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Reproduction and Growth of *Mugil cephalus* (Linnaeus, 1758) in the Moroccan South Atlantic

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ABSTRACT

The aims of the present study were to examine some aspects of reproductive biology, and analyze the relationship between length-length and length-weight of grey mullet *Mugil cephalus* sampled between February 2017 and January 2018 at several localities in South Atlantic Morocco. The individuals' weight and length were measured. The sex ratio of *Mugil cephalus* was 1, 0.46. The total length (L_t) at first maturity (L_{t50}) was estimated for both sexes. The spawning period of *M.cephalus* in South Morocco occurs most of the year in females and is focused in summer in males. The morphometric relationships between the different lengths TL (total length), SL (standard length), and FL (fork length) are linear for females, males and sexes combined. SL = 0.802TL + 13.608* TL = 0.9007 FL - 4.8959*FL = 0.8554SL + 32.911. The length-weight relationships were established for both sexes: WT= 0.00002*TL^2.89 (R^2 = 0.92), for females WT = 0.0007*TL^2.692 (R^2 = 0.86), and for males WT = 0.0003*TL^2.882 for males (R^2 = 0.872). Results showed that the grey mullet had negative allometry. Length grows more than weight in the South Atlantic Coast of Morocco. In addition, the parameters from von Bertalanffy's growth equation were estimated for *Mugil cephalus*, where $L\infty$ = 804 mm; $W\infty$ = 4979.82g; k =0.14, and t0 = –0.4949.

INTRODUCTION

The grey mullet *Mugil cephalus* **(Linnaeus, 1758)**, belonging to the group of Mugilidea, is considered cosmopolitan in the coastal waters of most tropical and subtropical zones **(Thomson, 1963)**. This species is globally distributed between the latitudes of 42°N and 42°S (**Thomson, 1963, 1981**). This euryhaline species lives in gregarious form in coastal waters **(Azeroual, 2003)**. The grey mullet plays an important role in the fisheries and the aquaculture of tropical and subtropical regions of the world **(Briggs, 1960)**. Moreover, in Morocco, this species has a big socio-economic importance. Despite the significant economic importance of this species along the South Moroccan Atlantic Coast, the available literature in Morocco is scarce; little information is known either on its ecology

or biology. Notably, there are some studies on diet analysis in Merja Zerga **(Ameur *et al.*, 2003)** and monograph **(Azeroual, 2003)**. This work has contributed to identify reproductive parameters of grey mullet *M. cephalus.* The morphometric measurements were conducted and the length-weight and length-length relationships of *Mugil cephalus* were addressed to determine some growth parameters which play a fundamental role in the analysis and management of fish populations.

MATERIALS AND METHODS

A total of 281 specimens of *Mugil cephalus* (**Linnaeus, 1758**) were sampled during the time period between February 2017 and January 2018 at several localities in South Moroccan Atlantic (Fig 1). Fishes were collected from different sample stations during the study period. They come from landings of longliners, purseseiners and small board. The sample individuals were identified, measured and weighted.

The all lengths including total length (TL) fork length (FL), standard length (SL) of individuals of the grey mullet were measured to the nearest 1.0 mm. Also the eviscerated and the total weight was determined (W, weight) to the nearest 1g.

Animals were dissected to identify sex and maturity. In Table 1, the stages of maturity are described from the morphological observation of the appearance of the gonads.

Sex ratio, maturity stages, monthly distribution of maturity stages, length at first sexual maturity, gonadosomatic index of mullet *Mugil cephalus* were registred.

Sex ratio (SR)

The sex ratio is defined as the proportion of male or female individuals by compared to the total. The sex of the fish was determined by macroscopic examination of the gonads after dissection for species.

SR = F x 100 / (M + F) and S.R = M x 100 / (M + F) with: F = females and M = males

Size at fist sexual maturity

Size at first maturity estimated size (cm) at which 50% of individuals in a population are sexually mature (TL 50).

The size at first sexual maturity was determined by grouping the individuals sampled during the study period, by size class.

Then, the proportion of mature individuals in each size class was calculated. The threshold of sexual maturity is set at stage III, corresponding the beginning of the development phase of the gonads.

The size-proportion pairs of mature individuals are fitted to a logistic curve of type symmetric sigmoid **(Pope *et al*., 1983**) whose mathematical expression is as follows:

$$P = 1 / (1 + e - (a + b * L))$$

- P: Proportion of mature people by size class
- L: Total length
- a: Y-intercept
- b: Slope

The parameters a and b are obtained, after the logarithmic transformation of the expression by the least squares method **(Sokal and Rholf, 1979**):

$$\ln ((1 - P) / P) = a + b * L$$

With: L50 = -a / b

The determination of L50 is carried out by considering all the pairs of values with the exception of those with a proportion: P = 0 and P = 1

Monthly distribution of maturity stages of Mugil cephalus

The stage of gonads maturation was determinated for 200 specimens of *Mugil cephalus* (males and females) between February 2017 and January 2018 in South Moroccan Atlantic. Gonads were weighted over 0.001 g.

Liver and gonad weights were used to describe reproduction cycle of *Mugil cephalus*. During gametogenesis, the weight of the gonads increases. The reproductive cycle of gonads was determinated for both sexes by the gonadosomatic index (GSI): GSI = g/W*100, where g is gonad weight in g, W is gutted fish weight in g.

Length-length relationship

The relationships between all body length parameters were established by linear regression analysis as:

$$Y = a + bX.$$

Where, Y is various body lengths, X is total length, a is proportionality constant and b is regression coefficient **(Le Cren, 1951).**

The means sizes of *Mugil cephalus* observed in this study were statistically compared between identified male and female specimens using Student't' test.

Table 1: Morphology and duration for gonad cycle of *Mugil cephalus*

Stages of maturity	Description
Immature (SI)	Stages of maturity Immature Thin cylindrical, ovaries and testes occupy nearly a third of the abdominal cavity.
Immature (SII)	the gonads appear under form fine whitish filaments. Each gonad is bordered by fine vessels clearly visible blood. The gonad does not exceed the anterior quarter of the cavity abdominal;
SIII	Ovaries and testes increase in size, occupy about a half of the abdominal cavity. the ovaries are pinkish and the testes are whitish.
SIV	Ovaries and testes increase in size. Ovaries are yellowish in color; eggs are observable with the naked eye and blood vessels can be seen within the ovary detected.
Ripe and spawning (SV)	Gonads reach its maximum development. Ovaries, orange yellow in color, Testicles white – creamy, soft.
Spent (SVI)	The gonads are reduced in size, their color is reddish-yellow, and they have a large number of blood vessels externally.

Length-weight relationship

The relationship of size-weight allows to convert the sizes measured in weight data and to estimate the weight of the catch in fisheries biology **(Vaitheeswaran et al., 2016)**. The relationship between length and weight was determined using the equation:

$$W(t) = aL^b$$

Where:

W = Weight of fish (g);

L = Total Length of fish (cm);

a = coefficient related to body form;

and b = an exponential expressing relationship between length-weight **(Le Cren, 1951)**.

If b is equal (or close) to 3, it is a perfect isometry and the weight growths in proportion to the size, and if b is different to 3 growth is allometry,

If b> 3, the weight is growing faster than the length then allometry is positive,

If b < 3, the weight is growing slower than the length and allometry is negative

The growth parameters L∞, K and t0 of von Bertalanffy growth fonction (FCVB) were estimated by (ELEFAN I) method **(Gayanilo *et al*., 1994**) combined with the Shepherd's length composition analysis (SLCA) method **(Shepherd, 1987)**, using the Windows version of FiSAT (FiSAT II):

$$L_t = L_\infty (1-e^{(-K(t-to))}).$$

Lt: is total length at age t;

L∞: is the asymptotic total length;

K: is body growth coefficient, it determines how fast the fish approaches L∞;

t: the age (years),

t0: the hypothetical age at zero length (**Bagenal, 1978**).

The Windows version of FiSAT (FiSAT II) is a program package developed mainly to analyze the length-frequency data, but also it allows related analyses, of size-at-age, capture-at-age, selection and other analyses.

Classes of age were determined by length frequency analyses with the Bhattacharya method (**Gayanilo et al., 2005**). The size-class interval used in the analysis is 10 mm, it's defined according to the size range collected for all specimen.

RESULTS

Size at first sexual maturity of Mugil cephalus:

The monthly variation of the maturity stages in females and males (*Mugil cephalus*) between February 2017 and January 2018 is shown in (Fig. 2). Percentages of stages differ from month to month and for both sexes.

The size at first sexual maturity in females is set at 459.59 mm, in males L50 set at 455.81 mm.

Sex-ratio

The Sex-ratio of *Mugil cephalus* showed more females than males:

A total of 281 specimens were sampled 52 males and 119 females, giving a sex- ratio of 1 female to 0.43 male.

Seasonal variation in stages of sexual maturity

Six stages of gonadal development were identified in both sexes. The stages are taken in this study are (III, IV, V and spawing) which mark the mature individuals. The monthly values of GSI were ranged from 0.44 to 7.38 in females and from 0.27 to 4.59 in males (Fig.3).

In males, the GSI values were very low from April to July; this period corresponds to many stages of the reproductive cycle, of which the most present are III and spawning. On the other hand the highest values correspond to IV and V.

In females, the values of GSI increase gradually from October until January. In this period the most noticed stages are IV and V. As to LSI, it decrease for both sex after october

A highest activity of fat was observed in March, April and August, September. It starts to decrease in september until february. It happens after the spawning period of summer.

Morphometric parameters

The grey mullet specimens showed a maximum size at 654 mm, a minimum size at 320 mm (table 2 and fig. 4), with a modal class of 490 mm and the mean size at 503,54 mm.

The decomposition of these structures in size by the method of Bhattacharya's reveals five cohorts (fig. 5). That means that the exploited population presented five ranges of age. Table (3) shows the different values of mean size in different classes. The ages “0” and “1”, “2”, “3”, are absents in the catches either because they escape the fishing gear or because they live in non-exploitable areas (Tables 4) (Fig. 6).

The values of (K),(L∞) (W∞) and t0 of *Mugil cephalus* were calculated as:

K = 0.14y-1 , L∞ = 804 mm, W∞= 4979.82 g and t0 = –0.4949

The equation of Von Bertalanffy growth parameters is written as:

$$L_t = 804\,(1 - e^{(-0.14\,(t - 0.4949))}).$$

Dankwa (2011) determined the Von Bertalanffy growth parameters for this species as well:

L ∞= 566 mm (SL); K = 0.31 /yr; t0 = -0.239 in the Volta and Pra estuaries. Other value of L ∞ is obtained in Tamaiahua lagoon Veracruz Mexico L ∞ = 642,4 mm (Ibanez and Gallardo, 1995).

The difference between L∞ estimated in the present study and the values cited may be due to maximal size found in Moroccan south atlantic (Lt max= 654mm).

Length-length relationships

The length-length relationships between total length, fork length, and standard length and also the estimated parameters of the length-length relationship and the coefficient of determination R2 of grey mullet are presented in Table 5.

Length-weight relationships

The 281specimens classified in the interval (319-654 mm (TL)) were ranged from 383g to 2520 g. The weight- length equations for grey mullet were described as follow:
WT = 0.0007TL2.692 for females (R^2 = 0.86), (fig,7)

WT = 0.0003TL2.882 for males (R^2 = 0.872),

WT= 0.00002TL2.89 (R^2 = 0.92) individually

And Wev= 0.0003TL2.83 (R^2 = 0.8) individually

Wev = 0.0007TL2.692 for females (R^2 = 0.857),

Wev = 0.00027TL2.861 for males (R^2 = 0.857), ev: eviscerated

In this study the value of b obtained is 2.89. That means that the grey mullet have a negative allometry; the length grows more than weight in the south Atlantic coast of Morocco.

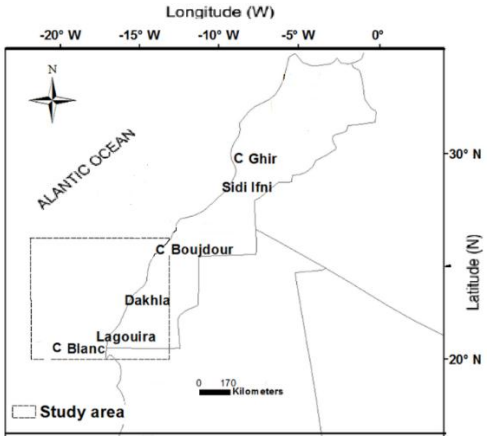

Fig. 1, Study area (Black Square)

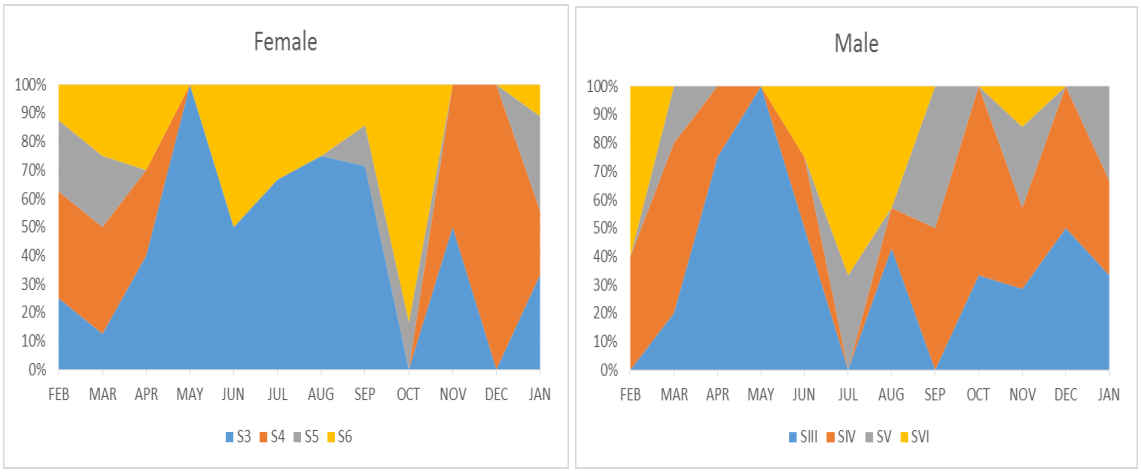

Fig. 2 Monthly evolutions of the percentage of gonadal maturity stages of M. cephalus male and female

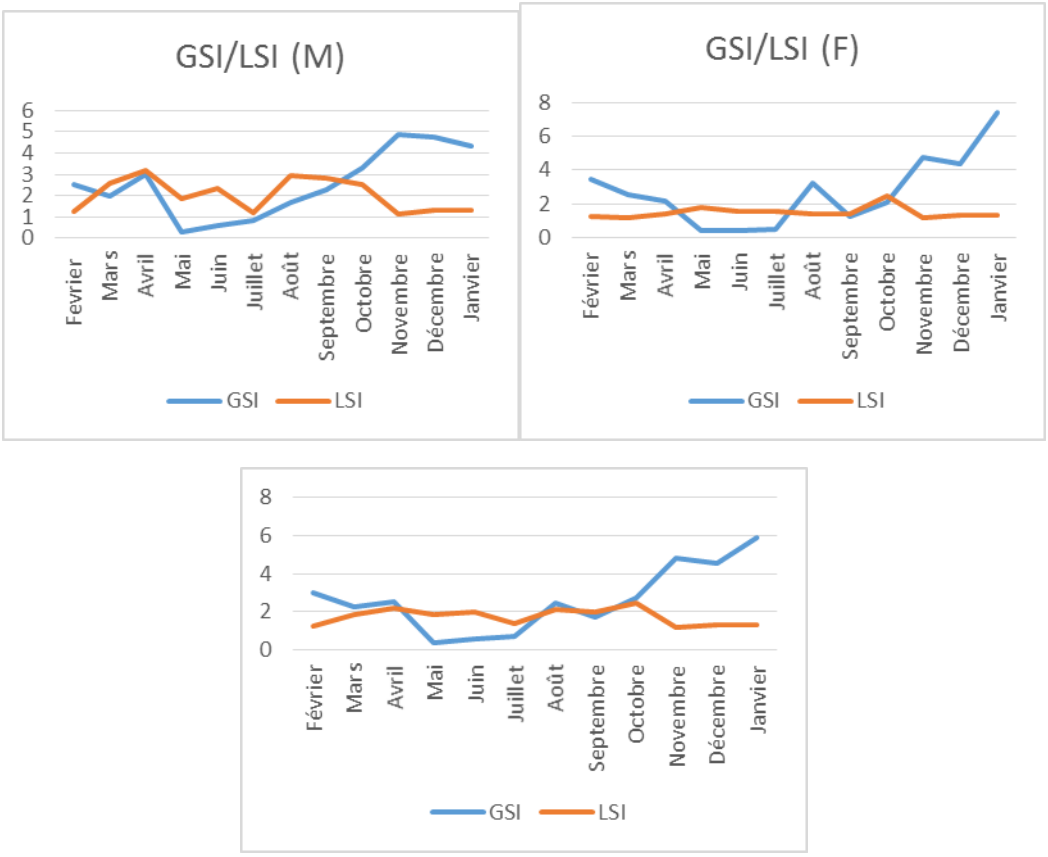

Fig. 3. Monthly variations of the gonado-somatic index (GSI) and liver-somatic index (LSI) of M. cephalus males (M), females (F) and both sex in the Bay of south Morocco.

Table 2. length of male and female samples of *Mugil cephalus*

	Both sexe	females	males
Maximum size (mm)	654	645	577
Minimum size (mm)	356	416	412
Standard deviation σ	37.71	30.065	26.894

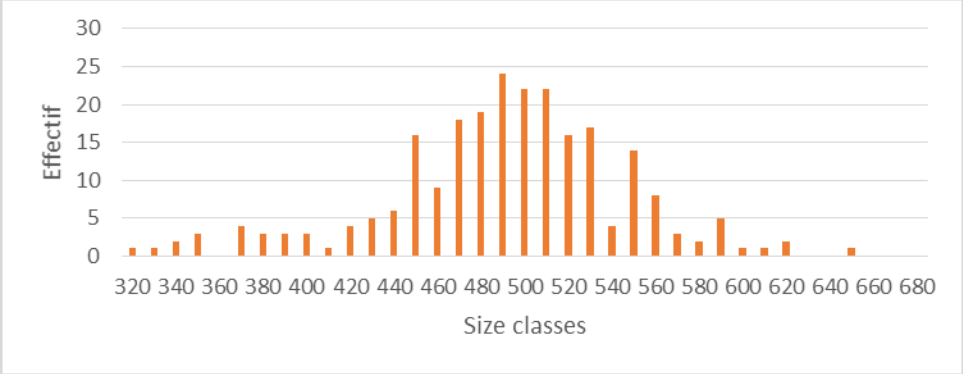

Fig. 4. Length samples of *Mugil cephalus*

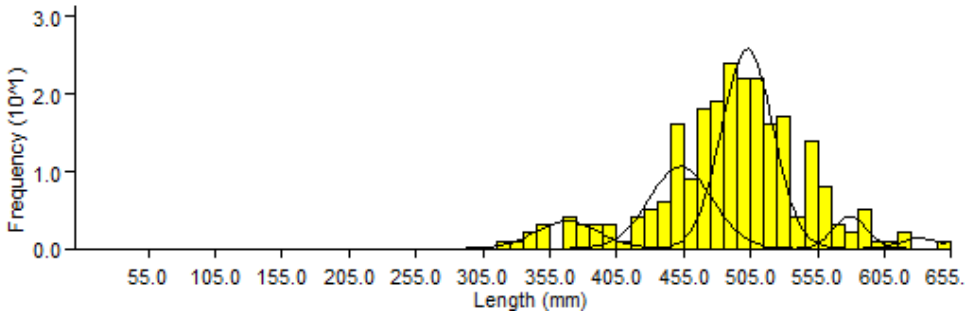

Fig. 5. Total length-frequency distribution (cm) for the grey mullet caught in the Atlantic coast of south Moroccan

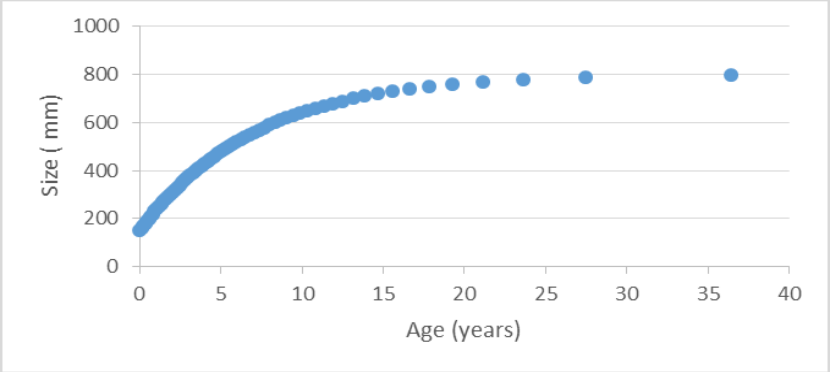

Fig. 6. Size-age Curve of *Mugil cephalus* from the south Moroccan Atlantic coast

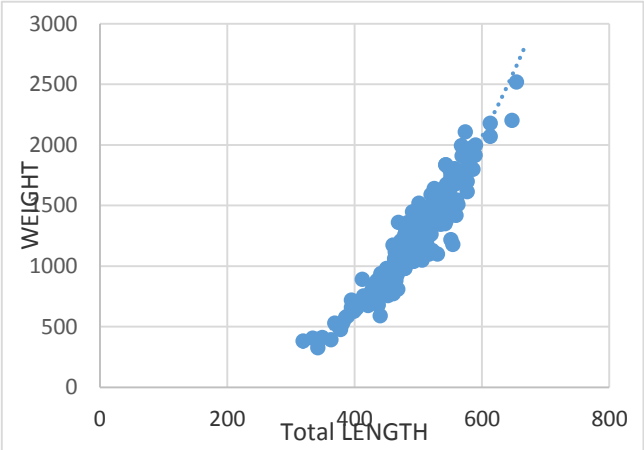

Fig. 7. Length- weight relations of *Mugil cephalus*.

Table 3. Mean size in different ages

MEAN SIZE	AGE
452.51	4.43518636
502.45	5.52979651
579.11	7.62497113
631.67	9.52640077

Table 4. Decomposition of distribution length using by Bhattacharya's method

Computed mean	sd	Population	si
367.97	23.78	21	
452.51	23.62	62.77	2.19
502.45	19.22	124.47	2.03
579.11	12.8	13.11	2.17
631.67	14.4	4.86	2.09

Table 5. Length–length relationships between total length (TL), fork length (FL), and standard length (SL) of grey mullet from South Atlantic Morocco.

	Regression Equation	N	R2
Both sex	SL = 0.802TL + 13.608	281	R^2 = 0.92
	TL = 0.9007 FL - 4.8959		R^2 = 0.94
	FL = 0.8554SL + 32.911		R^2 = 0.9147
Females	SL = 0.8808TL - 27.644	119	R^2 = 0.8694
	FL = 0.9292SL + 64.839		R^2 = 0.8849
	TL = 1.0521FL + 28.669		R^2 = 0.9639
Males	SL = 0.8669TL - 19.17	52	R^2 = 0.9462
	TL = 1.0407FL + 33.835		R^2 = 0.9407
	FL = 1.0392SL + 16.638		R^2 = 0.9752

DISCUSSION

Size at first sexual maturity of Mugil cephalus:

Almost specimens of *Mugil cephalus* smaller than 450 mm are immature. The size at first sexual maturity in females is set at 459.59 mm, while males L50 is set at 455.81 mm ; Males reached sexual maturity at a smaller size than females.

In Louisiana (USA) **Render *et al*. (1995)** Found the first reproduction size of *M. cephalus* (L50) was 36.95 cm. **Hubbs (1921)** found sizes of 33.00 cm in males and 35.00 cm in females with two years in Florida, USA.

In the present study males reached first reproduction length at 34.0 cm (4.64 years old) and females at 35.0 cm of total length and 4.98 years of age.

Sex-ratio

Males represent 30% of population sampled in this study. The preponderance of female's specimens over the males had been also noted in Australian southern estuaries, it was dominated by females (in the order of 2:1) **(Stewart, 2017)**. However in Australian northern estuaries **(Stewart, 2017)** males were more abundant than females.

The authors suggested that sex disparity shown in our study, could be a result of the differential survival of some environmental conditions (**Offem *et al*., 2009**). Females may migrate to spawning grounds towards feeding areas which are also catch areas.

A comparison of means sizes by using Student's test of significance and Kolmogorov-Smirnov test found significant differences in the observation made for males and females. Male's sizes were significantly lower than females.

Seasonal variation in stages of sexual maturity:

In the present study spawning of *M. cephalus* can happen during spring and part of summer, Similar spawning seasons found in the east and west coast of Australia **(Kailola *et al*., 1993)**

In females, post-spawning has been observed most of the year, which indicates that very likely during all year mature organisms (IV, V) are present. However, most of the organisms in spawning time occur during June, July and August for males and during june and october for females. In Tamiahua Veracruz reported that spawning happens during autumn and winter **(Ibáñez *et al*., 2004)**, in North Carolina and to lower Florida **(Scotton *et al.,* 1973)** and northeastern coasts of Taiwan **(Hsu *et al.,* 2007**) the spawning period of *M. cephalus* were observed from the end of autumn and during winter.

Generally the *Mugil cephalus* of the Moroccan Atlantic coast has a maximal spawning rate in summer especially for males, it corresponds to season of minimum upwelling. However it has a low spawning rate in winter, corresponding to season of maximum upwelling.

Mugil cephalus may adopt the same strategy of small pelagics, it reproduces outside the season of maximum upwelling (**Parrish *et al*., 1981**).

Length-length relationship

In this study b obtained is lower than 3. That means that the grey mullet have a negative allometry; the length grows more than weight in the south Atlantic coast of Morocco. This result is confirmed by **SAAR *et al.* (2012)** who studied this fish in the Senegal River estuary, by Ndimele (2010) in Ologelagoon (Nigeria). This result obtained in this study differ from those obtained by **Ibáñez *et al.* (1999)** in the Tamiahua lagoon, Veracruz, who found an isometric growth b=3.

The estimate for the b parameter of the weight length relationship ranged between 3,067 for individual lenghted 319 to 499 mm and 2.50 for individuals lenghted 500 to 654 mm. The slope (b values) indicated a positive allometric growth for individuals whose size is smaller than 500 mm. The weight growth rate is fast for young specimens. They grow more in weight than in lenght. For matures sexes combined, the slope indicated a negative allometric growth. The length growth rate is fast for matures. However, the slope "b" is higher for males than females.

CONCLUSION

The *Mugil cephalus* of the Moroccan Atlantic coast has a maximal spawning rate in summer especially for males, season of minimum upwelling. And it has a low spawning rate in winter, season of maximum upwelling. Then, we can conclude that there is a relationship between spawing and upwelling.This study has also allowed the identification of the growth pattern of *Mugil cephalus*.

Linear growth is practically the same for both sexes while weight growth is in favour males throughout their life. Estimation of age using helped to distinguish 5 age groups for the whole individuals. Von Bertalanffy's model allows an approach of the linear growth of *Mugil cephalus*. The estimated asymptotic value is 804 mm, which makes it possible to assign some credibility with the body growth coefficient k, making it possible to the average speed of growth with which the species tends towards the asymptotic value L∞.

REFERENCES

Ameur B. **;** Bayed A. **and** Benazzou T. (2003). Rôle de la communication de la Lagune de Merja Zerga (Gharb, Maroc) avec l'océan Atlantique dans la reproduction d'une population de *Mugil cephalus* L. (Poisson Mugilidea). Bulletin de l'Institut Scientifique, Rabat, Section Sciences de la Vie, 25: 77-82. (in French).

Azeroual, A. (2003). Monographie des poissons des eauxcontinentales du Maroc : systématique, distribution et écologie. Thèse, Université Mohamed V, Rabat. (October 2003), 193pp. (in French).

Bagenal T. B. (1978). Aspects of the fish fecundity. In: [Ecology of Freshwater FishProduction]. Shelby D. G., (Ed.), Blackwell Scientific Publication, Oxford 75-101.

Briggs JC (1960) Fishes of worldwide (circumtropical) distribution. Copeia, pp.171–180.

Dankwa HR. (2011). Length-Weight Relationship and Growth Parameters of Grey Mullets (Pisces: Mugilidae) in Two Estuaries in Ghana. West African journal of applied ecology,18: 53-61.

Gayanilo Jr, F.C., Sparre, P., Pauly, D., (1994). The FAO-ICLARM Stock Assessment Tools (FISAT): User's Guide.Computerized Information Series, Fisheries, RomeHora SL, Pillay TVR. (1962). Handbook on fish cultures in the Indo-Pacific region, FAO Fish Biol Tech Pap; 14:1-203.

Gayanilo FC.,Sparre P., Pauly D. (2005). FAO-ICLARM stock assessment tools II: user's guide. FAO.

Hsu CC; Han YS and Tzeng WN (2007) Evidence of flathead mullet *Mugil cephalus* L. spawning in waters northeast of Taiwan. Zool Stud 46: 717-725.

Hubbs CL (1921) Remarks on the life history and scale characters of American mullets. Trans Am MicroscSoc 40: 26-27.

Ibáñez AL. and Gallardo-Cabello M. (2004) Reproduction of *Mugil cephalus* and *M.curema* (Pisces: Mugilidae) from a coastal lagoon in the Gulf of Mexico. Bull of Mari Sci 75: 37-49.

Ibáñez, A.L.; Gallardo-Cabello M. and Chiappa-Carrara X. (1999). Growth analysis of striped mullet, *Mugil cephalus*, and white mullet, *M. curema* (Pisces: Mugilidae) in the Gulf of Mexico. Fishery Bulletin 97: 861-872.

Ibáñez-Aguirre, A. L. and Gallardo-Cabello, M. (1996). Age determination of the grey mullet Mugil cephalus L. and the white mullet Mugil curema V.(Pisces: Mugilidae) in Tamiahua Lagoon, Veracruz. Ciencias Marinas, 22(3): 329-345.

Kailola PJ; Williams MJ; Stewart PC; Reichelt RE; McNee A, *et al.* (1993) Australian fisheries resources. Bureau of Resource Sciences, Canberra, Australia p: 422.

Le Cren, E.D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Percafluviatilis*). Journal of Animal Ecology, 20: 201-219.

Ndime le Prince emeka, (2010). Length-Weight Relationships and Condition Factors of Twenty-One Fish Species in Ologe Lagoon, Lagos, Nigeria. Asian Journal of Agricultural Sciences 2(4): 174-179, 2041-3890.

Offem OB.; Akegbejo-Samsons Y. and Omoniyi IT. (2009). Length-weight relationship, conditionfactor and sex ratio of forty six important fishes in a Tropical Flood River. Research Journal of Fisheries and Hydrobiology;4(2):65-72.

Parrish R.H.; Nelson, C.N. and Bakun, A. (1981) Transport mechanisms andreproductive success of fiches in the California Current, Biol.Oceanogr. 1 (2): 175–203.

Pope, J.A.; Margetts, A.R.; Hamley, J.M. and Akyuz, E.F., 1983. Manual of methods for fish stock assessment, Pt. 3. Selectivity of fishing gear. FAO Fish. Tech. Pap. 41 (1):1–65.

Render JH; Thompson BA and Allen RL (1995) Reproductive development of striped mullet in Louisiana estuarine waters with notes on the applicability of reproductive assessment methods for isochronal species. Trans Am Fish Soc 124: 26-36.

Scotton LN; Smith RE; Smith NS, Price KS and de Sylva DP (1973) Pictorial guideto fish larvae of Delaware Bay: with information and bibliographies useful for the study of fish larvae. Delaware Bay Report Series. College of Marine Studies, University of Delaware p: 205.

Sokal, R.R. and Rohlf, F.J., 1979. Biometria. H. Blume Ediciones, Madrid, 832 pp. Terrados, J., 1991. Crecimiento y produccion de laspraderas de macrofitosdel Mar Menor, Murcia. Ph.D. Thesis, University of Murcia, 229 pp.

Thomson, J.M. (1963). Synopsis of biological data on the grey mullet (*Mugil cephalus*, Linnaeus.1758). Fish. Synop. Div. Fish. Oceanogr., CSIRO, Australia (1).

Thomson, J.M. (1981). The taxonomy of grey mullets. In: O.H. Oren (Editor), Aquaculture ofGrey Mullets. IBP, 26, Cambridge University Press, pp. l-l 5.

Vaitheeswaran T.; Malathi S. and S. Felix, (2016). Studies on length-weight relationship of *Mugil cephalus* (Linnaeus, 1758), (Family: Mugilidae) Chennai coast of Tamil Nadu, (ICV-Poland), International Journal of Fisheries and Aquatic Studies 2016; 4(4): 04-07, Impact Value: 5.62(GIF) Impact Factor: 0.352 IJFAS 2016; 4(4): 04-07.