International Journal of Fisheries and Aquatic Studies 2017; 5(4): 91-99

E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 5.62
(GIF) Impact Factor: 0.549
IJFAS 2017; 5(4): 91-99

www.fisheriesjournal.com
Received: 12-05-2017
Accepted: 13-06-2017

Khady Diop
(A). Institut de Recherche pour le Développement, UMR MARBEC, BP 1386, 18524 Dakar, Sénégal
(B). Institut fondamental d'Afrique Noir Cheikh Anta Diop, Laboratoire de biologie et d'écologie des poissons en Afrique de l'Ouest, BP 206, Dakar, Sénégal.

Khady Diouf
Institut fondamental d'Afrique Noir Cheikh Anta Diop, Laboratoire de biologie et d'écologie des poissons en Afrique de l'Ouest, BP 206, Dakar, Sénégal.

Méry Dialwé Ndione
Faculté des sciences et techniques, Université Cheikh Anta Diop, BP 206, Dakar, Sénégal

Hamet Diaw Diadhiou
Centre de Recherches Océanographiques de Dakar-Thiaroye, Pôle de Recherche de Hann, BP 2241, Dakar, Sénégal

Modou Thiaw
Centre de Recherches Océanographiques de Dakar-Thiaroye, Pôle de Recherche de Hann, BP 2241, Dakar, Sénégal

Papa Ndiaye
Institut de Recherche pour le Développement, UMR MARBEC, 34095 Montpellier cedex 5 France

Didier Jouffre
(A). Institut de Recherche pour le Développement, UMR MARBEC, 34095 Montpellier cedex 5 France
(B). Institut fondamental d'Afrique Noir Cheikh Anta Diop, Laboratoire de biologie et d'écologie des poissons en Afrique de l'Ouest, BP 206, Dakar, Sénégal.

Correspondence
M Ponnuraj
(A). Institut de Recherche pour le Développement, UMR MARBEC, BP 1386, 18524 Dakar, Sénégal
(B). Institut fondamental d'Afrique Noir Cheikh Anta Diop, Laboratoire de biologie et d'écologie des poissons en Afrique de l'Ouest, BP 206, Dakar, Sénégal.

Study comparing the reproductive traits of the catfish, *Arius latiscutatus* (Günther, 1864) inside and outside the bamboung marine protected area, Saloum Delta, Senegal

Khady Diop, Khady Diouf, Méry Dialwé Ndione, Hamet Diaw Diadhiou, Modou Thiaw, Papa Ndiaye and Didier Jouffre

Abstract
This study aims to determine whether Bamboung Marine Protected Area (BMPA) in the Saloum Delta, Senegal, had any effect on reproductive traits of the rough-head sea catfish, *Arius latiscutatus* (Günther, 1864). The monthly variations in condition factor were similar inside and outside the BMPA. The lowest values of K were 0.75 in both sites and the highest were 0.84 and 0.87 respectively inside and outside the BMPA. The reproductive period mainly occurred from March and July in both sites. The total length at first maturity depended on the sex and the site: 400 mm for females and 448 mm for males inside the BMPA and 419 mm for females and 375 mm for males outside. Inside the BMPA, the absolute fecundity was 29 ± 14 eggs, whereas outside, the absolute fecundity was 22 ± 10 eggs. The BMPA would appear to be the preferred spawning area for *A. latiscutatus* with a higher reproductive activity and higher fecundity. This study provides an essential knowledge base for defining fishery management plans or updating current conservation measures.

Keywords: *Arius latiscutatus*, reproductive traits, marine protected area, Sine-Saloum Delta

1. Introduction

In many countries, in particular in the poorest countries, fishing plays an essential role in generating employment and revenue as well as supplying animal protein to the population [1-4]. However, with growing demand, global landings seem to have reach a limit with 60 to 70% of marine fish stocks subject to full or over-exploitation [5]. In Senegal, fishing is of national importance. In 2013, 441 kt of sea fish were landed with a value of 144 billion XOF ($240M) [6]. The industry is a major source of foreign exchange for the country (with 1.9% of goods exports in 2013) and represents 1.7% of GDP [6]. Although fishing is an important part of the economy, it is under pressure from a number of factors, particularly the diminution of stocks, over fishing, the disappearance of some species, etc. [6]. The Senegalese government, like other governments around the world, designated a number of marine protected areas (MPAs) in 2004. MPAs are becoming widely accepted as measures for protecting stocks and for sustainable fishery management [7, 8]. The benefits of MPAs for the populations protected are well documented: in general there is an increase in abundance, biomass, mean size and species richness [9-12]. However, there are many underlying mechanisms and the contribution of each is a matter of conjecture: the effect of MPAs on the life history traits of the fish populations is still poorly understood and documented.

Arius latiscutatus (Günther, 1864), the rough-head sea catfish, is a member of the Ariidae sea catfish family. Its range is from Senegal to Angola including the archipelago of Cape Verde [13]. It is found at sea, in estuaries and, sometimes, in fresh water along the West African coast between 20° N and 20° S [14]. The growth of the sea catfish fishery in Senegal is relatively recent [15]. Large scale fishing started in 1977 with landings of about 1000 t/yr [15]. Each year landings increased to reach 8,892 t in 2014 [16]. Currently, sea catfish are one of the major coastal demersal resources in Senegal. Their high export value makes them very sought after and they form the basis of most of the local food processing industry [17]. They are at risk of overfishing [18].

However, there have been few studies of *Arius* spp. in West African waters, in particular Senegal, and there is little information about their biology and reproductive traits. The fishery must be managed to ensure that it is sustainable but effective fishery management requires in-depth knowledge of the life history traits of these species as well as the effect of designating MPAs.

This study set out to improve our knowledge of the reproductive traits of *A. latiscutatus* (Günther, 1864) and analyze the effect of the Bamboung MPA (BMPA) on the reproductive traits by comparing these traits inside and outside the BMPA.

Materials and Methods

Study location

The Sine-Saloum delta is in the sudano-sahelian zone on the Atlantic coast of West Africa (figure 1). It is in Senegal about 100 km south of Dakar. It lies between 13°55' N and 14°10' N and between 16°03' W and 16°50' W [19]. A reduction in river outflow combined with high evaporation and very low gradient has resulted in high sea water penetration increasing the overall salinity of the estuary [20, 21]. The salinity in the Sine-Saloum delta is always greater than seawater, increasing upstream. The dynamics in the Sine-Saloum delta no longer correspond to those of a normal estuary as defined by Pritchard [22]. The dynamics are currently reversed [23, 24] and it is, therefore, considered to be a "reverse estuary" [23, 24] or "inverse estuary" [23, 24]. Estuaries are distinct ecosystems which are particularly important for the reproduction and the larval and juvenile stages of many species of fish.

The Sine-Saloum delta has three main channels, le Saloum, the Diomboss and the Bandiala. The Bamboung creek (13°50 N – 16°33 W) joins the Diomboss (figure 2). The water is shallow and the area is renowned for its biodiversity, particularly birds, fish and marine mammals (dolphins and manatees) [25]. It is also used for artisanal fishing. The 6,800 ha BMPA was designated in 2004 within the Saloum Delta National Park, a UNESCO Biosphere Reserve.

Sampling

Samples were collected monthly during April 2015 to March 2016 using passive gillnets inside and outside (about 1 km from the boundary) the BMPA (figure 2) there were no samples from outside the BMPA in May. The target was to collect, each month, 30 fish from inside the reserve and 30 from outside the reserve, to include approximately five fish in each 100 mm size class in the population at each site. All the fish were measured (total length, L, in mm) and weighed (total weight, W, gonad weight, Wg, and tissue weight, Wt, in g) using an OHAUS® scale with 0.1 g precision. The sex and the sexual maturity stage were determined using the scale for Ariidae defined by Domain [26].

Length distribution and length-weight relationship

The mean, maximum and minimum lengths and the total number of fish were determined for each sex for each site (inside and outside the BMPA) and the length distribution was analyzed each site.

Student's paired samples t-test was used to compare the lengths of males and females.

The length-weight relationship was expressed using Ricker's allometric formula [27].

$$W = aL^b \tag{1}$$

where *W* is the total weight (g), L is total length (mm), *a* is a constant and *b* is the allometric coefficient.

Fulton's condition factor K [27] was estimated using the standard formula.

$$K = \frac{W}{L^3} \times 10^5 \tag{2}$$

Bartelett's test for the homogeneity of variances was used to ensure that one way analysis of variance (ANOVA) was applicable. Where the differences in variance were significant ($P < 0.05$), Kruskal-Wallis nonparametric tests were used to compare the means. Student's paired samples t-test was used to compare the mean values of K each month inside and outside the BMPA. All tests were carried out using Statistica® (V7. 0).

Reproduction

The mean gonadosomatic index (GSI) for each month was monitored to estimate the seasonal variation in reproduction.

$$GSI = \frac{Wg}{Wt} \times 100 \tag{3}$$

where Wg is the gonad weight and Wt is the tissue weight

The median length at first maturity (L_{50}) was defined as the total length at which 50% of the fish were at an advanced stage of the first sexual cycle (at least stage three of the maturity scale). The L_{50} was estimated fitting a logistic function to the percentage of mature fish in 20 mm size classes using a quasi-Newton method (Statistica® V7. 0).

$$M\% = \frac{100}{(1+e^{-a(L-L_{50})})} \tag{4}$$

where M% is the cumulative percentage of mature fish for each size class, L is the central value of the size class and *a* and L_{50} are adjusted to fit the data.

The sex ratio affects the maintenance of the reproductive potential of a population [28] which is essential for renewal. It was expressed as a percentage.

$$SR = \frac{F}{M+F} \times 100 \tag{5}$$

where F is the number of females and M is the number of males.

The fecundity and the egg diameter were estimates using gonads from females at maturity stage 5.

The absolute fecundity (Fa) is the number of eggs that would be released by a female at the next spawning. It was estimated by manual counts of the eggs from fish in the size class with the largest number of fish.

The relative fecundity (Fr), used to compare different populations, is Fa divided by W.

Both gonads were removed from each fish and preserved in Gilson's fluid (100 ml ethanol, 9 ml glacial acetic acid, 20 ml 60% nitric acid, 20 g mercuric chloride and 875 ml purified water) to facilitate mechanical separation of the eggs and manual counts. The eggs were scanned using a stereo microscope with built-in camera (Leica M80, 0.75x) connected to a computer with LAS V4.2 (Leica Application Suite). The egg diameter was obtained automatically using a specially developed macro in Image J®.

Results

Length distribution and length-weight relationship

345 individuals were collected from inside the BMPA and 173 from outside. Inside the BMPA, males ranged from 310 mm to 609 mm (L = 390 ± 54 mm, mean ± SD) and females from 296 mm to 750 mm (L = 424 ± 79 mm). Outside the BMPA, males ranged from 274 mm to 525 mm (mean L = 380 ± 48 mm) and females from 294 mm to 674 mm (mean L

= 402 ± 75 mm). Females were significantly longer than males, both inside the BMPA (Student's t-test: $p > 0.05$, t = - 6.4) and outside (Student's t-test: $p > 0.05$, t = - 8.1). More than 50% of the fish were in the 300 mm to 399 mm size class, both inside and outside the BMPA (figure 3). Inside the BMPA, W varied from 167 g to 4190 g (W = 630 ± 560 g) and outside from 137 g to 3270 g (W = 556 ± 430 g). Inside the BMPA, the length-weight relationship was $W = 5E^{-07} \times L^{3.45}$ ($R^2 = 0.98$) and outside it was $W = 9E^{-07} \times L^{3.37}$ ($R^2 = 0.97$).

The condition factor (K) showed a similar monthly pattern inside and outside the BMPA (figure 4). Inside the BMPA, K was high from December to April and August to October with the highest value in April (0.84) and low from May to July with the lowest value in May (0.75). Outside, K was high from February to April, in August and in October when it was at its highest value (0.87) and lowest in June (0.75). Inside, K in April was significantly higher than in May, June and July (Kruskal-Vallis test: $p < 0.05$) but there was no significant difference between April and any other months (Kruskal-Vallis test: $p > 0.05$). Outside, K in June was significantly lower than in February, March and October (Kruskal-Vallis test: $p < 0.05$) but there was no significant difference between June and any other months (Kruskal-Vallis test: $p>0.05$). There was no significant difference between the mean of the monthly K values inside and outside the BMPA (Student's t-test: $p > 0.05$, t = - 0.35).

Reproduction

The variations in gonadosomatic index (GSI) over the year showed that males and females had a single reproductive season from March to July both inside and outside the BMPA. Inside, there were two peaks, in April and June, while outside there was a single peak in June (figure 5).

Inside the BMPA, mature females ranged from 372 mm to 712 mm long and mature males from 340 mm to 609 mm long and the median length at first maturity (L_{50}) was 400 mm for females and 448 mm for males (figure 6). Outside the BMPA, mature females ranged from 362 mm to 672 mm long and mature males from 324 mm to 525 mm long and the median length at first maturity (L_{50}) was 419 mm for females and 375 mm for males (figure 6).

Inside the BMPA, of 345 fish, 247 were female and 98 were male, while outside, of 173 fish, 108 were female and 35 were male. The sex ratio was strongly biased in favor of females (~70%) with far fewer males (~30%) both inside and outside the BMPA. There were both males and females up to 650 mm long with a sex ratio in favor of females (figure 7). There were no males longer than 650 mm (figure 7).

Inside the BMPA, the absolute fecundity (Fa) of *A. latiscutatus* was 29 ± 14 eggs (n = 16) varying between 15 and 62 eggs. The relative fecundity (Fr) was 0.024 ± 0.007 eggs/g varying between 0.006 eggs/g and 0.034 eggs/g. The egg diameter was 12.9 ± 1.7 mm. Outside the BMPA, Fa was 22 ± 10 eggs (15 eggs and 29 eggs, n = 2). The relative fecundity (Fr) was 0.027 ± 0.005 eggs/g (0.024 eggs/g and 0.031 eggs/g). The egg diameter was 12.6 ± 1.3 mm. (table 1). There was a strong linear relationship between Fa and W with a coefficient of determination $R^2 = 0.87$ (figure 8).

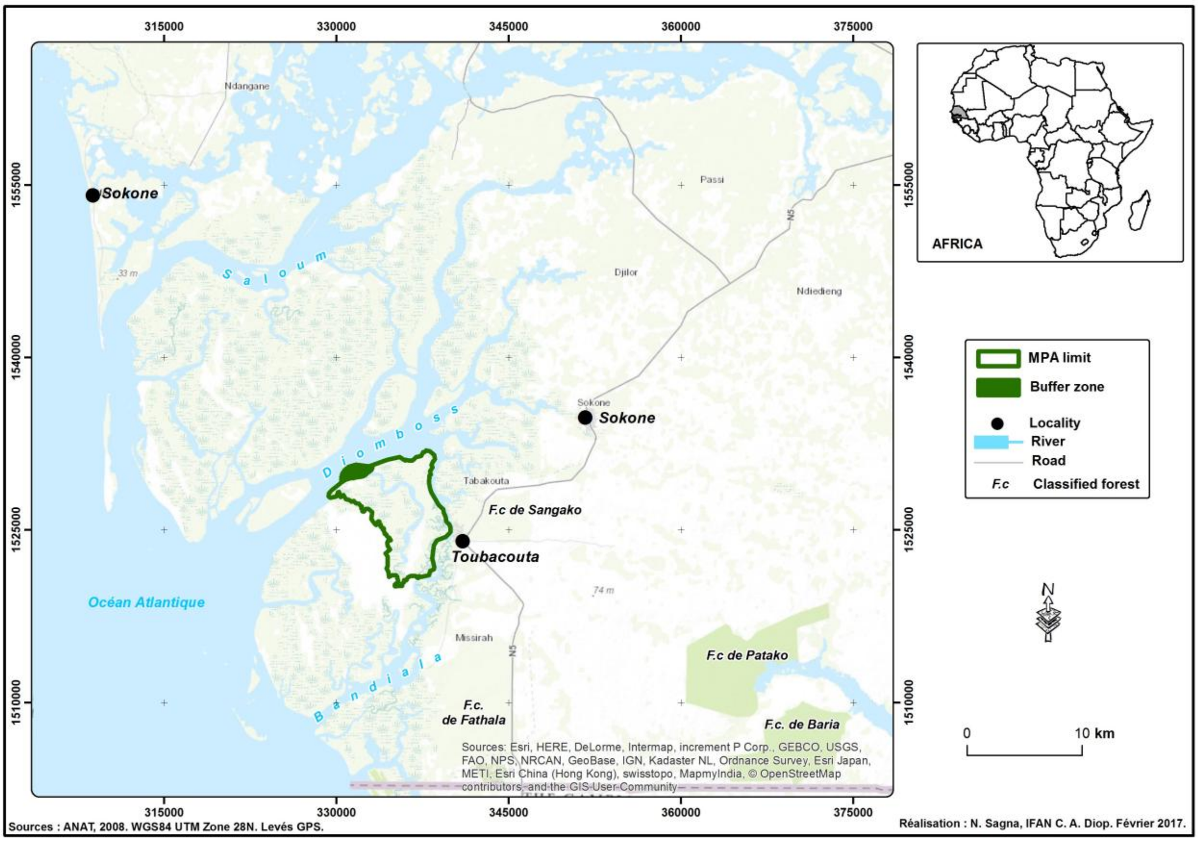

Fig 1: Location of the Sine Saloum estuary

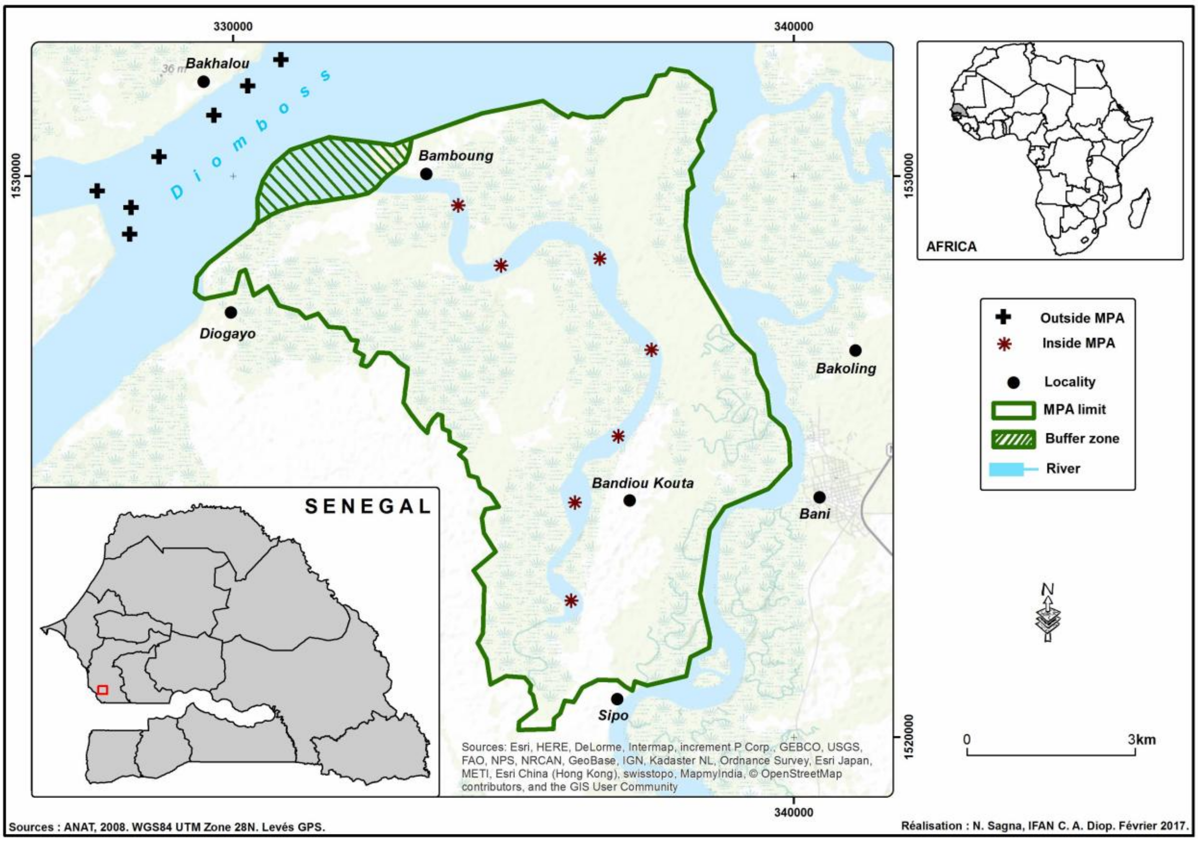

Fig 2: *A. latiscutatus* sampling areas inside and outside the Bamboung MPA.

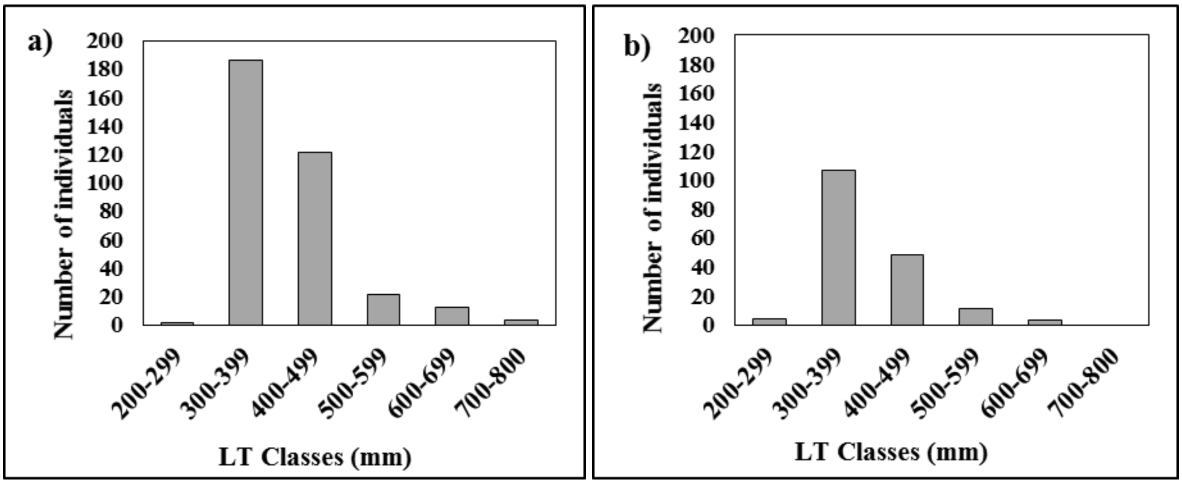

Fig 3: *A. laticutatus* length distribution inside (a) and outside (b) the Bamboung MPA

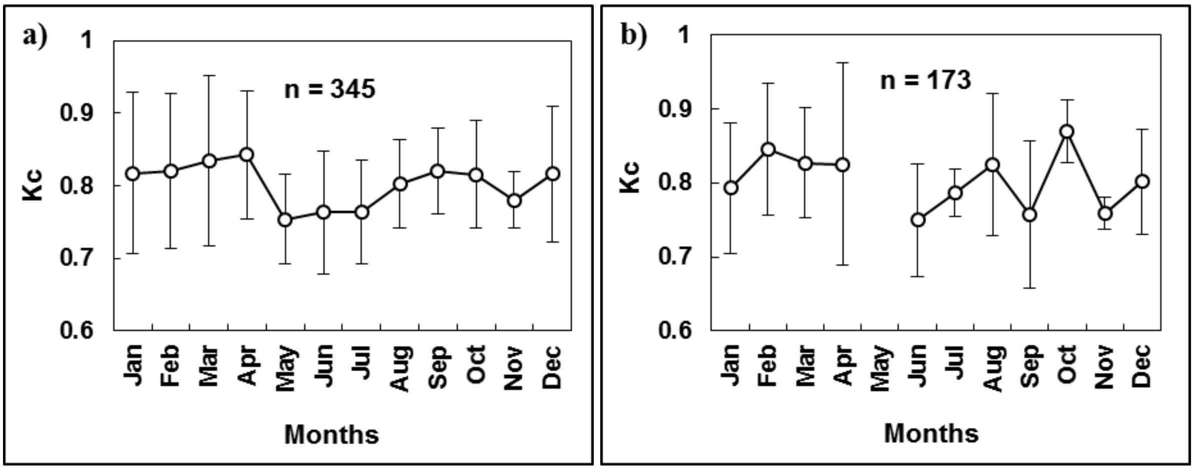

Fig 4: *A. latiscutatus* monthly condition factor (mean ± SD), inside (a) and outside (b) the Bamboung MPA

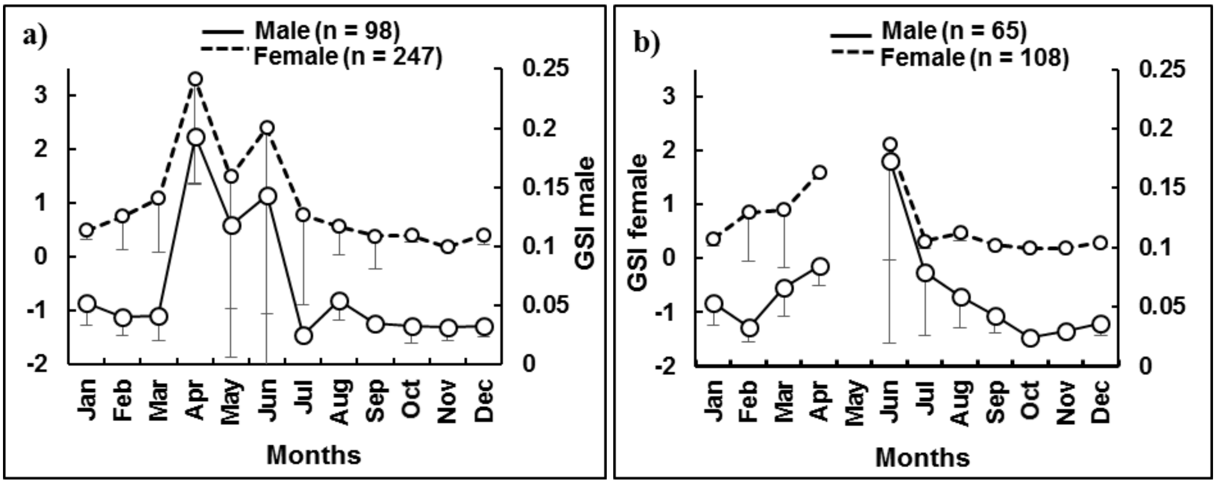

Fig 5: *A. latiscutatus* monthly gonadosomatic index (mean ± SD), inside (a) and outside (b) the Bamboung MPA

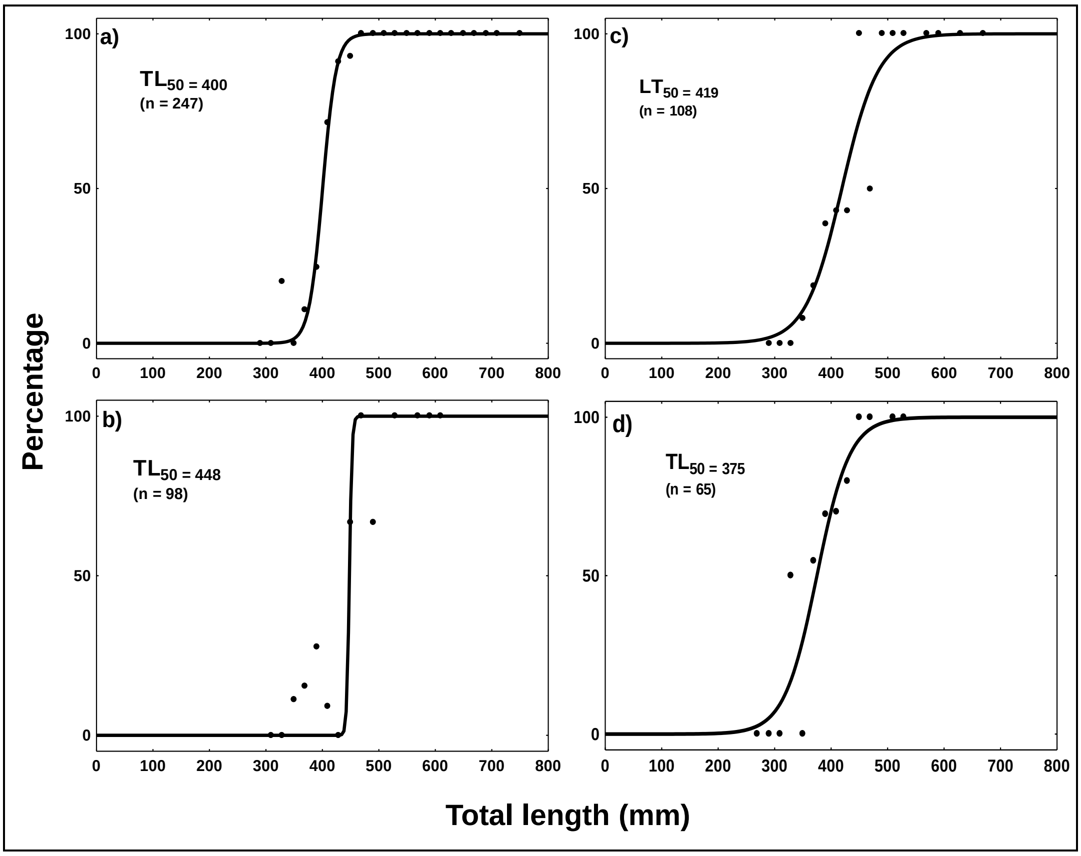

Fig 6: *A. latiscutatus* length at first maturity, inside (a: females, b: males) and outside (c: females, d: males) the Bamboung MPA

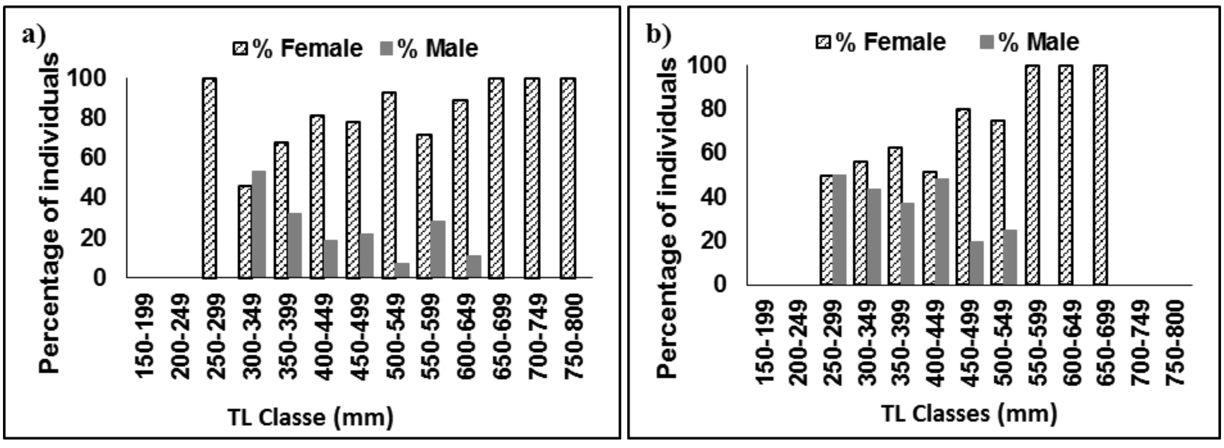

Fig 7: *A. latiscutatus* sex ratio by size class (mean ± SD), inside (a) and outside (b) the Bamboung MPA

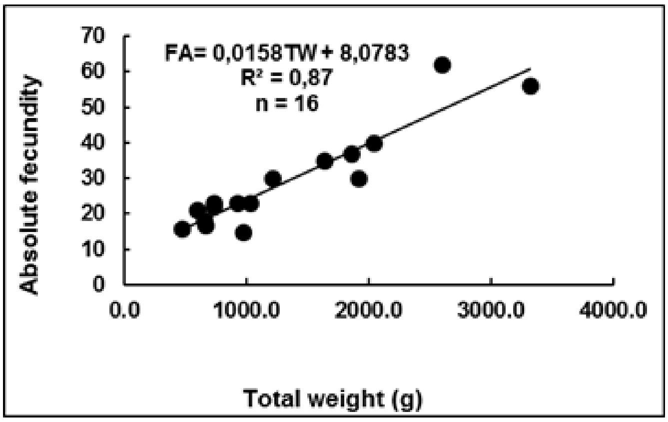

Fig 8: *A. latiscutatus* relationship between absolute fecundity (Fa) and weight (W) inside the Bamboung MPA

Table 1: *A. latiscutatus* fecundity inside and outside the Bamboung MPA

	Inside		**Outside**	
	Mean	SD	Mean	SD
Absolute fecundity (eggs)	29	14	22	10
Relative fecundity (eggs/g)	0.024	0.007	0.027	0.005
Diameter (mm)	114	30	110	21

Discussion

Length distribution and length-weight relationship

The length distribution was similar inside and outside the BMPA. However, the fish were larger and the abundance was higher inside (345 fish were caught inside and 173 outside). This would indicate that the protection provided by the BMPA has increased both the average size and the abundance inside the BMPA by comparison with area subject to fishing. This can be explained by the high fishing pressure owing to the high socio-economic value of this species. Overfishing results in a reduction in biomass and abundance which leads not only to landings leveling off or even declining but also to a reduction in the average size owing to the disappearance of larger fish [29]. This study also showed that *A. latiscutatus* males are smaller than the females.

The length-weight relationship showed a positive allometric growth pattern both inside (b = 3.45) and outside (b = 3.37) the BMPA. This is not in agreement with previous studies which reported nearly isometric growth with b = 3.028 in the Sine-Saloum Delta [30], b = 3.033 in Guinea [31] and b = 3.166 in the Gambia [32]. This discrepancy may be explained by biotic and environmental factors as the length-weight relationship can depend on the sex, the maturity, the geographic location and the environmental conditions [33, 34].

The annual variation of K was similar inside and outside the BMPA. K was highest during the two main seasons (cold and hot) and the lowest in the transition between the cold season and the hot season. This transitional season is characterized by the appearance of warm tropical waters [35]. The change in temperature may stress the fish and create unfavorable environmental conditions. This is in agreement with a study in Burkina Faso by Ouédraogo *et al.* [36] where, during the transition, fish such as the air-breathing catfish *Clarias gariepinus* (K = 0.62) and the bagrid catfish *Bagrus docmak* (K = 0.70) survived in unfavorable conditions. The present study found no difference between the mean K inside (K = 0.807) and outside (K = 0.803) the BMPA. This could be interpreted in various ways. (i) The BMPA does not any effect on the conditions for this species. (ii) Violations of the fishing regulations reduce the effectiveness of the fishing restrictions. (iii) The beneficial effect of the BMPA is balanced by the increase in abundance, increasing competition for habitat, food, etc. According to Alhassan *et al.*[37], if K is less than one, the fish are living in unfavorable conditions and if K is greater than one, the conditions are favorable. We can, therefore, conclude that the conditions are not optimal for *A. latiscutatus* inside or outside the BMPA. Inside, this could be the result of one of the three points made above and, outside, the species is probably overfished.

Reproduction

The variations in GSI over the year showed that *A. latiscutatus* males and females had a single reproductive season from March to July, both inside and outside the BMPA. This is in agreement with Barham *et al* [38] who reported a single reproductive season for both *A. latiscutatus* and *A. parkii* in the Banc d'Arguin National Park, Mauritania: for *A. latiscutatus*, the reproductive season was from April to July with spawning starting in May with 60% of females spawning. Kamukuru *et al.* [39] also found a single reproductive season for *A. thalassimus* in Tanzania. Sidibé *et al.* [31] found two reproductive seasons for *A. latiscutatus* in Guinea: the main season was from March to June with a peak in April. The present study showed a reproductive season for *A. latiscutatus* from March to July which corresponds to the end of the cold season and the start of the hot season when the daylight hours are at maximum and the water temperature increases to more than 25°C. Some authors have described only one reproductive season per year for Ariidae, in the hot season, when the water temperature is rising [40-42].

In Guinea, Domain *et al.* [26] reported that the fraction of reproductive females of certain species such as *A. latiscutatus* reduced in September or November or both. This was also observed in this study where the lowest condition factors were found in the middle of or at the end of the reproductive season. This would indicate that *A. latiscutatus* is able to draw on its reserves for the energy required for reproduction. The peak in reproduction in April-May inside the BMPA was not seen outside and the maximum GSIs were higher inside. Reproduction is, therefore less intense outside the BPMA. Of the 18 gravid females, 16 were collected from inside and only two from outside. The BMPA would, therefore seem to be the preferred spawning ground. The median lengths at first maturity (L_{50}, 400/419 mm for females and 448/375 mm for males) estimated in this study were greater than those reported by Domain *et al.* [26] (L_{50} = 300 mm) and Sidibé *et al.* [31] (L_{50} = 270 mm to 280 mm) in Guinea. This difference may be partly explained by the use of total length to estimate L_{50} in this study whereas the fork length was used for the other studies in Guinea. The difference could also be the result of different environmental conditions in Guinea and the Sine-Saloum Delta. In this study, the L_{50} for female *A. latiscutatus* was shorter inside the BMPA that outside while, for males it was longer inside. However, this result is uncertain as few fish were collected outside the BMPA. Analyses based larger samples would be required to determine the effect of the BMPA on L_{50}.

There were far more female *A. latiscutatus* than males. The sex ratio by size class shows that the males did not reach the same size as the females. This dominance of female *A. latiscutatus* has also been reported in Guinea and Mauritania [31, 38]. These variations in sex ratio as a function of the size and the predominance of one of the sexes amongst larger individuals seems to be relatively common in the animal kingdom as it has been reported for many species [43]. For fish, a certain number of explanations for the variation of the sex ratio with size and the dominance of females in larger size classes have been proposed by the authors of various studies. According to Fontana [43], in a literature review, it is probable that, in a natural environment, natural growth and mortality, which are largely programmed genetically, control the variation of the sex ratio as a function of the size or age of the individuals. On the other hand, the variations observed in samples collected using fishing gear, which may be more or less selective (as for this study), should be considered as not only due to natural growth and mortality, but also due to other factors, such as vulnerability and availability, which may hide or amplify the variations in the sex ratio for particular species. The results showed that *A. latiscutatus* had a low fecundity associated with large eggs. This agrees with studies by Etchvers *et al.* [44], Wallace *et al.* [45] and Yañez-Arancibia *et al.* [46] who found that the Ariidae had lower fecundity and larger eggs than other teleosts. The low fecundity and high length at first maturity indicates that *A. latiscutatus* is K-selected as described for fish by Paugy *et al.* [47]. According to Gomes *et al.* [48], low fecundity and large eggs are notable characteristics of K-selected species such as the Ariidae. During this study, mouth brooding by males was observed which confirms that *A. latiscutatus* uses this strategy to maximize the survival rates of eggs, larvae and fry. Mouth brooding in other species of Ariidae has been reported by several authors [39, 40, 48, 49]. The absolute fecundity reported for *A. latiscutatus* by Barham *et al.* [38] (40 eggs) in Mauritania, is much higher than that found in the present study (28 eggs inside the BMPA and 22 outside). This difference is probably due to the range of sizes which was higher in Mauritania (249 mm to 860 mm) than in the present study (276 mm to 750 mm). The absolute fecundity depends on the length and weight of the fish as well as the weight of the gonads. In the present study, there was a strong linear relationship between absolute fecundity and weight with a coefficient of determination $R^2 = 0.87$. It was not possible to test for significant differences in fecundity or egg size between the inside and the outside of the BMPA as only two gravid females were collected outside. However, the absolute fecundity seemed to be higher inside the BMPA (29 eggs) than outside (22 eggs). Relative fecundity is similar at both sites. However the AMP seems to have an indirect effect on absolute fecundity. This is probably because the largest females were found inside the BMPA and there is a strong correlation between absolute fecundity and weight.

Conclusions

This study provided two main deliverables. Firstly, it provides a major contribution to our understanding of life history traits of *Arius latiscutatus* and its population dynamics in the Sine-Saloum delta in Senegal, providing up-to-date data that is essential for the management of the fishery in the area. Secondly it presents a preliminary assessment of the effect of declaring the Bamboung Marine Protected Area (MPA) on this species which is both abundant and socioeconomically important in the area. The comparative analysis between the observations inside and outside the Bamboung MPA provides original data which are not restricted to the species considered and the local fishery to address the principle of using protected areas as a fishery management tool. Most studies of the effect of MPAs are limited to general demographic or easily collected data such as the abundance mean size, species richness or catch per unit effort. The originality of this work is the use of life history traits to study the effect of the MPA. However, this approach is complex and the results of this study are only preliminary and cannot show a clear, proven effect on the reproduction of *A. latiscutatus*. Despite this, the results indicate that the Bamboung MPA is a preferred spawning ground with more intense reproductive activity and higher fecundity than in the adjacent area. For the future, more detailed examination of *A. latiscutatus* using histological techniques will improve our knowledge of the reproductive biology of the species.

Acknowledgements

This project was part of the JEAI LEH-AO project financed by the IRD. Part of the sampling campaign was funded by the CRODT. We should also like to thank the staff of the DAMCP (MPA directorate), for their logistic and human resources support, Souleymane Sarr and Modou Sarr, fishermen at the Missirah fishing centre, Mamadou BAKHOUM, president of the Bamboung MPA management committee, El Hadji Ndao, the Keur Bamboung Lodge manager, and all his staff for their hospitality and support, Yacine Ndiour and Babacar Diop for their invaluable help collecting the samples, as well as Mangoné Seck, Amadou Diagne et El hadji Faye. All procedures performed in studies involving human participants were in ccordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

References

1. FAO. Indicateurs pour le développement durable des pêcheries marines. Rapport, Division des ressources halieutiques, Directives techniques pour une pêche responsable, Rome, 2001, 78.
2. FAO. Situation mondiale des pêches et de l'aquaculture (SOFIA). Rapport, Rome, 2004, 164.
3. Loayza EA, Lucian M. A strategy for fisheries development. Marine Policy. 1992; 18(3):287.
4. FAO. La situation mondiale des pêches et de l'aquaculture. Rapport, Rome, 2016, 211.
5. Garcia SM, Cochrane K, Van Santen G, Christy F. Towards sustainable fisheries: a strategy for FAO and the World Bank. Ocean & Coastal Management. 1999; 42(5):369-398.
6. ANSD. Situation économique et sociale du Sénégal en 2013. Rapport, Ministère de l'éconimie, des finances et du plan, Dakar, 2016, 211.
7. Pauly D, Watson R, Alder J. Global trends in world fisheries: impacts on marine ecosystems and food security. Philosophical Transactions of the Royal Society B. 2005; 360(1453):5-12.
8. Roberts CM, Bohnsack JA, Gell F, Hawkins JP, Goodridge R. Effects of marine reserves on adjacent fisheries. Science. 2001; 294(5548):1920-1923.
9. Botsford LW, Micheli F, Parma AM. Biological and ecological considerations in the design, implementation and success of MPAs. Rapport, FAO, Rome, 2007, 109-148.
10. Gell F, Roberts CM. The fishery effects of marine reserves and fishery closures. Rapport, Organisation mondiale de protection de la nature, Washington, DC 20037, USA. 2002, 89.

11. Halpern BS. The impact of marine reserves: do reserves work and does reserve size matter? Ecological Applications. 2003; 13:117-137.
12. Lester SE, Halpern BS, Grorud-Clovert K, Lubchenco J, Ruttenberg BI, Gaines SD. *et al*. Biological effects within no-take marine reserves: a global synthesis. Marine Ecology Progress Series. 2009; 384(2):33-46.
13. http://www.fishbase.org. 18 mai. 2016.
14. Conand F, Camara SB, Domain F. Age and growth of three species of Ariidae (Siluriformes) in coastal waters of Guinea. Bulletin of Marine Science. 1995; 56(1):58-67.
15. Jica-DPM. Etude de l'évaluation et de la gestion des ressources halieutiques en république du Sénégal. Rapport final, Agence Japonnaise de la Coopération Internationale, 2006, 171.
16. DPM. Résultats généraux des pêches maritimes. Rapport, Direction des pêches maritimes, Dakar, 2014, 131.
17. ANSD. Situation économique et sociale du Sénégal en 2009. Rapport, Ministère de l'économie, des finances et du plan, Dakar, 2010, 152.
18. COFREPECHE, NFDS, POSEIDON, MRAG. Évaluation prospective de l'opportunité d'un accord de partenariat dans le secteur de la pêche entre l'Union européenne et la République du Sénégal (sous le Contrat cadre MARE/2011/01 - Lot 3, contrat spécifique 5). Rapport, Bruxelles, 2013, 115.
19. Diouf PS. 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, Université de Montpellier II, Montpellier, 1996, 177.
20. Guy V. Estuarine and mangrove systems and the nursery concept: which is which? The case of the Sine Saloum system (Senegal). Wetlands Ecology and Management. 2000; 8(1):37-51.
21. Panfili J, Thior D, Ecoutin JM, Ndiaye P, Albaret JJ. Influence of salinity on the size at maturity for fish species reproducing in contrasting West African estuaries. Journal of Fish Biology. 2006; 69(1):95-113.
22. Pritchard DW. What is an estuary: physical viewpoint. In: Lauff, G.H. (Ed.), Estuaries. American Association for the Advancement of Science: Washington. 1967, 3-5.
23. Barusseau JP, Diop EHS, Saos JL. Evidence of dynamics reversal in tropical estuaries, geomorphological and sedimentological consequences (Salum and Casamance Rivers, Senegal). Sedimentology. 1985; 32(4):543-552.
24. Pagès J, Citeau J. Rainfall and salinity of a Sahelian estuary between 1927 and 1987. Journal of Hydrology. 1990; 113(1-4):325-341.
25. Albaret JJ, Simier M, Sadio O. Suivi biologique des peuplements de poissons d’une aire protégée en zone de mangrove : le bolon de Bamboung (Sine Saloum, Sénégal). Rapport, IRD, Dakar, 2005, 50.
26. Domain F, Chavance P, Diallo A. La pêche côtière en Guinée: ressources et exploitation. IRD, Centre National des Sciences Halieutiques de Bossoura, Institut de recherche pour le developpement, 1999, 393.
27. Ricker WE. Computation and interpretation of biological statistics of fish populations. Dept. of Fisheries and Oceans, Canada, 1987,
28. Kartas F, Quignard JP. La Fécondité des Poissons Téleostéens. Collection de Biologie des Milieux Marins. 5, Masson, Paris, 1984, 121.
29. Gascuel D, Henichart L. Etude sur l'etat de l'art du rôle des AMP dans la gestion des pêches. Rapport technique "volet bio-écologique", CSRP, 2011, 121.
30. Ecoutin JM, AlbAret JJ. Relation longueur-poids pour 52 espèces de poissons des estuaires et lagunes de l'Afrique de l'Ouest. Cybium. 2003; 27(1):3-9.
31. Sidibé A. Les ressources halieutiques démersales côtières de la Guinée: exploitation, biologie et dynamique des principales espèces de la communauté des Sciaenidés. Thèse de doctorat, Centre National des Sciences Halieutiques de Boussoura, Guinée, 2003, 320.
32. Ecoutin JM, Albaret JJ, Trape S. Length-weight relationships for fish populations of a relatively undisturbed tropical estuary: The Gambia. Fisheries Research. 2005; 72(2):347-351.
33. Bagenal T, Tesch FW. Method for assessment of fish production in freshwater, B. T., Blackwell Science Inc, Mishawaka, 1978, 101-136
34. Balon EK. Reflections on some decisive events in the early life of fishes. Transactions of the American Fisheries Society. 1984; 113(2):178-185.
35. Fall M. Pêcherie démersale côtière au Sénégal: essai de modélisation de la dynamique de l'exploitation des stocks. Thèse de doctorat, Université Montpellier II, Monpellier, 2009, 231.
36. Ouedraogo R, Soara AE, Oueda A. Description du peuplement piscicole du lac sahélien de Higa, un site Ramsar du Burkina Faso, Afrique de l'Ouest. Journal of Applied Biosciences. 2015; 95(1):8958-8965.
37. Alhassan EH, Abobi SM, Mensah S, Boti F. The spawning pattern, length-weight relationship and condition factor of elephant fish, Mormyrus rume from the Bontanga reservoir, Ghana. International Journal of Fisheries and Aquatic Studies. 2014; 2(2):109-114.
38. Barham CB, Yerba L, Sakho CI, Ahmed Deida H. Evolution de l'activité de pêche en 2009 au PNBA : effets environnementaux, rôles écologiques et socio-économiques. Rapport, IMROP, Iwik, 2011, 147.
39. Kamukuru AT, Tamatamah RA. The Distribution, Biological Characteristics and Vulnerability of the Giant Sea Catfish, Arius thalassinus (Rüppell, 1837), to Fishing at Mafia Island, Tanzania. Western Indian Ocean Journal of Marine Science. 2014; 13(2):163-175.
40. Dmitrenko EM. Reproduction of the sea catfish (Arius thalassinus Ruppel) in the Arabian Sea Journal of Ichthyology. 1970; 10:634-641.
41. Rimmer MA, Merrick JR. A review of reproduction and development in the fork-tailed catfishes (Ariidae). Proceedings of The Linnean Society of New South Wales. 1983; 107:41-50.
42. Yañez-Arancibia A, Curiel-Gomez J, Yañez VL. A biological and ecological account of the marine catfish Galeichthys cearulenscens (Gunter) in the Guerrero coastal lagoon system, Mexico (Pisces, Ariidae). Annais Centro del Mar y Limnology Universidad Nacional Autonoma Mexico. 1976; 3:125-138.
43. Fontana A. Milieu marin et ressources halieutiques de la Republique populaire du Congo. Trav. Doc. ORSTOM, A. Fontana, 138, ORSTOM, Paris, 1981, 153-211
44. Etchevers SL. Contribution to the biology of the sea catfish, Arius spixii (Agassiz) (Pisces-Ariidae), South of Margarita Island, Venezuela. Bulletin of Marine Science. 1978; 28(2):381-385.
45. Wallace RA, Selman K. Cellular and dynamic aspects of oocyte growth in teleosts. American Zoologist. 1981;

21(2):325-343.
46. Yañez-Arancibia A, Lara-Dominguez AL. Ecology of three sea catfishes (Ariidae) in a tropical coastal ecosystem-southern Gulf of Mexico. Marine Ecology Progress Series. 1988; 49:215-230.
47. Paugy D, Lévéque C. Les stratégies démographiques In: Lévêque C., P.D.s (Ed.), Les poissons des eaux continentales africaines : diversité, écologie, utilisation par l'homme, IRD, Paris, 1999, 121-128.
48. Gomes ID, Gerson AF. Reproductive biology of two marine catfishes (Siluriformes, Ariidae) in the Sepetiba Bay, Brazil. Revista de Biologia Tropical. 2004; 52(1):143-156.
49. Menon NG. Oral incubation in marine catfishes of the family. Indian Journal of Fisheries. 1991; 38(1):30-34.