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Impact of environmental factors on population dynamics and some biological aspects of the gilthead seabream (*Sparus aurata*) in Bardawill lagoon, North Sinai, Egypt

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ABSTRACT

This study was conducted in Bardawill lagoon during the fishing season 2021 on 958 specimens of the gilthead seabream *Sparus aurata* collected from two regions in the lagoon (R1 & R2), the first located in the middle of the lagoon in front of the artificial opening located directly under the influence of the waters of the Mediterranean Sea, and the second located in the southwest of the lagoon far from the influence of the waters of the Mediterranean Sea. The results indicated that R1 is characterized by its low water salinity, high dissolved oxygen and depth in comparisons with R2. For specimens from R1 and R2, the respective estimated b values of the length-weight relationship were 2.9542 and 3.0036 , von Bertlanffy growth parameters ($L\infty$ and K) were 33.6 cm and 29.4 cm and 0.29 and 0.87 year^{-1}. As well as their values of growth performance in length index (φ) were 5.7911 and 6.622). Also, their values of the Hepato-Somatic and Gut Repletion Indices were different. The results indicated that the environmental conditions in R1 in the middle of the lagoon and near the point of contact with the Mediterranean Sea provide more suitable conditions for seabream growth compared to those from the southwestern region of the lagoon. Therefore, the study recommends developing and improving the environment of the southwestern region of Bardawil Lagoon for the purpose of developing seabream stock with continuous keeping the inlets open.

Keywords: Seabream, *Sparus aurata*, environmental factors,biological aspects, Bardawill lagoon.

INTRODUCTION

The continuous population growth and human activities during the past years in coastal areas led to increase pressures on the water environment (Ayache *et al.*, 2009). The gilthead seabream (*Sparus aurata* Linnaeus, 1758) belongs to the superclass of ray-finned fishes Actinopterygii, class Osteichthyes, order of Perciformes and family of sparidae (Pavlidis *et al.*, 2011). It is the major economic and ecological importance, being exploited in Bardawill fisheries. Many previous studies investigated its growth, lifespan, reproduction, population dynamic, fisheries and biological aspects (Magoulas *et al.*, 1995; Pita *et al.*, 2002; Almuly *et al.*, 2005; Rossi *et al.*, 2006; Mehanna, 2007, Parati *et al.*, 2011, Salem, 2011, Al-Zahaby et al., 2018 and El-Aiq et al., 2021). Emam (2016) measured some water parameters including salinity, water temperature, pH and dissolved oxygen in addition to depth in different stations along the whole area of Bardawil Lagoon for sustainable management. However, there was no previous work that investigated the effect of some environmental factors in the middle and southwestern regions Bardawil lagoon on some biological aspects and population dynamics of the gilthead seabream *S. aurata.* Therefore,the current study examined the effects of ecological factors (salinity, temperature, water acidity (pH), dissolved oxygen and depth on the growth (size, biomass, mean individual weight) and some biological indices of Gilthead seabream (*S. aurata*) at a two different sites of the Bardawill lagoon.

MATERIALS AND METHODS

1. Study area description

This study was conducted in Bardawill lagoon (Fig. 1). It is a large marine depression located on the northern coast of the Sinai on the Mediterranean Sea. The lagoon is bordered by a sand dune belt from the south. It is a shallow water body with an average depth of 0.5 – 3.5 m and spreads over a length of 90 km and a width varying between 2 and 22 km (Emam, 2016). The study was conducted in middle and western regions of the lagoon. These regions vary according to their environmental traits such as temperature, depth and salinity. Region No. 1 (R1) is located in the middle of the lagoon in front of the artificial opening located directly under the influence of the waters of the Mediterranean Sea. It has a muddy bottom with partially dense black mud and rooted aquatic plants growing. The water depth ranged from 2-3.5 m. Sea currents are abounding in the area. Region No. 2 (A2), the located in the western of the lagoon and its area extends from the western side of the Rumiyat Islands to the end of the pharaonis on the western side. The area was characterized by a gravel bed and a mixture of mud and sand, and the water level was shallow and clear and there is slow water flow. The water level is shallow (0.5-1.5 m depth).

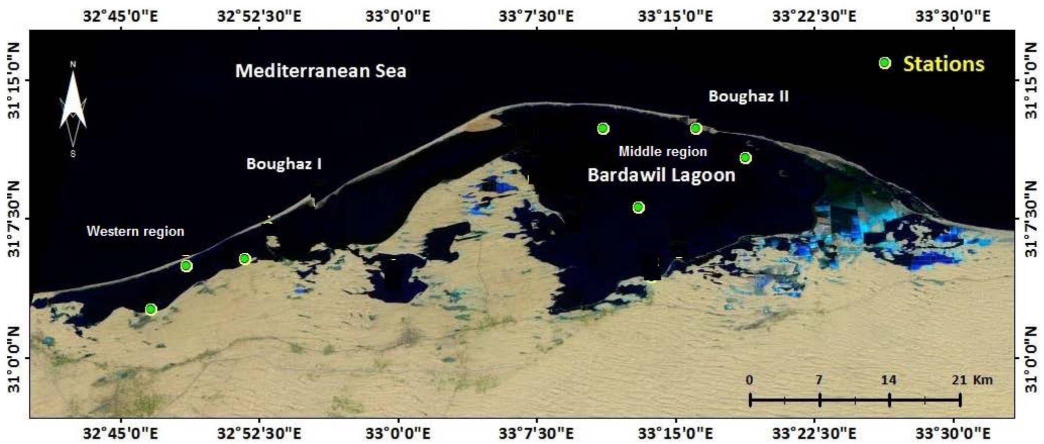


Fig. 1. Map of Bardawil lagoon showing its middle and western regions.

2. Sample collection

2.1 Ecological parameters

The ecological parameters including salinity, temperature, water pH, dissolved oxygen, depth and bottom nature were recorded. Environmental samples were collected from the study regions inside the lagoon during the period from May to November, 2021. Most of the environmental measurements were taken at a depth of 50 cm from the water surface using a water sampling bottle. Environmental parameters were determined using portable measuring devices. The water temperature (°C) was estimated using a simple mercury thermometer.

2.2 Fish Samples

Fish samples were monthly collected during the period from May to November, 2021from the local fishermen at the two investigated regions (R1 & R2) using the traditional bottom trammel nets and hand lines. 958 fish specimens of *S. aurata* [493 from Region (1) and 450 from region (2)] were collected. Fresh-caught fish were transported to the laboratory in iced boxes where the total length of each of the collected fish was measured to the nearest cm and weight to the nearest 0.01g. Then samples were dissected and gut contents and liver were weighed.

3. Population dynamics:

3.1 Length-Frequency Distribution

The analysis of the length-frequency distribution was used to determine the size modal distribution. Histograms were obtained from the distribution.

3.2The length–weight relationship:

The pooled data of males and females were considered. The length-weight relationship was estimated by using the formula of Le Cren (1951): $W = aL^b$

Where: W is the weight (g), L is the total fish length (cm), a and b are constants.

3.3 The coefficient of condition (Kn)

The coefficient of condition (Kn) **was** calculated from Fulton condition factor:

$$\text{Kn} = 100 * \left(\frac{W}{L^3}\right)$$

Where: W= weight in grams, L= total fish length in cm.

3.4 Growth parameters of the von Bertalanffy

The growth rate (K) and asymptotic length (L∞) of the fish was assumed to follow Von Bertalanffy (1938) Growth Function (VBGF). Growth parameters of the von Bertalanffy equation and recruitment were estimated using (FISAT II) (Sparre and Venema, 1992). According to VBGF as expressed below, individual fishes grow on average towards the asymptotic length at an instantaneous growth rate (K) with length at time (t) following the expression:

$$L_t = L\infty\{1 - e^{-k(t-t_0)}\}$$

Where, L_t = The total length of fish in cm at age t

L∞ = the mean length the fish would reach if they were to grow to infinite.

K = The Brody's coefficient of growth constant

t = The age in years

t_o = The theoretical time at which the fish would have been of zero size if it had always grown according to the equation

The theoretical Nil age (t_o) was calculated using (Pauly, 1979) the empirical formula:

$$\log_{10}(-t_0) = -0.3922 - 0.275 \times \log_{10} L_\infty - 1.038 \times \log_{10} k$$

3.5 Longevity

The longevity of the fish species was calculated from the relation:

$$t_{max} = \frac{3}{k} + t_0$$

Where:

t_{max} = the maximum longevity of the fishes.

K = Von Bertalanffy growth parameter.

3.6 Growth performance index

For the comparison of growth parameters between the two different regions in this study of Gilthead sea bream, *Sparus aurata*, the growth performance in length index (φ) was calculated (Pauly, 1979; Munro and Pauly, 1983) as follows:

$$\varphi = lnK + 2lnL\infty$$

Where, (φ) is growth performance

K is Von Bertalanffy growth parameter

$L\infty$ is the asymptotic length

For comparison between fish populations from regions (1& 2) the values of (φ) were plotted against annual average water temperatures, salinities, DO., pH to define the relationships between these environmental parameters and growth performance in the different two regions index and the linear regression analyses were conducted and plotted.

4. Biological Indices:

4.1 Hepato-Somatic Index (HSI)

HSI was determined (Biswas, 1993) by the following formula:

$$\text{HSI} = \frac{LW}{BW} \times 100$$

LW= wet weight of the fish liver

BW= body weight of the fish

4.2 Gut Repletion Index (GRI)

The feeding activity was estimated by using Hyslop (1980) equation for the gut relation index (**GRI**), in which the stomach is examined and the number of individuals that have an empty stomach is determined with the total number of the sample as follows:

Gut repletion index (GRI) is expressed as:

$$GRI = \frac{number\ of\ non-empty\ stomach}{Total\ number\ of\ specimens\ examined} \times 100$$

RESULTS AND DISCUSSION

Ecological parameters:

The results in Table (1) indicated that water temperature values ranged between 20.4 to 29.6 **°C** during the period May-November, 2020 at the Middle of the lagoon (R1), while it varied from 21.4 **°C** to 30.2 **°C** in the southwestern region (R2) as shown in Table (1). This result may be attributed to the inverse relationship with depth readings. Emam (2016) reported temperature values ranged between 15.21 ^{o}C at the center of the lagoon to 17.35 ^{o}C towards the southern shore during 2014.

In the current study the high salinity was recorded in the southwestern region (R1) in the lagoon and the lowest salinity in R2 (Table 1). Similar results were given by Emam (2016) who found salinity near the two artificial inlets was lower than the rest of the lagoon, due to the continuous seawater exchange, and salinity continued to increase towards the southern shore with the highest values recorded at southwestern arm of the lagoon. Also, Siliem (1989) found that the southern and western areas of Bardawil Lagoon recorded the highest salinities whereas, near the inlets, salinity was the lowest. Temporally, salinity increased in September (70.11‰). However, this increment was compensated by winter rain during December (39.1‰) (Touliabah *et al.*, 2002; Abd Ellah and Hussein, 2009).

The values of dissolved oxygen and depth in R1 were higher than that in R2 as indicated in Table (1). Generally there were significant ($p < 0.05$) variations between the two regions in water salinity, dissolved oxygen, and depth. Emam (2016) found that DO concentrations near the inlets were higher than the rest of the lagoon and decreased towards the south. She added that DO can be used as an index of lagoon's productivity and the majority of the lagoon lied within the range 5 – 6.2mg/l. According to Francis-Floyd (1992), this range supports fish and vegetation health. Emam (2016) indicated that the Brdawil lagoon was shallow, the depth readings in the lagoon during 2014 varied from 0.65 – 2.2 m in March; 0.9 – 3.7 m in June; 1 – 3.5 m in September, and 0.59 – 3.53 m in December 2014 with the deepest region of the lagoon occurred near the inlets and decreased towards the southern shore.

The pH spectrum of Bardawil lagoon was found to be alkaline ranging between 7.95 - 8.13in R1, as well as it was 7.9-8.1 in R2. According to Sahoo *et al*. (2015) this range is optimal for aquatic organisms to complete their life cycle. Emam (2016) reported similar results in the lagoon with pH 8.03 – 8.29 in June, 8.16 – 8.4 in September, and 7.68 – 8.53 in December 2014.She added that the pH values attained its peak in the middle and eastern area of the lagoon (in June 2014), shifted little to the left and to the southern shore (in September 2014) and was directed towards the north in December 2014. This could be attributed to the temporal variations in the growing seasons of aquatic plants dominating the lagoon.

Table 1. Monthly (mean ± SD) of environmental variables measured during the study period for May to November, 2020 in the middle region (R1) and southwestern region (R2) of Bardawil lagoon.

Ecological variables	Months						
	May	**Jun**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**
R1							
Temp. (°C)	22.3± 0.07	25.3± 0.14	28.3± 0.09	29.6± 0.07	28.9± 0.14	26.6± 0.28	20.4± 0.07
Salinity (ppt)	42.4± 1.27	43.15± 0.92	46.1± 1.13	44.85± 0.49	45.2± 0.85	44.8± 0.99	43.6± 1.56
DO (mg l^{-1})	5.1± 0.28	4.95± 0.21	4.6± 0.28	4.75± 0.07	5.1± 0.14	5.1± 0.14	5.2± 0.14
pH	8.13± 0.05	8.10± 0.00	7.95± 0.07	8.10± 0.01	8.13± 0.04	8.10± 0.08	8.09± 0.05
Depth (m)	2.35± 0.21	2.35± 0.07	2.35± 0.07	2.3± 0.14	2.35± 0.21	2.2± 0.14	2.3± 0.14
R2							
Temp. (°C)	22.5± 0.00	25.9± 0.14	29.4± 0.21	30.2± 0.07	29.7± 0.31	27.0± 0.13	21.4± 0.14
Salinity (ppt)	49.4± 1.34	50.3± 0.19	52.9± 0.78	50.8± 1.13	50.6± 1.56	50.9± 0.42	50.8± 0.71
DO (mg l^{-1})	4.3± 0.07	4.35± 0.07	4.1± 0.07	3.9± 0.07	4.05± 0.35	4.25± 0.21	4.15± 0.21
pH	8.0± 0.071	8.0± 0.071	7.9± 0.000	7.9± 0.071	8.0± 0.01	8.1± 0.06	8.0± 0.01
Depth (m)	1.55± 0.07	1.6± 0.14	1.5± 0.14	1.55± 0.21	1.45± 0.07	1.4± 0.28	1.3± 0.14

2- **Population dynamics**

Analysis of the length-frequency distribution is the first step to evaluate the selectivity of fishing gear caught by different types of fishing gear fished in the same waters (Bagenal**,** 1978) as well as determination of fish age (Tharwat *et al*., 1998). During the present study, a total of 943 specimens of *S. aurata* were collected, 493 individuals from region 1 at the middle of the lagoon in front of the artificial opening located directly under the influence of the waters the Mediterranean Sea, and 450 individuals from region 2 at southwestern of the lagoon which extends from the western side of the Rumiyat Islands to the end of the lagoon. The length frequency distributions of the studied fish species from R1 and R2 are illustrated in Figures (2 & 3), respectively.

The average total length of the examined individuals from R1 was 21.48cm and the most frequent length groups percentage were 9, 10.6 and 9% corresponding to length groups 20.5, 21.5 and 22.5, respectively. While, for R2 the average total length of the examined fish was 18.74 and the most frequent length group percentage were 11.13 and 10.06% corresponding to length groups 16.5 and 17.5 cm, respectively. There was significant difference ($P<0.05$) between the average length groups of fish individuals from R1 and R2.

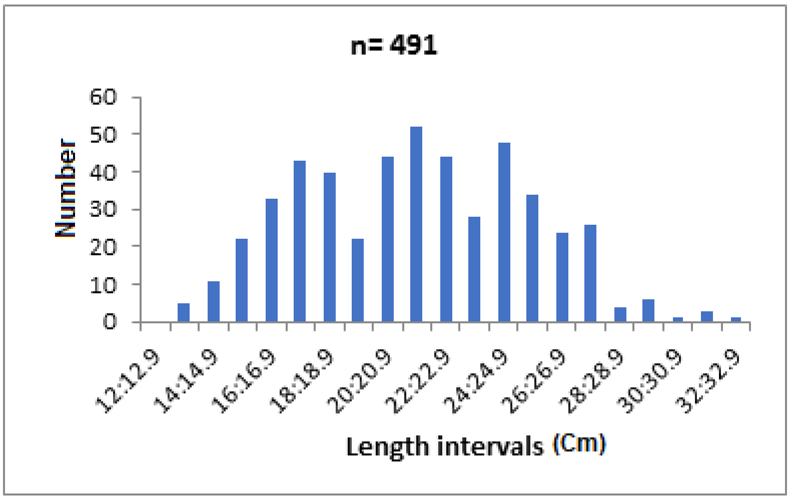


Fig.2. Length frequency distribution of *S. aurata* in the Middle region (R1) of Bardawill lagoon.

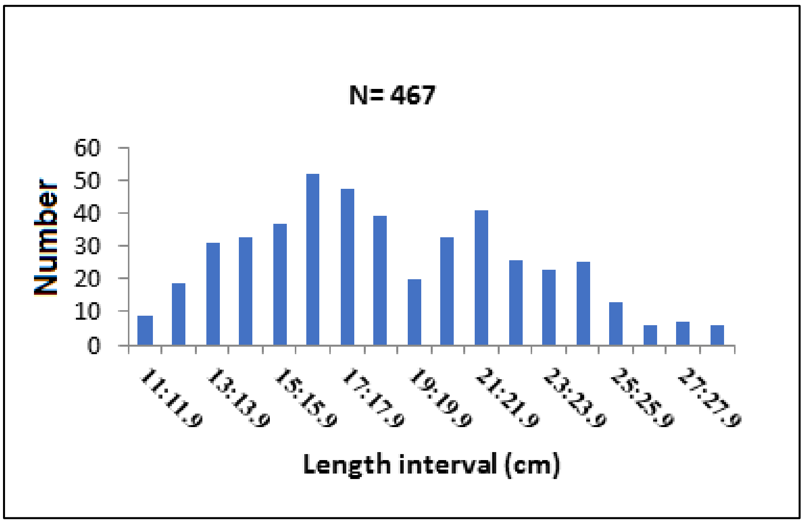
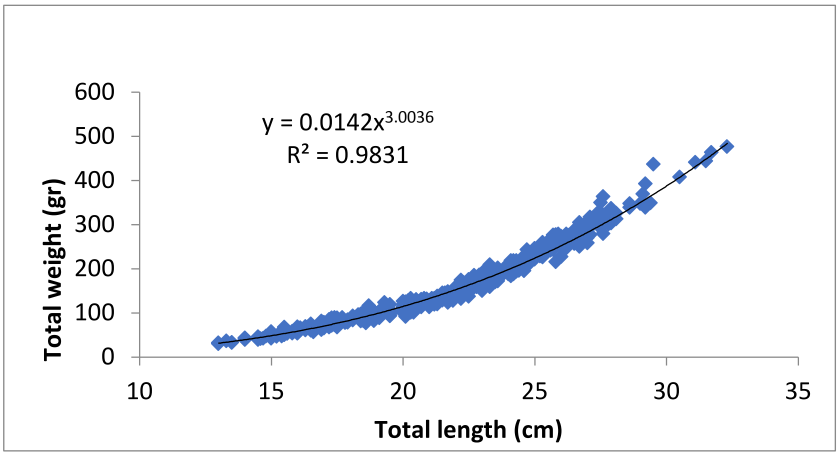


Fig.3. Length frequency distribution of *S. aurata* in the southwestern region (R2) of Bardawill lagoon.

Length-weight relationship:

The length–weight relationship for population of *S. aurata* from R1 and R2 in Bardawil lagoon was illustrated in Figures (4 and 5). The total length and weight of fish from R1 varied between 12.5- 32.3cm with an average of 20.9 cm and 26 - 486.3 g with an average of 149.2g. While, the values of TL for those from R2 were 11.2 - 28.6 cm with an average 18.6 cm and TW 25.2 - 375.2 g with an average 106.6 g.

Length-weight relationship of the Gilthead seabream, *S. aurata* with respect to R1 and R2 is shown in Figures (4 & 5) and is represented by the equations $W= 0.014*TL^{3.0036}$ (R^2 = 0.98) and $W=0.0215*TL^{2.9542}$ (R^2 = 0.97), respectively. There was a significant difference in values of b between individuals from the two regions ($p<0.05$). The b value was 2.813 for the combined sex of the same species in Bardawil lagoon during the fishing seasons 2009 and (Ahmed, 2011).



Fig,4. Length-weight relationship of *S. aurata* in Bardawil lagoon at Region 1.

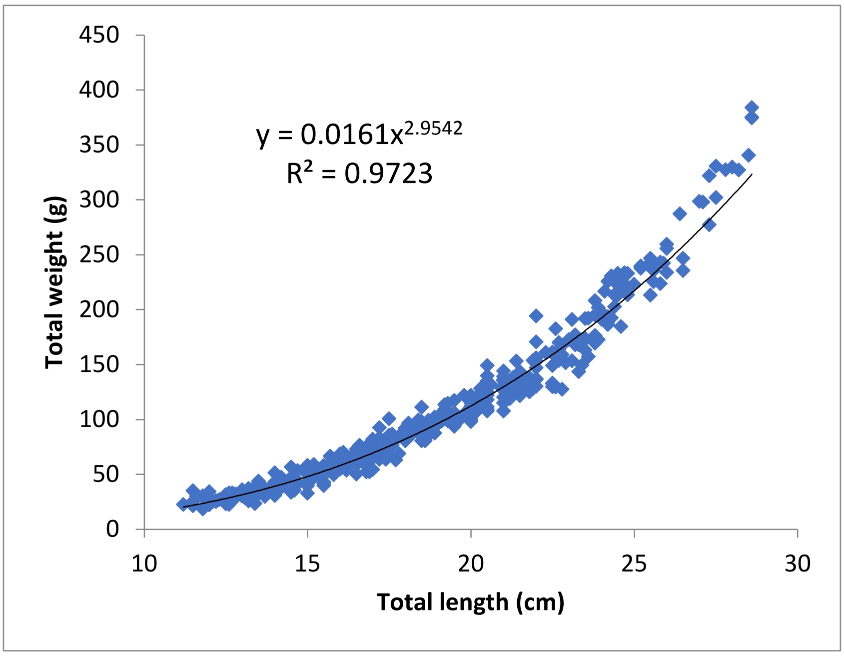


Fig. 5. Length-weight relationship of *S. aurata* in Bardawil lagoon at Region 2.

The average values of condition factor Kn were 1.644 and 1.548 in R1 and R2, respectively and there was a significant difference between these values for specimens from the two regions ($p<0.05$). Although the mean values of Kn were more than one, showed the well-being of fishes in the two regions, yet fish in R1 is more healthy than those in R2.

Theoretical growth in length

The values of the growth parameters of *S. aurata* from the Bardawil lagoon are shown in Table (2) as well as those from other regions on the Mediterranean Sea. The Estimated $L\infty$

of *S. aurata* varied between 33.6 cm and 29.4 cm TL for R1 and R2, while the respective estimated growth parameter (k) varied between 0.29 and 0.87 $year^{-1}$.

Table 2. Growth parameters values estimated using von Bertalanffy growth model for length data of the *S. aurata* stock from the two regions in Bardawil lagoon during the study period (2021).

Location	VBG Parameters			Author/Year
	t_0 (year)	L_∞ (cm)	K ($years^{-1}$)	
Bardawil lagoon (R1)	-0.557	33.6	0.29	Present study
Bardawil lagoon (R2)	-0.013	29.4	0.87	Present study
Bardawil lagoon	-0.08	38.5	0.299	Tharwat et al. (1998)
Bardawil lagoon	-1.68	36.0	0.39	Ahmed (2011)
Port Said on Mediterranean Sea	-0.78	34.2	0.48	Salem (2010)

The longevity

From the results, it was clear that the maximum age of S. aurata from the two regions is significantly different. It was calculated to be 9.78 and 3.43 years for specimens from R1 and R2, respectively. In previous studies the estimated age for the same species in Bardawil lagoon varied from 4 years (Khalifa, 1995) to 6 years (Tharwat *et al*., 1998). The difference in estimation of fish age can be related to the location of fishing in the lagoon or to environmental conditions or the method used for age determination. However, the small estimated age of fish *S. aurata* in the current study can be attributed to the great difference in ecological factors in R1 and R2 as indicated above. Minrui *et al*. (2021) reported that global climate change poses a great and increasing threat to the growth of marine organisms, which leads to an uncertain future for both the diversity of wild fish and global fisheries.

Growth performance index

The estimated values of the growth performance in length index (φ) for *S. aurata* in Bardawil lagoon were different in R1 and R2 (5.7911 and 6.622, respectively). Salem (2008) and Ahmed (2011) report that (φ) value was 6.22 and 6.76 respectively for the same species in this lagoon. The differences in (φ) values for the same species in Bardawil lagoon is highly related to variations in environmental conditions.

3- Biological Indices:

Hepato-Somatic Index (HSI)

The hepato-somatic index is associated with the liver energetic reserves and metabolic activity and gives information about the condition of liver and body of fish (Biswas, 1993). The values of HIS for *S. aurata* in Bardawil lagoon at R1 and R2 were 1.5±0.0259 and 1.35±0.0466, respectively (Table 3).

Table: 3. Hepato-somatic index of the *S. aurata* in Bardawil lagoon at R1 and R2 during the study period (2021).

Region	Av. length (cm)	Av. weight (g)	No.	HIS (av. ± SD)
R1	21.88	166.02	375	1.5±0.0259[a]
R2	19.06	110.66	228	1.35±0.0466[b]

Gut Repletion Index (GRI)

The gut relation index was used to know the feeding activity of *S aurata* in the two regions. A higher percentage of feeding activity was observed in A1 and low feeding activity in A2 as showed in Table (4).

Table 4. Gut relation index (GRI) of *S. aurata* in Bardawill lagoon t R1 and R2 during the study period (2021).

Region	Av. length (cm)	Av. weight (g)	No.	GRI (%)
R1	21.80	164.72	358	61.45[a]
R2	18.85	107.31	253	46.25[b]

Conclusion:

There were variations in the investigated population dynamic and biological aspects of *S. aurata* at the Middle and southwestern regions of Bardawil lagoon. These can be related to the ecological variations between these regions with respect to salinity, alkalinity, dissolved oxygen, depth). The ecological conditions in the Middle of the lagoon near inlets were optimum due to the continuous movement of sea currents between the Mediterranean and the lagoon. This study indicated that lower water salinity, higher dissolved oxygen values, and increased depth provide more suitable conditions for bream growth in the middle of the lagoon and near the point of contact with the Mediterranean Sea rather than those in the from the southwestern region of the lagoon. Therefore, the study recommends continuous removing of sediments and maintained inlets open by periodic dredging, creating communication channels and deepening the southwestern region of the lagoon.

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Impact of environmental factors on population dynamics and some biological aspects of the gilthead seabream (*Sparus aurata*) in Bardawill lagoon, North Sinai, Egypt

تأثير العوامل البيئية على ديناميكية العشائر وبعض الجوانب البيولوجية لأسماك الدنيس (*Sparus aurata*) في بحيرة البردويل بشمال سيناء، مصر

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المستخلص

أجريت هذه الدراسة في بحيرة البردويل خلال موسم الصيد ٢٠٢١ على ٩٥٨ عينة من أسماك الدنيس *Sparus aurata* تم جمعها من منطقتين في البحيرة (R2 & R1)، الأولى تقع في وسط البحيرة أمام الفتحة الصناعية الواقعة تحت تأثير مياه البحر الأبيض المتوسط مباشرة، والثانية تقع في جنوب غرب البحيرة بعيداً عن تأثير مياه البحر الأبيض المتوسط. أشارت النتائج إلى أن منطقة R1 تتميز بانخفاض ملوحة الماء وارتفاع نسبة الأكسجين المذاب وعمقه مقارنة مع R2. بالنسبة للعينات من R1 وR2، كانت القيم b المقدرة للعلاقة بين الطول والوزن هي ٢.٩٥٤٢ و٣.٠٠٣٦، وكانت معلمات نمو فون بيرتلانفي (L∞ ، K) كانت 33.6سم و٢٩.٤ سم و٠.٢٩ و٠.٨٧/السنة. وكذلك بلغت قيم أداء مؤشرالنمو في الطول (φ) (5.7911 و٦.٦٢٢). كما أن قيم مؤشرى الكبد والجسد وامتلاء الأمعاء كانت مختلفة. أشارت النتائج إلى أن الظروف البيئية في منطقة R1 في وسط البحيرة وبالقرب من نقطة الاتصال بالبحر الأبيض المتوسط توفر ظروفًا أكثر ملاءمة لنمو اسماك الدنيس مقارنة بتلك الموجودة في المنطقة الجنوبية الغربية من البحيرة. ولذلك توصي الدراسة بتطوير وتحسين بيئة المنطقة الجنوبية الغربية لبحيرة البردويل بغرض تنمية مخزون الدنيس مع إبقاء المداخل مفتوحة بشكل مستمر.