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Some biological aspects and population status of the bogue, *Boops boops* (Linnaeus, 1758) (Teleostei: Sparidae) caught by gillnets from the Egyptian Mediterranean waters off Alexandria

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ABSTRACT

The study of fishery biology and population dynamics was conducted for *Boops boops* collected from the commercial catches of gillnets operated in the Egyptian Mediterranean waters off Alexandria. A total of 880 specimens were sampled from the area between Sidi Kirayr to El-Montazah during the period 2018-2020. The length range varied between 11.0 and 20.0 cm TL with a mean of 13.98±1.19 cm and the total weight varied from 14 to 88 g with a mean total weight of 28.51±6.67 g. The length-weight relationship was computed as $W= 0.0119\ L^{2.9453}$ by using total weights and $W= 0.0112\ L^{2.9335}$ by using gutted weights. The mean condition factor (k) was 0.953±0.029 and the overall sex ratio (M: F) was 1.00:0.49. The von Bertalanffy growth parameters were estimated to be $K= 0.38\ yr^{-1}$, $L_\infty= 27.85$ cm and $t_o= -0.443$ yr. The growth performance index (Φ`) was 2.47. The values of natural (M), fishing (F) and total mortality (Z) were calculated as 0.865, 3.845 and 4.710 yr^{-1}, respectively. The current exploitation ratio ($E_{cur}= 0.816$) is high reflecting the high exploitation of this species. The yield per recruit and the relative yield per recruit were also studied and the results confirmed that the stock of *B. boops* is highly exploited and the management of the pelagic gillnets is required

INTRODUCTION

The genus *Boops* is belonging to family Sparidae **(Froese & Pauly 2021)**. This genus is represented worldwide by two species: *Boops boops* (Linnaeus, 1758) and *Boops lineatus* (Boulenger, 1892). Bogue, *B. boops* inhabits the eastern Atlantic, from Norway to Angola **(Bauchot & Hureau, 1990)** and the whole Mediterranean Sea, including the Black Sea **(Froese & Pauly, 2021)**. It is a demersal, semi-pelagic or pelagic species living on various kinds of bottoms (sand, mud, rocks, and seaweeds) to about 350 m depth and it is more abundant in the upper 100 m and sometimes in coastal water

(Whitehead *et al.*, 1986). It moves in groups and ascending to the surface at night **(Bauchot, 1987)**. It caught by bottom trawls, purse seines, beach seines, gillnets and trammel nets **(Whitehead *et al.*, 1986)**. The largest *B. boops* in the Mediterranean Sea (40.2 cm, 986 g) was caught at 55 m depth in Turkish waters **(Ceyhan *et al.*, 2018)**.

The production information of *B. boops* is inaccurate in the Egyptian Mediterranean waters. There are two fish species, bogue *B. boops* and picarel *Spicara smaris*, most similar ecologically or taxonomically **(Untunen *et al.*, 2014)** and have the same local name as "Mouza" in Egypt, consequently they are including under the same name in the statistical year book of the General Authority for Fish Resources Development (GAFRD). According to **GAFRD (2020)**, there are continuous decreasing in the productions of *B. boops* and *S. smaris* from 2013 (4202 ton per year) to 2020 (1022 ton per year) in the Egyptian Mediterranean waters. Not only the production of *B. boops* decreased but also the Egyptian capture fisheries from natural resources undergoes gradually decreasing in the last 20 years **(Mehanna, 2022)**. Sparidae is the most dominant teleost family observed in commercial landing sites of the Egyptian Mediterranean coast **(Mehanna & Farouk, 2021; Ragheb *et al.*, 2022)**. On the other hand, *B. boops* is the most abundant species in the local markets at Alexandria. *B. boops* is considered as the commercial target species of pelagic gillnets operated in Alexandria (Egyptian Mediterranean) and is represented as 36.90% and 36.45% by number and weight of the pelagic gillnet catches **(Ragheb *et al.*, 2022)**.

According to our best Knowledge for the last 20 years, many studies were conducted on Bogue biology and/or fishery in the Mediterranean waters: in Spain **(Valle *et al.*, 2003)**, in Greece **(Moutopoulos & Stergio, 2002)**, in Turkey **(Kara & Bayhan 2015; Soykan *et al.*, 2015; Cengiz, 2022)**, in Tunis **(Ghailen *et al.*, 2010)** and in Algeria **(Rachid *et al.*, 2014; Kherraz *et al.*, 2016; Dahel *et al.*, 2019)**.

In the Egyptian Mediterranean waters of Alexandria there are no study estimated the biology and/or fishery of *B. boops* population caught by the gillnet where **Abdallah (2002)** studied *B. boops* caught by trawl, **Allam (2003)** studied *B. boops* from the commercial catch of purse seine net, **El- Haweet *et al.* (2005)** investigated the species caught by trawl and purse seine, **Mehanna (2014)** from the trawling and **El-Okda (2008)** and **Azab *et al.* (2019)** from the total commercial catch. So, the present study aimed to add knowledge on the fishery biology and population dynamics of *B. boops* caught by gillnets in the Egyptian Mediterranean waters off Alexandria and hope adding a useful knowledge for its fisheries managements.

MATERIALS AND METHODS

During conducting the plan work carried by National Institute of Oceanography and fisheries, (NIOF), Egypt about the gillnet fisheries in the Egyptian Mediterranean waters of Alexandria, random monthly fresh samples of *B. boops* were collected from the commercial catch of gillnets operated along the coast from Sidi Kirayr (31^{o} 17' 04" N 30^{o} 00' 18" E) to El-Montazah (31^{o} 02' 03" N 29^{o} 36' 27" E) at periods from February 2018 to June 2018 and from December 2019 to November 2020. Total of 880 specimens (25.1 kg) were examined. They were mainly caught by pelagic gillnets that operate at sea surface level and have mesh numbers from 28, 32, 33, 34, 35 to 36 meshes in a half meter length and only 45 specimens out of the total collected specimens were caught by

demersal gillnets of mesh numbers 17, 18, 20, 22, 23, 25, 26 meshes in a half meter length.

In the laboratory, each specimen of *B. boops* was measured for the total length (L) in cm, the total weight (W) in g, the gutted weight (GW) in g, and then the sex was recorded. The L-W relationship was computed as the equation: $\mathbf{W = aL^b}$ where W= total weight or gutted weight of the fish (g), L = total length (cm) and a & b are constants and GW (g) was used for biological studies and W (g) for fisheries studies. GW was used to avoid the bias of gonads and stomach weights and therefore, the L-W relationship based on GW was most practical for biological studies. Biley's *t*-test was conducted to test the value of "b" from the expected value of 3 as: t = b-3/Sb **(Snedecor & Cochran, 1967)** where b is the regression coefficient and Sb is the standard error of (b). The condition factor $\mathbf{(k)=100*W/L^3}$ **(Le Cren, 1951)** where W= GW in gram, L= total length in cm.

The length frequencies data were analyzed using the FiSAT computer program Version 1.2.2 **(Gayanilo *et al.*, 2005)**. Shepherd's method was used to estimate the asymptotic length ($L\infty$) and growth coefficient (K). The theoretical age at which the length is zero (t_o) was determined from the equation of **Pauly (1983)** as: $\mathbf{\log(-t_o) = -0.3922 - 0.2752 \log(L\infty) - 1.038 \log(K)}$.

The von Bertalanffy growth equations for length and weight were determined as: $\mathbf{L_t=L_\infty[1-e^{-K(t-to)}]}$ and $\mathbf{W_t= W_\infty[1-e^{-K(t-to)}]^b}$, respectively. The growth performance index (Φ`) was estimated according to the equation of **Moreau *et al.* (1986)** as: $\mathbf{\Phi` = LogK+2Log\ L_\infty}$.

Mortalities were also estimated where the total mortality rate (Z) calculated from the linearized catch curve **(Pauly, 1983)**, the natural mortality **(M) = -0.0152 – 0.279 Ln L∞ + 0.6543 Ln K + 0.463 Ln T (Pauly, 1980)** where T is the annual mean water temperature (T = 22^{o}C in the present study). The fishing mortality (F) was computed as Z – M, while the exploitation ratio (E) was calculated from the equation **E = F / Z (Gulland, 1971).**

The length at first capture L_c was determined using the probability of capture **(Pauly, 1984),** while the length at recruitment L_r was considered as the smallest length in the catch. By using the von Bertalanffy growth parameters, the age at first capture (t_c), and the age at recruitment (t_r) were obtained as: $\mathbf{t_c = -1/K \ln(1- L_c / L_\infty) + t_o}$ and $\mathbf{t_r = -1/K \ln(1- L_r/L_\infty)+t_o}$.

The yield per recruit (Y/R) was calculated according to **Beverton & Holt (1957)** and the relative yield per recruit (Y/R`) was calculated according to the modified model of **Beverton & Holt (1966)** as described by **Pauly & Soriano (1986)**. The biomass per recruit (B/R) was calculated according to **Ricker (1975)** as **B/R = (Y/R)/F**.

RESULTS

Length distribution and growth patterns of *B. boops*

A sample of 25.1 kg composed of 880 specimens *B. boops* were collected by gillnets in the present study during the periods from Feberuary 2018 to June 2018 and from December 2019 to November 2020. No *B. boops* specimens were found in the catch of gillnets during February and March 2018 and 2020. The catch was found to be ranged

from 11 to 20 cm in total length with a mean length of 13.98±1.194 cm. The length groups from 13 - 15 cm represented the majority of the catch (83.07%), while the other length groups constitute small amount of the catch. The percentage frequency distributions of *B. boops* during the present study were given in **Table (1)**. On the other hand, the total weight of the collected specimens varied from 14 to 88 g with a mean total weight of 28.51±6.673 g **(Table, 1)**.

The length-weight relationship was described by power equation as: $W= 0.0119 L^{2.9453}$ ($R^2= 0.994$) by using total weights and $W= 0.0112 L^{2.9335}$ ($R^2= 0.991$) by using gutted weights **(Fig. 1)**. The "b" values by using total and gutted weights revealed tendency towards isometric growth and the insignificant value of Biley's *t*-test confirmed the isometric growth for *B. boops*. The observed and calculated total and gutted weights of *B. boops* for the different lengths were shown in **Table (1)**.

The values of condition factor (k) depending on the gutted weight and according to length groups of *B. boops* were fluctuated between 0.8402 and 0.9890 with a mean value of 0.9532 ± 0.0293 **(Table, 1)**.

Table (1): Percentage frequency distribution, observed and calculated total and gutted weights, the condition factor (k) and the sex ratio (M:F) of *B. boops* from the catch of gill nets from the Egyptian Mediterranean waters off Alexandria (n= 880)

TL (cm)	N	N%	W (g)	Cal. W	GW (g)	Cal. GW	k	Number of		Sex ratio
								unsexed	sexed	M : F
11	23	2.61	14.26	13.89	12.83	12.71	0.9639	21	2	1.00: 0.00
12	51	5.80	18.21	17.95	16.38	16.41	0.9479	33	18	1.00: 0.50
13	213	24.20	23.20	22.72	20.78	20.75	0.9458	55	158	1.00: 0.45
14	321	36.48	28.40	28.26	26.14	25.79	0.9526	83	238	1.00:0.53
15	197	22.39	33.49	34.63	33.38	31.57	0.989	52	145	1.00: 0.47
16	58	6.59	39.32	41.88	35.45	38.15	0.8655	17	41	1.00: 0.32
17	13	1.48	48.44	50.07	47.26	45.58	0.9619	-	13	1.00:1.25
18	3	0.34	58.67	59.25	49.00	53.90	0.8402	1	2	1.00:1.00
19	-	-	-	69.48	-	63.16	-	-	-	-
20	1	0.11	88.00	80.81	79.00	73.42	0.9875	-	1	1.00:0.00
Total	880		25086.9					261	619	1 : 0.49
Mean	13.98		28.51		26.61		0.9532			
±SD	1.194		6.673		6.773		0.0293			

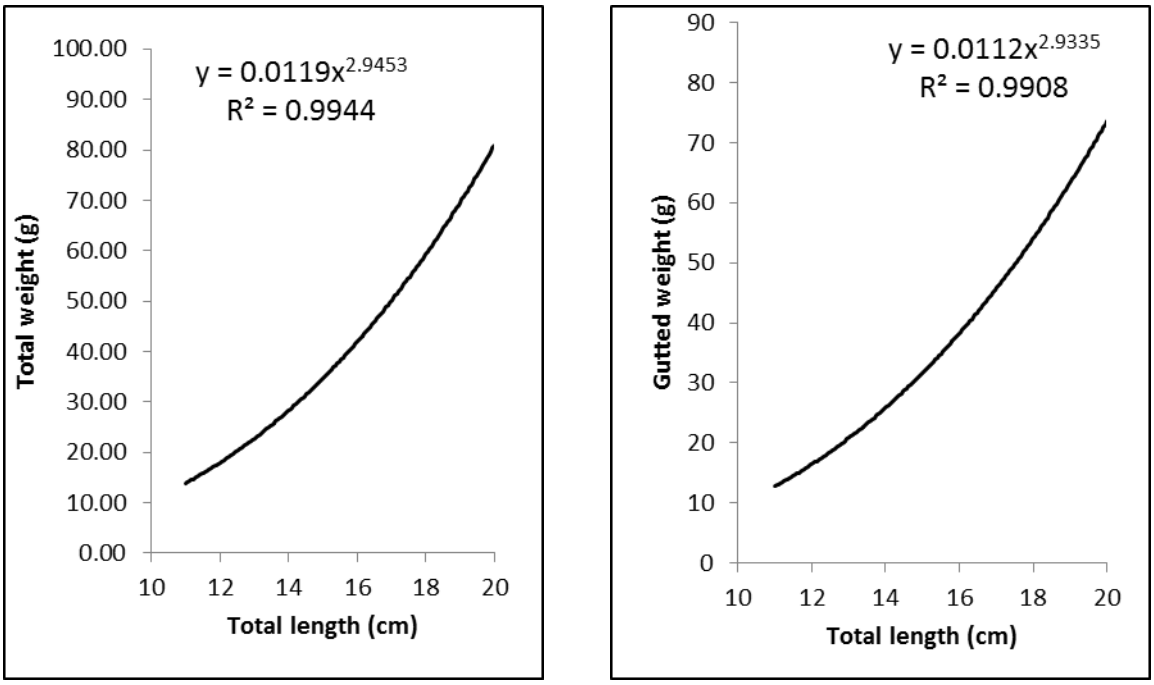

Fig. (1). Length-weight relationship of *B. boops* from the Egyptian Mediterranean waters.

In the present study, about 29.7% of the *B. boops* catches were unsexed and 70.3% are sexed specimens. The overall sex ratio for males to females (M: F) of *B. boops* was found to be 1.00: 0.49 and the chi-square test (χ^2 = 73.865; df = 1; P < 0.01) confirmed the existence of the highly significant difference between the males and female numbers in the population. On the other hand, the sex ratio in the different length groups shown the predominance of females only at 17 cm total length and the length group of 18 cm shown that males to females ratio (M: F) equal to 1:1. The length groups of 11 cm and 20 cm total length were only represented as males.

Depending on the length frequency analysis of *B. boops* population by the Shepherd's method, the von Bertalanffy growth parameters were estimated to be 0.380 yr^{-1} and 27.85 cm for K and L_∞, respectively and the theoretical age (t_o) was computed as -0.443 yr. The von Bertalanffy growth equations for length and weight were as follow: $L_t = 27.85[1 - e^{-0.380(t + 0.443)}]$ and $W_t = 214.00\ [1 - e^{-0.380(t + 0.443)}]^{2.9453}$

The maximum age (t_{max}) of *B. boops* was estimated to be 7.89 yrs. The Pauly's growth performance index (Φ`) depending on von Bertalanffy growth parameters K and L_∞ was 2.47.

Mortalities estimation and population parameters

The vital parameters such as mortalities, exploitation ratio and yield or relative yield per recruit are essential for assessing the stock. From the slop of catch curve **(Fig. 2)**, the total mortality (Z) of *B. boops* was showed as 4.710 yr^{-1} and the values of natural mortality (M) and fishing mortality (F) were calculated as 0.865yr^{-1} and 3.845 yr^{-1},

respectively **(Table, 2)**. The ratio of M/K was estimated as 2.276. The value of exploitation ratio (E) in the present study was 0.816.

The obtained value of length at recruitment (L_r), the smallest length at which the fish enters the fishing ground by using gillnets, was 11.00 cm and the corresponding value of age at recruitment (t_r) was 0.879 yr. Length at first capture (L_c), the length at which the fish may become vulnerable to fishing gears, value was 13.47 cm **(Fig. 3)**, and the corresponding age at first capture (t_c) which marks the beginning of the exploited phase was 1.30 yr. The ratio L_c/L_∞ was estimated as 0.484.

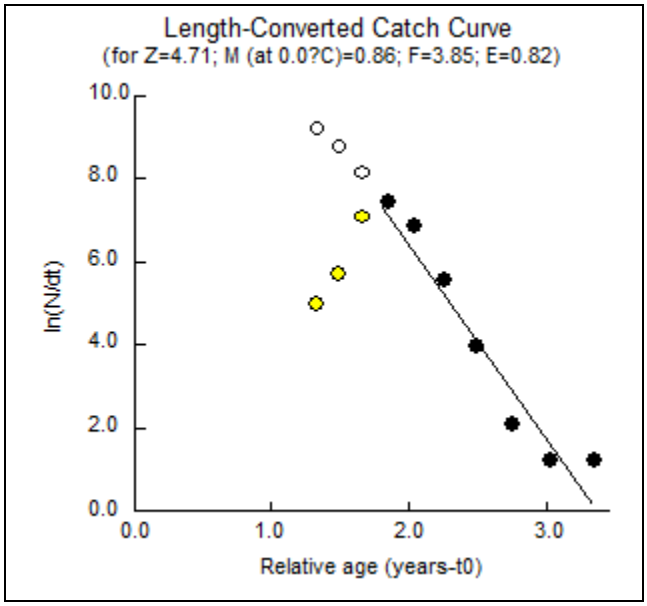

Fig. (2). The length converted catch curve of *B. boops* from the Egyptian Mediterranean waters.

Table (2): Values of population parameters of *B. boops* from the Egyptian Mediterranean waters.

Parameters	Values
Natural mortality (M)	0.865 yr^{-1}
Fishing Mortality (F)	3.845 yr^{-1}
Total Mortality (Z)	4.710 yr^{-1}
Lc (Length at capture)	13.47cm
L_r (Length at recruitment)	11.00 cm
t_c (Age at capture)	1.30 yr
t_r (Age at recruitment)	0.879 yr
S (Survival rate)	0.52
E (Exploitation ratio)	0.816
Y/R (Yield per recruit)	17.6224
Y'/R (Relative Y/R)	0.02621
B/R (Biomass per recruit)	4.5768
BV%	9.14
M/K	2.276
L_c/L_∞	0.484

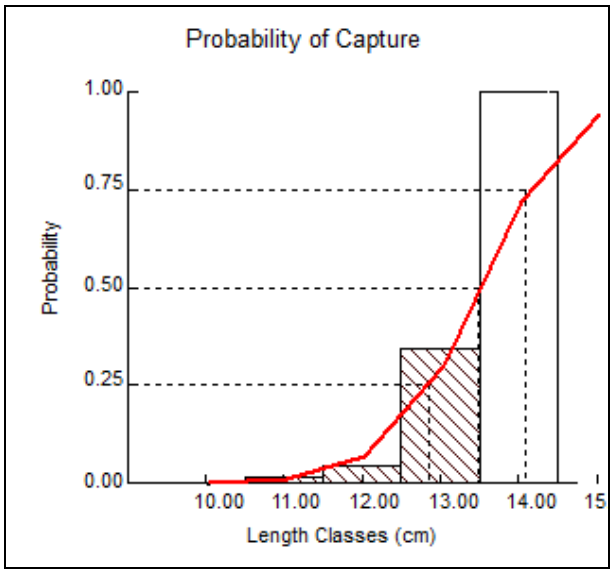

Fig. (3). The length at first capture of *B. boops* from the Egyptian Mediterranean waters

The yield per recruit (Y/R) for *B. boops* was 17.62 g, which corresponds to the current level of fishing mortality (F_{cur}) 3.85 yr^{-1} and the biomass per recruit (B/R) was estimated as 4.58 g **(Fig. 4)**. It is obvious that, the current value of fishing mortality (F_{cur}) is greatly higher than the value of fishing mortality (F_{max}= 0.5) that corresponding to the economic yield per recruit (MEY= 12.41 g) and protect 50% of the *B. boops* stock. **Figure (5)** represented the curve of the relative yield per recruit Y'/R and relative biomass per recruit B'/R of *B. boops* against the exploitation rate (E). From this figure, the maximum Y'/R was found at exploitation rate (E_{max}) = 0.811. The exploitation level which maintains the spawning stock biomass at 50% of the virgin spawning biomass (E_{50}) was estimated at 0.363, while (E_{10}) is equal to 0.652. From these results, we notice that the current value of exploitation ratio (0.816) is higher than that of $E_{max,}$ $E_{0.5}$ and E_{10}. At the current exploitation rate, only 9.14% of stock biomass is protected which reflect an overexploitation state and management is required.

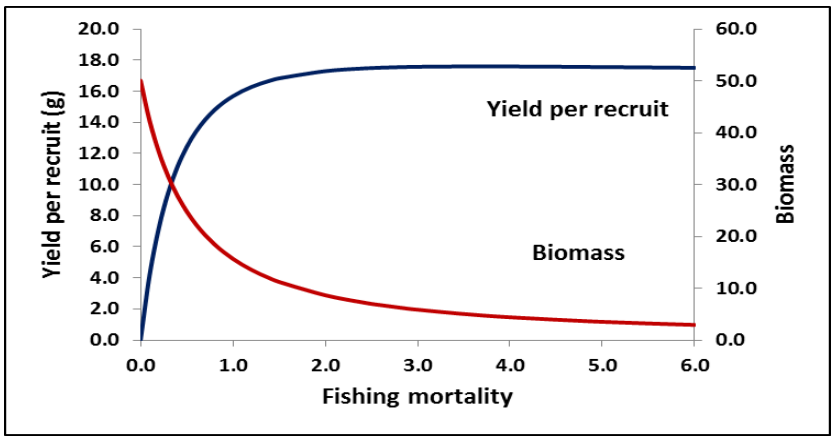

Fig. (4). Yield per recruit, biomass per recruit of *B. boops* in the Egyptian Mediterranean waters.

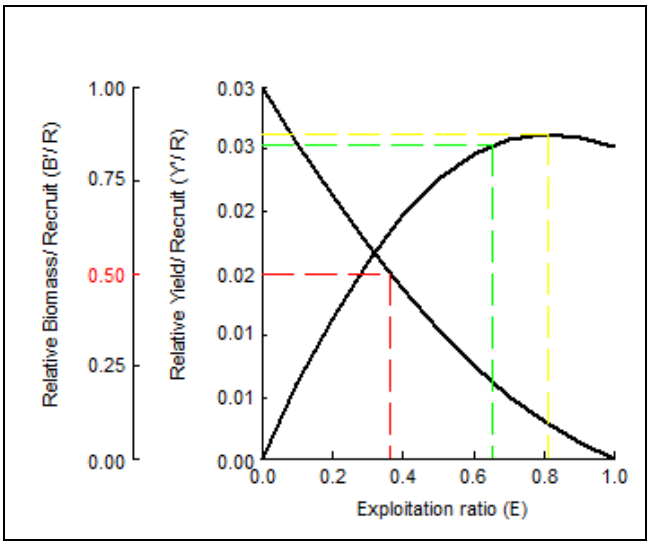

Fig. (5). Relative yield per recruit and relative biomass per recruit at the different exploitation rates.

DISCUSSION

The fishery biology studies of *B. boops* are required for a better understanding of the Egyptian Mediterranean *B. boops* stocks' of Alexandria and to make better management decisions. The length-weight relationship is one of the most important biological characters of fishes where weight of the fish increases as a function of its length. From **Table (3)**, the value of exponent (b) of the length-weight relationship for *B. boops* in different localities was found to be varied between 2.66 and 3.42, reporting different patterns of growth: isometric growth pattern (b =3), negative allometric growth pattern (b < 3) or positive allometry growth pattern (b > 3). In the present study the value of the exponent (b) were found to be 2.945, reflected tendency towards isometric growth and the Biley's *t*-test confirmed the isometric growth for *B. boops*. The regional differences in the obtained (b) values may present spatial variations caused by the influence of water quality or food availability on fish growth **(Sparre *et al.*, 1989; Mommsen, 1998)**.

On the other hand, the relationship of log (a) vs (b) for the length-total weight relationship from the different studies in the Mediterranean was in **Fig. (6)**. Analysis of the result shows a close inverse relationship and predicts that there are similar weights for a given length and this result was agreed with the description of **Ulman *et al.* (2021)** and **Ragheb & Akel (2022)**. According to **Pauly (2019)**, the differences between log (a) vs (b) are due to different sampling periods of the length-weight data at different locations. In our opinion, it may also due to the different sampling methods, as the number of specimens and length ranges of the species belong to distinct regions.

Table (3): Length-weight relationship parameters, von Bertalanffy growth parameters and growth performance index for *B. boops*, as given by different authors in different geographic areas.

Author	Location	Sex	$L\infty$ (cm)	K (yr^{-1})	t_o (yr)	Φ'	t_{max}*	L-Wt. parameters	
								a	b
Abdallah, 2002	Egypt	Whole sample	-	-	-	-	-	0.007	3.13
Moutopoulos & Stergio, 2002	Greece	Whole sample	-	-	-	-	-	0.01467	2.877
Allam, 2003	Egypt	Whole sample	31.68	0.153	-1.78	2.19	19.61	0.007	3.1031
Valle et al., 2003	Spain	Whole sample	-	-	-	-	-	0.0161	2.8121
El- Haweet *et al*., 2005	Egypt	Whole sample	29.7	0.25	-0.7	2.34	12	-	-
Monteiro *et al*., 2006	Portugal	Whole sample	28.06	0.22	-1.42	2.24	13.64	$9.1*10^{-5}$	3.01
El-Okda, 2008	Egypt	Whole sample	30.105	0.151	-1.51	2.14	19.85	0.0254	2.66
Ghailen et al., 2010	Tunisia	Whole sample	-	-	-	-	-	0.0102	3.034
Mehanna, 2014	Egypt	Whole sample	27.24	0.54	-0.33	2.6	5.56	0.0061	3.1529
Rachid *et al*., 2014	Algeria	Whole sample	29.66	0.33	0	2.46	9.09	0.016	2.798
Kara & Bayhan, 2015	Turkey	♂	29.87	0.243	-0.98	2.34	12.35	0.0028	3.42
		♀	30.79	0.239	-0.9	2.36	12.55	0.0069	3.128
		Whole sample	-	-	-	-	-	0.005	3.237
Soykan *et al*., 2015	Turkey	Whole sample	29.58	0.266	-1.14	2.37	11.28	0.005	3.25
Kherraz *et al*., 2016	Algeria	♂	26.78	0.38	-0.75	2.44	7.89	0.013	2.86
		♀	34.13	0.26	-1.5	2.48	11.54	0.012	2.88
Azab *et al*., 2019	Egypt	Whole sample	30.65	0.279	-0.16	2.42	10.75	0.011	2.96
Dahel *et al*., 2019	Algeria	Whole sample	32.03	0.28	-0.58	2.46	10.71	0.016	2.815
Cengiz, 2022	Turkey	Whole sample	27.9	0.21	-1.57	2.21	14.29	0.008	3.13
The present study	Egypt	Whole sample	27.85	0.38	-0.44	2.47	7.89	0.0119	2.9453
Mean (only for Mediterranean whole populations)			**29.5**	**0.28**	**-0.88**	**2.35**	**10.79**		

* t_{max} calculated by the authors as $t_{max} = 3/K$ **(Taylor, 1958)**

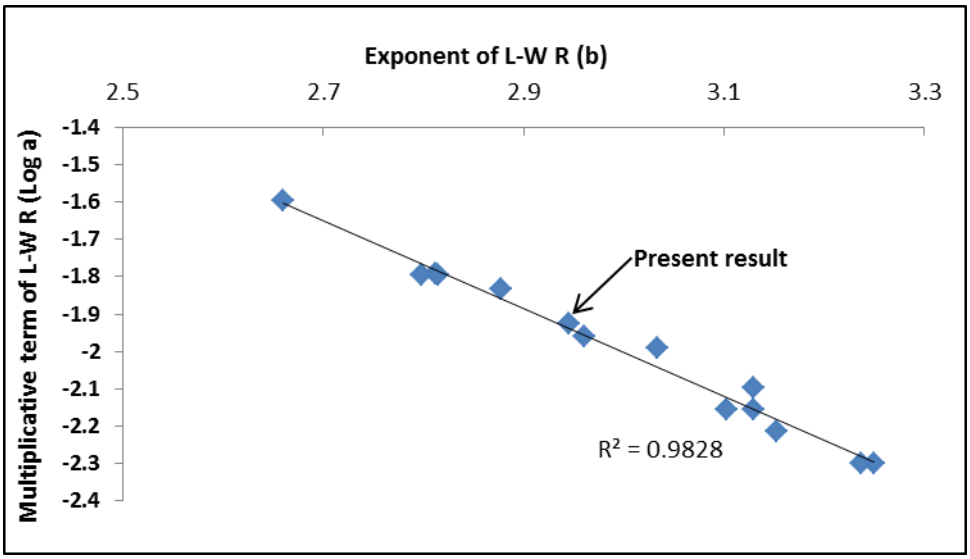

Fig. (6). Relationship between the multiplicative term (a) and the exponent (b) of length-weight relationship for *B. boops*. (Based on the results of different population studies that depend on total length and total weight)

The values of von Bertalanffy growth parameters predict the relation between fish stock assessment and fishery resource management. There are variations of the von Bertalanffy growth parameters for *B. boops* among various geographic localities **(Table, 3)** which may be due to the variations in the environmental conditions as well as sampling techniques and computations **(Hernandez, 1989)**. The mean values of von Bertalanffy growth parameters for the Mediterranean waters populations **(Table, 3)** are $L\infty$ = 29.5 cm, K= 0.28 yr^{-1} and t_o = -0.88 yr. Also, from **Table (3)**, the variation of t_o from -0.156 to -1.78 yr reflect that the growth of *B. boops* did not agree with the von Bertalanffy growth model during the first months of its life and the variations of the growth performance (Φ') from 2.14 to 2.60 (mean = 2.35) for the Mediterranean populations reflect growth rate variations as described by **Moreau *et al.* (1986).** On the other hand, the longevity of fish (t_{max}) which affected by the variations of temperatures **(Wootton, 1990)** was estimated in the present study as 7.89 yrs and it was lower than the mean value of t_{max} (10.79 yrs) for the Mediterranean waters populations. On the other hand, the t_{max} was varied between 19.61 yrs **(Allam, 2003)** to 5.56 yrs **(Mehanna, 2014)** in the Mediterranean waters.

The natural mortality for *B. boops* in the present study (M = 0.865) is slightly larger than that obtained by **Azab *et al.* (2019)** which was M = 0.671, and greatly different from that of **Allam (2003)** which was 0.458, reflecting negative impact of environmental conditions on the *B. boops* stock in the Egyptian Mediterranean coast of Alexandria. On the other hand, the total mortality (Z) and fishing mortality (F) were greatly higher than that obtained by **Azab *et al.* (2019)** and **Allam (2003)**. The increasing in the total and fishing mortalities occurred due to the increasing in fishing efforts and it is explained the continuous decreasing of the *B. boops* catch productions in the Egyptian Mediterranean waters.

The length at first capture (L_c = 13.47 cm) which is corresponding to the mesh size and the percentage of about 29.7% unsexed catch means that more than 29.7% of this species is subjected to fishing gear before they been in sexual identification. Also, the present estimated value of the L_c at t_c = 1.3 yr. reflected great fishing efforts of a great numbers of small fish lengths were caught.

The current exploitation ratio (E_{cur}= 0.816) was greatly more than the optimum exploitation ratio (E) suggested by **Gulland (1971)** to be around 0.5 and that recommended by the General Fisheries Commission for the Mediterranean **(GFCM, 2012)** as E = 0.4. The value of E_{cur} indicated the presence of overexploitation state of *B. boops* in the Egyptian Mediterranean waters and this result was agreed with the result of **Azab *et al.* (2019)**. Also the study of the yield per recruit and relative yield per recruit confirmed the presence of overfishing state and reflected an overexploitation state with only 9.14% of stock biomass is protected. The fishing effort must be decreased and management of pelagic gillnets must be well controlled for sustainable fishery production.

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