Acta Ichthyologica et Piscatoria 53, 2023, 37–43 | DOI 10.3897/aiep.53.100933

PENSOFT

ACTA ICHTHYOLOGICA ET PISCATORIA

Reproductive biology of largescaled mullet, *Parachelon grandisquamis* (Actinopterygii: Mugiliformes: Mugilidae), in the Marine Protected Area of Niamone–Kalounayes (Casamance estuary, Senegal)

Patrick DIEDHIOU[1], Alassane SARR[1], Ousseynou SAMBA[1], Modou SENE[1], Alexandre Langlais BOURASSA[2], Waly NDIAYE[1]

1 *Cheikh Anta Diop, University of Dakar, University Institute of Fisheries and Aquaculture (UCAD/IUPA), Dakar, Senegal*

2 *AECOM Consultants Inc., Montreal, Quebec, Canada*

https://zoobank.org/11E149EC-7CCB-4394-9DF5-FDC4743268B5

Corresponding author: Patrick Diedhiou (patrickdiedhiou76@yahoo.com)

Academic editor: Sanja Matić-Skoko ♦ **Received** 23 January 2023 ♦ **Accepted** 11 March 2023 ♦ **Published** 20 April 2023

Citation: Diedhiou P, Sarr A, Samba O, Sene M, Bourassa AL, Ndiaye W (2023) Reproductive biology of largescaled mullet, *Parachelon grandisquamis* (Actinopterygii: Mugiliformes: Mugilidae), in the Marine Protected Area of Niamone–Kalounayes (Casamance estuary, Senegal). Acta Ichthyologica et Piscatoria 53: 37–43. https://doi.org/10.3897/aiep.53.100933

Abstract

In Senegal, studies on the family Mugilidae are rare and little data is available on their reproductive biology. This study, carried out in the MPA of Niamone–Kalounayes (Casamance River estuary, Senegal) aims to enhance our knowledge of the reproductive biology of the largescale mullet, *Parachelon grandisquamis* (Valenciennes, 1836), a species highly prized by the local population as a food source. To better understand its reproductive biology, a series of monthly samplings over twelve (12) months from July 2021 to June 2022 was carried out. Experimental fisheries were carried out at six (6) stations located in secondary channels lined with mangroves, using a seine net (250 m long and 25 mm mesh side). A total of 361 individuals were sampled, including 321 female specimens and 40 male specimens. The calculated sex ratio was in favor of females (1:8), with a significant difference between the calculated sex ratio and the theoretical 1:1 sex ratio ($\chi^2 = 218.73$; P-value < 0.05). In the MPA of Niamone–Kalounayes, the breeding period of *P. grandisquamis* extends from March to July, from the end of the dry season up to the beginning of the wet season. The sizes at first sexual maturity were 17 cm in males and 18 cm in females, showing that in the MPA of Niamone–Kalounayes, males and females of *P. grandisquamis* reach sexual maturity at very close sizes ($\chi^2 = 0.02$; $P > 0.05$). As this species is subject to the intense fishery by many actors in the area, these findings may be proven useful in the process of developing a management plan for this particular species.

Keywords

Casamance estuary, experimental fisheries, marine protected area, *Parachelon grandisquamis*, reproductive biology, Senegal

Introduction

Studies on fish reproduction are inherently biological and ecological in essence (Albaret and Legendre 1985). Mugilidae, a family of fish commonly known as mullets, are permanent residents and often abundant fish in marine environments and brackish water ecosystems such as estuaries, lagoons, and small creeks around mangroves (Harrison 2008). Represented by two genera present in West Africa, *Chelon* and *Mugil*, the Mugilidae is one of the most abundant taxa in the estuaries of Senegal (Albaret 1984).

In the Casamance region, these species are highly prized by the local population as an important food source and are often the subject of specialized fisheries. These

taxa are also widely distributed in West African estuaries (Albaret 2003; Diedhiou unpublished*; Dieme unpublished**) and constitute along with the Cichlidae one of the most abundant families. The abundance of mullets in estuarine and coastal areas is linked to the permanent presence of food in the area, but also to their feeding habits (Diouf 1996). They occupy a relatively low position in the food web (Wright 1988). However, studies on the fisheries and biology of Mugilidae, and more precisely on the largescaled mullet, *Parachelon grandisquamis* (Valenciennes, 1836), in Senegal, are rare. This study, carried out in the Marine Protected Area (MPA) of Niamone–Kalounayes, located in the Casamance River estuary, aims to deepen our knowledge on the reproductive biology of *P. grandisquamis*, but also help the development of a management plan for this species in the different areas of the MPA where fishing is authorized and regulated. Specifically, the goal of this study is to better describe the reproductive biology of this species, using biological parameters such as the sex ratio, the period and duration of reproduction, the gonadosomatic index, and the size at the first sexual maturity.

Methods

Presentation of the study area. Located right in the Ziguinchor region of the Casamance River basin, the MPA of Niamone–Kalounayes covers the maritime, estuarine, and freshwater portions of the Casamance River and covers an area of 63 894 ha. It is formed by a complex and diffuse system of channels commonly called *bolongs* and is bordered by mangroves that are characteristic of intertropical brackish wetlands. This MPA is delimited in the north by the classified forest of Kalounayes, in the east by the Soungrougrou River, in the west by the backwater of Bignona to the Affiniam Dam, and in the south by the south shore of the Casamance River (Fig. 1). The main objectives of the creation of this MPA were the restoration of habitats and natural resources, the improvement of living conditions of animal populations and the establishment of an adapted governance system (DAMPC unpublished***).

Sampling method. Data collection was conducted following a monthly sampling series, from July 2021 to June 2022. The experimental fisheries were carried out in secondary channels bordered by mangroves, using a 250 m long beach seine (25 mm mesh). Captured individuals of *Parachelon grandisquamis* were identified using fish identification keys (FAO 1992; Paugy et al. 2003; Seret and Opic 2011). At each site, every individual's total length (TL; cm), total weight (TW; g), eviscerated weight (EVW; g), and gonad weight (GW; g) were recorded. The fish were measured using a 1 mm precision ichthyometer and weighed with a digital electronic scale of precision 0.1 g and a maximum reach of 3000 g. The sex and the stage of sexual maturity of each individual were determined after gonad examination and the size of the oocytes, based on the work of Fontana (1969) (Table 1).

Sex ratio (SR) expresses the relative abundance of males and females in a given population. This ratio is necessary for the evaluation of the reproductive potential of fish and can also be used for estimating the size of stocks. For this study, the SR was calculated according to the formula from Kahn and al. (2021)

$$\mathrm{SR} = \frac{N_{\mathrm{M}}}{N_{\mathrm{F}}}$$

where N_{M} is the number of males and N_{F} is the number of females.

Gonadosomatic index and reproductive period. The gonadosomatic index (GSI) is used to determine spawning periods during the sexual cycle of a given species. The GSI is determined from the individual data of each fish and is calculated according to the following formula (Analbery unpublished****)

$$\mathrm{GSI} = \frac{W_{\mathrm{G}}}{W_{\mathrm{EV}}} \times 100$$

where W_{G} is the gonads' weight [g] and W_{EV} is the eviscerated weight [g].

Size at first sexual maturity. The size of the first sexual maturity (L_{m}) corresponds to the length for which 50% of the captured individuals are mature during the breeding season. It is used to monitor the degree of sexual maturity according to the size of the individuals (Amenzoui et al. 2004–2005). The percentage per size class of females or males having reached stage 3 and above was calculated in relation to the total number of sexually mature females or males. A logistic function relating the percentages of mature fish to length (Ghorbel et al. 1996) was used:

$$M_{\%} = \frac{100}{1 + e^{-\alpha(\mathrm{TL} - L_{\mathrm{m}})}}$$

where $M_{\%}$ is the percentage of individuals that have attained sexual maturity, e is a constant, TL is the total length of the fish, and L_{m} is the length where 50% of the sampled individuals are mature, and α is the relation parameter.

* Diedhiou P (2019) Contribution à l'étude des peuplements de poissons de l'aire marine protégée de Niamone–Kalounayes (Casamance). Mémoire Masteur Ecologie et Gestion des Ecosystèmes Aquatique, IUPA, UCAD, Dakar, 32 pp.

** Dieme S (2021) La diversité des Mugilidae dans les aires marines protégées Niamone–Kalounayes et Kassa–Balantacunda. Mémoire Masteur Aménagement et Gestion durable des Ecosystèmes forestiers et Agroforestiers (AGDEFA), UFR (ST), UASZ, Sénégal, 43 pp.

*** DAMPC (2015) Plan de gestion de l'AMP de Niamone–Kalounayes 2016–2020. Dakar, 92 pp.

**** Analbery M (2004) Biologie, écologie et pêche de *Hemiramphus brasiliensis*. Thèse de doctorat, Université de Bretagne, France.

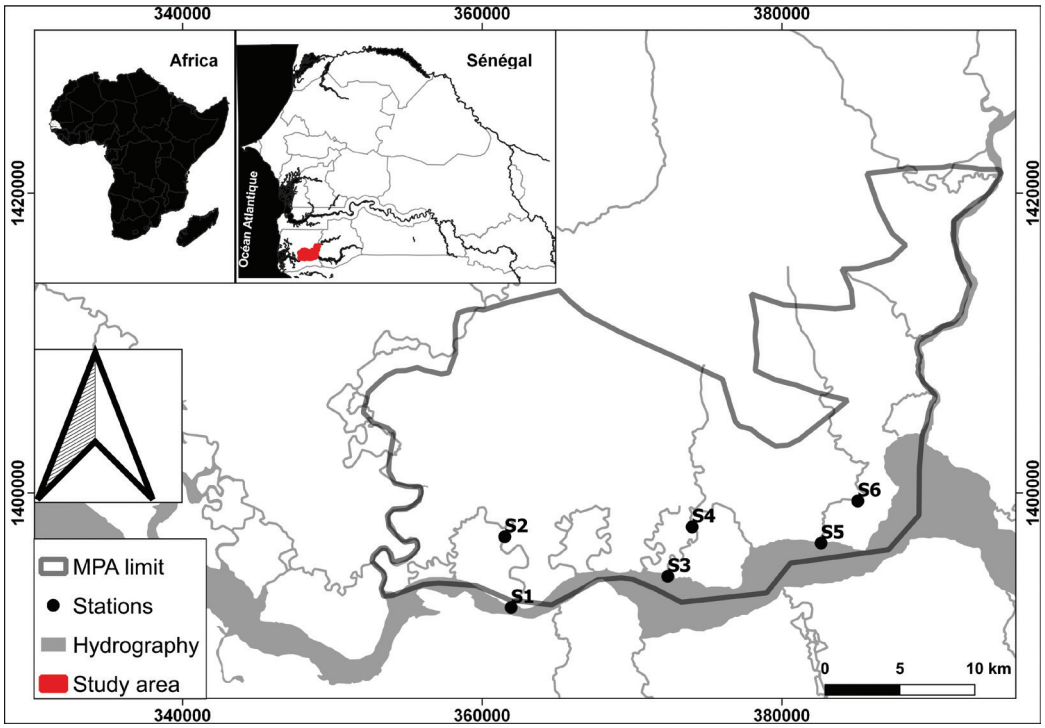

Figure 1. Map of the Marine Protected Area of Niamone–Kalounayes (Senegal) and sampling stations.

Table 1. Representation of the different stages of sexual maturity according to Fontana (1969).

Stage	External macroscopic features of gonads	
	Female	Male
I (immature)	Firm, small size, transparent, or light pink; oocytes invisible	White or slightly translucent, very thin and resembling knife blade
II (sexual rest)	Substantially identical to stage I	Substantially identical to stage I
III (ripening)	Firm and colored (pale pink to light orange), some oocytes visible through ovarian membrane	Firm and whitish; no liquid flowing if an incision is made
IV (advanced ripening)	Larger and less firm, usually light orange; oocytes visible through ovarian membrane; surface of ovary granular	Softer and whiter; whitish fluid flowing as soon as an incision is made
V (ripe individual)	Very large occupying entire abdominal cavity; ovarian membrane very thin; hyalin and large eggs perfectly visible and are expelled at slightest pressure exerted on abdomen	Large and soft; semen flows at the slightest pressure on the abdomen
VI (post-spawning)	Very vascularized and flaccid; color varying from salmon pink to red; oocytes not visible through ovarian membrane; multiple hyaline spaces	Flaccid and delicately vascularized, particularly in posterior part
VII (spent)	Completely collapsed and very flaccid; red color due to very strong vascularization; characteristic appearance of empty sack	Very flaccid, exhausted, and highly vascularized

Statistical analyzes. A chi-square test (χ^2) was used to compare the sex ratio with the theoretical sex ratio (1:1) for each sampled month. An analysis of variance (ANOVA) was used to compare the change in mean gonadosomatic index (mean GSI) between months for the same sex. Differences were considered significant at $P < 0.05$. All statistical analyses were performed within the R software (version 3.6.0) (R Core Team 2018).

Results

Sex ratio (SR). Among the 361 individuals of *Parachelon grandisquamis* sampled in the MPA of Niamone–Kalounayes, 40 were males and 321 were females (1:8). This unbalanced overall SR found in the presently reported study was significantly different from the theoretical sex ratio of 1:1 ($\chi^2 = 218.73$; $P < 0.05$) (Table 2). Very significant monthly variations ($P < 0.05$) in SR in favor of females were also encountered during all sampling months (Table 2). It seems that during the time of this study, female individuals of *P. grandisquamis* were highly dominant in the MPA.

Sexual maturity. The monthly variation of the sexual maturity stages in both sexes showed a variation over the whole year with variable proportions from one month to another (Fig. 2). Indeed, in males, immature individuals of sexual maturity stages (I and II) were encountered throughout the year, except for May and June. The highest percentages were recorded in August (100%), December (100%), November (80%), and January (80%). In female individuals, however, they were present throughout the year. The maximum number of individuals were observed in October (89%), August (84%), and January (82%).

Table 2. Monthly changes in the sex ratio of *Parachelon grandisquamis* in the Marine Protected Area of Niamone–Kalounayes (Senegal) from July 2021 to June 2022.

Months	Males	Females	Total	Sex ratio (M:F)	χ^2	*P*-value	Significance
January	5	29	34	1:5.8	16.94	3.86e–05	$P < 0.001$
February	1	29	30	1:29.0	26.13	3.19e–07	$P < 0.001$
March	2	28	30	1:14.0	22.53	2.06e–06	$P < 0.001$
April	1	32	33	1:32.0	29.12	6.80e–08	$P < 0.001$
May	3	28	31	1:9.3	20.16	7.12e–06	$P < 0.001$
June	2	34	36	1:17.0	28.44	9.64e–08	$P < 0.001$
July	4	26	30	1:6.5	16.13	5.90e–05	$P < 0.001$
August	5	19	24	1:3.8	8.16	0.004	$P < 0.001$
September	9	21	30	1:2.3	4.80	0.02	$P < 0.05$
October	2	27	29	1:13.5	21.55	3.44e–06	$P < 0.001$
November	5	19	24	1:3.8	8.16	0.004	$P < 0.001$
December	1	29	30	1:29.0	26.13	3.19e–07	$P < 0.001$
Total	**40**	**321**	**361**	**1:8.0**	**218.73**	< 2.20e–16	$P < 0.001$

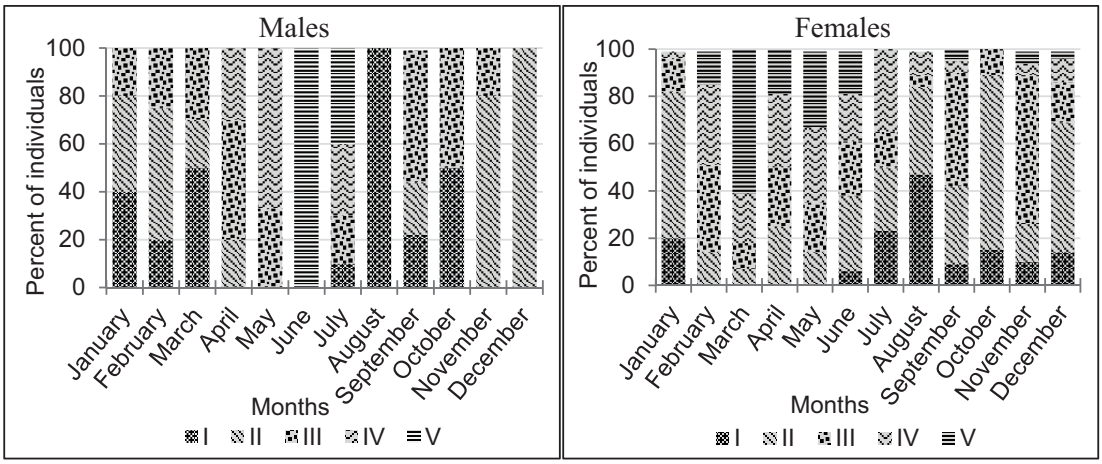

Figure 2. Monthly evolution of the sexual maturity stages of males and females of *Parachelon grandisquamis* in the Marine Protected Area of Niamone–Kalounayes (Senegal), from July 2021 to June 2022.

Mature individuals of sexual maturity stages (III, IV, and V) were present every month of the year for both sexes outside the month of December for males, reaching a maximum in the months of May (100%), June (100%), and July (90%) in males, and March (93%), May (85%), and February (85%) in females. No individual at the post-laying stage (stage VI) had been reported in the samples.

These results show that *Parachelon grandisquamis* exhibits continuous breeding throughout the year in the MPA of Niamone–Kalounayes, with a peak in sexual maturity from May to July in males and from March to June in females.

Gonadosomatic index and reproductive period. During the entire study, the calculated mean GSI was overall higher in females than in males. In females, higher GSI values were found from March to June, with a peak in May (3.96). The lowest values were observed in October and January (0.53 and 0.75, respectively). Females also seem to reach sexual maturity a bit earlier than males (May and June). For male individuals, the highest GSI values were recorded from April to July, with a peak observed in June (0.99). From January to March and from August to December, the GSI values are relatively low (Fig. 3). These

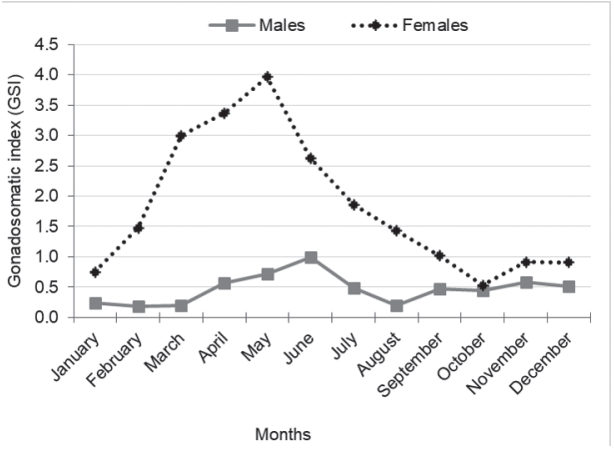

Figure 3. Monthly evolution of the GSI of *Parachelon grandisquamis* in the Marine Protected Area of Niamone–Kalounayes (Senegal), between July 2021 and June 2022.

results show that individuals of *Parachelon grandisquamis* roaming the MPA probably have a single breeding period that spread over five months, from March to July (ANOVA, $P < 0.05$). These findings show that this species prefers to spawn between the end of the dry season and the beginning of the wet season.

Size at first sexual maturity. In males, the smallest total length recorded is 15 cm and the largest is 24 cm (mean 19.55cm ± 1.98). In female individuals, the smallest total length is 14 cm and the largest is 27 cm (mean 21.36 cm ± 2.04). The size at first sexual maturity (L_m) observed is 17 cm for males and 18 cm for females (Fig. 4). Female *Parachelon grandisquamis* in the MPA reached sexual maturity at a size very close to that of males. The observed difference in mean sexual maturity length (L_m) between the two sexes was not significant ($\chi^2 = 0.02$; $P > 0.05$).

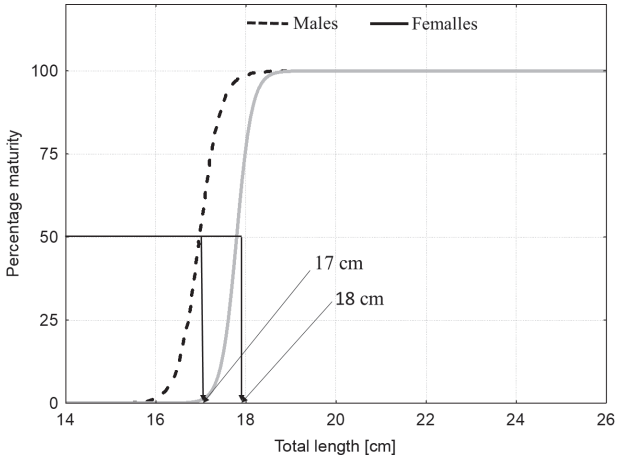

Figure 4. Size determination curve at first sexual maturity (L_m) for males and females of *Parachelon grandisquamis* in the Marine Protected Area of Niamone–Kalounayes (Senegal).

Discussion

This study was conducted with the aim of providing basic elements allowing the curator and the management committee of the MPA of Niamone–Kalounayes to have strong and up-to-date scientific information for better management of this species in view of its importance for the local population.

The sex ratio observed in this study highly favored females (1:8). These results are different from those obtained in other similar studies conducted in Côte d'Ivoire, where a higher proportion of males in the *Parachelon grandisquamis* population was observed (Diaby et al. 2012; Alla and Adepo-Gourene 2020). The imbalance in the sex ratio is a relatively common natural phenomenon in many fish species (Atsé et al. 2009). Generally, the majority of mullets have an unbalanced sex ratio that can be either in favor of females (Albaret and Legendre 1985; Ergene 2000; Ameur et al. 2003; Abou-Seedo and Dadzie 2004) or in a few instances, of males (Fehri Bedoui et al. 2002; Katselis et al. 2002). Several hypotheses have been put forward to explain this imbalance in the sex ratio (Bruslé and Bruslé 1977): (1) segregation of the sexes according to the seasons, the fish moving in separate schools; (2) differential distribution by height and age; (3) selective natural mortality; (4) a different migratory activity; (5) selectivity of fishing gear, which would catch one group more than another. The difference observed in the sex ratio of *P. grandisquamis* could also be explained by the influence of physicochemical parameters of the species' living environment but also by reproduction (Yao et al. 2017). The variation in the sex ratio observed also depends on the physiological state of the fish studied (Aka et al. 2004). Furthermore, among teleosts generally, males are more abundant during the reproductive period, whereas during the period of sexual rest, females are most often predominant in experimental fisheries (Djadji et al. 2013). During the breeding season, males regroup around females, which would explain the considerable increase in the number of males compared to females (Koné et al. 2014). In addition, among the Mugilidae, there is segregation by sex and age group during their movement (Vall unpublished*). Therefore, the most accessible school for fishing gear would show a predominance of one of the sexes in catches. This was not the case in this study, as the abundance of males was relatively constant and low during all sampling months.

Another factor that can also explain this difference in the sex ratio is the size of the sample. Since this study was carried out in the Marine Protected Area, and not on the entire Casamance River estuary, these results might only be an artifact of the limited sampling size and effort that could be made during this study. Apart from the post-spawning and spent stages (VI and VII), all other stages of sexual maturity were observed in this study, with different percentages from month to month. Changes in the percentage of maturity showed that mature individuals in stages IV and V remained dominant during the period from March to July for both sexes, with a greater proportion in May for females and in June for males. These peaks in maturity are coinciding accordingly with peaks in GSI found for the presently reported study. Just as observed in the MPA of Niamone–Kalounayes, a breeding period ranging from the mid-dry to early wet season has also been reported in *P. grandisquamis* in Côte d'Ivoire (Alla and Adepo-Gourene 2020). Other studies have shown that gonadal maturation can begin in the dry season and end in the wet season in the majority of Mugilidae, corroborating results from this study (Albaret 1984; Albaret and Legendre 1985; Djadji et al. 2018). At this time of year, environmental and trophic conditions are therefore more favorable to ensure larval development and survival of fry (Pagès and Citeau 1990).

Based on the results of the presently reported study, *Parachelon grandisquamis* males reach sexual maturity at a slightly smaller size (17 cm) than females (18 cm) in

* Vall MOV (2004) Etude de la dynamique des systèmes d'exploitation et de l'écobiologie de la reproduction de trois Mugilidés: *Mugil cephalus* (Linnaeus, 1758), *Liza aurata* (Perguria, 1892) et *Mugil capurrii* (Risso, 1810). Analyse de leurs Stratégies d'Occupations des secteurs littoraux Mauritaniens et de leurs possibilités d'Amenagement. Thèse de Doctorat, Université de Nice-Sophia Antipolis, France.

the MPA. This result could be related to early sexual maturity of males or faster growth of females as observed in the majority of teleosts (Toguyemi et al. 1997; Poulet unpublished*). A smaller length at first sexual maturity for males has been observed in other Mugilidae populations elsewhere in West Africa (Albaret and Legendre 1985; Diaby unpublished**; Djadji unpublished***), and more recently for the same species (Alla and Adepo-Gourene 2020). According to some authors, this difference observed in sizes at first sexual maturity could be related to environmental conditions (availability of food, temperature, salinity, the quantity of dissolved oxygen, etc.) that would favor faster growth of females to the detriment of males. It could also simply be due to genetic properties which will make males more precocious and reach the first sexual maturity before females (Yao et al. 2017).

Conclusion

Reproductive parameters such as sex ratio (SR), gonadosomatic index (GSI), and size at first maturity (L_m) for *Parachelon grandisquamis* were determined for the first time in the MPA of Niamone–Kalounayes. Results from this study could be used as a reference for better fishing regulations practices, but also in future work on the biology of the species or other Mugilidae at the MPA level. Overall, 361 individuals were sampled, including 321 females and 40 males. The sex ratio was in favor of females (1:8). Males reach sexual maturity (17 cm) at a size very close to that of females (18 cm). *Parachelon grandisquamis* spawned in the MPA, with a breeding period ranging from the end of the dry season in March to the beginning of the wet season in July. The timing of this reproductive activity is clearly shown in this study by a higher proportion of individuals in advanced stages of maturation (stages III, IV, and V) during this period. From the results of this study, it is clearly shown that *P. grandisquamis* is spawning in the MPA during a single spawning event between March and July and that the sex ratio is greatly imbalanced in favor of females, even though the sizes at first sexual maturity for both sexes are very similar. These results, obtained after twelve months of sampling, provide information on the reproduction of *P. grandisquamis* that can help in decision-making for better management of the resource.

From a sustainable management perspective of this species, it would be beneficial to add the size at first sexual maturity (L_m) as a management measure. Values of L_m could be calculated and used as a threshold to code for the selectivity of fishing gear (e.g., appropriate mesh size). In that sense, the minimum catch size should be variable depending on the season. The minimum catch size should be adjusted to be bigger than the size at first sexual maturity, so that it would allow this species to reproduce at least once before being caught. Finally, the exploitation of this species should be limited during the main breeding season (March–July), to encourage higher levels of reproductive activity and consequently, better recruitment each and every year.

Acknowledgments

The authors would like to thank Professor Alassane Sarr, the Director of the University Institute of Fisheries and Aquaculture, for his supervision and guidance in carrying out this study. We would like to thank all the fishermen of the MPA management committee for their support during the experimental fisheries. Our thanks to Captain Sarany Diedhiou, curator of the MPA, and all the staff for their assistance and support in carrying out this study.

References

Abou-Seedo F, Dadzie S (2004) Reproductive cycle in the male and female grey mullet, *Liza klunzingeri* in the Kuwaiti waters of the Arabian Gulf. Cybium 28(2): 97–104. https://doi.org/10.26028/cybium/2004-282-002

Aka Z, Koç HT, Turan C (2004) A study on growth of the anchovy *Engraulis encrasicolus*, Linnaeus (1758) in Turkish Seas, Turkey. Pakistan Journal of Biological Sciences 7(7): 1121–1126. https://doi.org/10.3923/pjbs.2004.1121.1126

Albaret JJ (1984) Premières observations sur la faune ichtyologique de la Casamance. Archives du Centre de Recherches Océanographiques de Dakar-Thiaroye, 22 pp.

Albaret JJ (2003) Caractérisation de l'état de référence des peuplements de poissons d'une aire protégée en zone de mangrove: le bolon de Bamboung (Sine Saloum, Sénégal). Rapport de convention Narou Heuleuk/ AFD/ IRD, Dakar, décembre, 50 pp.

* Poulet N (2004) Le sandre (*Sander lucioperca*): Biologie, comportement et dynamique des populations en Carmargue (Bouches du Rhône, France). Thèse de Doctorat, Université Toulouse III-Paul Sabatier, France.

** Diaby M (2014) Distribution spatio-temporelle, pêche et dynamique de la population des Mugilidae (poissons, téléostéens) de la lagune de Grand-Lahou (Côte d'Ivoire). Thèse de Doctorat, Université Nangui Abrogoua, Côte d'Ivoire.

*** Djadji ELG (2015) Etude des traits biologiques et du régime alimentaire de deux espèces de Mugilidae, *Liza falcipinnis* (Valenciennes, 1836) et *Mugil cephalus* (Linnaeus, 1758) dans les complexes lagunaires Ebrié et Grand-Lahou, Côte d'Ivoire. Thèse de Doctorat, Université de Cocody, Côte d'Ivoire.

Albaret J-J, Legendre M (1985) Biologie et écologie des Mugilidae en lagune Ebrié (Côte d`Ivoire) Intérêt potentiel pour l`aquaculture lagunaire. Revue d'Hydrobiologie Tropicale 18(4): 281–303.

Alla EYGH, Adepo-Gourene AB (2020) Stratégies de reproduction de trois espèces de Mugilidae, *Liza dumerili* (Steindachner, 1870), *L. grandisquamis* (Valenciennes, 1836) et *L. falcipinnis* (Valenciennes, 1836) dans la lagune Ebrié, Sud, Côte d`Ivoire. Afrique Science 16(1): 279–299.

Amenzoui K, Ferhan-Tachinante F, Yahyaoui A, Mesfioui HA, Kifani S (2004–2005) Etude de quelques aspects de la reproduction de *Sardina pilchardus* (Walbaum, 1792) de la région de Laâyoune (Maroc). Bulletin de l'Institut Scientifique, Rabat, section Sciences de la Vie 26–27: 43–50.

Ameur B, Bayed A, 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* (Poisson Mugilidae). Bulletin de l'Institut Scientifique, Rabat, section Sciences de la Vie 17: 77–82.

Atsé BC, Konan KJ, Kouassi NJ (2009) Biologie de la reproduction du Cichlidae *Tylochromis jentinki* dans la lagune Ébrié (Côte d`Ivoire). Cybium 33(1): 11–19. https://doi.org/10.26028/cybium/2009-331-002

Bruslé J, Bruslé S (1977) Les muges de Tunisie: pêche lagunaire et biologie de la reproduction de trois espèces (*Mugil capito*, *Mugil cephalus* et *Mugil chelo*) des lacs d'Ichkeul et de Tunis. Rapports et procés-verbaux des réunions Commission internationale pour l'exploration scientifique de la Mer Méditerranée 24(5): 101–130.

Diaby M, N'da K, Akadje CM (2012) Distribution spatio-temporelle des poissons Mugilidae dans la lagune de Grand-lahou (Côte d`Ivoire). International Journal of Biological and Chemical Sciences 6(4): 1608–1623. https://doi.org/10.4314/ijbcs.v6i4.20

Diouf PS (1996) Les peuplements de poissons des milieux estuariens de l'Afrique de l'Ouest: l'exemple de l'estuaire hyperhalin du Sine–Saloum. Thèse de Doctorat 3e cycle, Université de Montpellier II, France.

Djadji ELG, Atse BC, Sylla S, Konan JK, Kouassi JN (2013) Reproduction du Mugilidae *Mugil cephalus* Linné, 1758 dans deux complexes lagunaires (lagunes Ébrié et de Grand-Lahou) de la Côte d`Ivoire. International Journal of Biological and Chemical Sciences 7(4): 1701–1716. https://doi.org/10.4314/ijbcs.v7i4.25

Djadji ELG, Sylla S, Zan-bi TT, Atse BC (2018) Reproductive biology of the mullet *Liza falcipinnis* (Valenciennes, 1836) in two African complexs lagoons (Ebrié and Grand-Lahou) (Côte d`Ivoire). International Journal of Research—Granthaalayah 6(5): 114–127. https://doi.org/10.29121/granthaalayah.v6.i5.2018.1433

Ergene S (2000) Reproduction characteristics of thinlip grey mullet, *Liza ramata* (Risso, 1826) inhabiting Akgöl–Paradeniz lagoons (Göksü Delta). Turkish Journal of Zoology 24(2): 159–164.

FAO (1992) Guide de terrain des ressources marines commerciales du golf de Guinée. FAO, Rome, 268 pp.

Fehri Bedoui R, Gharbi H, El Abed A (2002) Période de reproduction et maturité sexuelle de *Liza aurata* (Poisson, Mugilidae) des côtes Est et Sud tunisiennes. Bulletin de l'Institut National des Sciences et Technique de la Mer, Salammbô 29: 11–15.

Fontana A (1969) Etude de la maturité sexuelle des sardinelles *Sardinella eba* (Val) et *Sardinella aurita* C. et V. de la région de Pointe-Noire. Cahiers ORSTOM, Serie oceanographie 7(2): 101–114.

Ghorbel M, Jarboui O, Bradai MN, Bouain A (1996) Détermination de la taille de première maturité sexuelle par une fonction logistique chez *Limanda limanda*, *Pagellus erythrinus* et *Scorpaena porcus*. Bulletin de l'Institut National des Sciences et Technique de la Mer, Salammbô Num. Spéc. 3: 24–27.

Harrison IJ (2008) Mugilidae. Pp. 450–471. In: Stiassny MLJ, Teugels GG, Hopkins CD (Eds) Poissons d'Eaux Douces et Saumâtres de Basse Guinée, Ouest de l'Afrique Centrale (vol. 2). IRD Editions, Paris, France.

Kahn JE, Watterson JC, Hager CH, Mathies N, Hartman KJ (2021) Calculating adult sex ratios from observed breeding sex ratios for wide-ramping, intermittently breeding species. Ecosphere 12(5): 1–11. https://doi.org/10.1002/ecs2.3504

Katselis G, Koutsikopoulos C, Kaspiris P (2002) Age determination and growth of leaping mullet, (*Liza saliens*, R. 1810) from the Messolonghi Etoliko lagoon (western Greece). Mediterranean Marine Science 3(2): 147–158. https://doi.org/10.12681/mms.253

Koné A, N'da K, Kouassi SK, Agnissan JPA (2014) Dynamique de la population exploitée de deux requins: *Sphyrna zygeana* (Linnaeus, 1758) et *Isurus oxyrinchus* (Rafinesque, 1809) des côtes ivoiriennes. International Journal of Biological and Chemical Sciences 8(4): 1633–1643. https://doi.org/10.4314/ijbcs.v8i4.25

Pagès J, Citeau J (1990) Rainfall and salinity of a sahelian estuary between 1927 and 1987. Journal of Hydrology 113(1–4): 325–341. https://doi.org/10.1016/0022-1694(90)90182-W

Paugy D, Lévêque C, Teugels DD (2003) The fresh and brackish water fishes of West Africa. Muséum national d'Histoire naturelle, Paris, France, 1272 pp.

R Core Team (2018) A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Seret B, Opic P (2011) Poissons de mer de l'Ouest africain tropical, IRD, Marseille, France 450 pp.

Toguyemi A, Fauconneau B, Boujard T, Fostier A, Kuhn ER, Mol KA, Baroiller JF (1997) Feeding behaviour and food utilisation in tilapia, *Oreochromis niloticus*: Effect of sex ratio and relationship with the endocrine status. Physiology and Behavior 62(2): 273–279. https://doi.org/10.1016/S0031-9384(97)00114-5

Wright JM (1988) Seasonal and spatial differences in the fish assemblage of the non-estuarine Sulaibikhat Bay, Kuwait. Marine Biology 100(1): 13–20. https://doi.org/10.1007/BF00392950

Yao N, Diaha N'guessan C, Monin Amande J, Angui Kouame JP, Abekan E, N'dri Assan F, N'da Konan (2017) Sex-ratio, stades de maturité, taille de première maturité et facteur de condition de *Canthidermis maculata* capturé dans l'océan Atlantique Est. Sex ratio, maturity stages, first maturity size and condition factor of *Canthidermis maculata* caught in the eastern Atlantic Ocean. International Journal of Biological and Chemical Sciences 11(6): 2876–2886. https://doi.org/10.4314/ijbcs.v11i6.25