Original Research Article

Biology of the Reproduction of Mugilidae *Neochelon falcipinnis* (Valenciennes, 1836) in the Protected Marine Area of Niamone-Kalounayes (Casamance Estuary)

ABSTACT

The reproduction of *Neochelon falcipinnis* was studied in the Marine Protected Area (MPA) of Niamone-Kalounayes located in the Casamance estuary (Senegal) from July 2021 to June 2022. The results of this study are presented after twelve (12) months of experimental seine fishing. Reproductive parameters such as length-weight relationship, condition factor (K), sex ratio (SR), gonadosomatic index (GSI) and size at first maturity (Lm50) were determined. A total of 386 individuals (150 males, 221 females and 15 of undetermined sex) were sampled. The sex ratio was in favour of females (0.68 or 1:1.47). The length-weight relationship showed a minor allometric growth with allometric coefficient *b* values of 2.70 for both sexes combined, 2.60 for males and 2.79 for females. The ANOVA test showed no significant difference in condition factor in males ($P > 0.05$). In contrast, in females, there was a significant difference at the beginning of the cold season ($P < 0.05$). The monthly change in gonadosomatic index associated with the different stages of sexual maturity indicated a breeding period in the dry season (May, June and July). Peaks of sexual maturity are observed in June for both sexes. Sizes at first sexual maturity were 18 cm for males and 19 cm for females. These results, obtained provide information on the reproduction of *Neochelon falcipinnis* that can help in decision-making for better management of the resource.

Keywords: Reproduction, Neochelon falcipinnis, Marine Protected Area, Niamone-Kalounayes, Estuary Casamance.

1 INTRODUCTION

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Mugilidae are marine-dwelling fish found in all temperate, tropical and subtropical seas [1]. However, they are fond of brackish estuarine and lagoon waters with a high variation in salinity that they recover during tides [2, 3]. Their presence in West African estuaries and lagoons has been documented by various authors [4, 5, 6]. Together with the Cichlidae, these species constitute some of the most abundant fish families in the Casamance estuary, and in particular in the Marine Protected Area (MPA) of Niamone-Kalounayes [7, 8]. Their commercial, foraging [9] and ecological [10, 11] importance mean that this family deserves special attention [12]. Only the genera Mugil and Neochelon are found in West Africa, in brackish water. In Senegal, these two genera are represented by six species (*Mugil cephalus*, *Mugil bananensis*, *Mugil curema*, *Chelon dumerili*, *Parachelon grandisquamis* and *Neochelon falcipinnis*) that generally colonize estuaries and lagoons [13]. *Neochelon falcipinnis*, like all species of the Mugilidae family, is permanently present and occupies an important place in artisanal fishing in Casamance. This importance is also explained by high commercial value but also by high local consumption [7].

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However, literature reviewed for this study shows that papers on the ecology, and especially on the biology of the reproduction of this species are still not widespread in the West African coasts. Knowledge of the biology of fish reproduction is an essential asset in defining a management plan for the proper control of fish resources [14]. The objective of this study is to evaluate the different aspects of *Neochelon falcipinnis* reproduction such as sex ratio, period and duration of reproduction, and size at first maturity. All of this updated data could be used to better plan fishing strategies such as defining minimum catch sizes, and/or establishing a biological recovery plan for this species.

2 MATERIAL AND METHODS

2.1 Study area

The MPA of Niamone-Kalounayes was created on November 4, 2015, by Decree N° 2015-1724 and covers an area of 63.894 ha. It extends up to the Kalounayes Classified Forest in the North, to the Soungrougrou river in the East, to the Bignona marigot in the West and to the Casamance River in the South (Fig. 1). The MPA of Niamone-Kalounayes covers the marine, estuarine and freshwater parts of the Ziguinchor region, and is formed by a complex and diffuse system of canals called bolongs, and mangroves, common features of brackish intertropical wetlands [15]. The main objectives for the creation of this MPA were the restoration of habitats and natural resources, the improvement of living conditions of populations and the establishment of an adapted governance system.

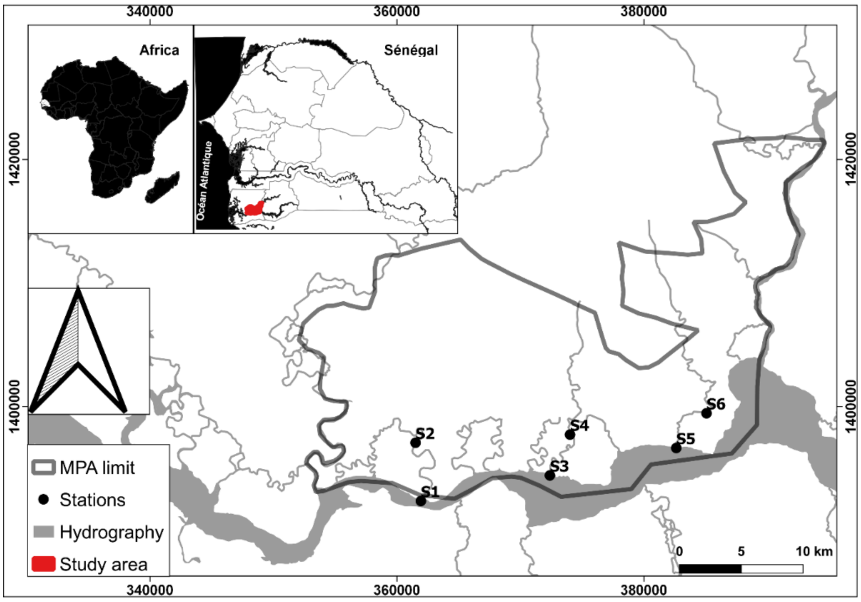


Fig. 1 . Map of the MPA of Niamone-Kalounayes, with the ~~different~~ sampling points

2.2 Sampling strategy

Individuals of *N. falcipinnis* were sampled monthly from July 2021 to June 2022. The samples were taken in three secondary channels (or bolongs) bordered by mangroves. For each station, fish caught were identified using fish identification keys [16, 17, 18]. For the entire study, a total of 386 specimens were collected. The fish sampled were caught by local fishermen using a 250 m long, 7 m height and 25 mm mesh size experimental seine specially designed for the study. All fish were measured (total length, TL, in mm; fork length, FL, in mm) using an ichthyometer with a precision to the closest millimeter, and weighed (total weight, TW; eviscerated weight, EVW) in grams with an electronic balance to the nearest tenth of a gram. The sex and maturity of the gonads were determined using the Fontana scale [19]. The maturity scale described by Fontana consists of 7 stages and is determined by the macroscopic appearance and structure of the gonad.

2.3 Length-weight relationship

The relationship between total length and total weight is a power function. It was calculated first for all sexes and then separately for both sexes, according to the formula [20]:

$$TW = a \times TL^b \qquad (1)$$

where *TW*= total weight, *TL* = total length, a = constant and b = allometry coefficient.

2.4 Condition Factor (K)

Condition factor (K) is an indicator of the physiological and biological status of fish, relative to its feeding conditions, parasitic infections, and physiological and other ecological factors [21]. The condition factor is given by the ratio of the weight of the fish to the cube of its length, according to the equation:

$$K = (TW / TL^3) \times 10^5 \qquad (2)$$

where TW = total weight and TL = total length.

The condition factor was first calculated for all sexes, and then separately for both sexes. The condition factor was then compared between months for the same sex using an analysis of variance (ANOVA).

2.5 Sex-ratio (SR)

Sex-ratio is defined as the proportion of male or female individuals on the total population. Sex-ratio gives an idea of gender balance in a given population [22]. The proportion of both sexes is a characteristic of the species whose variations are sometimes related to the environment. Sex-ratio (SR) was calculated following sex identification and was expressed using the following formula:

$$SR = F / M \qquad (3)$$

where F = the number of female individuals and M = the number of male individuals.

SR was then compared between months for the same sex using the Khi-two test (χ^2).

2.6 Gonadosomatic index (GSI)

In females and males, variations in the gonadosomatic index in the population was reported in order to establish the sex cycle and determine the spawning period. The GSI was calculated from the equation [23]:

$$GSI = (GW / EVW) \times 100 \quad (4)$$

where GW = gonads weight in g, EVW = eviscerated weight in g. The GSI was then compared between months for the same sex using an analysis of variance (ANOVA).

2.7 Size at first maturity (Lm50)

The size at first maturity (Lm50) was derived using the total length in centimetres (cm). The percentage of mature individuals in each size class was calculated by setting the maturity threshold at stage III, which corresponds to the beginning of the gonad maturation phase in the Fontana scale (1969). It tracks the degree of sexual maturity by size and accurately estimates the size at first maturity, which is often used in stock assessment models from the following equation [24]:

$$P\% = \frac{100}{1+e^{-\alpha(TL-TL_{m50})}} \quad (5)$$

P% = percentage of individuals at sexual maturity, e = constant, TL = total length of the fish, and TLm50 = total length where 50% of the sampled individuals are mature. The TLm50 was then compared between males and females using the Khi-two test (χ^2).

3 RESULTS

3.1 Length-weight relationship

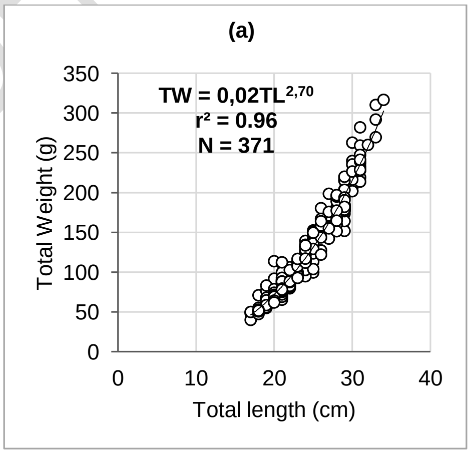
In *N. falcipinnis*, the males sampled had a total length between 17 and 33 cm and a total weight varying between 48 and 291.80 g. In females, the total length measured ranged from 17 to 34 cm and the total weight ranged from 40 to 316.60 g. There was no significant difference between the total length and total weight of males and females (χ^2, *P = 0.98*). The weight ratio of individuals of *N. falcipinnis* was determined according to the two sexes combined and then for the two separate sexes. The results were recorded in Table 1 below.

Table 1. Summary of the length-weight relationship in Neochelon falcipinnis

Sexes	N	Length (cm)			Weight (g)			LWR parameters		
		Min	Mean	Max	Min	Mean	Max	a	b	r²
Males	150	17	23.61	33	48	118.22	291.80	0.03	2.60	0.96
Females	221	17	23.52	34	40	118.42	316.60	0,02	2.79	0.94
Sex Combined	371	17	23.56	34	40	118.46	316.60	0.02	2.70	0.96

N = Number of individuals; Min = minimum; Max = maximum; a = Constant; b = allometry coefficient and r² = coefficients of determination

The results of the analysis showed an allometry coefficient of 2.70 for both sexes combined while males and females are respectively represented by coefficients of 2.60 and 2.79 (Fig. 2). These results showed a minor allometry. In other words, in *N. falcipinnis*, the weight of individuals grew relatively slower than the total length ($b < 3$) in both males and females. The figure also showed a positive correlation with a coefficient of correlation $r^2 = 0.96$ in males, $r^2 = 0.94$ in females and $r^2 = 0.95$ for both sexes combined indicating a strong correlation between the two studied variables.



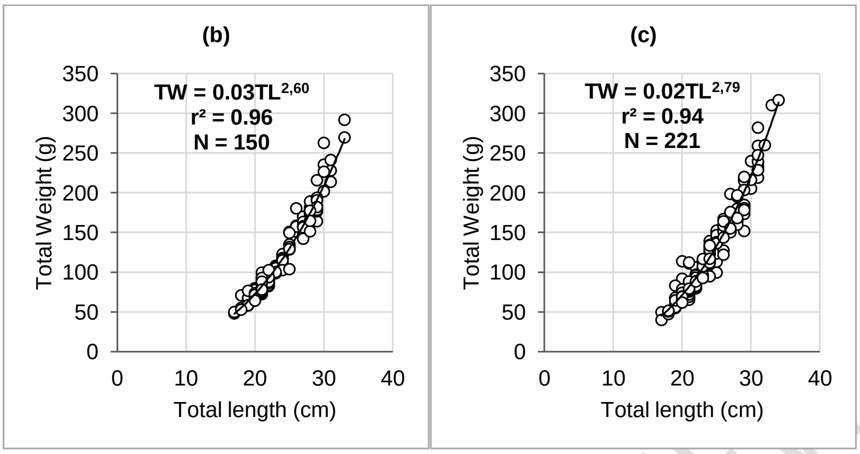


Fig. 2. Length-weight relationship of *Neochelon falcipinnis* based on an allometric model; (a) = sex combined, (b) = males and (c) = females, TW = total weight, TL = total length, r^2 = correlation coefficient, N = number of fish sampled

3.2 Monthly variation of the coefficient of condition

Figure 3 shows the monthly variation in condition factor (K) of male and female individuals in *N. falcipinnis*. It reflects a similar and very close evolution from one month to the next between the two sexes. Maximum condition factor (K) values in males were observed in July (1.21 ± 0.10), October (1.11 ± 0.09), May (1.07 ± 0.05) and August (1.01 ± 0.80). The minimum values were recorded in January (0.89 ± 0.05) and February (0.87 ± 0.05). In females, the condition factor (K) was higher in July (1.42 ± 0.11), February (1.21 ± 0.10), June (1.21 ± 0.11), August (1.14 ± 0.07) and October (1.00 ± 0.05). The lowest values were observed in January (0.49 ± 0.09) and February (0.51 ± 0.10). The ANOVA test showed no significant difference in condition factor in males ($P > 0.05$). In contrast, in females, there was a significant difference at the beginning of the cold season ($P < 0.05$). This difference resulted in a slight decrease in the condition factor in November, December and January. This small difference could be related to a variation of the conditions of the water during this period, especially the physicochemical factors like the temperature, but also the salinity.

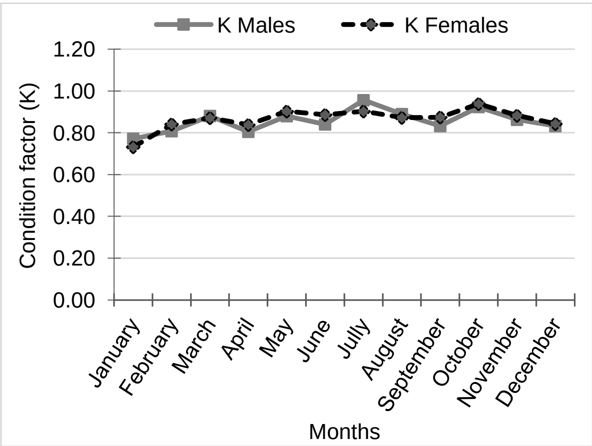


Fig. 3. Monthly variation in the condition factor of *Neochelon falcipinnis* in the MPA of Niamone-Kalounayes, from July 2021 to June 2022.

3.3 Sex-ratio

Overall, 386 individuals of *N. falcipinnis* were captured, including 221 females, 150 males and 15 individuals of undetermined sex. Numerically, females were much more numerous than males, although small insignificant variations in favor of males are noted for some months (Table 2). Thus, the sex ratio (male to female) was 0.68 or 1:1.47. In other words, 1.47 females were represented by a male individual. This sex ratio was significantly different from the theoretical sex ratio of 1:1 (χ^2 = 13.58, $P < 0.05$). However, significant monthly variations were noted (χ^2 = 20.82, p < 0.05; χ^2 = 20.16, $P < 0.05$; χ^2 = 11, $P < 0.05$; χ^2 = 19.61, $P < 0.05$) in favour of females for February, May, July and August (Table 2).

Table 2. Monthly changes in the sex ratio of *Neochelon falcipinnis* in the MPA of Niamone-Kalounayes from July 2021 to June 2022.

Months	Female	Male	Total	Sex ratio (M:F)	χ^2	p-value

January	13	17	30	1 : 0.76	0.53	0.46
February	31	4	36	1 : 7.75	20.82	0.001**
March	17	12	30	1 : 1.42	0.86	0.35
April	22	17	40	1 : 1.29	0.64	0.42
May	3	28	31	1 : 0.11	20.16	0.02*
June	15	13	30	1 : 1.15	0.14	0.70
July	33	11	45	1 : 3.00	11	0.001**
August	40	9	49	1 : 4.44	19.61	0.02*
September	13	5	20	1 : 2.60	0.14	0.70
October	7	15	22	1 : 0.47	2.90	0.08
November	13	11	28	1 : 1.18	0.16	0.68
December	14	8	25	1 : 1.75	1.63	0.20
Total	221	150	386	1 : 1.47	13.58	0.000**

*: Significant at $P < 0.05$, **Significant at $P < 0.001$

3.4 Sexual maturity

The estimations of monthly variations in the different stages of sexual maturity in both sexes showed a year-round variation, with seasonal varying proportions from month to month (Fig. 4). Indeed, in males, immature individuals of sexual maturity stage (I and II) were encountered throughout the year except the month of June. The highest percentages of males were recorded in August (100%), November (90%) and September (80%). On the other hand, females were present throughout the year except in January. The maximum numbers of female individuals were observed in November (93%) and December (71%). Stage III maturity was observed throughout the sampling period in males except February, August and October. However, in females, it was absent only in October. The highest percentage was reached in January for both sexes 54% (females) and 35% (males). However, individuals in the pre-egg and laying stages (stages IV and V) were present every month of the year except for the months of July, August, September and November in males. The maximum number of stage IV individuals was observed in February (50%) for males and January (46%) for females. The maximum number of stage V individuals was recorded in May for males (75%) and October (86%) for females. No individuals at the post-spawning stage (Stage VI) were reported. *Neochelon falcipinnis* therefore had a continuous year-round reproduction (Fig.4).

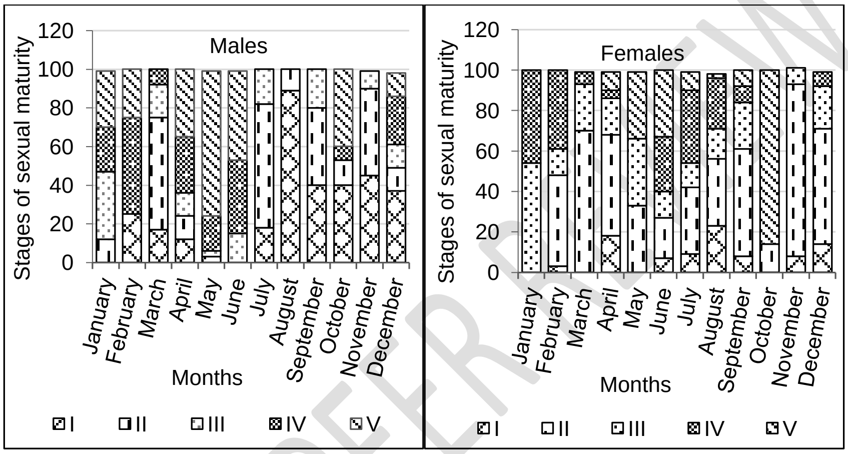


Fig. 4. Monthly evolution of the sexual maturity stages of males and females of *Neochelon falcipinnis* in the MPA of Niamone-Kalounayes, from July 2021 to June 2022.

3.5 Monthly variation of the gonadosomatic index and reproductive period

The analysis of the evolution of the GSI showed an almost similar evolution in both sexes from one month to the next (Fig. 5). With more individuals than their male counterparts, the GSI curve for females was higher than for males with peaks in October (3.94 ± 1.84), June (3.23 ± 3.71) and January (2.34 ± 1.63), while for males the GSI peaked in February (2.16 ± 1.81). Other peaks were observed in January (1.44 ± 0.91), December (0.74 ± 0.82) and October (0.57 ± 0.62). The lowest GSI values were recorded in March (0.26 ± 0.15), November (0.35 ± 0.21) and September (0.89 ± 1.11) for females and August (0.17 ± 0.035), March (0.19 ± 0.20) and November (0.32 ± 0.20) for males. Monthly variations in the GSI for *Neochelon falcipinnis* showed that this species reproduced year-round with greater intensity in the dry season (May, June and July) and late rainy season (October, January and February; ANOVA, $P < 0.05$).

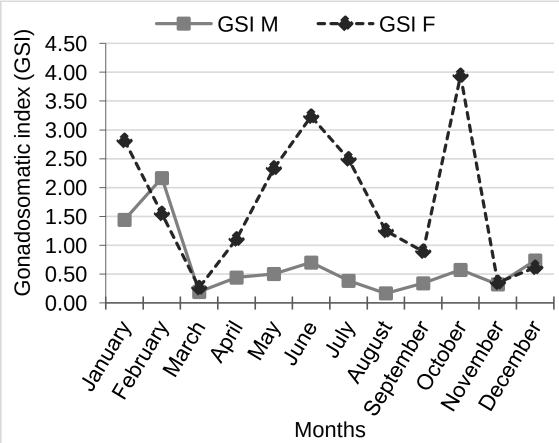


Fig. 5. Monthly evolution of the GSI of *Neochelon falcipinnis* in the MPA of Niamone-Kalounayes, between July 2021 and June 2022.

3.6 Size at first maturity

The sizes at first maturity for *N. Falcipinnis* were 18 cm for males and 19 cm for females (Fig. 6). Thus, in this study, the males of *Neochelon falcipinnis* reached sexual maturity at a slightly smaller size than the females. However, the difference in size was not statistically significant ($P > 0.05$).

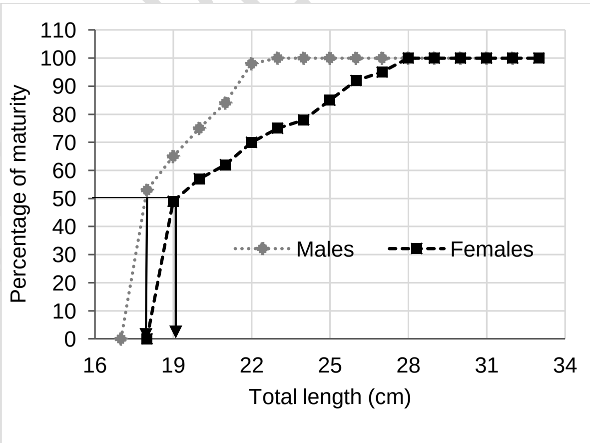


Fig. 6. Size determination curve for first maturity (Lm50) in males and females of *Neochelon falcipinnis* in the MPA of Niamone-Kalounayes.

4 DISCUSSION

The study of the length-weight relationship in fish population is an important tool in the assessment of fish stocks. The results obtained from this study of 386 individuals of *N. Falcipinnis* in the MPA of Niamone-Kalounayes show a minor allometric growth with b values of 2.70 for both sexes combined, 2.60 for males and 2.79 for females. *Neochelon falcipinnis* would have a relatively smaller growth in weight than the growth in length. This may explain the compressed form of the body observed in the species, corroborating work made on the Australian mullets [25], a close parent in the *Mugilidae* family. Work on the *Neochelon falcipinnis* on the Ivory Coast also showed a minor allometry with b values of 2.48 for males and 2.91 for females [26]. The positive correlations obtained (r^2 = 0.96, 0.94 and 0.95 respectively for males, females and sexes combined) explained a strong relationship between the total length measured in the species and total body weight. Minority allometry could be explained by several factors including habitat, food availability, seasonal effects, but also physicochemical factors such as temperature and salinity [27].

The sex ratio observed for all individuals captured in this study was predominantly female (1:1.47). An unbalanced sex ratio in mullets has been observed by several authors with a predominance of females [28, 29, 30, 31, 32]. On the other hand, other authors have reported male dominance [33, 34, 35, 3]. Several factors, such as displacement for foraging, reproductive period, sex-specific mortality rates, and highly sex-related gregarious behaviour may explain this trend in favour of females [36]. This predominance of one sex remains a relatively common phenomenon in many teleostean fish including *Sarotherodon melanoteron* [37, 38], *Mullus barbatus* [39], *Trachinotus teraia* [14], and other Mugilidae species [40, 41]. The variation in sex ratio also depends on the physiological status of fish [42]. In fact, in teleosteans, males are generally more abundant during the reproductive period, while in the period of sexual rest, females are predominant [43]. During breeding, males congregate around females, which would explain the significant increase in males relative to females [44]. In addition, Mugilidae are segregated by sex and age group during their displacement [45]. As a result, the bank most accessible to fishing gear might show a predominance of one sex in the catches.

The variation in gonadosomatic index associated with different stages of sexual maturity showed a similar pattern over most of the year with greater intensity in the dry season (April, May, June and July) and late rainy season (October, November December January and February). Thus, peak spawning was more pronounced in June and October, corresponding respectively to the beginning of the rainy season and the flood period. The peak also showed that the highest proportions of males and females in stages 4 and 5 were observed during this period. The work of [26] on the Ivory Coast on the same species showed that gonadic maturation began in the dry season and ended in the rainy season. These results were also similar to the work of several authors on *Neochelon falcipinnis* [10, 13, 33]. Indeed, the rainy season created the ideal environmental and trophic conditions for the survival of larvae and fry. Nutrients are drained by runoff rich in organic matter during the flood season. The decomposition of organic matter enriches the environment with mineral salts, which would lead to the proliferation of algae [46]. Food availability during this period is used so that larvae and fry do not have to make an effort to travel long distances to feed [47]. In Senegal, work on other species of *Mugilidae* such as *Chelon dumerili* [32] and *Mugil cephalus* [48] have shown the same results. However, reference [49] reported the presence of many mature males and females of *Chelon dumerili* spawning in March, although there was still intense reproductive activity, although at a lower level in June. The instability of the reproductive period observed in some species can be assimilated to a response to adaptation strategies developed to cope with variations in environmental factors.

The size at first maturity is slightly larger (19 cm) in females than in males (18 cm) of *N. falcipinnis*. As with most Mugilidae, females often reach sexual maturity at a larger size than males [29, 30]. Similar results have been found on the same species in the Arabian Gulf [29], Pakistan [50] but also in the Ivory Coast [33, 26]. At the same age, length and weight are more important in females than in males [3]. The study of the size of first maturity is of paramount importance in fish especially for determining the minimum size of first catch [51].

Analysis of the monthly variation in the GSI and condition factor showed a similar pattern for both indices. However, the laying period was the period when the condition factor was the lowest. This result was explained by a weight loss of the species suggesting that *Neochelon falcipinnis* would use its energy reserves in the muscles and viscera to ensure its reproduction [34].

5 CONCLUSION

Reproductive parameters such as sex ratio (SR), length-weight relationship, condition factor (K), gonadosomatic index (GSI), and size at first maturity (Lm50) for *N. falcipinnis* were determined. From the results of this study, it is clearly shown that *Neochelon falcipinnis* spawned in the marine protected area of Niamone-Kalounayes. Indeed, two breeding periods are reported, one from April to July and a second from October to February with a first peak in June for both sexes and a second peak in

January for females and February for males. The sex ratio being in favour of females, the length-weight relationship showed a minor allometry, which was explained by a greater growth in length than in body weight for this species. Thus, the species would be able to use its energy reserves contained in the muscles and viscera to ensure its reproduction in view of the evolution of the gonadosomatic index associated with the condition factor. The size at first maturity (Lm50) was reached at a greater length in females (19cm) than in males (18cm). The information obtained in this study will contribute to a better understanding of the reproductive biology of *Neochelon falcipinnis* in the MPA in order to put in place management measures to better protect this resource.

REFERENCES

1. Pombo L, Elliott M, Rebelo JE. Environmental influences on fish assemblage distribution on an estuarine coastal lagoon, Ria de Aveiro (Portugal). Cientia Marina Journal. 2005;69(1):143-159.
Available: https://scientiamarina.revistas.csic.es/index.php/scientiamarina/article/view/241

2. Albaret JJ. Characterization of the reference state of fish populations in a protected area in a mangrove zone: the Bamboung bolon (Sine Saloum, Senegal). Convention report Narou Heuleuk/ AFD/ IRD, Dakar; 2003.
Available: https://core.ac.uk/download/pdf/39844794.pdf

3. Bernardon M, Vall MOM. The Mullet in Mauritania: biology, ecology, fishing and management. Regional Program for the Conservation of the Coastal and Marine Zone in West Africa (PRCM), Nouackchott, Mauritania; 2004.
Available: https://portals.iucn.org/library/sites/library/files/documents/2004-065.pdf

4. Albaret JJ, Simier M, Darboe FS, Ecoutin JM, Raffray J, Tito de Morais L. Fish diversity and distribution in the Gambia Estuary, West Africa, in relation to environmental variables. Aquatic Living Resource. 2004;17(1):35-46.
Available: https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers15-10/010038145.pdf

5. Harrison J. Fresh and Brackish Water Fishes of Lower Guinea, West Central Africa, IRD Editions, Paris. 2008;2:450-471.

6. Soyinka OO, Kuton MP, Ayo-Olalusi CI. Seasonal distribution and richness of species in the Badagry Lagoon, South West, Nigeria. Estonian Journal of Ecology. 2010;59:147-157.

Available: https://www.kirj.ee/public/Ecology/2010/issue_2/ecol-2010-2-147-157.pdf

7. Diedhiou P. Contribution to the study of fish populations in the marine protected area of Niamone-Kalounayes (Casamance). Master's thesis in Ecology and Management of Aquatic Ecosystems, IUPA, UCAD, Dakar; 2019.

8. Nzale A. Contribution to the study of fish populations in the Kassa-Balantacunda Marine Protected Area (MPA) (Senegal). Master's thesis in Ecology and Management of Aquatic Ecosystems, IUPA, UCAD, Dakar; 2019.

9. Pandaré D, Cap Deville B. Fish fauna of Casamance. EPEEC End Report;1986:59-88.

10. Albaret JJ. First observations on the ichthyological fauna of Casamance. Archives of the Oceanographic Research Center of Dakar-Thiaroye; 1984.

Available: https://www.documentation.ird.fr/hor/fdi:32500

11. Diouf PS, Bousso T. Senegal River, Aquatic Environment and Fisheries. Dowry. Scient. Oceanographic Research Center of Dakar Thiaroye; 1988.

Available: https://idl-bnc-idrc.dspacedirect.org/handle/10625/5825

12. Diouf PS. Quick identification guide for Senegalese estuary mullets. Scientific document, Oceanographic Research Center of Dakar Thiaroye; 1991.

Available: https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers13-05/010023576.pdf

13. Albaret JJ. The fish populations of Casamance (Senegal) in times of drought. Journal of Tropical Hydrobiology. 1987;20(3):291-310. English.

Available: https://horizon.documentation.ird.fr/exldoc/pleins_textes/cahiers/hydrob-trop/25852.pdf

14. Sylla S, Atse BC, Kouassi NGJ. Reproductive strategy of the Carangidae Trachinotus teraia cuvier, 1832 in the Ebrié lagoon (Côte d'Ivoire). Natural Science. 2009;6(1):83-94. English.

Available: https://www.ajol.info/index.php/scinat/article/view/48662

15. Department of Community Marine Protected Areas. Niamone-Kalounayes MPA Management Plan 2016-2020, Dakar; 2015.

Available: https://www.damcp.gouv.sn/content/plan-damenagement-et-de-gestion-amp-niamone-kalounaye

16. Paugy D, Lévêque C, Teugels DD. Brackish Water Fishes of West Africa, National Museum of Natural History, Paris; 2003.
Available: https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers21-03/010034145.pdf
17. Seret B, Opic P. Marine fishes of tropical West Africa, IRD, Marseille; 2011.
Available: https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers12-09/010052625.pdf
18. FAO, Field Guide to Commercial Marine Resources in the Gulf of Guinea, Rome; 1992.
Available: https://renatura.org/wp-content/uploads/2019/05/Guide-de-terrain-des-ressources-halieutiques-Golf-de-Guin%C3%A9e.pdf
19. Fontana, A. Study of the sexual maturity of Sardinella Sardinella eba (Val) and Sardinella aurita from the Pointe-Noire region. ORSTOM Notebooks Oceanography Series. 1969;101-114.
Available:
https://horizon.documentation.ird.fr/exldoc/pleins_textes/cahiers/oceanographie/19560.pdf
20. Pauly D. Linear regressions in fisheries research. Journal of the Fisheries Research Board of Canada. 1993;30:409-434.
Available: http://202.4.186.66/AJAS/article/view/20220
21. Tabassum S, Baloch WA, Elahi N. Comparison of Condition factor of the Ribbonfish Trichiurus lepturus (Linnaeus, 1758) and Lepturacanthus savala (Cuvier, 1829) from Karachi Coast, Pakistan. Sindh University Research Journal. 2013;45(4):657-660.
Available: https://sujoold.usindh.edu.pk/index.php/SURJ/article/viewFile/2071/1825
22. Kartas F, Quign ard JP. The fecundity of teleost fishes. Biology of marine environments collection. Edition Masson, Paris; 1994.
23. Analbery M. Biology, ecology and fisheries of Hemiramphus brasiliensis. Doctoral thesis from the University of Brittany; 2004.
24. White T, Hall G, Potter C. Size and age compositions and reproductive biology of the nervous shark Carcharhinus cautus in a large subtropical embayment, including an analysis of growth during pre-and postnatal life. Marine Biology. 2002;141(6):1153-1164.

25. Grant CJ, Spain AV, Jones PN. Studies of sexual dimorphism and other variation in nine species of Australian mullets (Pisces: Mugilidae). Australian Journal of Zoology. 1977;25(4):615-630.

Available: https://www.publish.csiro.au/zo/zo9770615

26. Djadji ELG, Tizié TZ, Sylla S, Atse BC. Reproduction and biology of the mullet Liza falcipinnis (Valenciennes, 1836) in two African lagoon complexes (Ebrié lagoon and Grand-Lahoo) (Ivory Coast), International Journal of Research-Granthaalayah,. 2018;6(5):114-127.

Available: https://doi.org/10.29121/granthaalayah.v6.i5.2018.1433

27. Froese R, Ginpaolo C, Kristin K, Nazli D. Revisiting safe biological limits in fisheries. Fish and Fisheries. 2016;17:193-209.

Available:

https://www.researchgate.net/publication/266613389_Revisiting_Safe_Biological_Limits_in_Fisheries

28. Ergene S. Reproduction characteristics of thinlip grey, Liza ramata (Risso, 1826), Inhabiting Akgöl-Paradeniz lagoons (Göksü Delta). Turkish Journal of Zoology. 1998;24(2):159-164.

Available:https://journals.tubitak.gov.tr/cgi/viewcontent.cgi?article=2707&context=zoology

29. Ameur B, Bayed A, Benazzou T. Role of the communication of the lagoon of Merja Zerga (Gharb, Morocco) with the Atlantic Ocean in the reproduction of a population of Mugil cephalus (Poisson Mugilidae). Bulletin of the Scientific Institute of Rabat. 2003;17(25):77-82. English.

Available: http://srv1-israbat.ac.ma/wp-content/uploads/2015/03/07-%20Ameur%20et%20al.%20(77-82).pdf

30. Abou-seedo F, Dadzie S. Reproductive cycle in the male and female gray mullet, Liza klunzingeri in the Kuwaiti waters of the Arabian gulf. Cybium International Journal of Ichthyology. 2004;28(2):97-104.

Available: http://pascalfrancis.inist.fr/vibad/index.php?action=getRecordDetail&idt=15949214

31. Ndiaye K. Effect of environmental parameters on the reproduction of white mullet (Mugil curema, Valenciennes, 1836) in the Saloum Delta (Senegal). Master's thesis in Ecology and Management of Aquatic Ecosystems, IUPA, UCAD, Dakar; 2018.

32. Dieng C. Contribution to the study of reproduction and growth of Liza Dumerili in the Saloum delta (Senegal). Master's thesis in Ecology and Management of Aquatic Ecosystems, IUPA, UCAD, Dakar; 2019.

33. Albaret JJ, Legendre M. Biology and ecology of Mugilidae in the Ebrié lagoon (Côte d'Ivoire) potential interest for lagoon aquaculture. Journal of Tropical Hydrobiology. 1985;18(4):281-303. English.
Available: https://horizon.documentation.ird.fr/exldoc/pleins_textes/cahiers/hydrob-trop/24993.pdf

34. Bedoui RF, Gharbi H, Abed AE. Reproductive period and sexual maturity of Liza aurata (Fish, Mugilidae) from the east and south coasts of Tunisia. Bulletin of the National Institute of Science and Technology of the Sea, Salammbô; 2002.

35. Katselis G, Koutsikopoulos C, Kaspiris P. Age determination and growth of leaping mullet, (Liza saliens, R. 1810) from the Messolonghi Etoliko lagoon (western Greece). Mediterranean Marine Science. 2002;3(2):147-158.
Available:https://www.researchgate.net/publication/228715906_Age_determination_and_growth_of_leaping_mulletLiza_saliens_R_1810_from_the_Messolonghi_Etoliko_lagoon_western_Greece

36. King RP, Etin L. Reproduction, growth, mortality and yield of Tilapia mariae Boulenger, 1899 (Cichlidae) in Nigerian rain Forest Westland Stream. Journal Applied Ichthyologic. 2004;20(6):502-510.
Available: https://onlinelibrary.wiley.com/doi/10.1111/j.1439-0426.2004.00545.x

37. Koné T. Diet and reproduction of a lagoon tilapia (Sarotherodon melanotheron Rüppell, 1852) in the Bia river and the Ayamé dam lake (Ivory Coast). Doctoral thesis. Katholieke Universiteit Leuven (Belgium); 2000.

38. Chicken N, Sander (Sander lucioperca): Biology, behavior and population dynamics in Carmarque (Bouches du Rhône, France). Doctoral thesis, University of Toulouse III (France); 2004.

39. Layachi M, Melhaoui M, Srour A, Randani M. Contribution to the study of the reproduction and growth of red mullet (Mullus barbatus L., 1758) of the Mediterranean littoral zone of Nador

(Morocco) . Bulletin of the Scientific Institute, Rabat, Life Sciences section. 2007;29:43-51. English.

Available: http://www.israbat.ac.ma/wp-content/uploads/2015/02/06-%20Layachi%20et%20al.%20(43-51).pdf

40. Diaby M. Spatio-temporal distribution, fishing and population dynamics of the Mugilidae (fish, teleosts) of the Grand-Lahou lagoon (Côte d'Ivoire). Doctoral thesis . Nangui Abrogoua University, Ivory Coast; 2014.

41. Djadji ELG. Study of the biological traits and diet of two species of Mugilidae, Liza falcipinnis (Valenciennes, 1836) and Mugil cephalus (Linnaeus, 1758) in the Ebrié and Grand-Lahou lagoon complexes, Ivory Coast. Doctoral thesis. University of Cocody, Ivory Coast; 2015.

42. Aka Z, Koç HT, Turan A. Study on the anchovy Engraulis encrasicolus, Linnaeus (1758) in Turkish Seas, Turkey. Pakistan Journal of Biological Sciences. 2004;7(7):1121-1126.

Available: http://www.docsdrive.com/pdfs/ansinet/pjbs/2004/1121-1126.pdf

43. Djadji ELG, Atse BC, Sylla S, Konan JK, Kouassi JN. Reproduction of the Mugilidae Mugil cephalus (Linné, 1758) in two lagoon complexes (Ébrié and Grand Lahou lagoons) in Côte d'Ivoire. International Journal of Biological and Chemical Sciences. 2013;7(4):1701-1716. English.

Available: https://www.ajol.info/index.php/ijbcs/article/view/101277

44. Koné A, N'da K, Kouassi SK, AGnissan JPA. Dynamics of the exploited population of two sharks: Sphyrna zygeana (Linnaeus, 1758) and Isurus oxyrinchus (Rafinesque, 1809) from the Ivorian coasts. International Journal of Biological and Chemical Sciences. 2014;8(4):1633-1643. English.

Available: https://www.ajol.info/index.php/ijbcs/article/view/111392

45. Vall MOV. Study of the dynamics of the exploitation systems and the ecobiology of the reproduction of three Mugilidae: Mugil cephalus (Linnaeus, 1758). Liza aurata (Perguria, 1892) and Mugil capurrii (Risso, 1810). Analysis of their Occupation Strategies of the Mauritanian coastal sectors and their development possibilities. Doctoral thesis. University of Nice-Sophia Antipolis, France; 2004.

46. Komoé K. Distribution of phytoplankton in the lagoon complex of Grand-Lahou (Côte d'Ivoire). Doctoral thesis. Abidjan Cocody University; 2010.

47. Offem BO, Adegbejo-Samsons Y, Omoniyi IJ. Biological assessment of Oreochromis niloticus (Pisces: Cichlidae, Linne, 1958) in a tropical flood plain river. African Journal of Biotechnology. 2007;6(16):1966-1971.

Available: https://www.ajol.info/index.php/ajb/article/view/57864

48. Ndour I, Diadhiou HD, Thiaw OT. Reproduction of yellow mullet Mugil cephalus on Northern Coast of Senegal, West Africa. AACL Bioflux. 2013;6(5):439-445.

Available:

https://www.researchgate.net/publication/269100077_Reproduction_of_yellow_mullet_Mugil_cephalus_on_Northern_Coast_of_Senegal_West_Africa

49. Albaret JJ, Simier M, Sadio O. Biological monitoring of fish populations in a protected area in a mangrove zone: the Bamboung bolon (Sine Saloum, Senegal). Final report, IRD, Dakar; 2005.

50. Hoda SMS, Qureshi N. Maturity, sex ratio and ovary diameter and fecundity of the mullet Liza klunzingeri (Day) from Karachi-Sind waters. Indian Journal of Fisheries. 1989;36:183-192.

51.Mehanna SF. Stock assessment and management of the Egyptian Sole Solea aegyptiaca Chabanaud, 1927 (Osteichthyes: Soleidae), in the South-eastern Mediterranean, Egyptian. Turkish Journal of Zoology. 2007;31(4):379-388.

Available: https://dergipark.org.tr/tr/download/article-file/134862