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ESTIMATING OF SOME BIOLOGICAL PARAMETERS AND YIELD PER RECRUIT FOR FISHERY MANAGEMENT OF GREY MULLET, *Mugil cephalus* IN BARDWILL LAGOON

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Abstract

Biological parameters provide fundamental information for re-stocking in fisheries. Growth, mortality and yield per recruit of Grey mullet (Mugil cephalus**)** were studied in Bardawill lagoon. A total of 961 specimens (12.8 to 49.8 cm total Length and 28 to 1222 gm total weight), were collected from April to December, 2015. Age was determined by scales where age groups 0 to 6 years. Growths in length and weight at the end of each year were calculated as 21, 28.5, 33.8, 37.4, 40.7 and 43.9 cm for the 1, II, III, IV, V and VI year of life respectively. The relationship between length and weight was W= $0.0108*L^{\mathbf{2.963}}$.The growth parameters of von Bertalanffy equation were calculated as ($L\infty$= 52.19 cm, K = 0.261 $year^{-1}$ and t_0 = -0.9698 year). Growth performance index (φ' = 2.85). Mortality rates were 0.7425 yr^{-1}, 0.3681 $yr^{-1}$and 0.3744yr^{-1} for total, natural and fishing mortality respectively. The currently exploitation rate E = 0.504. The length at first capture (L_c) was 27.5 (1.898 year). The results of age at first capture and the current exploitation rate indicated that the small fish were caught at higher fishing effort level. The current mesh size should be increased in order to increase the t_c to 2.5 year which achieves the highest yield at current fishing effort. Thus, the current effort of M. cephalus should be stabilized at increase of t_c to 2.5 year and if possible should be reduced. So, fishers must searching for a way to catch fish bigger than 31 cm with no increase in fishing effort but must reduce of fishing effort. Also, adjustment work in the mesh size of fishing nets to catch fish larger than 31 cm (fish at mature stage).

Keywords: Bardawil lagoon, Mugil cephalus, age, growth, mortality, per-recruit analysis, stock enhancement.

INTRODUCTION

There are many kinds of fishing gear methods in Bardawill lagoon as trammel, verandah, gill nets, trawl nets and lines. More than three species of family Mugilidae are presented at a catches; *M. cephalus*, *Liza ramada* and *L. aurata*. These fishes are widely distributed in a region and constitute a major component of catches. Grey mullet, *M. cephalus* is the most important target fish species and it is important aquatic resources in fisheries as they contributed about 34% of the total fish production (GAFRD, 2015). Overfishing is the cornerstone of grey mullet in lagoon, where it was exploited by three fishing methods, verandah, trammel and gill nets. Age and growth parameters are the most important study to our understanding of the fish biology was enable to control of fishing. Because of the high level of fishing mortality, the population continually declined and had stayed at a low level (Kuo *et al.*, 2017). El-Ganainy, 2002 concluded that, population dynamic studies should be undertaken to assess the resource of this species in Bardawil lagoon. The present work is aims at developing an appropriate management plan to maintain of stock of *M. cephalus* in Bardawill lagoon, North Sinai, Egypt**.**

MATERIALS AND METHODS

Bardawill lagoon (Fig. 1) is an area of study. The lagoon is a shallow and saline bond bordered by the Mediterranean Sea; it lies between Lat 33^{o} 0' East 31^{o} 0' North in North Sinai Peninsula.

A total of 961 specimens of Grey mullet, *M. cephalus* were collected during eight months from mid April to mid December 2015 (one fishing season), while the biological close period during January to March. The specimens were collected from well mixed catch of fishing gears (verandah, trammel and gill nets). Total length was measured to the nearest mm and total weight was recorded to nearest 1 g. The relationship between length and weight was described by the potential equation $W = aL^b$, where W is the total weight (g), and L is the total length (cm) and a & b are constants. For age determination, the scales were used after cleaning and reading under reflected light at 33 x magnifications. The back-calculated total length at the end of each year was determined from scale measurements using Lea's (1920) equation as

$$L_n = (L - a)\, S_n / S + a$$

Where: L_n equals length of fish at formed of ring n (*age at n year*), L equals the fish length at capture, S_n equals the scale radius at fish length L_n and S is the total radius of scales (a: constant). The calculated weight at the end of each year was estimated by applying length-weight equation.

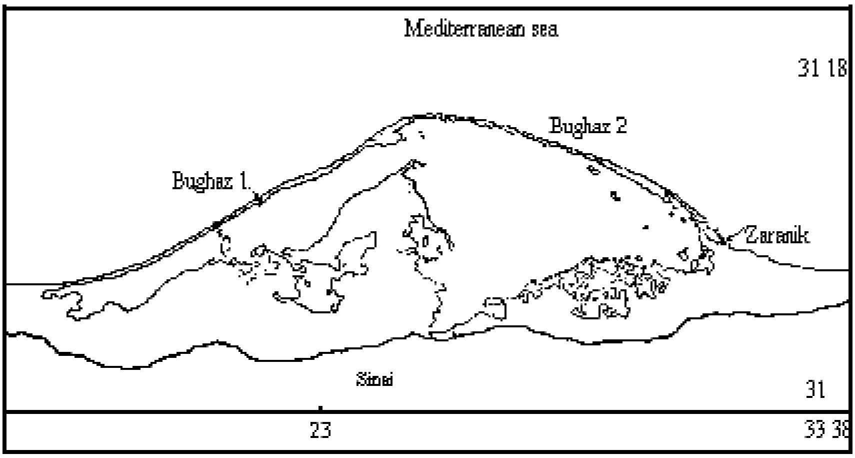

Fig. 1. Bardawill lagoon.

The von Bertalanffy growth parameters were estimated by the least squares method for length observed (Sparre and Venema, 1998): $L_t = L_\infty\,(1- e^{-k(t - t_0)})$, where L_t is the length at age t, L_∞ the asymptotic length, K the body growth coefficient and defines the growth rate towards L_∞ and t_0 the hypothetical age at which a fish would have zero length. The values of L_∞, K and t_0 were estimated by plotting L_t *vs* L_t+1 (Ford, 1933, Walford, 1946). The growth performance index was calculated by using the phi prime test (φ') = $\log(k) + 2\log(L_\infty)$ which can also be used for comparing growth rates among species (Munro and Pauly, 1983). The maximum length (L_{max}) was obtained from extreme value theory (Formacion *et al.*, 1991). Estimate of life span (T_{max}) according to Taylor, 1958 where it is the approximate maximum age that fish of a given population would reach ($T_{max} = 3/k$). Length with the highest biomass in an unfished population (L_{opt}), estimated according to Beverton, 1992 from the parameters of the von Bertalanffy growth function and natural mortality as $L_{opt} = L_\infty [3/ (3+M/K)]$.

Total mortality coefficients were obtained by using of Powell-Wetherall plot based Powell,1979 which discussed in Wetherall *et al.*, 1987 as $Z = 1-k$. Natural mortality coefficient (M) was estimated by using Alverson and Carney, 1975 equation as $M = 3 * K / [exp^{(T_{max} * 0.38 * K)} - 1]$ where T_{max} is the age of the oldest fish ($T_{max}=3/k$). Fishing mortality $F=Z-M$. The exploitation rate (E) equal F/Z (Gulland, 1971).

Yield per recruit (Y/R) was estimated by Gulland, 1969 model as:

$$Y/R = F\, e^{-M(tc-tr)}\, W_\infty [(1/Z) – (3S/Z + K) + (3S^2/ Z + 2K) – (S^3/ Z + 3K).$$

Biomass per recruit (B/R) was obtained by Beverton and Holt, 1957 equation as B/R = Y/R / F where "F" is the fishing mortality. Biological reference points "BRP", "F_{max}" and "$F_{0.1}$" were obtained according to Cadima, 2003. The effects of age and length at first capture on yield per recruit at the present value of fishing mortality and at different fishing mortality values were calculated using Gulland, 1969 model.

RESULTS

Length – weight relationship.

The observed total length of 961 individuals of Grey mullet, *Mugil cephalus* which caught from Bardawill lagoon during period April to December, 2015 ranged from 12.8 to 49.8 cm (Fig. 2) and the observed total weight from 28 to 1222 g. The length – weight relationship (Fig.3) was described by the power equation as: $W= 0.0108\, L^{2.963}\, (R^2 = 0.9694)$.

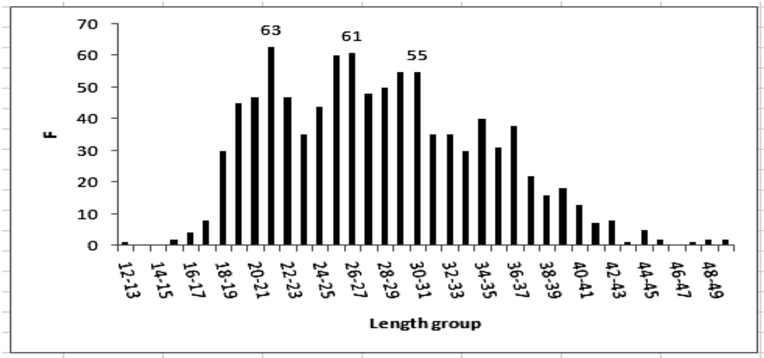

Fig.2. Length frequency distribution of *Mugil cephalus* in Bardawil lagoon during season, 2015.

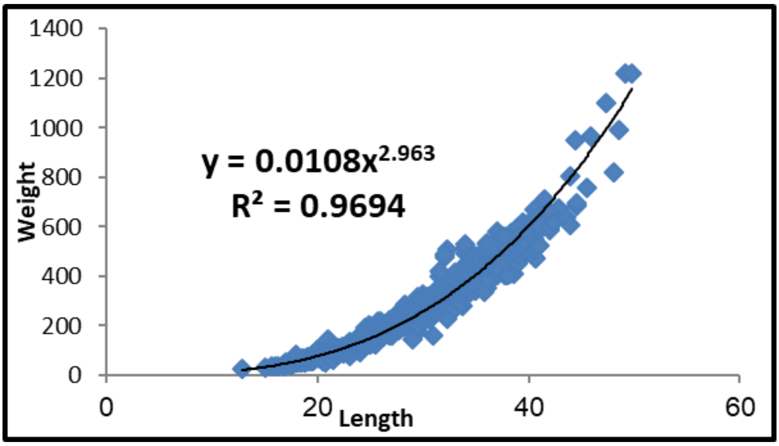

Fig.3. Length weight relationship for *Mugil cephalus* in Bardawil lagoon during season, 2015.

Age determination.

Scales reading of individuals showed a six age classes. Age - length key were calculated. Table 1 revealed that, six age groups were identified as 10, 40.8, 26.1, 13.8%, 5.1, 2.8 and 1.4 as a percent for 0, 1st, 2nd, 3rd, 4th, 5th and 6th age groups respectively.

Back – calculation lengths and weight.

The following formula was derived to obtain the back-calculated total length at the end of each year of life: $L_n = (L - 9.3934)\, S_n / S + 9.3934$.

Average back – calculation lengths and annual increment of *M. cephalus* (Fig. 4) as 21, 28.5, 33.8, 37.4, 40.7 and 43.9 cm for age 1, 2, 3, 4, 5 and 6 years respectively. Back–calculation weights at the end of each year of life were estimated by applying the length – weight relationship and the results are 89.1, 219.7, 365.1, 495.2, 637.0 and 792.4 g for age 1, 2, 3, 4,5 and 6 years respectively and the annual increment of weight given in Fig 5.

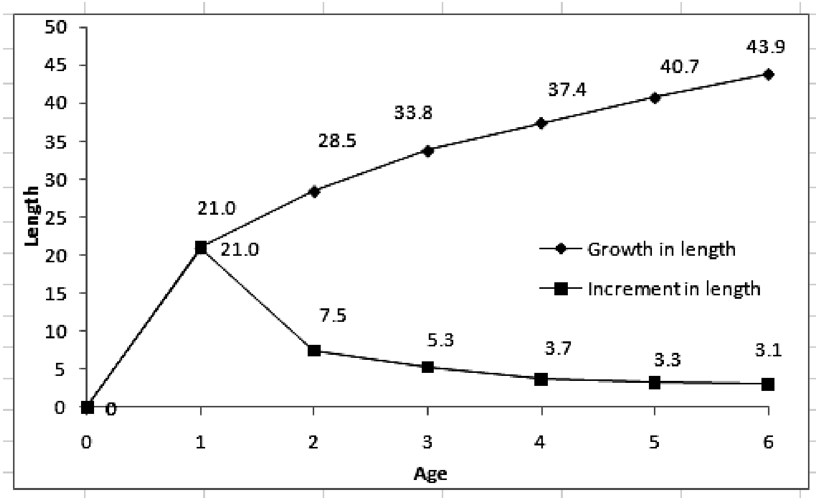

Fig.4. Back calculation length (*TL cm*) at the end of life years of *M. cephalus* in Bardawill lagoon.

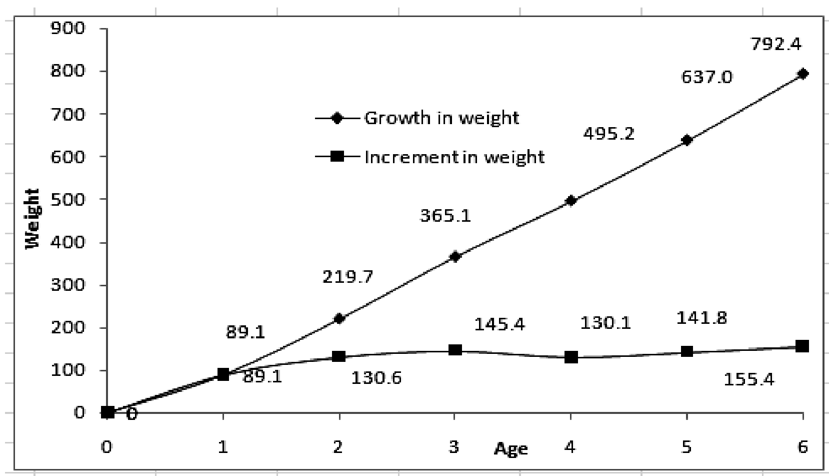

Fig.5. Back calculation weight (gm) at the end of life years of *M. cephalus* in Bardawill lagoon.

Table 1. Age - length key for *M. cephalus* in Bardawill lagoon during season 2015.

L. groups	Age classes							Total
	0	1	2	3	4	5	6	
12--13	1							1
13-14	0							0
14-15	0							0
15-16	2							2
16-17	4							4
17-18	8							8
18-19	30							30
19-20	41	4						45
20-21	8	39						47
21-22	2	61						63
22-23		47						47
23-24		35						35
24-25		44						44
25-26		60						60
26-27		59	2					61
27-28		30	18					48
28-29		12	38					50
29-30		1	54					55
30-31			55					55
31-32			35					35
32-33			35					35
33-34			14	16				30
34-35				40				40
35-36				31				31
36-37				37	1			38
37-38				9	13			22
38-39					16			16
39-40					16	2		18
40-41					2	11		13
41-42					1	6		7
42-43						7	1	8
43-44						0	1	1
44-45						1	4	5
45-46							2	2
46-47							0	0
47-48							1	1
48-49							2	2
49-50							2	2
Total	96	392	251	133	49	27	13	961
%	10	40.8	26.1	13.8	5.1	2.8	1.4	100

Growth parameters.

The von Bertalanffy growth parameters were estimated as $L\infty = 52.19$, $K = 0.2610$ and $t_0 = 0.9698$ respectively. The von Bertalanffy growth equations were obtained as follows

For length: $L_t = 52.19(1-e^{-0.2610\,(t+0.9698)}))$

For weight: $W_t = 1326.59\,(1 - e^{-0.2610\,(t+0.9698)}))^{2.963}$

Growth performance index (φ').

The growth performance index (φ and φ') as defined by computed for *M. cephalus* in Bardawill lagoon and found to be 2.85 for length and 1.4984 for weight.

Estimation of L_c

The length at first capture (*Lc*) which 50% of fishes retained by the gear of *M. cephalus* in Bardawill lagoon were estimated at 27.5 cm (Fig 6).

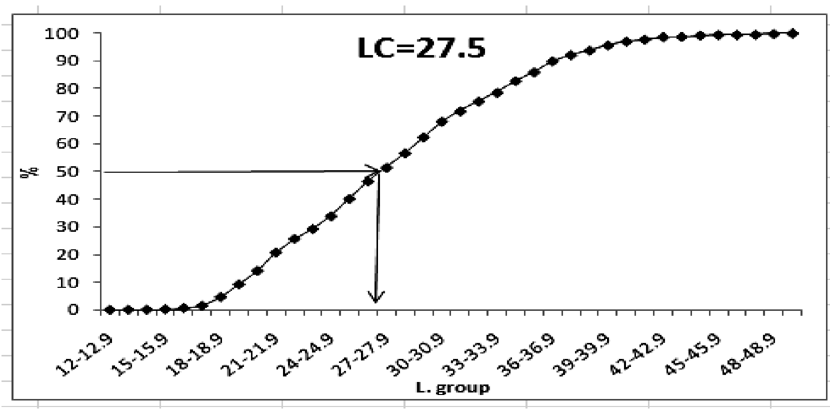

Fig. 6 *Lc* of *M. cephalus* in Bardawill lagoon

Mortalities and exploitation rate.

Total mortality (Z), natural mortality (M) and fishing mortality F for *M. cephalus* were estimated at 0.7425, 0.3681and 0.3744 year^{-1} respectively. Exploitation rate (E) was estimated as E=F/Z =0.504.

Yield per recruit (Y/R) and biomass per recruit (B/R).

The yield per recruit (Y/R) and biomass per recruit (B/R) of *M. cephalus* in Bardawill lagoon were found to be 101.268 g and 270.5g at the actual fishing mortality 0.3744year^{-1} respectively. Biomass per recruit was decreased with the increasing of fishing mortality where it maximum Biomass per recruit (770.839 g) at F=0 (Fig.7).

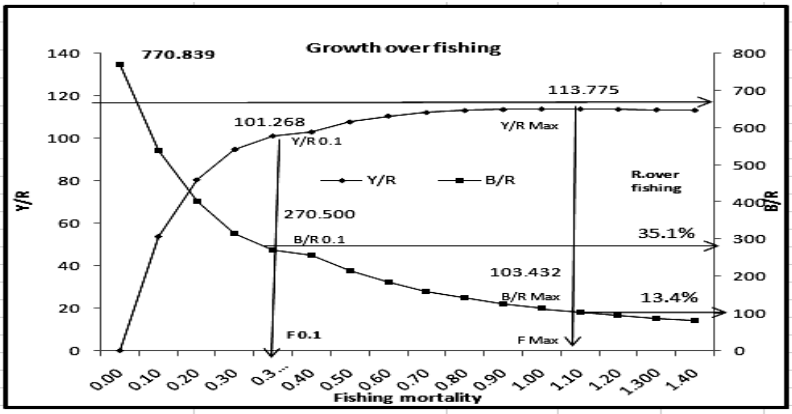

Fig. 7. Yield per recruit and biomass per recruit of *Mugil cephalus* in Bardawil lagoon.

The effect of different values of "tc" in (Y/R) with different values of "F".

The yield-per-recruit as a function of fishing mortality with age at first catch (t_c), was calculated taking values of t_c ranging from 1.0 to 2.5 years (Fig. 8). The higher values of yield per recruit: 98.12, 107.564, 113.797 and 120.605 with different age at first capture: 1, 1.5, 1.898, and 2.5 years can be obtained at fishing mortalities: 0.6, 0.8, 1.1 and 2.1 respectively. The increase of fishing mortality coefficient from 0.3744 (current) to 1.1 [(1.1 – 0.3744) / 0.3744] * 100 = 193.82%) would be increase the yield per recruit by only 12.51% [113.797 – 101.284/ 101.284 * 100 = 12.51%].

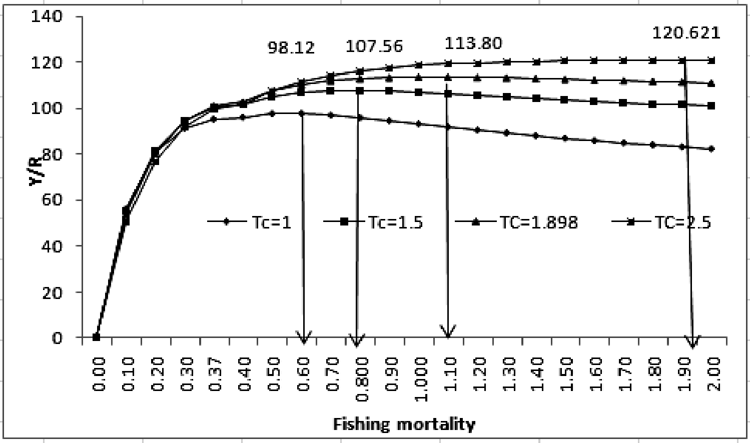

Fig. 8. Yield per recruit with different values of (F and tc) of *M. cephalus* in Bardawill lagoon, season 2015.

DISCUSSION

Growth and age structures of fishes are the main rule to make a decision managing in fisheries; the length – weight relationship is essential in fishery research and management, where used to estimate a condition index and provides indicators about the ecology of species (Anderson and Neumann, 1996). In present study, the exponent (b value) equal 2.963, around isometric value (b closed to 3). The values obtained in this study are narrow or higher at compared with previous results in the same lagoon as b equals 2.82 (Bebars, 1986), 2.86 (El Ganainy *et al*., 2002) and 2.67 (Attia, 2013).This results were confirmed by Espino-Barr *et al.* (2015) where they found the b value equal 2.95 in Mexican Central Pacific. Geographical and environmental parameters are one of the major reasons for b value difference. Lagoon located in arid area (unstable temporally and spatially), where the Mediterranean climate, added, it is shallow water with irregular bottom type and it has a high fluctuation in salinities (Salem, 2004). Our results confirmed by previous studies in region, established that, the b values differs as seasonality and yearly.

Fishermen appear to be catching all ages. Six age groups were identified, 1st age group dominated (40.8%), followed by 2nd age group (26.1%) with 10% of 0-age, while larger groups represented by 23.1% only. These results indicated that, stock of Grey mullet in lagoon were unbalanced, dominated by small fishes (76.9 % of young age group). These results confirmed by El Ganainy *et al.* (2002) where they indicating that small-age fish are predominant in landing in the same lagoon. The annual increment in first year of life is the best compared with previous results in the same lagoon according to Hamza, 1999 (1^{st} age equal 14.2 yr). This means that the environment is appropriate during the study period. Growth of successive ages may differently depending on environmental conditions (FAO, 1998).

From the above results clear that the mesh size of fishing nets were very small and need adjustment to catch big size only. Also, results indicated the need to activate strict control on the size of fishing net openings in the lagoon in order to preserve the catch.

Growth parameter ($L\infty$) values are lower in relation to previous studies. These differences can be explained the effective of over-fishing. Growth performance index (φ') was 2.85, which can be used to compare growth rates among species and to evaluate growth performance under environmental stresses (Pauly, 1984). In this study, the phi prime (φ') was lower than previous studies for the same species in same place, due to lower of $L\infty$ in this study. This means that, despite the stability of environment at the age of 0 and 1 age, the old groups have been affected by over-fishing.

Determination of fish mortality is necessary to fisheries management. Instantaneous coefficient of total mortality (Z) and growth are antagonistic as the ratio Z/K is higher than 2, (Z/K ≈ 2.85 in this study) meaning of the stock is overexploited according to Barry and Tegner (1989). Exploitation ratio (E=0.504) which express overfishing according to Pauly (1987), where he proposed F optimum equal to 0.4 M. Thus, the stocks under two problems; catch the younger fish and the overfishing.

The length at first capture was estimated as L_{c50} = 27.5, corresponding ages were 1.9 year. These length lower than the length at first mature (L_m = 31, corresponding ages were ≈2.5 years) according to Attia, 2013. Thus, this study will be introducing some fisheries management strategies to decline in fishing of immature fish to spawn in near future. The ratio of M/K equal 1.41 falls in normal range of 1- 2.5 according to Beverton and Holt (1959).

For fisheries management purposes, it is important to determine the Y/R at different values of fishing efforts. The variation in Y/R of Grey mullet with changing of Tc related to the optimum mesh size. Firstly, Y/R increased with increasing in F, reaching a peak, and slightly decreased with further increasing in F. With current F (0.37 yr^{-1}) and Tc (1.898 yr), the maximum sustainable yield per recruit is about 100 g. Y/R will be increased by 12.5% with increasing of F to 1.1 at current Tc, but the increasing of effort from F = 0.37 (current fishing mortality) to F_{max} (F = 1.1) associated with negligible increase in the yield per recruit, meaning of, the increase in fishing effort by 193.82% over production as much as 12.5% only. This is unacceptable biologically and at this rate, the catch may not be sustained in the long run and it will have to be followed by a period of much lower yield. Also, the increasing of current F to high levels will be cause decrease in B/R. The value of Tc (which is a proxy of mesh size) and the current exploitation rate (which is a proxy of effort) indicated that the small fish are caught at higher effort level. Also, Tc of catches in this study (1.9 yr) is younger than the age at first maturity ($Tm_{50\%}$ ≈2.5 yr). Then, increasing Tc to $Tm_{50\%}$ protected the stock and will be improve the yield status of these fish in a long run. Thus, changing Tc through changes in mesh size would be a more effective to manage Grey mullet, *M. cephalus* stock.

RECOMMENDATION:

We can recommend that; supervise on fishermen to respect the regulation. Attempts should be made to increase the age at first capture from 2 to 2.5 year by adjustment work in the mesh size of fishing nets to catch fish larger than 31 cm (change of current mesh to optimum mesh size of fish mature catching) to help escapement of immature fish that in turn may help recoup the fishery from the intense fishing activity in subsequent years. Also, the decrease in fishing effort will help maintain the state of *M. cephalus* stocks.

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تقدير بعض العوامل البيولوجيه والانتاج النسبى بغرض ادارة مصايد اسماك البورى فى منخفض البردويل

عطيه على عمر[1] ، محمد سالم[2]

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الملخـص العربـى

دُرست بعض الصفات البيولوجيه لاسماك البورى مثل النمو والنفوق وكذلك الانتاج النسبى فى منخفض البردويل على عينه عشوائية (961 سمكه)، والتى تراوحت اطوالها من 8,12 الى 48,9 سم والاوزان من 28 الى 1222 جم) تم جمعهم فى الفتره من من ابريل حتى ديسمبر 2015 (موسم صيد واحد). كانت العلاقة بين الطول والوزن ($W= 0.0108*L^{2.963}$). تم تحديد العمر عن طريق قراءه القشور وكانت المجموعات العمريه من عمر سنه الى 6 سنوات عمريه. اظهرت النتائج ان الوفره النسبيه كانت للمجموعه العمريه الاولى (40,8%) والثانيه (26,1%). وكان الطول عند نهاية كل سنه عمريه (21، 28,5، 33,8، 37,3، 40,7 و43,5 سم) من السنة الأولى الى السادسة على الترتيب. تم حساب ثوابت فون برتلانفى للنمو على النحو التالى: ($L\infty= 52.19$ cm, $K = 0.261$ year^{-1} and $t_0 = -0.9698$ year).. ودليل النمو φ = 2,85. وتم قياس النفوق الكلى =0,7425 والنفوق الطبيعي 0,3681 والنفوق بالصيد 0,3744 سنوياً. كان معدل الاستغلال ($E= 0.504$). وتشير النتائج الى ان الطول عند بداية الصيد كان 27,5 سم بما يقابل عمر 1,9 سنه وهو عمر اقل من العمر عند بدايه النضج الجنسى وهو العمر السائد فى المصيد. مما يتطلب عدم زيادة جهد الصيد الحالى مع التوصية بزيادة فتحات شباك المصيد الحالي من أجل زيادة العمر عند بداية الصيد إلى 2,5 سنه والذي يحافظ على مخزون هذا النوع ويحقق أعلى عائد للإنتاج النسبي كما يتيح فرصه في زياده جهد الصيد الحالى على المدى البعيد.