Stock Status Assessment of *Diplodus sargus* (L., 1758) in the Syrian Marine Waters (Banyas Coast)

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□ ABSTRACT □

The estimation of fish stocks is an important part of fisheries management and the study of economic fish stocks is the main goal of any fisheries' assessment process; as this supports the social and economic stability of fishermen. *Diplodus sargus* (Linnaeus, 1758) is one fish species of Sparidae family, and it is an important economic fish in the catch. The stock assessment of *Diplodus sargus* in Banyas coast had been studied. The results showed that *D. sargus* population was distributed into six age groups, growth was allometric (b=3.2), Von Bertalanffy parameters were (K=0.3/year, L_∞=31.15 cm, t_0= -0.35/year), Y/R =15.38g, and B/R=33.48g. Thus, the stocks of *D. sargus* is suffering from overfishing and overexploitation.

Keywords: Syrian waters, Banyas coast, *Diplodus sargus*, Fish stock.

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تقييم حالة مخزون أسماك السرغوس (*Diplodus sargus* (L., 1758 في المياه البحرية السورية (ساحل بانياس)

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□ ملخّص □

يُعدّ تقدير مخزون الأسماك جزءاً مهماً من إدارة المصائد السمكية، حيث تُشكل دراسة المخزونات السمكية الاقتصادية الهدف الرئيسي لأي عملية تقييم لمصائد الأسماك؛ إذ أنّها تدعم بشكل أساسي الاستقرار الاجتماعي والاقتصادي للصيادين. النوع *Diplodus sargus* هو أحد أنوع عائلة الاسبورات، التي هي من الأسماك الاقتصادية الهامة في صيديات الساحل السوري. تمّ في هذه الدراسة تقدير العمر والنمو وحالة المخزون للنوع *D. sargus* والتنبؤ بمستقبله في ساحل بانياس. أظهرت النتائج أن أسماك هذا النوع قد توزعت في ست فئات عمرية، وكان النمو الوزني أكبر من النمو الطولي (b=3.2)، معاملات فون–بيرتلانفي كانت (K=0.3/year، L_∞=31.15 cm، t_0=-0.35/year)، قيمة الإنتاج من الإمداد (Y/R) هو 15.38g، وقيمة الكتلة الحيوية من الإمداد (B/R) هي 33.43g. تشير هذه النتائج إلى أنّ مخزون هذه الأسماك يُعاني من الصيد الجائر والاستغلال المفرط.

الكلمات المفتاحية: المياه السورية، ساحل بانياس، *Diplodus sargus*، المخزون السمكي.

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Introduction:

The estimate of fish stocks is an important part of managing fisheries, as any fisheries sustainable management plan needs to concentrate on the status of the fish populations, especially for economic fishes, which are a direct target for fishermen. In addition, the stock assessment should determine if the fish populations are exposed to overfishing and heading towards extinction, or if these species must be fished to create a state of balance in the fisheries populations (Beverton and Holt, 1957; FAO, 2018).

The economic fish stocks assessment is the main goal of any fisheries process; as it primarily supports the social and economic stability for fishermen and fish supply throughout the year (Kilduff *et al.*, 2009). It also seeks to preserve these species by defining the prohibition periods and permitting fishing along the year, to allow fish reproduction and fish stocks regeneration (Worm *et al.*, 2009). In addition, such studies aid in identifying the environmental status of fisheries, aiming at improving the natural habitat of fish (Mcclanahan *et al.*, 2015) and determining the conditions that must be met to establish marine protected areas (Pomeroy *et al.*, 2004).

Sparidae family is one of the most important families in the eastern Mediterranean; most of its species have a high economic value, and are desirable to consumers. Its species are deep-bodied compressed fish, with a small mouth separated by a broad space from the eye, a single dorsal fin with strong spines and soft rays, a short anal fin, long pointed pectoral fins and rather large firmly attached scales. They can be found in shallow temperate and tropical waters and are bottom-dwelling carnivores (Whitehead *et al.*, 1986).

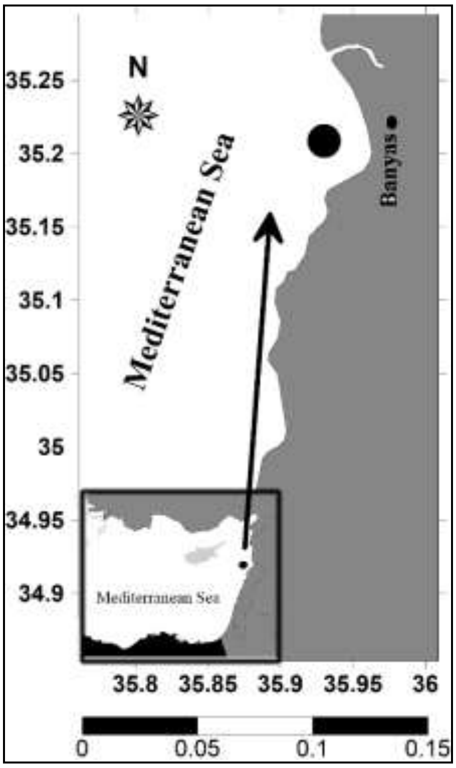
The white seabream *Diplodus sargus* (Linnaeus, 1758) is one of Sparidae species, exists in most coasts of the Mediterranean Sea. It is highly preferred to consumers and consequently is a target for fishermen. This would make the stocks of *D. sargus* undergo overfishing in many areas of the Mediterranean. Therefore, this study is carried out to preliminarily evaluate the stock of *D. sargus* in the Syrian coast in order to give a comprehensive idea about its status and sustainability.

Research importance and objectives:

This study aimed to know the status of *D.sargus* stock at Banyas coast in order to develop a sustainable plan for fisheries in the area**.** Thus, the most important tools are the assessment and forecasting the stock, which will provide us with the required scientific proposals for fish population sustainability in the Syrian coast.

Materials and Methods:

From Sep. 2018 to Dec. 2019, monthly field trips were performed in the marine waters off Banyas coast, Syria (N: 35°14'35.11", E: 35°55'12"; Fig.1.a). Samples of white seabream (Fig.1.b) were collected using the available local fishing techniques such as longline and gillnet…etc. (Pope *et al.*,1975; Erzini *et al.*,1996; Aydın and Bolat,2014) with assistance of fishing boat (9.5m, 19HP). Total length (TL) of the individuals was measured to the nearest cm. and total weight (TW) was recorded to the nearest g. A total of 175 individuals of *D.sargus* (56 males, 72 females, 47 unsexed), were caught and separated into six age groups.



a

B

Fig.1: a- Map of fishing area-Banyas coast, b- *D.sargus* sampled during the present study

Stock Assessment of *D.sargus*:

The stock assessment of *D.sargus* included a study of age and growth, and the status of fish stocks.

1-Age and Growth:

Age of fish was estimated by examining the growth rings on fish scales under a suitable binocular microscope, and growth was calculated using **the back-calculation lengths method.** This method is proven to be useful for estimating length at age and growth rates of species. It is obtained by Lee's equation (Lee,1920):

$$L_n = \frac{S_n}{S} * (L - a) + a$$

L_n: the length at "**n"** age, **S**: the distance from scale centre to the edge, **a**: the constant of weight-length relationship. **S_n**= the distance from scale centre to the edge of ring at **n** age L= the total length of the fish.

Weight -Length Relationship: It is of great importance in fishery assessment studies since it provides information about the growth and the weights that fish can reach. This was estimated according to Richer (1975) as,

$$W = aL^b$$

W= total weight of fish, **L**: total length of fish

where b value determines the type of growth; if (b=3) then the growth is Isometric, if (b<3) then the growth is negatively Allometric, and if (b>3) then the growth is positively Allometric.

The Condition Factor, Cf: It is a reflection of a good growth and expresses the suitability of the environment to the fish species. It compares the value of 'Cf' in various localities (Cadima, 2003), and can be calculated as:

$$Cf = \left(\frac{TW}{TL^{3}}\right) * 100$$

TW: total weight**, TL:** total length

Growth Parameters: They were estimated using the Von Bertalanffy growth model (Ricker, 1975):

$$L_t = L_\infty\left(1 - e^{-k(t-t0)}\right)$$

$$W_t = W_\infty\left(1 - e^{-k(t-t0)}\right)^b$$

L_∞: the ultimate length that a fish would achieve if it continued to live and grow, $L_\infty = L_{max}/0.95$(Gayanilo,1997); **k:** the growth coefficient, which determines how fast the fish approaches the value of **L_∞**. **t_0**: the hypothetical age when the length is zero, which was calculated by applying the inverse Von Bertalanffy growth equation:

$t_0 = t + \left[\left(\frac{1}{k}\right)\left(Ln\frac{(L\infty - Lt)}{L\infty}\right)\right]$, $W_\infty = aL_\infty^{\ b}$ (according to Pauly, 1984). t= the age of fish.

2-The stock status of *D.sargus* was studied using several factors:

2-1-Total Mortality Rate *(Z)*, Natural Mortality Rate *(M)* and Fishing Mortality Rate *(F)*:

Total mortality rate (Z): It is expressed by natural mortality rate and fishing mortality rate in the fish population, it is calculated by the following equation (Beverton and Holt, 1957):

$$Z = K\frac{(L_{max} - L_{mean})}{(L_{mean} - L_{min})}$$

K: Von Bertalanffy growth model constant, **L_{max}**: the mean length of fish samples **L_{mean}**: the mean length of fish samples, **L_{min}**: the shortest length in the fish samples.

Natural Mortality Rate (M): It is the removal of fish from the stock due to causes not associated with fishing. Such causes can include disease, competition, predation, old age, pollution or any other natural or human factors that cause the fish death (Pauly, 1984):

$$logM = -0.0066 - 0.279\log L_\infty + 0.6543 logK + 0.4634\ log\ T$$

K: Von Bertalanffy growth model constant, **L_{mean}**: the mean length of fish samples, **L_{min}**: the shortest length in the fish samples. **L_∞:** the infinity length, **T**: the temperature of seawater.

Fishing Mortality Rate (F): It is the removal of fish from the stock due to fishing activities using any fishing gear; it is calculated after determination of Z and M:

$$F = Z - M$$

2-2-Exploitation Rate (E):

It determines the degree of fish stock exploitation, which should not exceed 0.5 (Gulland, 1971):

$$E = \frac{F}{Z}$$

F: fishing mortality rate, Z: the total mortality rate.

2-3-The Maximum Age:

It is the maximum age that fish can reach in the habitat, when perfect environmental conditions are available:

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

K: Von Bertalanffy growth model constant

2-4- Survival Rate:

The number of fish expected to survive after a specified period of time, usually a year (Ricker,1975):

$$S = e^{-z}$$

e: exponential function, z: the total mortality rate.

2-5-Length and Age at First Capture (L_c-t_c):

This indicates the length and age at which 50% of the fish individuals have reached a suitable size on the appearance in the catch for the first time (Beverton and Holt, 1957):

$$L_c = \bar{L} - \frac{K(L_\infty - \bar{L})}{Z}$$

$$t_c = \left(-\frac{1}{k}\right) * (Ln((1 - \frac{L_c}{L_\infty}) + t_0)$$

K, L_∞ and t_0: Von Bertalanffy growth model constants, $\bar{L}$: fish mean length.

L_c: length at first capture**,** t_c: age at first capture

2-6-Length and Age at Recruitment (L_r-t_r):

It is the length and age of fish, which have reached the perfect size that permits them entering the fishing area, and living there (Von Bertalanffy, 1938):

$$L_r = \bar{L} - \frac{K(L_\infty - \acute{L})}{Z}$$

$$t_r = \left(-\frac{1}{k}\right) * (Ln(1 - \frac{L_r}{L_\infty}) + t_0)$$

K ,L_∞,t_0: Von Bertalanffy growth model parameters, $\bar{L}$: mean length of fish, $\acute{L}$: length at the first capture.

2-7-Estimation of Yield per Recruitment (Y/R):

It is used to estimate the quantity of production, on the condition that the same natural conditions continue to exist in the fishing area, at the same catch rate; this gives a primary idea of the quantity of production when supplied. It is calculated from the model proposed by Beverton and Holt (1957), and written in the formula suggested by Gulland (1969):

$$Y/R = F.e^{-M(t_c - t_r)}.W_\infty \left[\left(\frac{1}{Z}\right) - \left(\frac{3S}{Z+K}\right) + \left(\frac{3S^2}{Z+2K}\right) - \left(\frac{S^3}{Z+3K}\right)\right]$$

F: fishing mortality rate, **Z**:total mortality rate, **K,t_0**: Von Bertalanffy constant, t_c: the age at first capture, t_r: the age at first recruitment, **S** = exp[-K (t_c-t_0)], **W_∞**: final body weight.

2-8-Estimation of Biomass per Recruitment (B/R): It is a reflection of the impact of fishing operations on the mass of the new individuals and on the condition that they undergo to reach the age at the first catch or older (Adam, 2010). It is calculated from the equation proposed by Beverton and Holt (1957):

$$B/R = \frac{Y/R}{F}$$

F: fishing mortality rate

2-9-Forecasting the State of *D.sargus* Fish Stock:

It is expressed by the relationship between **Y/R**, **B/R** and **F**. This could be done by giving different values to fishing mortality **F**(0-3), adjusting the age at the first catch t_c in order to match the age at first sexual maturity, and modifying natural mortality rate **M** to the minimum value in order to obtain the best forecast of the state of the stock.

Results and Discussion:

1-Age and Growth Estimations:

1-1-The Back-Calculated Lengths: The fish were separated into six age groups, with total length ranged from (12.7 to 27.3cm). The young individuals (1^+) was the dominated group (Tab.1), which is a primary indication of the exposure of *D.sargus* fish stock to overfishing.

Table.1. Back-calculated lengths of *D.sargus* individuals during this study.

age	No. fish	Mean length ±SD	Total length (cm)					
			TL1	TL2	TL3	TL4	TL5	TL6
1^+	70	15.33±0.95	11.42					
2^+	26	17.35±0.33	10.8	13.9				
3^+	49	18.78±0.53	10.55	13.97	17.12			
4^+	12	20.42±0.32	10	13.74	16.71	19.41		
5^+	15	21.77±0.64	9.66	13.04	15.72	18.42	20.25	
6^+	3	26.36±0.8	9.83	13.09	16.35	19.94	22.12	24.08
Mean length			10.38	13.55	16.48	19.26	21.19	24.08
SD			0.77	0.67	0.45	0.59	1.32	
Increment			10.38	2.93	2.78	1.93	2.90	2.28
% Increment			39.35	11.10	10.54	7.31	10.97	8.64

This result agrees with that of Al-Beak *et al.* (2017), Adam (2010) in the Egyptian waters and Jisr *et al.* (2018) in Tripoli- Lebanon. Another evidence of *D.sargus* population overfishing is that the mean maximum length was only 27.3 cm, whereas it has higher value in the areas which are subjected to some rules of fish stocks protection; i.e. 35cm in Gulf of Lions (Man-Wai and Quignard, 1982), 39cm in Portuguese waters (Abecasis *et al.*,2008) and 34cm in north Sinai waters (Al-Beak *et al.*, 2017).

1-2-The Condition Factor, Cf: Its values were 1.87, 2 and 1,98 for all individuals, males and females respectively. This agrees with Darmanin *et al.* (2019) in the Maltese waters and with El-Maghraby *et al.* (1981) in the Egyptian waters. The values of **Cf** reveal that *D.sargus* has a great ability to benefit from food available in the habitat, and has a good food conversion ratio. This may suggest that this fish species can be used efficiently in mariculture.

1-3-The Weight-Length Relationship: The result (Fig.2.a-b-c) reveals that the growth mode of this species is Allometric+, where the **b** value is 3.2159, 3.2011 and 3.242 for all individuals, males and females respectively. This result is in agreement with Darmanin *et al.* (2019), Al-Beak *et al.* (2017) and Mouine *et al.* (2007).

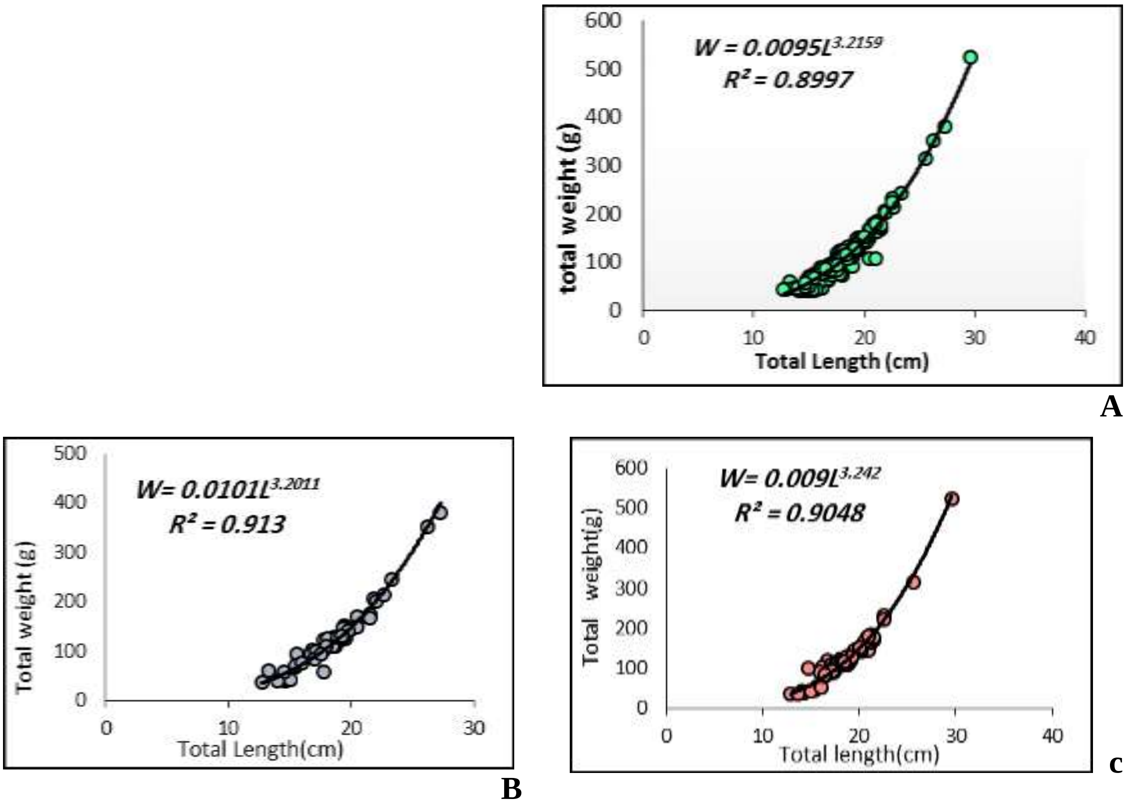


Fig.2. The weight-length relationship of *D.sargus*; a-total individuals, b- males, c-females

1-4-Growth Parameters: Table (2) presents the values of Von Bertalanffy equation parameters obtained during the present study and compared to those obtained in other geographical locations.

Table.2. Von Bertalanffy parameters for *D.sargus*, in the Syrian waters and other locations.

Location	Reference	K (year)	t_0 (year)	L_∞ (cm)
Syria	Present study	0.3	-0.35	31.15
South Africa	Mann and Buxton (1997)	0.25	-1.25	30.9
Egypt	Lahlah (2004)	0.13	-1.84	32.7
Turkey	Balık and Emre (2016)	0.27	-1.75	39.9
Egypt	Al-Beak *et al.* (2017)	0.25	-0.28	40.7
Malta	(Darmanin *et al.*,2019)	0.286	-1.61	30.86

The values obtained during this study are slightly different from other studies; this is due to the effect of the local habitat conditions (Mizanur *et al.*, 2014) on the growth of *D.sargus*.

2-Stock study:

2-1-Mortality Rate: The results show that the total mortality rate (**Z**) is 1.24/year, the natural mortality rate (**M**) is 0.78/year, and the fishing mortality rate **(F)** is 0.46/year. The value of natural mortality (M) gives an idea about habitat quality of *D.sargus,* which is a high value and reflects a high individuals mortality because of disease, predators or the inability of juvenile fish to withstand the environmental changes. In addition, **(M)** value indicates the deterioration of the marine environment by various human activities. Fishing mortality was high which indicates the large exploitation of fish stock, due to illegal fishing. Therefore, to reduce these rates, the natural habitat of *D.sargus* must be improved, the small individuals must be protected, and reproduction sites must be protected in order to reduce the natural mortality rate. On the other hand, *D.sargus* fishing mortality rate should be minimized by changing the fishing method, increasing the mesh size and/or preventing using small hooks of the longline.

1-2-Exploitation Rate: The exploitation rate value **(E)** was 0.37, while the maximum value which should not be exceeded should be 0.5 (Gulland, 1969). This result indicates over-fishing of *D.sargus*, and that a slight increase in the rate of exploitation will lead to depletion of this stock and its inability to replenish itself. The high rate of exploitation is caused by the increase in all mortality rate values (**Z-M-F**) at the fishing area. Thus, in order to reduce this percentage, it is necessary to improve habitat quality of this fish, and choose the fishing gears that allow juveniles to escape, and avoid catching fish until they exceed the length at the first sexual maturity; i.e. to give *D.sargus* individuals the chance of reproduction once at least.

2-3-Maximum Age: The maximum age (t_{max}) of *D.sargus* in the Syrian marine waters is 10.34 years. This value is less than that obtained from the Maltese waters (17 years; Darmanin *et al.*,2019), from the coast of north Sinai (12 years; Al-Beak *et al.*,2015) and from the south Portuguese waters (16 years; Abecasis *et al.*, 2008). This result directly reflects the habitat conditions and, as a primary consequence, this habitat does not provide the appropriate components of food and protection to increase the age of this fish (Mizanur *et al*., 2014).

2-4-Survival Rate: The survival rate **(S**) for the fish was 0.3/year, whereas it was 0.5/year in north Sinai and 0.34/year in Alexandria waters. These values are close to each other, but in general, they are low and indicate high mortality rates in the studied areas, as the survival rate is a reflection of mortality rates. Thus, reducing mortality rates leads to an increase in the survival rate of *D. sargus*.

2-5-Length and Age at First Capture (L_c-t_c): The length at first capture (L_c) for *D.sargus* in the study area was 11cm, which means that the first fish catch for the new year is 11cm. This length is small and gives an evidence that the fishermen used illegal fishing gears which led to catch juvenile fish; hence, the fish were not allowed to reach the appropriate length for reproduction. On the other hand, the age at first capture (t_c) in this study was 0.6year, while in Alexandria, the length (L_c) and age (t_c) were 12.51cm and 1.2 year respectively (Adam, 2010)**;** our results are very similar to those recorded in Alexandria.

2-6-Length and Age at Recruitment (L_r-t_r): The results indicated that the length at recruitment (L_r) was 9.28cm and the age at recruitment (t_r) was 0.4year. These values are similar to those in the Alexandrian wasters; L_r=10.5 cm and t_r=0.81 year (Adam,2010). These results indicate that the juvenile fish must be protected, because they will form the basis for replenishing the stock of *D. sargus*. As shown above, the difference between the length at first capture and the length at recruitment is small, which signifies that the fish grew only a little after entering the fishing area, and then they were caught.

2-7-Yield per Recruit (Y/R): The value of Y/R in this study was 15.38g which is less than that in Alexandrian water (31.12g; Adam, 2010), and less than that in the north Sinai water (88.84 g; Al-Beak *et al.*, 2017). The yield per recruit in this study confirms that *D.sargus* undergoes overfishing**.**

2-8-Biomass per Recruitment (B/R): The biomass of recruitment (B/R) value was estimated, based on the fishing mortality rate, to be 33.43g; it is higher than that obtained from the Alexandrian water (57.16 g; Adam, 2010). B/R value in this study is still small, which indicates that the individual's biomass (body size) is also small and even not suitable for marketing; this means that fishing at this level will lead to a loss of *D. sargus* stock.

According to the above results, the small individuals of *D.sargus* dominate the fish community. The exploitation rate (E=0.4) is at its maximum and the maximum age (t_{max}=10 year) is less than that obtained from the nearby areas; the length and age at first capture (L_c=11cm, t_c=0.6year) and Y/R values of the individual are low. Similarly, B/R value of the individuals is small and the fish are not suitable for marketing. In addition, the fish suffer from poor habitat conditions in the study area (M=0.79/year). Thus, the stock of *D. sargus* in Banyas coast is suffering from overfishing and measures should be imposed in this habitat such as reducing natural mortality and exploitation rates and/or increasing the age at first capture up to two years or more. Consequently, stock state prediction should be done to impose the best solutions and overcome stock deterioration.

2-9-Forecasting *D. sargus* Fish Stock: Figure (3) shows different values for fishing mortality rate **(F)** that ranged between (0- 3). It can be noticed that the stock is at the highest level of exploitation, and any slight increase in fishing will lead to a decline in the stock.

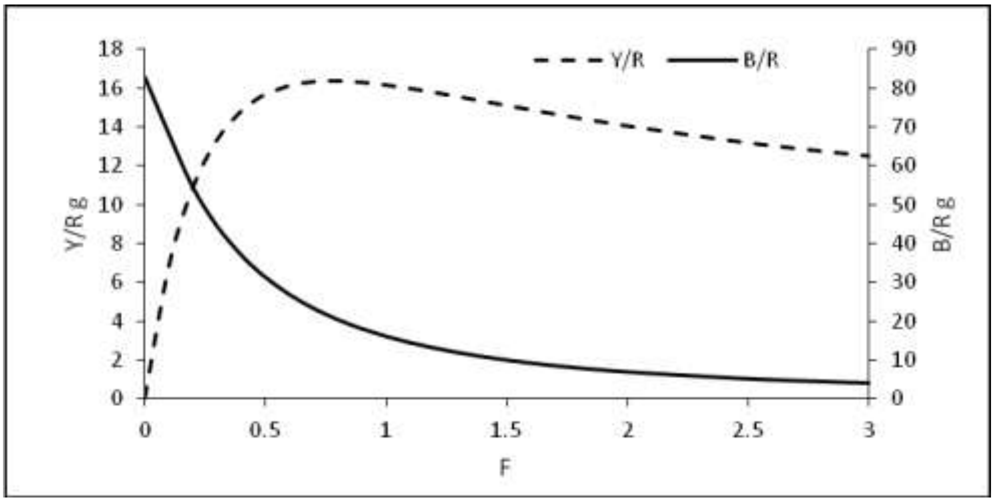


Fig.3. Relationship between Y/R, B/Y and F for *D. sargus* in the present study.

In order to permit the *D. sargus* stock to regenerate itself, fishing mortality rate should be reduced to F=0.4/year, the habitat conditions should be improved to reduce the natural mortality rate to M=0.3/year and the individuals of less than two years old should not be caught until they reach the sexual maturity (with total length = 17cm). These regulations will support a good productivity of *D. sargus* stock in Banyas coast, and conserve its sustainability (Fig.4).

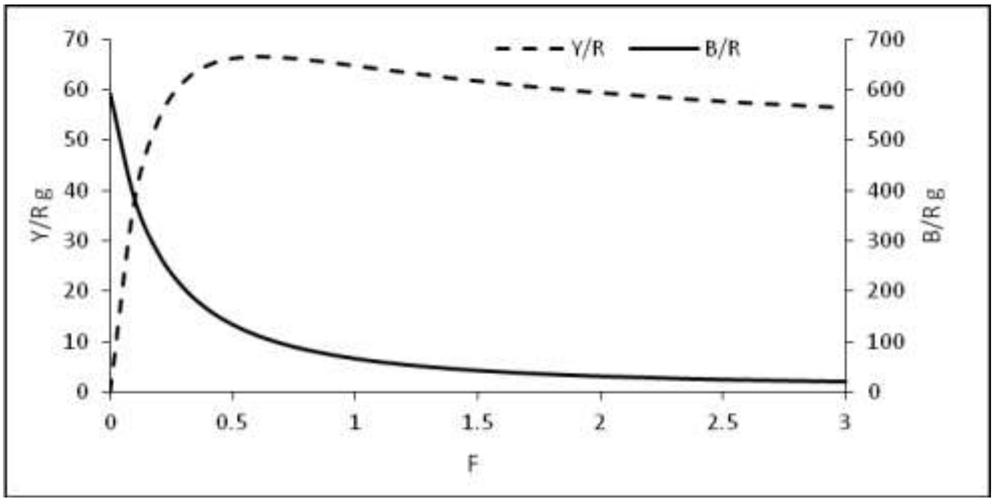


Fig.4.Relationship between Y/R, B/Y and F for *D. sargus* after prediction of the fish stock status (F=0.4, M=0.3, t_c=2 year)

In this prediction, a good return will be obtained from the individual of B/Y=100g, but the stock still undergoes the exhaustion if the fishing mortality rate (F) increased. Accordingly, a new forecast would be made by raising the age at the first capture to 3 years to ensure the fish reproduction and give new generations to support *D. sargus* stock, and get individuals with good marketing weight as well (B/R=170g with TL=22 cm; Fig.5).

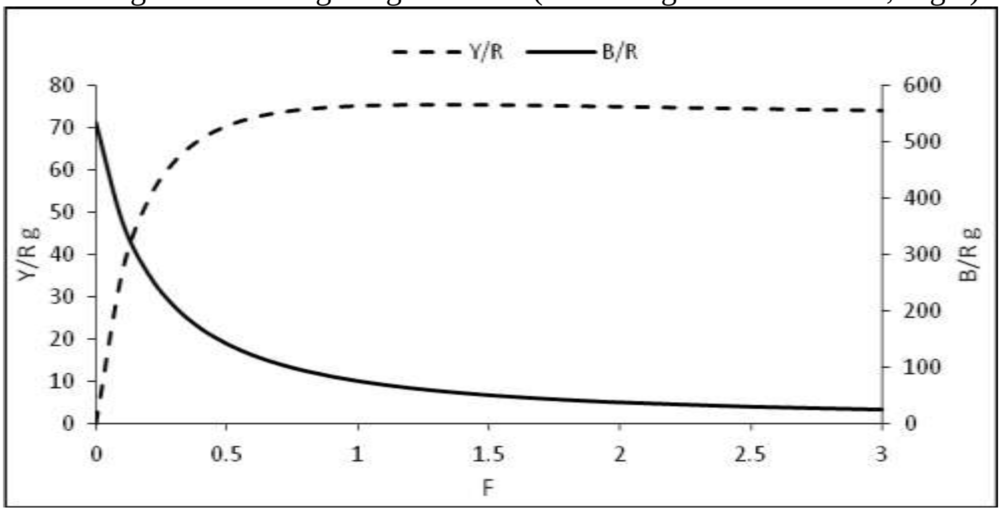


Fig.5.Relationship between Y/R, B/Y and F for *D. sargus* after prediction of the fish stock status (F=0.4, M=0.3, t_c=3 year)

Conclusion:

The fish stock of *D.sargus* in Banyas coast suffers from overfishing, and the habitat conditions in the studied area are poor. The intensity of fishing operations are very high and illegal fishing gears have obvious effects. Thus, effective protection measures, habitat improvement and minimizing fishing rate will ensure returning the stock to its natural state.

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