Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 26(4): 1381 – 1393 (2022)
www.ejabf.journals.ekb.eg

Growth, mortality and exploitation level of *Mugil cephalus* (Linnaeus, 1758) in El Mellah Lagoon (Algeria)

Lamia Bensaâd-Bendjedid[1]*, Mardja Tahri[2], Anis Mokrani[1], Mounira Rachedi[2]
1. National Center for Research and Development of Fisheries and Aquaculture (CNRDPA), Experimental Station of El Kala, Algeria.
2. Department of Marine Sciences, Faculty of Natural Sciences and Life, Chadli Bendjedid University, El-Tarf, Algeria.
*Corresponding Author: lamiabendjedid@gmail.com

ARTICLE INFO

Article History:
Received: Sept. 17, 2021
Accepted: May 28, 2022
Online: Aug. 25, 2022

Keywords:
Mugil cephalus,
Growth,
Mortality,
Lagoon,
Algeria

AABSTRACT

The present study addressed a knowledge gap in the population characteristics of flathead grey mullet *Mugil cephalus* in the Algerian waters. For the first time, the growth, mortality rates, and exploitation status of this species were investigated from the commercial fishery of El Mellah, the unique lagoon in the country. The length-weight equation was expressed as log TW = 2.9565 log TL - 1.8999. The length-frequency data was analyzed using ELEFAN I in the FiSAT II program package routines to provide information on the von Bertalanffy growth function parameters ($L\infty$ =58.8cm, K=0.30 year^{-1}). Longevity (t_{max}=10 years) and the growth performance index (Φ′= 3.02) were also calculated. The instantaneous rate of total mortality (Z) was 0.75 yr^{-1}. The analysis of the natural (M) and the fishing mortality, as well as exploitation rate (E) using two empirical approaches, showed that *Mugil cephalus* from El Mellah lagoon is not under fishing pressure.

INTRODUCTION

Mugil cephalus (Linnaeus, 1758) is a cosmopolitan species from tropical, subtropical, and temperate coastal waters in all the world's major oceans **(Briggs, 1960; Thomson, 1966)**. This catadromous fish, a member of the family Mugilidae, occurs in the fresh, brackish, hypo saline lagoons and coastal marine waters **(Schneider, 1990)**. Flathead grey mullet is a species of great importance in fisheries and aquaculture **(Saleh, 2009; Maitland & Herdson, 2009)**. Apart from being a foodfish, in several parts of the world, primarily in the Mediterranean, *Mugil cephalus* is captured during the spawning migration to harvest the egg roe, which is salted and dried to be sold at a high price as a delicacy **(Livi *et al.*, 2011)**.

A large number of research and reviews have been conducted on *M. cephalus* across the world, covering all the aspects of its biology, ecology, and fisheries **(Thomson, 1966; Whitfield *et al.*, 2012; Ibanez, 2016)**. However, in Algeria, although

M. cephalus is found and caught along its coastline and continental waters **(Djabali *et al.*, 1993; Bacha & Amara, 2007; Belhabib *et al.*, 2012)**, very little is known about this species. Furthermore, the few available published studies on the subject mainly focused on parasitism **(Boualleg *et al.*, 2010)**, microbiologic contamination **(Saoudi & Aoun, 2012)**, and the use of *M. cephalus* as a tool to evaluate trace metal concentrations in the marine environment **(Bouhadiba *et al.*, 2015; Ouali *et al.*, 2018)**; information on its life history characteristics and fishery remain extremely rare, although such data are prerequisite for rational management of fish stocks.

El Mellah is the only coastal lagoon in Algeria. It is located in the heart of the protected national park of El Kala (Northeastern Algeria) far from any source of pollution; this paralic ecosystem faces low anthropogenic disturbances and could be considered as a reference of the South Mediterranean lagoons **(Draredja *et al.*, 2019)**. Since the 1920s, when its fish weir "Bordigue" was built, El Mellah has been transformed into a large basin supporting extensive aquaculture, based principally on the interception and the trapping in fixed structures and the migratory fishes throughout their seasonal movements when trying to return to the sea **(Cataudella, 1982; Chaoui *et al.*, 2006a)**.

The family Mugilidae is represented by five species *Chelon labrosus* (Risso, 1827); *Liza ramada* (Risso, 1810); *Lisa saliens* (Risso, 1810); *Liza aurata* (Risso, 1810) and *Mugil cephalus* (Linnaeus, 1758), which constitute the bulk of El Mellah fish production **(Cataudella, 1982; Chaoui *et al.*, 2006b)**. However, to date and apart from some papers describing the diversity of fish communities and their assemblage structure **(Chaoui *et al.*, 2006b; Embarek *et al.*, 2017)**, no research works specifically dedicated to mullets of El Mellah have yet been carried out. Indeed, data currently available on the lagoon resource species concern mainly high commercial value fish such as the European sea bass *Dicentrarchus labrax* (Linnaeus, 1758), gilthead sea bream *Sparus aurata* (Linnaeus, 1758) **(Kara & Chaoui, 1998; Chaoui *et al.*, 2006b)**, and the threatened species *Anguilla Anguilla* (Linnaeus, 1758) **(Djebbari *et al.*, 2009; Ladjama *et al.*, 2016; Zard-Gharsallah *et al.*, 2021)**. Consequently, the purpose of the present work was twofold:

- To provide the first estimate of growth, longevity, mortality rates, and the state of the fishery of *Mugil cephalus*, one of the most abundant species caught in El Mellah Lagoon.
- To contribute new knowledge on the biology and the exploitation of *M. cephalus* in the Algerian waters.

MATERIALS AND METHODS

1. Sudy area

El Mellah is a brackish coastal lagoon located in the extreme Northeast of the Algerian coasts (36°54’ N- 8°20’ E) (Fig. 1). This shallow body of water covers a surface area of 865ha, with an average depth of 2.7m **(Embarek *et al.*, 2017)**. El Mellah connects with the Mediterranean Sea by a long and narrow channel of 900m long and 10m wide, and it receives freshwater inputs from three streams; namely, oued R'kibet, oued El Mellah and oued Boularoug. The lagoon water temperature and salinity vary between 11.95°C - 30.05°C and 28.48 -39g/l, respectively **(Bensafia *et al.*, 2020)**.

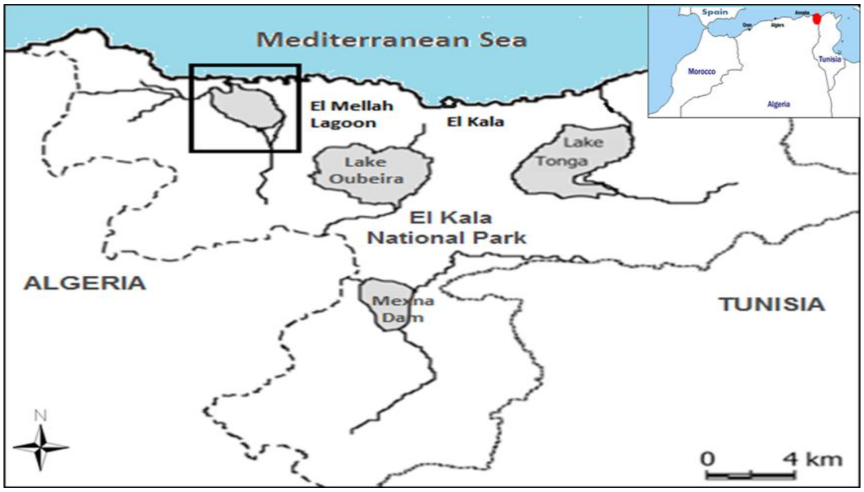

Fig. 1. Location of El Mellah Lagoon

2. Fish sampling and data analysis

407 *Mugil cephalus* specimens were sampled from the commercial fishery of El Mellah Lagoon. Fish were caught mainly by the lagoon fixed fishing gear "Bordigues", **(Cataudella, 1982)** and to a lesser extent, by monofilament nets during the annual mullet fishing season (late June to October). Individuals presenting signs of pathologies or injuries inflicted during fishing were rejected. To prevent damaging mullets which were intended to local fresh-fish market and to avoid potential spoilage of their quality and freshness, measurements of total length (TL) to the nearest 0.1cm and total body weight (TW) to the nearest 0.1 g were performed quickly and carefully in situ at the landing place for each sampled fish.

Length-weight relationship (LWR) was investigated using the equation $TW= aTL^b$ **(Ricker, 1973)**. This formula was log-transformed as log W= log a+ b logTL **(Froese, 2006)** to calculate the intercept of regression line "a" and the regression coefficient "b", which expresses the type of allometry. The relation is considered as isometric when b is equal to 3 and, allometric when b is higher or lower than 3 (positive allometry and negative allometry respectively). To establish if b was significantly different from the isometric value, a student's t-test was applied as described by **Sokal and Rohlf (1987)**.

The growth parameters of the von Bertalanffy function of *M. cephalus* from El Mellah Lagoon, namely asymptotic maximum length ($L\infty$, cm) and growth coefficient (K, $year^{-1}$) were obtained from length-frequency data analysis (2 cm constant intervals) using ELEFAN I program incorporated in FiSAT II software **(Gayanilo et al., 2005)**. The theoretical age at zero-length size (t_0) was calculated by the empirical equation of **Paul (1979)**: Log ($-t_0$) = -0.392-0.275 log L∞-1.038 log K.

Once growth parameters were estimated, LWR was used to convert the asymptotic length (L∞, cm) to the corresponding asymptotic weight (W∞, g). The and theoretical maximum age and the growth performance index (Φ′) were calculated, respectively, as t_{max}= 3/k **(Pauly, 1980)** and Φ′= log K+ 2log L∞ **(Pauly & Munro, 1984)**,

Total mortality rate (Z, year^{-1}) was estimated using the model of length-converted catch curve method **(Pauly, 1983)**, incorporated in FiSAT II, which outputs Z as well as the 95% confidence intervals surrounding Z were based on the goodness of fit of the regression. The instantaneous natural mortality rate (M, year $^{-1}$) was estimated using the following empirical estimators:

- **Pauly's (1980)** model: log M= – 0.0066 × 0.279 × log L∞ + 0.6543 × log K+ 0.4634 × log T, where T is water temperature.
- **Djabali *et al.* (1994)** model : log M = 0.0278 – 0.1172 × log L∞ + 0.5092 × log K

After Z and M were calculated, the fishing mortality (F, year $^{-1}$) was estimated as F= Z-M.

Gulland's (1971) relationship (E= F/Z = F/(F+M)) was applied to obtain the exploitation rate (E).

RESULTS

1. Population structure and length-weight relationship

Fishes total length ranged from 18.3 to 55.6cm, with a mean value of 41.28 ± 4.11cm; the majority of the population (75.18%) belonged to the size classes between 35 and 47cm (Fig. 2). The total weight of *Mugil cephalus* from El Mellah Lagoon peaked between 62.7 and 1680g; LWR is shown in Fig. (3. The allometric index b was equal to 2.9565; the t-test indicated an isometric growth.

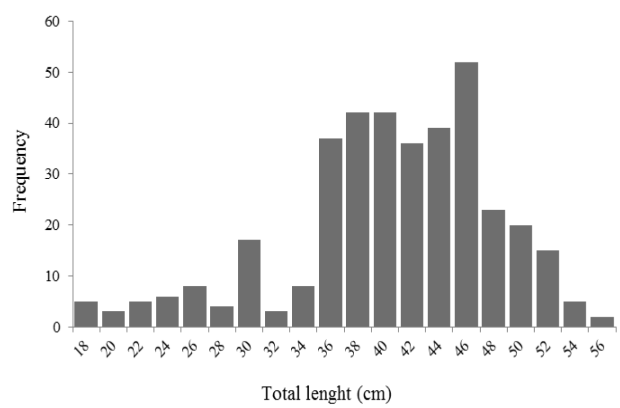

Fig. 2. Length frequency distribution of *M. cephalus* from El Mellah Lagoon

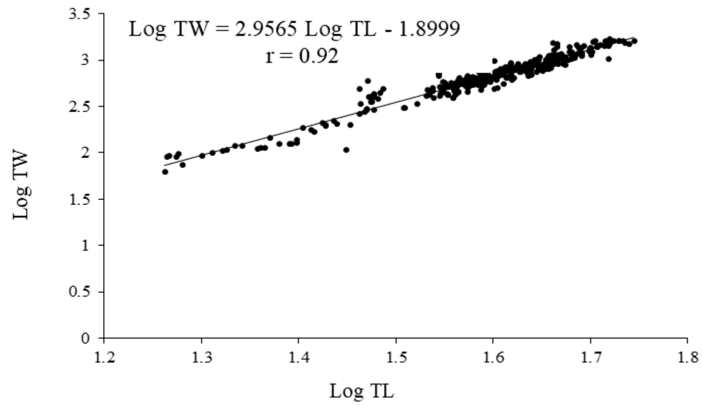

Fig. 3. Length–weight relationship of *M. cephalus* from El Mellah Lagoon

2. Biological parameters, mortality and exploitation rate

By relying on length-frequency distribution analysis using ELEFAN I and the calculated t_0 from **Pauly's equation (1979)**, the von Bertalanffy's growth equation for *Mugil cephalus* from El Mellah Lagoon can be expressed as $L_t = 58.8\ (1 - e^{-0.3\ (t\ +\ 0.461)})$. The asymptotic total weight was $W\infty$= 2144.34g. Results of biological parameters of *M. cephalus* from El Mellah Lagoon are summarized in Table (1).

Table 1. Population parameters data of *M. cephalus* from El Mellah lagoon

Parameter (unit)	**Value**
Total length range (cm)	18.3 - 55.6
Weight range (g)	62.7 - 1680
Asymptotic length ($L\infty$, cm)	58.8
Growth coefficient (K, yr^{-1})	0.30
Theoretical age at length zero (t_0, yr)	-0.461
Asymptotic weight ($W\infty$, g)	2144.34
Growth performance index (Φ')	3.02
Longevity (t_{max}, yr)	10
Number of sampled individuals (n)	407

The length-converted catch curve analysis (Fig. 4), using $L\infty$ and K showed an annual instantaneous rate of total mortality (Z) of 0.75 yr^{-1}. The results of estimating natural (M) and fishing (F) mortalities as well as the exploitation rates (E) of *M. cephalus* from El Mellah Lagoon are shown in Table (2). The value of M obtained through the **Djabali *et al.* (1994)** model (M= 0.36 yr^{-1}) was lower than that based on **Pauly's empirical formula (1980)** (M= 0.56 yr^{-1}). Consequently, the estimated exploitation levels among the population under investigation were correspondingly different from

0.25 to 0.52. The optimum exploitation rate for any fish stock according to **Gulland (1971)** is about 0.5 or F= M; thus, the exploitation state of *M. cephalus* in El Mellah lagoon varies from “not fully exploited” to “optimally exploited”. Our findings could indicate that the species in the lagoon under study is not under fishing pressure.

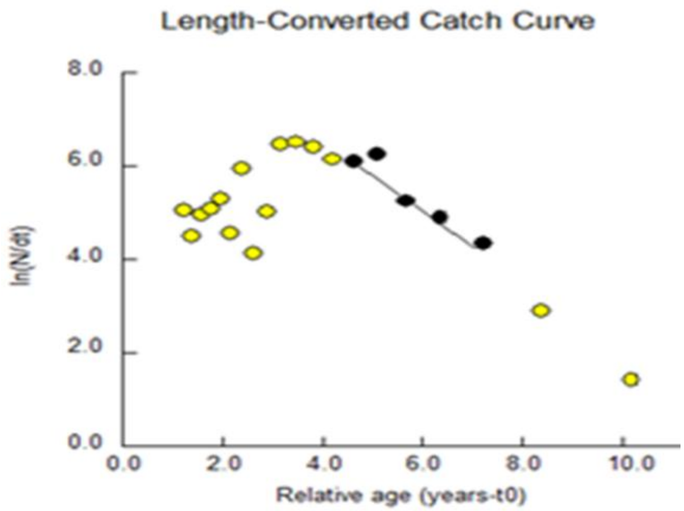

Fig. 4. Length-converted catch curve of *M. cephalus* from El Mellah Lagoon

Table 2. Estimates of natural mortality (M), fishing mortality (F) and exploitation rate (E) OF *M. cephalus* from El Mellah lagoon

Parameter (unit)	**Pauly (1980)**	**Djabali *et al.* (1994)**
Natural mortality (M, yr^{-1})	0.56 (T= 18,5°C)	0.36
Fishing mortality (F, yr^{-1})	0.19	0.39
Exploitation rate E	0.25	0.52

DISCUSSION

Since the study of **Quignard and Farrugio (1981)** to the present day, there is much information in the Fishbase database **(Froese & Pauly, 2021)**. In addition, other specialized databases (ISI Web of Knowledge, Scopus, Biological Abstract) on the subject of grey mullet age and growth are found in various parts of the world **(Ibanez, 2016)**; however, these data are scarce for *M. cephalus* caught off the Algerian coast.

In El Mellah Lagoon, the value of the allometry coefficient of the length-weight relationship indicated an isometric growth (b= 2.9565); similar results were observed in Nigeria **(Aleleye-Wokoma *et al.*, 2001)**, India (**Sahoo *et al.*, 2012; Panda *et al.*, 2018)**, the Central Mexican Pacific **(Espino-Barr *et al.*, 2015)** and in Tunisia **(Mili *et al.*, 2015)**. While, they differ from those obtained in Egypt **(Zaky-Rafail, 1968)**, **Greece (Koutrakis & Tsikliras, 2003)**, Gana **(Dankwa, 2011)** and Turkey **(Acarli *et al.*, 2014)**.

According to the study of **Ibanez (2016)**, grey mullets have an average value of the slope "b" in the order of 2.95 ± 0.25, without any significant differences neither between species nor geographical areas. However, several authors attributed the variability of "b" to the impact of various factors such as sex, stage of maturity, temperature, salinity, turbidity and food availability **(Wootton, 1990; Dankwa, 2011; Mili *et al.*, 2015)**.

The VBGF parameters $L\infty$ and K were evaluated at 58.8cm and 0.30 yr^{-1}, respectively; the comparison of our results with those of previous studies (Table 3) brought to light the relatively high value of K and the slightly small value of $L\infty$ calculated for *M. cephalus* of El Mellah Lagoon. The current results are consistent with the fact that the values of K are higher in the coastal lagoons and barrier ponds; whereas, the $L\infty$ values are lower in relation to those obtained for the marine areas **(Kesteven, 1942; Thomson, 1963, Quignard & Farrugio, 1981)**. These large differences are mainly linked to the environmental conditions and the availability of food **(Mili *et al.*, 2015)**. Additionally, they are related to the genetic origin of stocks **(Gautier & Hussenot, 2005)**. In her review of "Age and Growth of *Mugilidae*", **Ibanez (2016)** explained that variations in growth parameters are the result of the use of different methods to ageing mullets. Nevertheless, **Whitfield *et al.* (2012)** considered that since research approaches have not been uniformly applied for estimating the age and growth of *M. cephalus*; it makes global comparisons of the data difficult.

Phi prime (Φ') calculated for *M. cephalus* from El Mellah was 3.02; it is within the range values of Φ' (2.421–3.468) reported in the literature for the species **(Ibanez, 2016)**. Nevertheless, the relatively high growth performance index of *M. cephalus* from El Mellah can be related to the favorable local environmental conditions. Eminently, temperature and high productivity were cited as main reasons to explain the fast growth of a few other species occurring in the lagoon, as gilthead sea bream *Sparus aurata* **(Chaoui *et al.*, 2006a)**, clam *Ruditapes decussatus* **(Bensaâd-Bendjedid *et al.*, 2017)** and cockle *Cerastoderma glaucum* **(Bensaâd-Bendjedid *et al.*, 2018)**.

The estimated level of exploitation (E) of flathead grey mullet from El Mellah Lagoon ranged from not fully exploited (E=0.25) to optimally exploited (E=0.52), depending on the approach employed to determine natural mortality (M). According to The model of **Djabali *et al.* (1994)**, natural (M) and fishing mortality (F) rates were estimated at 0.36 and 0.39 yr^{-1}, respectively, showing that the species is relatively at an optimum level of exploitation (F=M). However, using **Pauly's empirical approach (1980)** obtained M value was about 36% greater than that estimated by **Djabali *et al.* equation (1994)**. In this case, total mortality (Z= 0.75 yr^{-1}) of the species would be more impacted by natural mortality (M= 0.56 yr^{-1}) than fishing activities (F= 19 yr^{-1}), showing an under-harvested state of *M. cephalus* in the lagoon. These findings were similar to what had previously been observed among two other resource species in the lagoon. On the other hand, **Benyacoub *et al.* (2011)** reported very low rates of fishing mortality compared to natural mortality in *Dicentrarchus labrax* (M= 0.56, F= 0.05) and *Sparus* *aurata* (M= 0.9, F= 0.44), and they suggested to increase the exploitation level of sea bream and sea bass as well as Mugilidae species.These authors claimed that, given the specific nature of El Mellah (extensive pond of aquaculture), and the fact that fish recruitment is entirely dependent on sea brooding stock, a fishery based on catching as much fish as possible during their migratory movements would be more appropriate than maintaining a balanced fishery in the lagoon.

Table 3. Von Bertalanffy growth parameters of *M. cephalus* from El Mellah Lagoon and other localities

L_∞ (cm)	K (yr^{-1})	t_0 (yr)	Method	Locality	Author
58.8	0.30	- 0.461	LFQ	El Mellah Lagoon/ Algeria	This study
70	0.70	- 0.097	LFQ	Chilika Lake/ India	Panda *et al.* (2018)
60.0	0.115	-2.630	otoliths	Central Mexican Pacific	Espino-Barr *et al.* (2015)
71.36	0,16	0,04	scale	Bir Mchergua and Joumine dams/ Tunisia	Mili *et al.* (2015)
68.78	0.42	-0.012	LFQ/ scale	Senegal River Estuary/ Sénégal	Saar *et al.* (2012)
56.6	0.31	-0.239	LFQ	Volta estuary/ Ghana	Dankwa (2011)
37	0.22	-1,8	LFQ	Lagos lagoon/ Nigeria	Lawson and Jimoh (2010)
72,792	0.229	-0.575	LFQ/ scale	Bardawil lagoon/ Egypt	El-Ganainy *et al.* (2002)
33.2	0.55	0.15	LFQ	Bonny Estuary/ Nigeria	Aleleye-Wokoma *et al.* (2001)
64.24	0.10	-2.85	otoliths	Tamiahua lagoon/ Gulf of Mexico	Ibanez-Aguirre *et al.* (1999)
61.5	0.40	0.44	scale	Orbetello lagoon / Italy	Alessio (1976)
40.7	0.32	-0.71	scale	Texas/ USA	Cech and Wohlschlag (1975)
69.3	0.19	-0.63	scale	Tunisia	Farrugio (1975)
41.77	0.47	-0.169	otoliths	France	Ezzat (1964)
62.04	0.65	-0.048	scale	Tunisia	Heldt (1948)

CONCLUSION

The present study provided baseline data on several biological and population parameters of *M. cephalus* harvested in the Algerian waters. The possible under-fishing status detected in the El Mellah population may be evidence of poor management of living resources in the lagoon, most likely due to a lack of a sustainable fisheries management scheme. Our findings could be used as a general starting point for further research to determine management priorities for the rational exploitation of grey mullet in this water body.

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