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Original Article

Population dynamic parameters of the red mullet *Mullus barbatus* (Mullidae) in the Arzew Gulf, Algeria

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Abstract: Population dynamic parameters of red mullet, *Mullus barbatus* (n=592) caught by trawlers operating in Arzew Gulf (Algeria) in the western Mediterranean were studied. Samples were collected between February 2003 and January 2004. Females ranged from 10.9-23.2 cm in total length and 12-149.2 g in weight whereas males length was comprised between 12.6 and 19.7 cm and weight between 21.3 and 99.9 g. The relationship between length and weight was $W=0.00167L^{2.842}$ ($r^2=0.850$). Growth parameters of the von Bertalanffy equation were: $L_\infty=208.9$ cm, $K=0.66$ year^{-1}, and $t_0=-0.143$ year for males, while for females: $L_\infty=250.9$ cm, $K=0.6$ year^{-1}, and $t_0=-0.015$ year. Estimates of total (Z), natural (M) and fishing (F) mortalities were: 1.58, 0.8 and 0.79, respectively and the estimated exploitation ratio 0.5 indicating that the resource is being exploited at its limit in this area. The virtual population analysis of *M. barbatus* by VIT software showed that the number of recruits per year was estimated at 4447304.6 individuals, balanced total biomass was estimated at 168 486 tons, the gains are represented by recruitment 51.71 tons (30.69%) and growth 116.76 tons (69.31%), losses are represented by natural mortality 98.48 tons (58.45%) and fishing mortality 70 tons (41.55%). The current yield per recruit was estimated to Y/R=15.74 g and maximum sustainable yield can be reached by increasing the current fishing effort to stabilize it at MSY=17.91 g.

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Introduction

Red mullet, *Mullus barbatus* is a demersal fish living on muddy, sandy or gravel bottoms of the continental shelf between 10 to 500 m of depth. It is usually caught by trawlers (Bauchot and Hureau, 1986) and represents one of the economically most important species for trawl fishery at Oranian coasts. Several works have already been made on its biological features in the Mediterranean basin (Ardizzone, 1998; Jukic-Peladic, 1998; Marano et al., 1998; Morey et al. 2003; Gharbi et al., 2004; Ozbilgin et al., 2004; Layachi, 2007; Joksimović et al., 2008; Maximov et al., 2008; Mehanna, 2009; Giacalone et al., 2010; Sieli et al., 2011; Aydın and Karadurmuş, 2013; Cherif, 2014; Çiçek, 2015).

Arzew Gulf is located between Stidia and Mostaganem towns in the Algerian shoreline of Mediterranean with the geographical coordinates of 35°49'59"N and 00°10'00"W. It constitutes one of the biggest petroleum harbors and many industrial complexes are situated in this area making it an industrial and commercial hub for Algerian economy. Arzew fishery is the second one in the area after Oran town fishery and supplies the surrounding towns in sea products.

The aim of this work was to describe some population dynamical parameters of *M. barbatus* in the Arzew Gulf to ensure the renewal of the resource given that it is under over fishing pressure during these last decades (Bensahla Talet and Boutiba, 2000) similar to benthic species of this Gulf. Also, this study will contribute enriching the available data on growth and fisheries of this species in the Western Mediterranean.

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Materials and Methods

A total of 594 specimens of *M. barbatus* were caught by a commercial bottom trawlers, operating in the Gulf of Arzew (Fig. 1) at depths of 150-300 m between February 2003 and January 2004. The total length (L) was measured with an ichtyometer to the nearest 1 mm; total weight (W) was measured with a precision balance to the nearest 0.1 g, and sex of individuals was determined after opening their abdominal cavity.

The length-weight relationship (LWR) is generally expressed by the following equation: $W = \alpha * L^b$ (Ricker, 1973), where W is the total weight (g) and L= total length (cm). The parameters α and b were estimated by the method of least squares obtained by logarithmic transformation to correct the nonlinearity of the original curve and the heterogeneity of variances:

$$\text{Log}\, W = b * \text{Log}\, L + \text{Log}\, \alpha$$

The null hypothesis for the isometric growth (H_0: b=3) was analyzed by t-test, using the following statistical formula: ts = (b-3)/Sb, where Sb is the standard deviation of the parameter b, for α=0.05 (Morey et al., 2003). The parameters of the equation of von Bertalanffy growth were estimated using the ELEFAN method (FISAT II Gayanilo et al., 2005): $L_t = L_\infty [1 - e^{-k(t-t_0)}]$, where L_t is total length in cm at a given age L_∞ is asymptotic length, k is growth curve parameter, and t_0 is hypothetical age for a length equal to zero.

The Jones and Van Zalinge plot (Jones and Van Zalinge, 1981) was used to estimate total mortality using FISAT II (Gayanillo et al., 2005), the natural mortality was calculated using Pauly's empirical equation (Pauly, 1980) as following:

$$\ln(M) = -0.0152 - 0.279 \ln(L_\infty) + 0.6543 \ln(K) + 0.463 \ln(T)$$

Where T is the mean annual habitat temperature (in °C) considered here at 17.5°C, and F the fishing mortality was deducted from the subtraction of M from Z (Z=M+F). The selection length which corresponds to the probability of capture of each individual by the fishing gear was determined by plotting the cumulated catch curve (Pauly, 1984). The exploitation ratio E was estimated from Gulland formula (Gulland, 1971): E=F/Z. (E<0.5 underexploited stock, and E>0.5 overexploited stock). VIT Software (Lleonart and Salat, 1997) was developed initially for assessing Mediterranean fisheries dealing with pseudo-cohorts when information about annual catch at length or age is limited to a short period of individual or few consecutive years (Ratz et al., 2010). The program has as entry data: growth parameters of von Bertalanffy (L, k, t_0), LWR, natural mortality (M), fishing mortality (F), and length at first maturity. Also it only requires knowledge of annual catches for a given exploited species (70 tons in the case of this study) instead of a long historical series of ten years (Bouaziz et al., 2010).

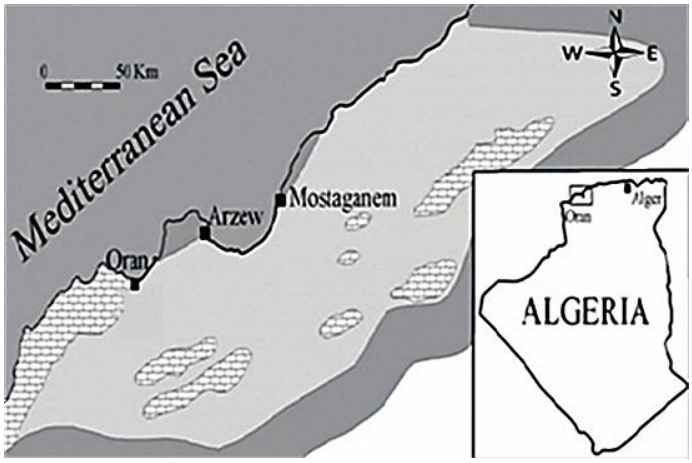

Figure 1. Sampling area (Arzew Gulf).

Results

From 594 collected specimens of *M. barbatus*, 258 were males (43.58%), 318 were females (53.37%) and 18 were unsexed (3.04%). The sex ratio was in favor of females 1:0.81 (Fig. 2) but the χ^2 test did not reveal any significant difference (χ^2=2.93>$\chi^2_{t\ 1,0.05}$=3.84). The total length of males ranged 12.6-19.7 cm and their weight 21.3-99.9 g. The total length of females ranged 10.9-23.2 cm and their weight 12-149.2 g. The length frequency distribution of the entire population of *M. barbatus* is presented in Figure 3.

The LWRs are shown in Table 1 and Figure 4a, b, c. Males exhibits a positive allometric growth pattern, while females had a negative allometric

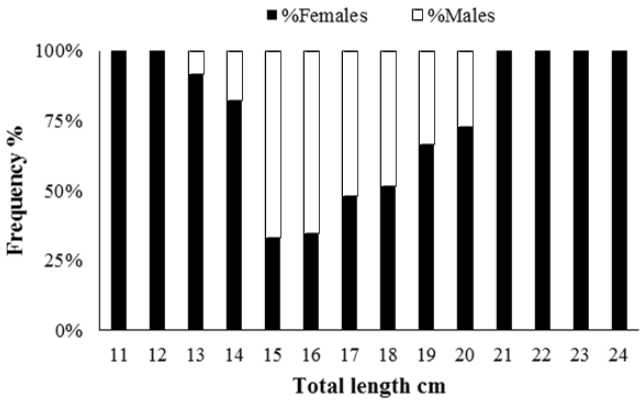

Figure 2. Sex ratio distribution in relation to length of *Mullus barbatus* caught in Arzew Gulf.

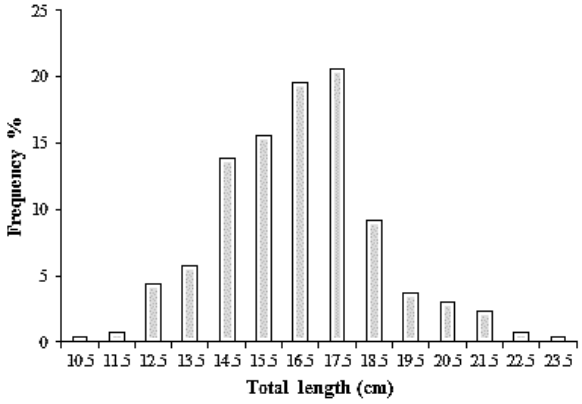

Figure 3. Length frequency distribution of *Mullus barbatus* caught in Arzew Gulf.

Table 1. Parameters of the length-weight relationship of *Mullus barbatus* caught in Arzew Gulf.

	n	α	*b*	se of *b*	r^2
Combined	594	0.0172	2.83*	0.015	0.83
Males	258	0.0079	3.11*	0.041	0.84
Females	318	0.0176	2.82*	0.057	0.86

n: number, se of *b*: standard error of *b*, *: significative test-t (t-test, $P<0.05$).

Table 2. Parameters of the von Bertalanffy growth equation, the rates of total (Z), natural (M) and fishing (F) mortalities and exploitation ratio (E) of *Mullus barbatus* caught in Arzew Gulf.

	L_∞ (mm)	K (Yr^{-1})	t_0 (Yr)	Z	M	F	E
Combined	250.9	0.49	-0.185	1.580	0.794	0.786	0.490
Males	208.9	0.66	-0.143	1.560	1.010	0.550	0.350
Females	250.9	0.60	-0.150	1.700	0.906	0.794	0.467

Table 3. Virtual population analysis parameters of *Mullus barbatus* caught in Arzew Gulf obtained by VIT 1.3 software.

Class (cm)	Catch in Weight (g)	Catch in number	Z	F	VPA parameters	Result
10.5	62226.66	4447304.6	0.808	0.008	Total Biomass Balance, D	168.486 t
11.5	163381.13	3971900.97	0.817	0.017		
12.5	1354669.35	3513191.49	0.917	0.117	Spawning Stock Biomass (SSB)	79.48 t
13.5	2201490.45	3027695.76	0.965	0.165		
14.5	6495585.79	2554243.99	1.246	0.446	Stock Mean Age	1.537 year
15.5	8796137.83	2008513.55	1.392	0.592		
16.5	13215384.38	1493064.51	1.752	0.952	Stock mean length	13.872 cm
17.5	16378226.85	984290.21	2.265	1.465		
18.5	8495328.58	534870.29	1.814	1.014	Virgin stock mean age	1.674 year
19.5	4015651.3	304651.16	1.4	0.6		
20.5	3785692.09	182491.4	1.526	0.726	Virgin stock mean length	15 cm
21.5	3353111.66	92335.88	1.813	1.013		
22.5	1083359.34	32727.46	1.401	0.601	Biomass/Rercuit	27.681 g
23.5	599754.59	10696.75	1.586	0.786	SSB/Recruit	17.87 g
Total	70000000	23157978.02	-			

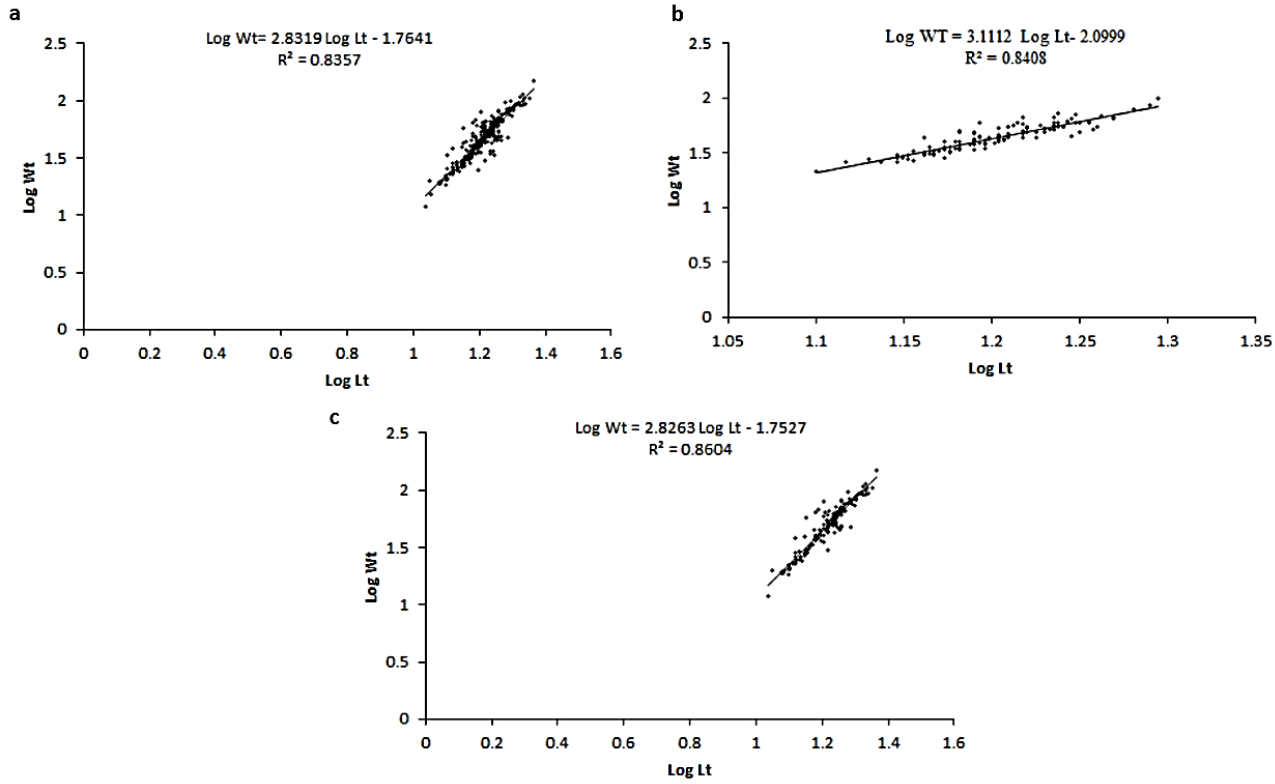

Figure 4. Parameters of the length-weight relationship of *Mullus barbatus* caught in Arzew Gulf. (a) all individuals, (b) males, and (c) females.

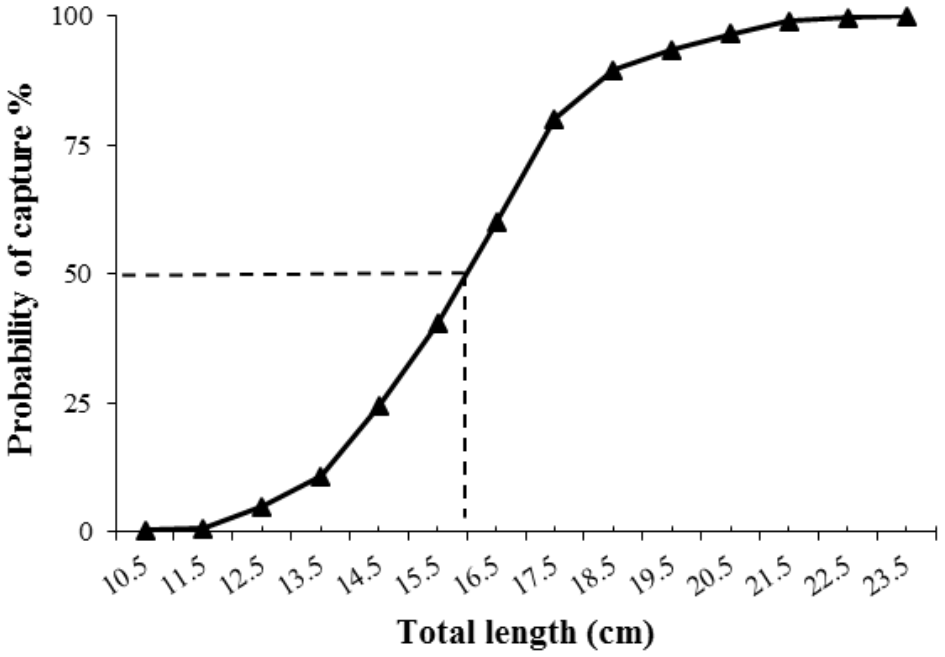

Figure 5. Gear selection ogive for *Mullus barbatus* caught by trawl in Arzew Gulf (codend mesh size of 4 cm).

growth pattern (t-test, $P<0.05$). The selection length at which 50% of individual can be captured by the fishing gear was determined graphically (Fig. 5) and was evaluated at 16.08 cm of L_t. The von Bertalanffy growth parameters, mortalities (Fig. 6a, b) and exploitation ratio are shown in Table 2. The exploitation ratio (E=0.49) reflects a fishing situation near the equilibrium concerning the

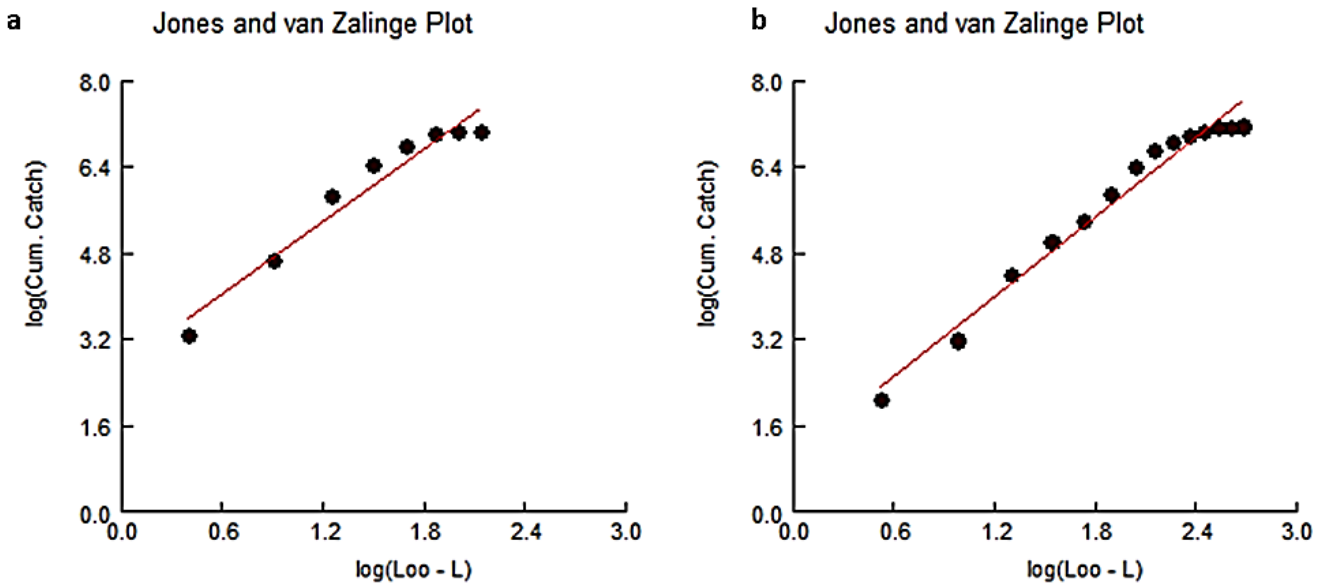

Figure 6. Total mortality of *Mullus barbatus* fished in Arzew Gulf. (a) males and (b) females.

Table 4. Length-weight relationship parameters for *Mullus barbatus* in the previous studies.

Locality	sex	n	α	*b*	se of *b*	r^2	Author
Turkey (Black Sea)	C	1435	0.00880	3.03	-	-	Aydın and Karadurmuş, 2013
Turkey (Iskenderun Bay, Mediterranean)	C	212	0.0072	3.1618	-	0.95	Çiçek, 2015
Romania (Black Sea)	C	680	0.00842	3.12	-	0.99	Maximov et al., 2008
Montenegro (Adriatic Sea)	C	-	0.00773	3.09	-	-	Joksimović et al., 2008
	M	-	0.00729	3.11	-	-	
	F	-	0.00767	3.10	-	-	
Italy (Castellammare Gulf)	C	18932	0.00820	3.09	0.00	0.98	Giacalone et al., 2010
	M	9596	0.00660	3.17	0.01	0.94	
	F	4730	0.00630	3.19	0.01	0.98	
Egypt (Mediterranean)	-	-	0.00770	3.10	-	-	Mehenna, 2009
Morocco (Mediterranean)	C		0,000009	3,03	-	0.98	Layachi et al., 2007
Algeria (Arzew Gulf)	C	594	0.01720	2.83	0.150	0.83	Present study
	M	258	0.00790	3.11*	0.041	0.84	
	F	318	0.01760	2.82*	0.057	0.86	

n: number, M: males, F: females, C: combined sexes, se of *b*: standard error of *b*, and r^2: coefficient of regression.

exploitation of this Mullidae.

The virtual population analysis of *M. barbatus* by VIT software showed that the mean number of *M. barbatus* specimen in Arzew Gulf is 23.15 10^6 while the number of recruits per year was estimated at 4447304.6 represented by size class 10.5 cm (Table 3). Individuals between 16.5 and 19.5 are the most affected by the fishing gear deployed (bottom trawl). The average age of the current stock is 1.53 years and the average size 13.87 cm.

The total balanced biomass is equal to 168.48 tons with gains mainly represented by growth 116.76 tons (69.31%) and recruitment 51.71 tons (30.69%) and losses are represented by natural mortality 98.48 tons (58.45%) and fishing mortality 70 tons (41.55%). The current yield per recruit was estimated to Y/R=15.74 g (for F=0.79) and maximum sustainable yield can be reached by increasing the current fishing

Table 5. Growth parameters of *Mullus barbatus* given by different authors.

Locality	Sex	n	$L_{t\infty}$ (mm)	K (Yr^{-1})	t_0 (Yr)	Author
Tunisia (Gabes Gulf)	**C**	-	267.3	0.51	-0.010	Gharbi et al., 2004
Montenegro (Adriatic Sea)	**C**	671	301.2	0.11	-3.182	Joksimović et al., 2008
	M	-	178.1	0.28	-3.013	
	F	-	274.7	0.14	-2.688	
Romania (Black Sea)	**C**	680	163.2	0.37	-1.390	Maximov et al., 2008
Turkey (Izmir Bay)	**C**	110891	242.6	0.56	-0.305	Ozbilgin et al., 2004
Turkey (Iskenderun Bay)	**C**	212	219.8	0.19	-1.168	Çiçek, 2015
Italy (Castellammare Gulf)	**F**	595	221.2	0.38	-0.940	Sieli et al., 2011
Egypt (Mediterranean)	**C**	-	271.0	0.66	-	Mehenna, 2009
Morocco (Mediterranean)	**C**	-	270.0	0,43	-0.090	Layachi et al., 2007
Algeria (Arzew Gulf)	**C**	594	250.9	0.49	-0.158	Present study
	M	258	208.9	0.66	-0.143	
	F	318	250.9	0.60	-0.150	

n: number, M: males, F: females, and C: combined sexes.

Table 6. Total (Z), natural (M), fishing (F) mortalities and exploitation ratio (E) of *Mullus barbatus* in different areas.

Locality	Sex	n	Z	M	F	E	Author
Montenegro (Adriatic Sea)	**C**	671	0.749	0.342	0.407	0.54	Joksimović et al., 2009
Italy (Adriatic Sea)	-	-	3.51	0.91	2.60	0.74	Ardizzone, 1998
	-	-	1.2-1.9	0.43-0.77	0.77-1.13	0.59-0.64	Marano et al., 1998
Croatia (Adriatic Sea)	-	-	1.48	0.58	0.90	0.6	Vrgoč, 2000
Turkey (Izmir Bay)	**C**	110891	3.85	1.07	-	0.71-0.72	Ozbilgin, 2004
Turkey (Iskenderun Bay)	**C**	212	1.39	0.45	0.93	0.67	Çiçek, 2015
Algeria (Arzew Gulf)	**C**	594	2.86	0.82	2.03		
	M	258	-	-	-	0.71	Present study
	F	318	-	-	-		

effort to stabilize it at MSY=17.91 g (F=1.73).

Discussion

The growth pattern of *M. barbatus* in the Arzew Gulf seems to be different between the two sexes. In fact, males of this species grow faster than females as reported by Joksimović et al. (2008) from the Adriatic. Based on the results, females' asymptotic length is important than that of males due to the fact that males do not attain lager sizes in their natural habitat given that the males (F=1.23) are under a more fishing pressure than females (F=0.79). Furthermore, the females had a negative allometric growth pattern compared to the males (b>3) which confirms that males gain weight faster than length and this was in agreement with the results of Papaconstantinou et al. (1981) for this species in Termaikos Gulf. Growth differences between sexes can be explained by the fact that females undergo significant physiological changes compared to males during their sexual cycle. The positive allometric growth pattern have been reported for this species in some other areas of Mediterranean (Table 4) which is not the case of females caught in Arzew Gulf probably due to weight loss after the spawning period.

The growth parameters of the von Bertalanffy equation differ greatly from one region to another (Table 5) probably due to the biotic and abiotic differences of their habitat. In fact, Magnan (1988), Walker (1997) and Svanbäck (2004) noticed that inter-population variation in LWR parameters are correlated with differences in the availability of resources or by geographical differences in

ecological conditions such as water temperature, salinity, and food supply. The maximum value of the growth constant (k) in the Arzew Gulf reflects fast growth of this species in agreement with findings of Mehenna (2009). This shows the fertility of Algerian waters probably due to entrance of the enriched water with plankton from the Atlantic and coastal upwelling (Taupier-Letage and Millot, 1988). Mortier (1992), Taupier-Letage and Millot (1988), and Salas et al. (2001) found that the Algerian current has a higher nutrient content than the other parts of the Mediterranean being supplied directly from the entering Atlantic current. Furthermore, Bosc et al. (2004) noted that nutrients concentrations are higher in the western Mediterranean basin than the eastern basin allowing the development of phytoplankton and zooplankton. The values of exploitation ratio differ from one region to another (Table 6) depending on the environmental factors affecting the natural mortality and the fishing effort deployed.

Conclusion

Based on the results, the stock of *M. barbatus* in Arzew Gulf is exploited at its maximum limit. In order to maintain a sustainable exploitation of this resource, it would be wise to increase reasonably the fishing effort for a better yield per recruit ensuring the renewal of this resource in Arzew Gulf. Algerian legislation had already set a minimum landing size (15 cm of total length) to preserve the resource but to our knowledge, it is insufficient.

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چکیده فارسی

پارامترهای پویایی‌شناسی جمعیت کفال قرمز، ***Mullus barbatus*** **(Mullidae) در خلیج آرزو، الجزایر**

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چکیده:

در این تحقیق پارامترهای پویایی‌شناسی جمعیت کفال قرمز، *Mullus barbatus* (به تعداد ۵۹۲) صید شده به وسیله ترال در خلیج آرزو (الجزایر) در غرب مدیترانه مطالعه شد. نمونه‌برداری‌ها بین فوریه ۲۰۰۳ و ژانویه ۲۰۰۴ انجام شد. طول کل و وزن ماده‌ها به‌ترتیب ۲۳/۲-۱۰/۹ سانتیمتر و ۱۴۹/۲-۱۲ گرم بودند، در حالی‌که طول کل و وزن نرها به‌ترتیب ۱۹/۷-۱۲/۶ سانتیمتر و ۹۹/۹-۲۱/۳ گرم بود. رابطه طول-وزن نمونه‌ها $W=۰/۰۰۱۶۷L^{۲/۸۴۲}$ ($r^۲=۰/۸۵$) بدست آمد. پارامترهای رشد معادله وان‌برتلانفی عبارت بودند از: $L_\infty=۲۰۸/۹$ cm، $K = ۰/۶۶$ year^{-1} و سال $t_0=۰/۱۴۳$ برای نرها و $L_\infty=۲۵۰/۹$، $K = ۰/۶$ year^{-1} و سال $t_0=۰/۰۱۵$ برای ماده‌ها. مرگ و میر کل (Z)، طبیعی (M) و صیادی (F) به ترتیب ۱/۵۸، ۰/۸ و ۰/۷۹ تخمین زده شدند و نسبت بهره‌برداری نیز ۰/۵ تخمین زده شد که بیانگر بهره‌برداری این منبع در حد نهایی در این منطقه می‌باشد. تحلیل مجازی جمعیت گونه *M. barbatus* توسط نرم‌افزار VIT نشان داد که تعداد بازسازی‌ها به میزان ۴۴۴۷۳۰۴/۶ قطعه در سال می‌باشد، زی‌توده کل بالانس‌شده ۱۶۸۴۸۶ تن تخمین زده شد، افزایش زی‌توده به‌واسطه بازسازی به‌میزان ۵۱/۷۱ تن (۳۰/۶۹ درصد) و به‌واسطه رشد به میزان ۱۱۶/۷۶ تن (۶۹/۳۱ درصد) را نشان داد، تلفات به‌واسطه مرگ و میر طبیعی به‌میزان ۹۸/۴۸ تن (۵۸/۴۵ درصد) و به‌واسطه مرگ و میر صیادی به‌میزان ۷۰ تن (۴۱/۵۵ درصد) را نشان داد. بازده جاری به بازسازی به‌صورت $Y/R=۱۵/۷۴$ g تخمین زده شد و حداکثر محصول پایدار که می‌تواند به‌وسیله افزایش تلاش صیادی بدست آید باید در حد $MSY=۱۷/۹۱$ g ثابت شود.

کلمات کلیدی: بهره‌برداری، صیادی، مرگ و میر، رابطه طول-وزن، وان‌برتلانفی.