

Reproduction of yellow mullet *Mugil cephalus* on Northern Coast of Senegal, West Africa

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Abstract. The study of reproductive parameters of *Mugil cephalus* on the Northern Coast (Grande côte) of Senegal was made based on biological sampling between 2010 and 2012. In total, 1587 individuals of size between 11 cm and 58 cm FL were captured. Reproduction was followed by analysis of monthly changes in the gonadosomatic index and sexual maturity stages as well as the determination of the size at first sexual maturity of the species. The monthly changes in the gonadosomatic index and sexual stages of the population of *M. cephalus* indicate an advanced maturation of gonads in December and January, which assumes that the reproduction of *M. cephalus* could begin in December and would be already completed in June because of post-spawning stages (stage ≥ 6) observed during this month. The size at first sexual maturity is estimated at 39 cm FL for males and 42 cm FL for females. This study has contributed to the updating of reproductive parameters of yellow mullet *M. cephalus*. This will strengthen the basis of biological knowledge for the management of the species.

Key Words: Reproduction, *Mugil cephalus*, Grande côte, Senegal.

Résumé. L'étude paramètres de reproduction de *Mugil cephalus* sur la côte nord (Grande côte) du Sénégal a été faite sur la base d'échantillonnage biologique entre 2010 et 2012. Au total, 1587 individus de taille comprise entre 11 cm et 58 cm LF ont été capturés. La reproduction a été suivie par une analyse de l'évolution mensuelle de l'indice gonadosomatique et des stades de maturité sexuelle ainsi que par la détermination de la taille à la première maturité sexuelle de l'espèce. Les variations mensuelles de l'indice gonadosomatique et des stades de maturité sexuelles de la population de *M. cephalus* indiquent une maturation avancée des gonades en décembre et janvier, et suppose que la reproduction de *M. cephalus* pourrait commencer en décembre et serait déjà achevée en Juin en raison de stades post-ponte (stade ≥ 6) observés au cours de ce mois. La taille de première maturité sexuelle est estimée à 39 cm LF pour les mâles et 42 cm LF pour les femelles. Cette étude a contribué à réactualiser des paramètres de la reproduction du mullet jaune *M. cephalus*. Cela va renforcer la base de connaissances biologiques au profit de la gestion de l'espèce.

Mots clés: Reproduction, *Mugil cephalus*, Grande côte, Sénégal.

Introduction. The Mugilidae (or grey mullets) is a speciose family of teleostean fishes. It includes 62 species belonging to 14 genera (Thomson 1997). Representatives of this family are distributed in various coastal aquatic habitats of the world's tropical, subtropical and temperate regions (Thomson 1997; Harrison 2003). Along the West Coast of Africa, between Senegal and Angola, 10 species including yellow mullet *Mugil cephalus* (Linnaeus, 1758) are currently registered (Albaret 2003; Trape et al 2009).

With a robust body, cylindrical slightly laterally compressed, with a large head and a yellow caudal fin (Albaret 1992) the yellow mullet (*M. cephalus*) is a migratory species (Bernardon & Vall 2004). *M. cephalus* feed on zooplankton, benthic organisms and detritus (Farrugio 1976). Spawning occurs at sea and varies according to geographical location (Brusle 1981). It can also occur in brackish waters (Bartulović et al 2011).

The yellow mullet, targeted by artisanal fisheries is caught on the Northern Coast of Senegal. The fishing effort of gear that provides the bulk of the landings of the species (drift nets surface) has increased during the 2000s in this area. Due to the ecological and economic importance of *M. cephalus* (Thomson 1997), information on the life history

traits of the species are available in some parts of the world (Ke et al 2009; Durand et al 2012; Whitfield et al 2012).

However, recent information on life history traits of the species, are rare in Senegal (Sarr et al 2012; Ndour et al 2013). Indeed, in the current context of management of fishery resources in Senegal, updating knowledge on the biology of yellow mullet, given its economic importance, is fundamental. The present work aimed to study the reproduction of yellow mullet *M. cephalus* on the Northern Coast of Senegal fits perfectly into this dynamic.

Material and Method

Data. Biological sampling were carried out on three landing sites (Kayar, Fass Boye, Saint Louis) on the Northern Coast of Senegal (Figure 1) at sea and on the Senegal River in 2010 (July, August, September), 2011 (June, October, November, December) and 2012 (January). The choice of these months can be explained partly by the fact that they cover the abundance and reproduction periods of the species in the area and on the other hand, by the fact that the presence of the species is very seasonal (Lawson & Jimoh 2010) in particular in the study area. It also explains the lack of data for some months. Whenever the species was landed at least 100 individuals were measured in fork length ((FL) in cm), weighed (in g) and sexed and sexual stage determined provided that there are so many individuals caught. The sample consists of 570 individuals caught at sea, with a size between 19 cm and 58 cm and 1017 individuals from the river, varying in size from 11 cm to 55 cm.

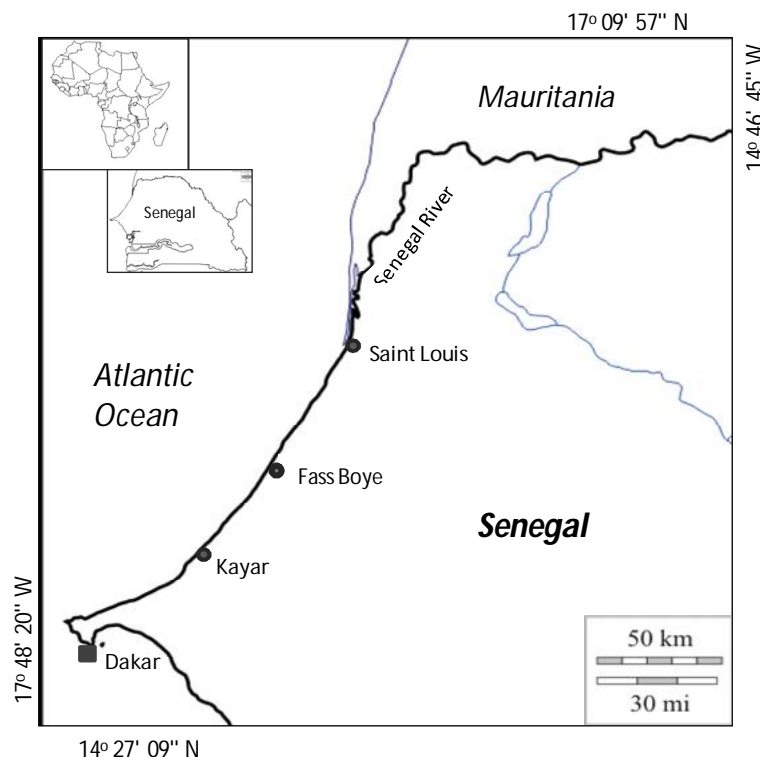


Figure 1. Location map of the study area (landing sites) along the coastline of the Northern Coast of Senegal.

Treatment

Size at first sexual maturity. The size at first maturity (L_{50}) is the size at which 50% of individual's gonad stage greater than 3 or equal to 3 on the scale of sexual maturation (Albaret & Legendre 1985). The L_{50} was determined by a logistic function modelling the percentage of mature individuals by size range 1 cm (FL). The logistic function is expressed by the equation:

$$\% M = 1 / (1 + \exp. * (-a (CI-L_{50})))$$

Where '% M' = percentage of sexually mature individuals by size class, 'a' = constant that depends on the increase in the proportion of mature individuals, 'CI' = central value of each size class, and 'L₅₀' = length corresponding to 50% of mature individuals in the population.

Gonadosomatic index (GSI). The gonads were removed and weighed in grams to calculate the gonadosomatic index of individuals. It is calculated using this formula:

$$GSI = (Pg / P) \times 100$$

Where, Pg is the gonad weight (g) and P is the total fresh weight unviscerated (g).

Sexual stages. The scale of sexual maturity described by Albaret & Legendre (1985) was used for the determination of sexual stages of *M cephalus*. It defines seven sexual stages:

- Stage 1 corresponds to immature individuals. Gonads are slightly elongated and enlarged. They do not yet superficial vascularization.
- Stage 2: on the surface of the gonads, is a slight vascularization.
- Stage 3: oocyte growth starts with the input of real part of oocytes undergoing vitellogenesis (incorporation of vitellogenin).
- Stage 4: almost all of the abdominal cavity is occupied by the gonads that have significant superficial vascularization.
- Stage 5, fleeting, this stage corresponds to the emission of genital products and ovulation. Eggs (females) and seminal fluid (males) are expelled at the slightest pressure on the abdomen.
- Stages 6-2 and 6-3 are consecutive spawning and are primarily distinguished from stages 2 and 3 by the presence in the ovary of a small number of large residual oocytes.

Results

Size at first sexual maturity (L₅₀). An examination of sexual maturity concerned individual's gonads belonging to stages ≥ 3 as those of sexual stage 1 and 2 were considered immature. Males reached sexual maturity from size 39 cm FL while the sexual maturity of females is reached at 42 cm FL (Figure 2). For both sexes, the estimated L₅₀ was 40 cm LF.

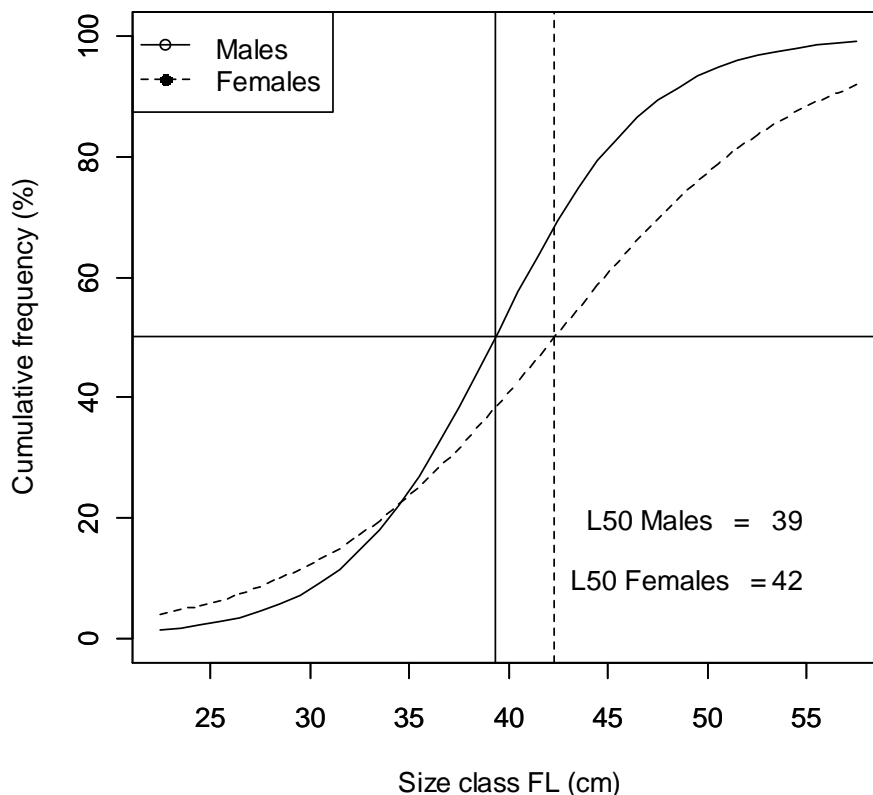


Figure 2. Size at first sexual maturity (L₅₀) in males and females of *Mugil cephalus* on Northern Coast of Senegal. FL = fork length.

Gonadosomatic index (GSI). Variation of gonadosomatic index showed that the highest values of the index were observed during the period from November to January at sea. The GSI was 3.7 in November, 5.7 in December and 5.5 in January (Figure 3a). On the river, the GSI obtained was less than 2. Indeed, the highest mean GSI on the river during the study period was observed in November, it did not exceed 1.0 (Figure 3b).

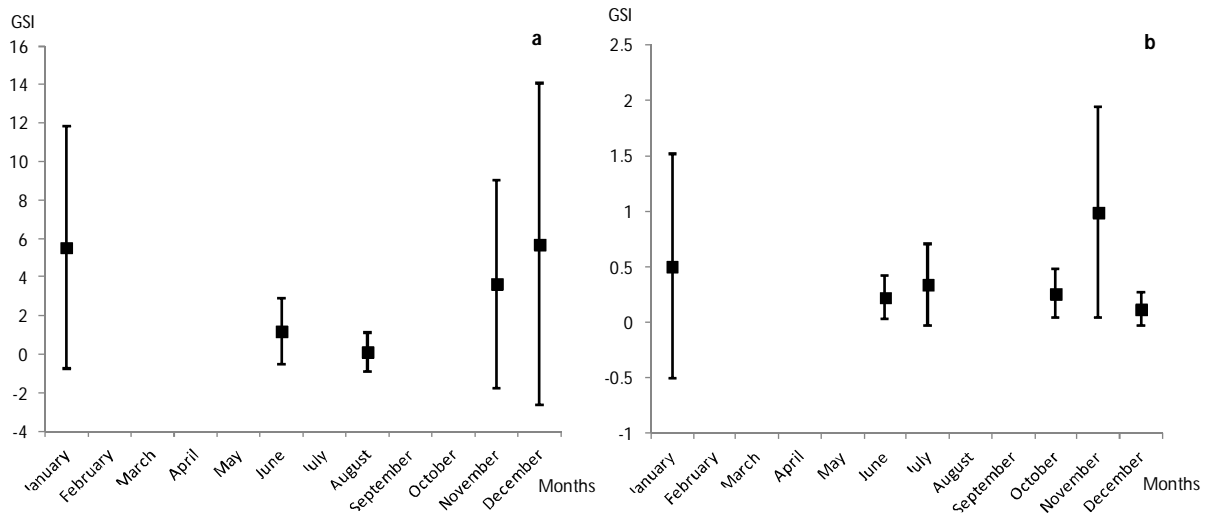


Figure 3. Monthly variations of the gonadosomatic index (GSI) in populations of *Mugil cephalus* in sea (a) and in the river (b) on the Northern Coast of Senegal.

Sexual stages. A high frequency of sexual stages 4 and 5 were noted between November and January. The proportions of the sexual stages ≥ 6 were higher in June. A strong presence of immature individuals (stage < 3) was also recorded from June to October (Figure 4a). On the river the sexual stages ≤ 2 were the most representative (99.4%). In contrast, the sexual stages ≥ 3 accounted for only 0.6% (Figure 4b).

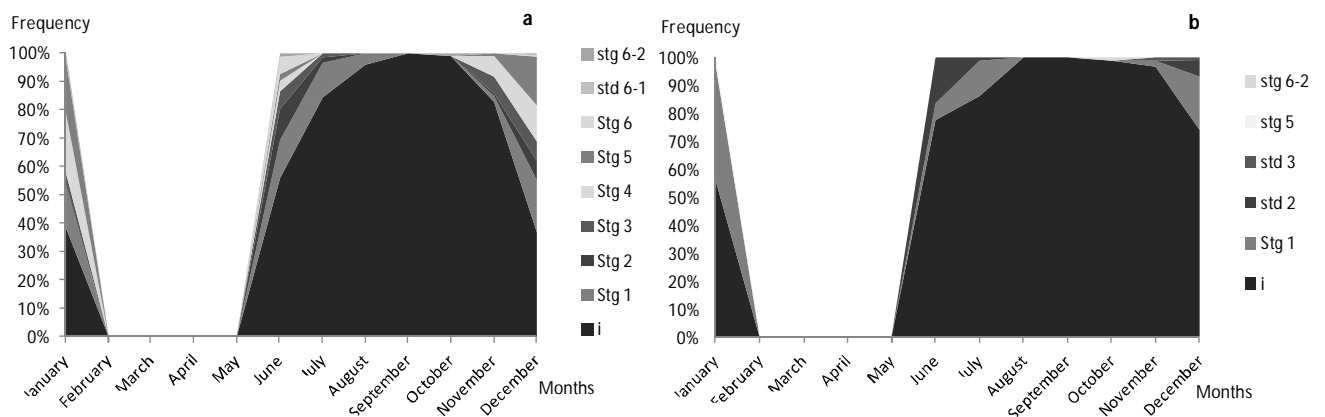


Figure 4. Monthly variations of sexual maturity stages in populations of *Mugil cephalus* in sea (a) and in the river (b) on the Northern Coast of Senegal. Stg= stages; i= Indeterminate sex.

Discussion. Monthly changes in the gonadosomatic index and sexual stages in populations of *M. cephalus* on the Northern Coast of Senegal indicate an advanced maturation of gonads in December and January, which assumes that the reproduction of *M. cephalus* could begin in December and would be already completed in June because of post-spawning stages (stage ≥ 6) observed during this month. This situation can be explained by the good conditions of temperature and upwelling index settling at the area from December to February. Our results are consistent with the findings of McDonough et al (2005) in South Carolina, who shows that the spawning period of the species is from

November to December. They are also consistent with those of Bernardon & Vall (2004) in Mauritania, Landret (1974) in Senegal, Ibañez & Gallardo-Cabello (2004) in the Gulf of Mexico and Greely et al (1987) in Florida (Table 1). In contrast, our results are different from those obtained by Bartulović et al (2011) in Croatia and Ameer et al (2003) in Morocco, who note a spawning period of *M. cephalus* extending respectively from July to September and from July to October. This discrepancy may be due to evolutionary adaptation of different populations of the species in different ecological properties of specific ecosystems (temperature and salinity, environmental productivity, nutrient status etc). Through gonadosomatic index and sexual stages observed in individuals on the river it turns out that the maturation of gonads did not occur in this environment, but the species enters to spend the juvenile phase.

Table 1

Synthesis of various results on the maturation of gonads and spawning periods in populations of *Mugil cephalus* in different geographical areas. (1): Maturation of gonads

Regions	Spawning periods	References
South Carolina	October-April	McDonough et al (2003)
South Carolina	October-April	McDonough et al (2005)
Gulf of Mexico	November-February	Ibañez & Gallardo-Cabello (2004)
Mauritania	November-February ⁽¹⁾	Bernardon & Vall (2004)
Atlantic Coast (Senegal)	November-December	Landret (1974)
Atlantic Coast (Morocco)	July-October	Ameer et al (2003)
Neretva Estuary (Croatia)	July-September	Bartulović et al (2011)
Atlantic Coast (USA)	December-January	Greely et al (1987)
Northern Coast (Senegal)	December-January ⁽¹⁾	This study

The L_{50} determined in *M. cephalus* (39 cm FL for males and 42 cm for females FL) is similar to those obtained in Tunisia (38-40 cm TL) by Brusle & Brusle (1977) and Brusle (1981) for females (40-41 cm TL) and also in the Marmara Sea (40-41 cm FL) by Erman (1959). It is also consistent with the results of other authors (Broadhead 1956; Thomson 1966; Chubb et al 1981), who determined size at first sexual maturity, ranging from 29 cm to 43 cm in populations of the species. The L_{50} obtained is also similar to that determined in the lagoon of Merja Zerga in Morocco (37 cm) by Ameer et al (2003). In contrast, it is lower than that obtained in Mauritania (52 cm) by Vall (2004) (Table 2). This difference is related to the nature of the data used in the determination of this parameter, because in Mauritania, the data used are from commercial fishing, in contrast, the data used in our study are both commercial and experimental fishing data, covering a wider range of sizes including small individuals.

Table 1

Synthesis of various results on the size at first sexual maturity in populations of *Mugil cephalus* in different geographical areas. TL = Total length; FL = Fork length

Regions	Size at first sexual maturity (cm)	References
Mediterranean (Marmara sea)	40-41 FL	Erman (1959)
Mediterranean (Tunisia)	36-41 TL	Brusle (1981)
African Atlantic Coast (Senegal)	28-35 FL	Landret (1974)
Atlantic Coast (Morocco)	37 FL	Ameer et al (2003)
Banc d'Arguin (Mauritania)	52 FL	Vall (2004)
Mediterranean (Tunisia)	30-40 TL	Brusle & Brusle (1977)
Northern Coast (Senegal)	39-42 FL	This study

Conclusions. Though based on partial data, this study has allowed updating the reproductive parameters of yellow mullet *Mugil cephalus* in the Northern Coast of Senegal. The spawning period was determined through analysis of the gonadosomatic index (GSI) and the sexual maturity stages. The advanced maturation of gonads of *M. cephalus* occurs in December and January. The reproduction of *M. cephalus* could begin in December and would be already completed in June. It occurs at sea. Size at first

sexual maturity (L_{50}) was 39 cm FL for males and 42 cm FL for females. This study contributed to the updating of biological knowledge of *M. cephalus*, as it was formulated by the fisheries authorities of Senegal for the management of the species.

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