. The differences in the 'b' values presented in Table (4) may be attributed to variations in the sample size, the season of collection, and the sampling method.

Table 4. Length-weight relationships of *Pagellus erythrinus* in different regions

Length-weight relationship	Area	Author
W = 0.0209 **L** $^{2.84}$	North Aegean Sea	**Cengiz (2013)**
W = 0.016 **L** $^{2.905}$	Southern Tyrrhenian	**Busalacchi *et al* (2014)**
W = 0.0137 **L** $^{2.9600}$	Aegean Sea, Gökova Bay	**Yapıcı & Filiz (2019)**
W = 0.017 **L** $^{2.912}$	Lebanese marine waters	**Lteif *et al* (2021)**
W = 0.0106 $^{L3.0416}$	North Sinai Egypt	**Present study**
W = 0.019 **L** $^{3.00}$	Aegean Sea, Izmir Bay	**Özaydın *et al*. (2007**
W = 0.0109 **L** $^{3.030}$	Mediterranean Sea, Tunisia	**Ghailen *et al.* (2010)**
W = 0.0062 **L** $^{3.2581}$	Northern Aegean Sea	**Kale,*et al* 2021**
W = 0.0090 **L** $^{3.2180}$	North Aegean Sea, Gökçeada Island	**Altin *et al.* (2015)**
W = 0.0096 **L** $^{3.1180}$	Mediterranean Sea, Egypt	**Mehanna & Farouk (2021)**
W = 0.0062 **L** $^{3.2581}$	North Aegean Sea, Gökçeada Islan	**Kale *et al* (2021))**
W = 0.0106 **L** $^{3.0416}$	Mediterranean, North Sinai Egypt	**Present study**

The growth parameters of *P. erythrinus* in our study, based on the Bhattacharya method, were L∞ = 29.98cm, K = 0.3838, t0 = -0.9580, and W∞ = 329.2g for combined sexes. Using the ELEFAN method, the growth parameters were L∞ = 28.35cm, K = 0.72, t0 = -0.13625, and W∞ = 277.6g for combined sexes. Table (5) shows the differences in the von Bertalanffy growth equation constants between our results and those from other regions.

In the present study, the exploitation rate (E) suggests that the stock of common pandora in the Mediterranean Sea is overexploited, in contrast to findings in the Adriatic Sea, where common pandora is not overexploited **(Hossucu & Cakır, 2003)**. To maintain the stock of *P. erythrinus*, the current exploitation rate of 0.7 should be reduced to 0.381 (a 45% decrease), and the length at first capture should be increased. According to **Gulland (1971)**, to optimally exploit fish resources, the exploitation rate should be 0.5, at which the natural mortality rate equals the fishing mortality rate (F = M). To protect the stock of *P. erythrinus*, the exploitation rate should not exceed 0.381, meaning the current rate of 0.7 must be reduced by 45%.

Table 5. Growth parameters for *P. erythrinus* in different areas

L∞	K	T0	φ	Locality	Authors
47.1	0.08	--4.42	2.25	Portugal	**Erzini *et al.* (2001)**
27.8	0.32	-0.74	2.40	Cretan Shelf	**Somarakis and Machias (2002)**
24.0	0.16	-2.6	1.96	Edremit Bay	**Hossucu and Cakır (2003)**
33.4	0.37	-0.23	2.62	Egyptian Medit.	**Mehanna and Fattouh (2009)**
54.3	0.12	-1.12	2.54	Tyrrhenian Sea	**Abella *et al*. (2010)**
47.1	0.084	-4.42		Southern Portugal	**Coelho *et al*. (2010)**
40.1	0.17	0.75	2.44	South Levant Sea	**ElHaweet *et al*. (2011)**
40.0	0.18	--1.00	2.45	Sicilian Channel	**Fiorentino *et al.* (2012)**
51.1	0.061	-4.96		Aegean Sea	**Ayyidiz *et al.* (2019)**
34.1	0.153	-1.922	2.25	Northern Tunisia	**Fassatoui *et al.* (2019)**
28.02	0.150	-3.961	2.07	southern Tunisia	**Fassatoui *et al.* (2019)**
29.98	0.38	-0.958	2.538	North Sinai Egypt	**Present study**

CONCLUSION

The relationship between length and weight for the common pandora (*Pagellus erythrinus*) on the Mediterranean coast of Sinai indicates an isometric growth. Four age groups were recorded in this study. To manage this resource sustainably, the current exploitation rate needs to be reduced by 45% of its present value.

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