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Growth, Mortality and Yield Per Recruit of the Bogue *Boops boops* (Linnaeus, 1758) from the Mediterranean Coast, North Sinai, Egypt

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ABSTRACT

The current study's objectives were to investigate the growth parameters, mortality, and yield per recruit of the bogue fish, *Boops boops* (Linneaus, 1758), in North Sinai, Egypt (Mediterranean coast) from January to December 2022. A total of 868 specimens of the bogue were monthly collected from the main landing site of El Arish Fisheries. The length and weight of the sampled fish ranged from 8.4 to 23.1cm and 6.1 to 138.2g, respectively, with an average total length of 13.57cm and body weight of 29.84g. The length-weight relationship was expressed using the equation $W = 0.0097L^{3.0433}$. The von Bertalanffy growth equations were calculated giving $L\infty$ = 24.15cm, k = 0.34 year^{-1} and t_0 = -1.2916 year. The growth performance index (Φ') was calculated as 2.2973. The length at first capture was estimated to be 11.37cm. The total mortality rate, natural mortality rate, fishing mortality rate and exploitation rate were 2.19 year^{-1}, 0.86 year^{-1}, 1.33 year^{-1} and 0.61 year^{-1}, respectively. The relative yield per recruit analysis (Y'/R) revealed that the current level of exploitation is much higher than $E_{0.5}$ (0.362), indicating that the population is overexploited and subject to fishing pressure. To ensure sustainable management of this resource, the existing extraction rate should be reduced by 40% (*i.e.* from 0.610 to 0.362).

INTRODUCTION

The Mediterranean bouge, or bogue, *Boops boops* (Linneaus, 1758), is a commercially significant sea bream belonging to the Sparidae family. It is a pelagic species that can survive up to 350 meters below the surface on a range of habitats, including mud, rocks, seaweed, and sand. The output of *B. boops* and *Spicara smaris* in the Mediterranean Sea of Egypt has steadily declined, from 4202 tons annually in 2013 to 1022 tons annually in 2020, according to **GAFRD (2020)**. Over the past 20 years, not only has the productivity of *B. boops* decreased but also the Egyptian catch fisheries from natural resources **(Mehanna, 2022)**. *B. boops* inhabits the Mediterranean Sea including the Black Sea, and the eastern Atlantic, which stretches from Norway to Angola **(Bauchot & Hureau, 1986; FishBase, 2018)**. The length-weight relationship (LWR) in fish is described by the power function W = aLb, where W stands for weight, L for length, and the species-specific parameters of the function, a and b, can be computed using regression analysis **(Le Cren, 1951)**. The life stage, gender, nutritional state, season, and location all have an impact on the LWR, which is connected to fish condition **(Le Cren, 1951; Jennings *et al*., 2001; Froese, 2006)**.

In Egypt's Mediterranean Sea, some research on bogue biology has been conducted **(Allam, 2003; El-Okda, 2008; Mehanna, 2014; Azab *et al*., 2019)**. The current study intends to provide the biological information on the bogue that is required for fisheries development, management, and sustainability in the coastal area of Sinai's Mediterranean coast.

MATERIALS AND METHODS

The study area

From January to December 2022, a total of 868 samples of *B. boops* were monthly collected from main landing site on the Mediterranean coast, North Sinai; (31°09'24.7''N 33°50'25.1''E) (Fig. 1).

Fig. 1. Map of Egypt showing fishing boat landing area on the Mediterranean coast, North Sinai, during the present study (2022)

1. Samples and data collection

Fish samples were transported to the laboratory in an ice box and measured for overall length (0.1cm) and gutted weight (0.1g). Fig. (2) depicts the flowchart for our proposed methodology.

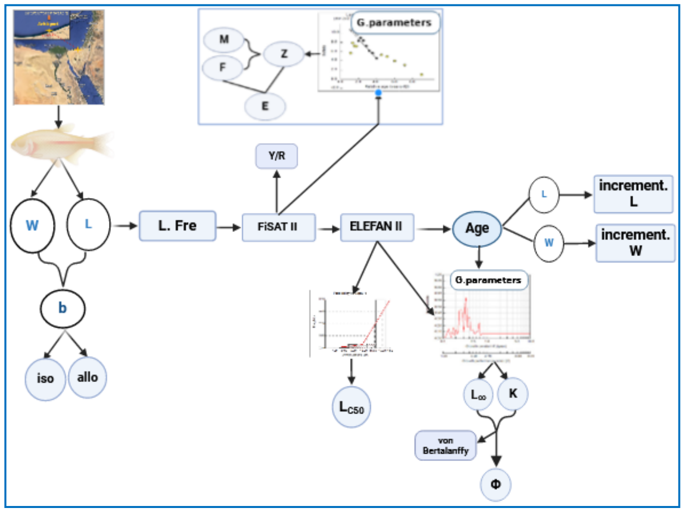

Fig. 2. The flowchart of the current study's methodology

2. Data analysis

2.1. The length frequency

The length frequency data were grouped into 8.4- 23.0cm class intervals and organized into a time series from January to December 2022 for subsequent analysis. In order to account for length frequencies, **Jones and van Zalinge (1981)** updated the virtual population analysis (VPA). The length frequency data analysis was carried out by electronic length frequency analysis (ELEFAN I) following the FiSAT package.

2.2. The length-weight relationship

Samples were weighed (W) recording a 6.1 to 138.2g. The power equation of logarithmic modification, $W = aL^b$, was used to calculate the length-weight relationship of *B. boops* **(Ricker, 1975)**.

2.3. Age group

To identify size groups reflecting age classes in length-frequency data, the method of **Bhattacharya (1967)** was used to facilitate dividing the length frequency data into age groups.

2.4. Growth parameters

The modal class progression analysis **(Gayanilo *et al*., 1988)** in the complete ELEFAN I computer program, which gives growth increments and growth parameters, ($L\infty$ and K) was estimated using the ELEFAN I computer software **(Pauly & David, 1981; Pauly, 1987; Gayanilo *et al*., 1988)**. ELEFAN I was used to fit the best growth curve since it allows the curve to pass over the maximum number of peaks in the length frequency distribution according to **Sparre and Venema (1989)**. This program applies the von Bertalanffy growth function on length data samples **(Beverton & Holt, 1957)**. It has the form: $Lt = L\infty\,[(1 - e^{-k(-L-t_0)})]$. In this case, t_0 is the hypothetical time at which length equals zero; K is the growth coefficient; L_t is the length at a time, and L∞ is the asymptotic length. An empirical equation is used to determine the t_0 value **(Pauly, 1980)**: $Log10\,(-t0) = -0.3922 - 0.2752\,Log10L\infty - 1.038\,Log10K$. The growth performance index (Φ) was utilized to compare this study's growth parameters to those published by other authors for the same species **(Pauly & Munro, 1984)**. This index is expressed as $\Phi = Log\,(K) + 2 * Log\,(L\infty)$, where K is the growth coefficient, and L_∞ is the asymptotic length.

2.5. Mortalities and exploitation rates

Mortality rates

2.5.1. Total mortality "Z"

The total mortality is computed using the length-converted catch curve **(Pauly, 1984)**.

2.5.2. Nature mortality "M"

The nature mortality (M) was calculated using Pauly's empirical equations, which are as follows: $ln(M) = -0.0152 - 0.279\,ln(L\infty) + 0.6543\,ln(K) + 0.463\,ln(T)$.

2.5.3. Fishing mortality "F"

The formula $F = Z - M$ was used to calculate fishing mortality (F).

2.5.4. Exploitation rates "E"

The rate of exploitation was estimated using the formula provided by **Cushing (1968)** (E):

$$E = F/Z.$$

2.6. Length at first capture (*LC_{50}*)

ELEFAN II, following **Pauly (1984)**, was used to create a selection algorithm based on the probability of capture by length extrapolation of the length-converted catch curve.

2.7. Relative yield per recruit "Y/R"

The knife-edge selection model **(Beverton & Holt, 1966)** was used to predict yield, relative yield, biomass, and relative biomass-per-recruit. FISAT II software was used for figures, calculations, and statistical operations. The data were assessed using the FiSAT II program (FAO-ICLARM Stock Assessment Tools) according to **Gayanilo *et al.* (2003)**.

2.8. Ethical Approval

All fish were subjected to the general protocol standards for the Care and Use of Laboratory Animals, which were approved by Arish University's Animal Care and Ethical Committee (No: #ARU/ Agri.24#).

RESULTS

Length frequency

Along the Mediterranean coast of North Sinai, Egypt, the length frequency distribution of 868 *B. boops* was used to estimate the fishing mortality, which was found to be 1.33 per year. Using these mortality values, the exploitation rate was estimated at 0.61 per year. The fish lengths ranged from 8.4 to 23.0cm, with predominant lengths between 9.0 and 17.9cm, constituting approximately 93.9% of the total bogue caught (Fig. 3).

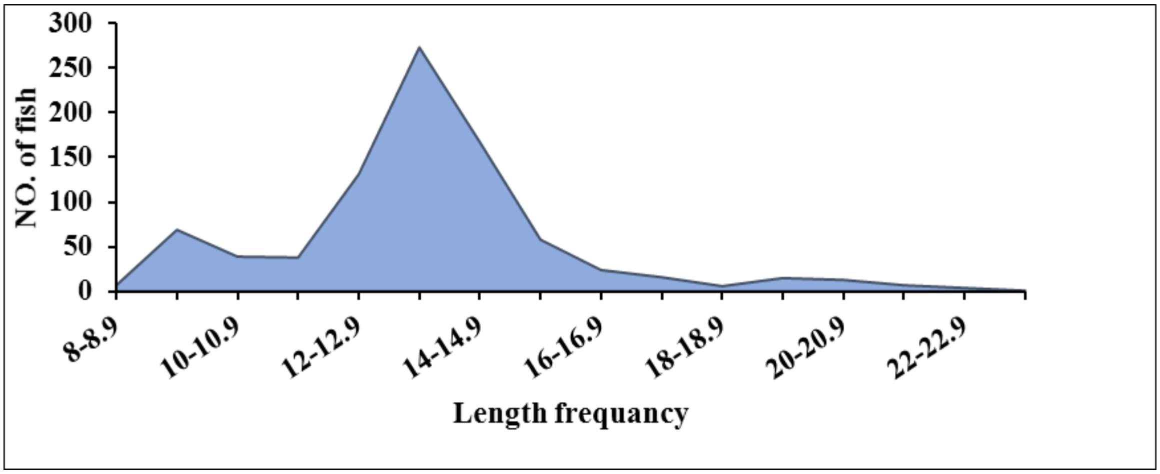

Fig. 3. Length frequency of *B. boops* off the Mediterranean coast, North Sinai, Egypt during fishing season (2022)

Length-weight relationship

According to estimates made during the fishing season of 2022, the length-weight relationship of *B. boops* on the Mediterranean coast of North Sinai, Egypt, (Fig. 4) was $W = 0.0097L^{3.0448}$, ($r^2 = 0.9595$).

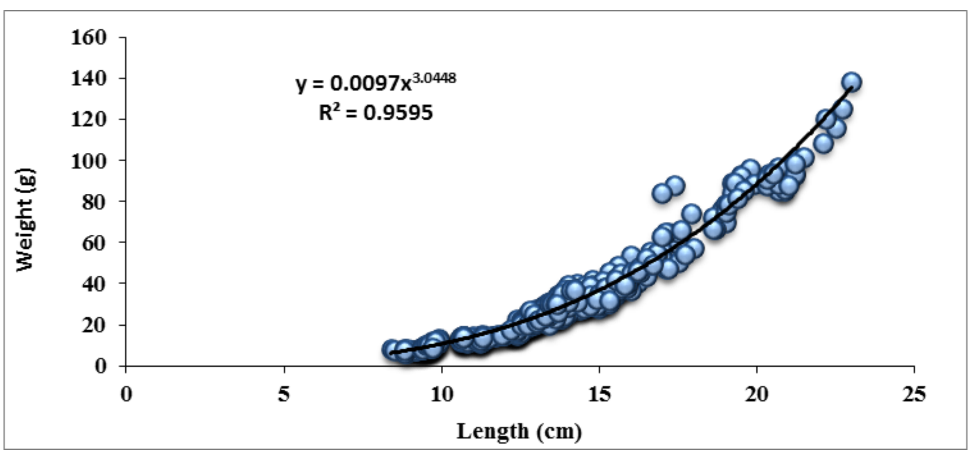

Fig. 4. Length-weight relationship for *B. boops* during the fishing season of 2022

Growth parameters

Using the FiSAT II software and length frequencies, five age groups were identified in *B. boops* for the current study, as explained by **Bhattacharya (1967)**. The age group (I+) accounted for 13.82% of the total *B. boops* caught; the average length of an individual was 9.3cm. The average length of the age group (II+), which makes up roughly 75.23% of the sample, is 13.07cm. With an average length of 16.48cm, the age group (III+) accounted for 5.53% of all *B. boops*. 5.18% of *B. boops* with an average length of 18.78cm were found to represent the age group IV+, whereas 0.23% of *B. boops* with an average length of 20.83cm were found to represent the age group V+ (Fig. 5). The age groups (I+, II+, III+, IV+, and V+) had average weights of 8.59, 24.21, 49.02, 72.89, and 99.99g, respectively (Fig. 6).

The growth parameters were estimated by ELEFAN I program **(Pauly & David, 1981)**; Length (L_∞) = 24.15cm, growth coefficient (K) = 0.34 year^{-1} (Fig. 7). Age at zero size (t_o)= -1.2916 years, and W_∞=156.82g. Growth performance index, ϕ =2.2973.

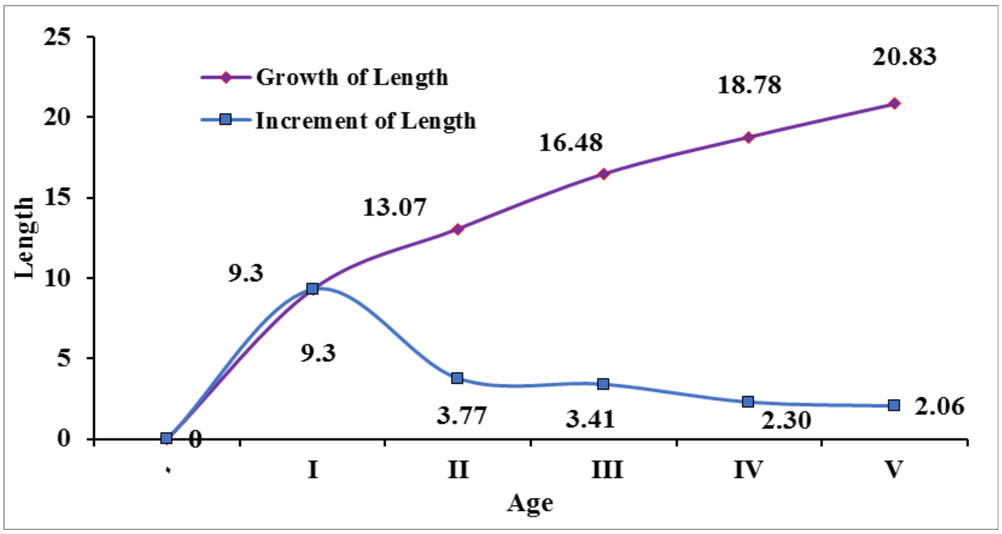

Fig. 5. The length at the end year live and increment of length of the bogue, *B. boops*, during fishing season (2022)

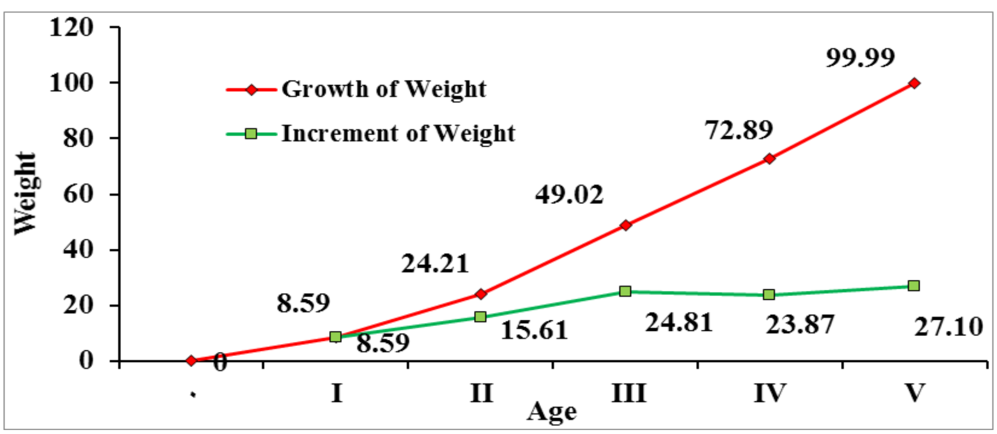

Fig. 6. The weight at the end of year's lives and increment of weight of *B. boops* during fishing season 2022

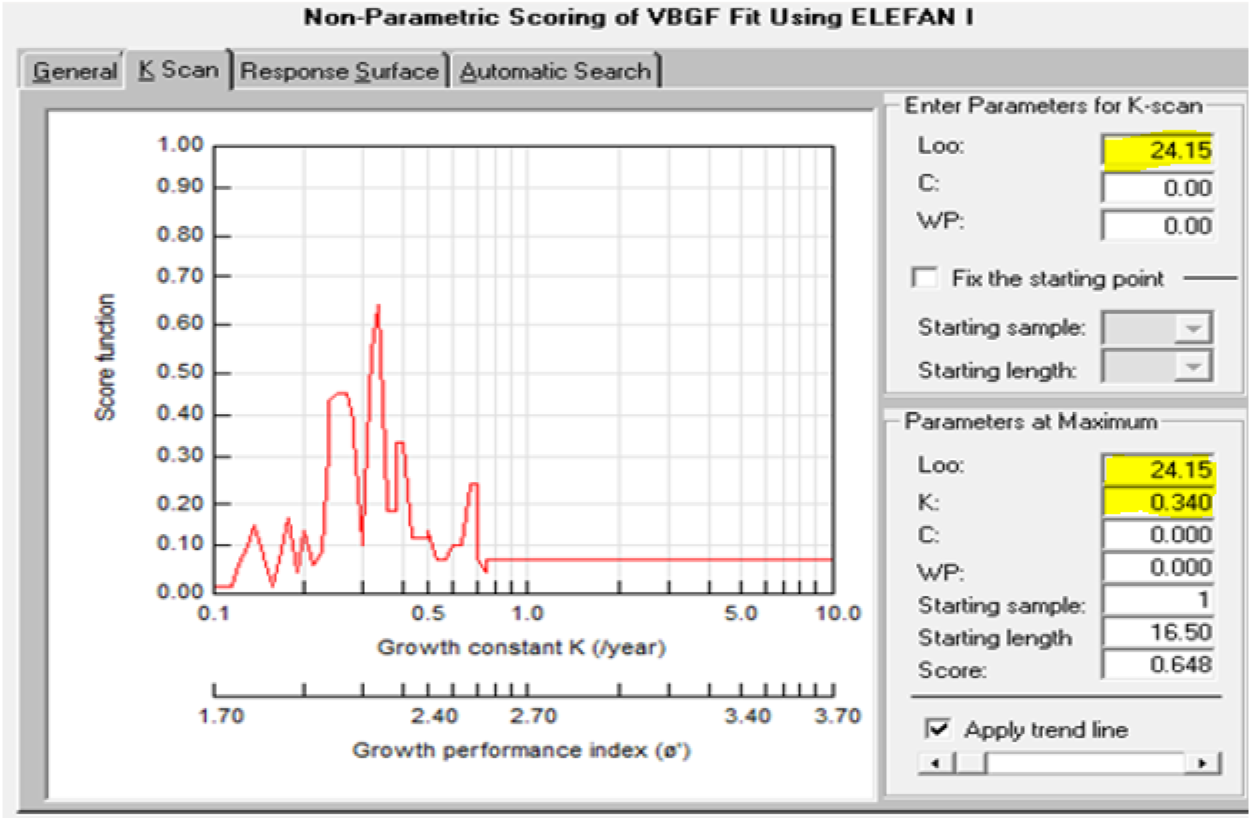

Fig. 7. The growth parameters (L∞ and K) by ELEFAN I program of *B. boops* during fishing season 2022

Mortality and exploitation rate

The length-converted catch curve was utilized to estimate overall mortality (Z) as Z=2.19. Using the growth parameters (L∞ and K) and the average water temperature (T = 23.5°C), the natural mortality (M) was calculated using the equation determined in the study of **Pauly (1983)** as 0.86. Fishing mortality was estimated at a value of 1.33 per year, and using these mortality values, the exploitation rate was estimated at the value of 0.61 year^{-1}.

The growth parameters for *B. boops* are shown in Table (1). The natural mortality rate (M), fishing mortality rate (F), and total mortality (Z) for *B. boops* are shown in Fig. (8).

Table 1. Growth parameters for *B. boops* along Mediterranean coast, North Sinai, Egypt in fishing season 2022

Species	Common name	Local name	Location	L_∞	K	φ	Z	M	F	E
Boops boops	Bogue	Moza	M. coast, North Sinai, Egypt	24.15	0.34	2.3	2.19	0.86	1.33	0.61

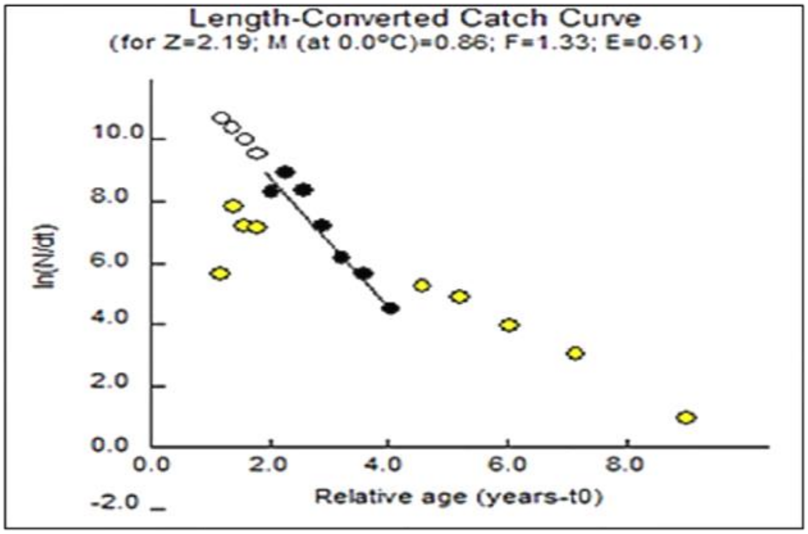

Fig. 8. Mortality and exploitation rate of *B. boops* during fishing season 2022

Probability of capture

Fig. (9) shows the fishing probability for *B. boops*. The length at first capture was estimated at 25, 50, and 75% as follows: 10.56, 11.37, and 12.18cm, respectively.

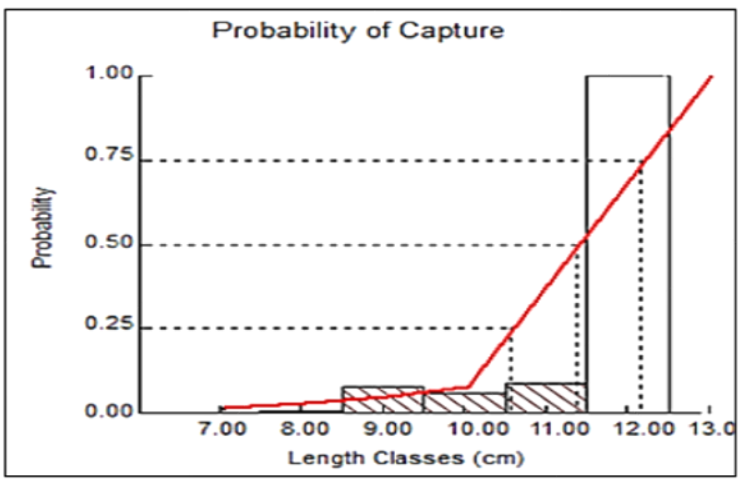

Fig. 9. Length at first capture of *B. boops* during fishing season 2022

Relative yield per recruit

According to Fig. (9), the maximum yield per recruit (E_{max}) was 0.829; the level of exploitation at which 50% of the biomass is fished ($E_{0.5}$) was 0.362, and the level of exploitation at which the yield is economically viable ($E_{0.1}$) was 0.707. For every length group, the numbers of survival, natural loss, fishing mortalities, and catches were computed using virtual population analysis (VPA). Fish in length groups between 12 and 14 were the most prevalent in catch and were exposed to higher fishing mortalities due to the fishing gear, according to VPA, while fish in smaller groups were more likely to be lost naturally (Figs. 10, 11).

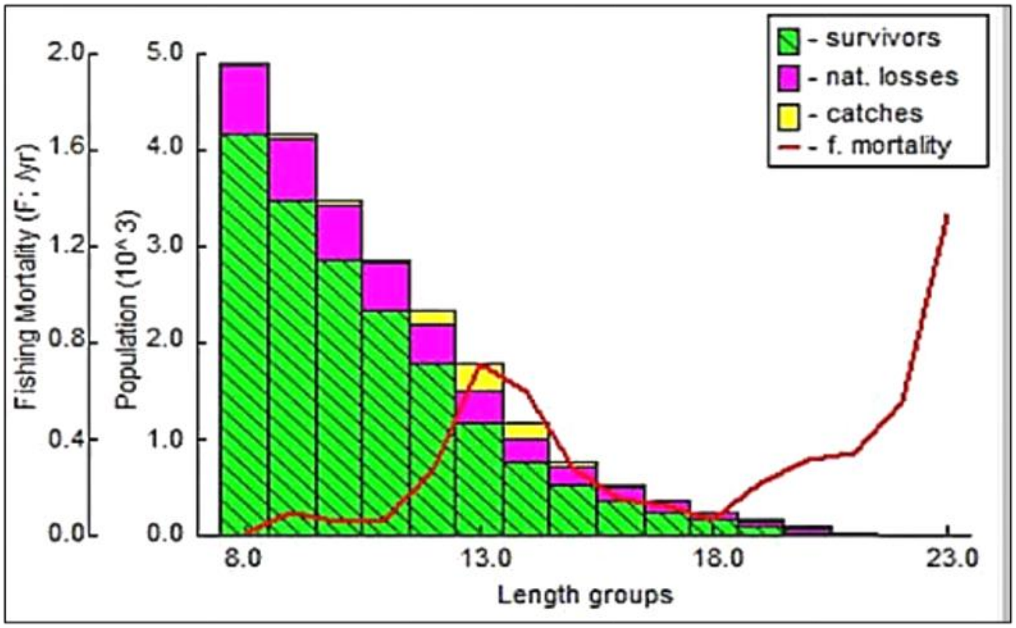

Fig. 10. Virtual population analysis for *B. boops* during fishing season 2022

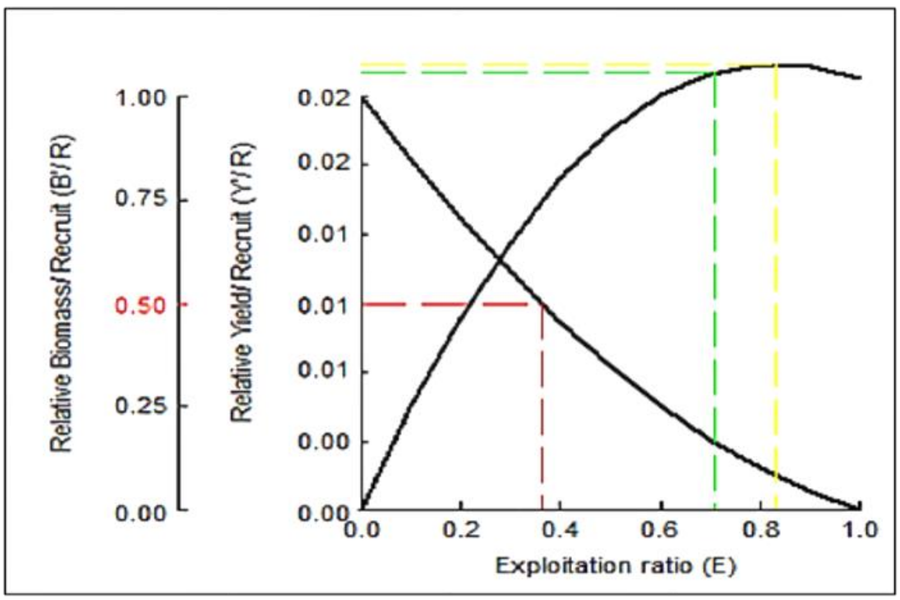

Fig. 11. Relative yield and biomass per recruit and *B. boops* during fishing season 2022

DISCUSSION

According to **Jennings *et al.* (2001)** and **Froese (2006)**, the life-history stage, gender, nutritional state, season, and location all have an impact on the LWR, which is related to fish condition. Even as they mature into adults, fish can experience changes in their body shape due to size-related factors such as isometric growth (b = 3) or positive or negative allometric growth (b> 3 or b< 3). According to **Froese *et al.* (2011)**, the parameters of the LWR are frequently employed in fisheries management and conservation research to translate lengths into weights, ascertain fish conditions, and examine temporal or geographical variability in fish growth. The length-weight relationship of *B. boops* in different parts of Egypt is shown in Table (2).

The length-weight relationship of *B. boops* had a "b" value of 3.045 in the current experiment. Given that it was close to the optimal value, isometric growth was preferred **(Allen, 1938)**. According to **Abdallah (2002)**, *B. boops* displayed positive allometry growth (b> 3) in the Egyptian seas. However, **El-Okda (2008)** and **Azab *et al.* (2019)** reported negative allometry growth (b< 3) in Alexandria, Egypt. Season, habitat, gonad age, gender, nutrition, stomach fullness, health, and preservation methods are some of the variables that affect the parameters **(Hossain *et al.*, 2006)**.

Table 2. The length-weight relationship of *B. boops* in Egypt

Area	a	b	Authors
Alexandria Egypt	0.0254	2.6604	**El-Okda, (2008)**
Alexandria, Egypt	0.011	2.960	**Azab *et al*. (2019)**
Alexandria, Egypt	0.0070	3.130	**Abdallah, (2002)**
M. coast of Sinai, Egypt	0.0097	3.045	**The Present study**

The growth parameters for the von Bertalanffy equation, as determined by the current study and other investigations, are displayed in Table (3). In the coastal waters of North Sinai, the maximum length of a *B. boops* fish is approximately 23 centimeters. On the other hand, the L∞ estimated from other sources is significantly bigger than the projected value obtained in the current study, ranging from 24.0 to 46.5cm. While 'K' values in previous studies of the same species varied from 0.08 to 0.530 in different regions, this study produced a 'K' value of 0.34. The varying methodology and calculation methods used by numerous authors at different eras and locations could be the source of these differences. Variability in growth would be influenced by temperature changes, changes in the quality of the food that is available, changes in the environment, and fishing activities. The causes of the variations in growth parameters between the study areas may include the selectivity of the fishing tool, which can also impact growth parameter estimates **(Potts *et al.*, 1998)**; water temperature **(Santic *et al.*, 2002)**; food size, quantity, and quality; sample characteristics (sample sizes) and geographic variations **(Monterio *et al.*, 2006)**, and inaccurate age interpretation **(Bayhan *et al.*, 2008)**. Parameters related to the physiological condition or genotype of the fish were studied by **Khemiri *et al*. (2005)**. The calculated growth performance index (φ) was 2.3. The growth performance index (φ) of *B. boops* is compared to other members of the same species from various locations, as shown in Table (3). An improved growth performance (φ) indicates superiority over other sites.

The natural mortality for *B. boops* in this study (M = 0.86) is marginally higher than that found by **Azab *et al.* (2019)** at M = 0.671, but it is comparable to that found by **El Samman *et al.* (2022)**. However, it is ignificantly different from that of **Allam (2003)**, which showed how the environment negatively impacted the *B. boops* stock found along the Egypt's Mediterranean coast.

However, compared to **Allam (2003)**, the present study findings of total mortality (Z) and fishing mortality (F) were significantly higher, but lower than those obtained by **Azab *et al.* (2019)** and **El Samman *et al.* (2022)** (Table 4). Increased fishing efforts contributed to the rise in overall and fishing mortality rates, which makes sense given the continued decline in the production of *B. boops* fish in the Mediterranean Sea off the coast of Egypt. Diverse biological circumstances, fishing techniques, and procedures may contribute to differences in death rates between locations **(Joksimović *et al*., 2009)**. As a result, *B. boops* are more vulnerable to fishing gear than they are to being natural sea victims.

According to the current findings, the estimated value of LC was 11.37cm. This result is less than the length (13.2cm) on the Mediterranean coast near our study area at the onset of sexual maturity, as determined by **Azab *et al.* (2019)**. Since they were prevented from reproducing at least once before being taken, this was a sign of overfishing. The VPA data indicate that smaller fish were overfished, with the majority of fishing effort focused on the 12 to 14cm size range. This situation prevents the stock from reaping the benefits of healthy renewal through recruitment, which could lead to very significant biomass losses through shifting demographic structures. Estimated by LC50/L∞ (0.471) and M/K (2.53), the relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) showed exploitation ratios of E0.1 = 0.707, E0.5 = 0.362, and Emax = 0.829, which were lower than the current exploitation rate of E = 0.61. This demonstrates that the population of *B. boops* in this study has been overfished. Therefore, rational management strategies need to be put in place to avert a likely collapse. Reducing fishing effort from 0.61 to 0.362 (50%) and increasing the mesh size would enable this fishery to be sustainably conserved and managed.

Table 3. Growth parameters and growth performance index for *B. boops* from different locations in Egypt

Location	L_∞	K	T_0	φ	Reference
Egypt	30.11	0.15	-1.51	2.14	**El-Okda (2008)**
Egypt	27.24	0.54	-0.33	2.60	**Mehanna (2014)**
Egypt	30.65	0.279	-0.16	2.42	**Azab *et al*. (2019)**
Egypt	27.85	0.38	-0.44	2.47	**El Samman *et al*. (2022)**
M. Coast of Sinai, Egypt	24.15	0.34	-1.29	2.3	**The present study**

Table 4. The mortality and exploitation rates of *B. boops* in different locations in Egypt

Area	Z	M	F	E	Author(s)
Alexandria (Egypt)	1.28	0.46	0.82	0.64	**Allam (2003)**
Alexandria (Egypt)	4.710	0.865	3.845	0.82	**El Samman *et al*. (2022)**
Alexandria, Egypt	2.26	0.671	1.589	0.70	**Azab *et al*. (2019)**
M. Coast of Sinai, Egypt	2.19	0.86	1.33	0.61	**The present study**

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ARABIC ABSTRACT

النمو والنفوق والعائد النسبي للإمداد لسمكة الموزة، *Boops boops*، في ساحل البحر الأبيض المتوسط شمال سيناء، مصر

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تهدف هذه الدراسة إلى تحديد قياسات النمو والنقوق والإنتاج النسبي لسمكة الموزه، *Boops boops*، في ساحل البحر الأبيض المتوسط في شمال سيناء، جمهورية مصر العربية. حيث تم الحصول على 868 عينة من أسماك الموزه من الصيادين من أماكن الإنزال شهرياً في الفترة من شهر يناير 2022 حتى شهر ديسمبر 2022. وقد تراوح الطول الكلي للأسماك ما بين 8.4 إلى 23.1 سم والوزن الكلي ما بين 6.1 الى 138.2 جم بمتوسط 13.57 سم و29.48 جم، على الترتيب. وتم حساب العلاقة بين الطول والوزن بمعادلة القوى ($W=0.0097TL^{3.0433}$). وتم حساب معادلة النمو لفون بيرتالانفي لتكون L_∞ = 24.15 cm، t_0= -1.2916 للسنة، k = 0.34 للسنة. وتم حساب مؤشر أداء النمو (Φ') على أنه 2.2973. كما تم حساب كلاً من الطول عند بداية الصيد وكان 11.37 سم ومعدل النقوق الكلي، ومعدل النقوق الطبيعي، ومعدل النقوق بالصيد ومعدل الاستغلال لسمكة الموزة فكان 2.19 و0.86 و1.33 و0.61 للسنة، على الترتيب. كما أظهر تحليل العائد النسبي للإمداد (Y'/R) = 0.362 أن المستوى الحالي لمعدل الاستغلال أعلى بكثير من قيمته عند مستوى معنوية $E_{0.5}$ مما يشير إلى أن المخزون يتعرض للصيد الجائر. ومن أجل الادارة المستدامة لهذا المخزون يجب تخفيض معدل الاستغلال الحالي بنسبة 40% أي من 0.610 إلى 0.362.