Reproductive Biology of ~~two~~ Marine Catfish~~es,~~ *Arius latiscutatus* Günther, 1864 and *A.~~rius~~gigas* Boulenger, 1911 ~~in~~ fromthe ~~Tabounsou and Sangareah~~ Bays~~,Republic~~ of Guinea

ABSTRACT

Background and objectives. Marine catfish are abundant in the bays of Tabounsou and Sangareah in Republic of Guinea, but the knowledge on their biology is still scanty. The reproductive biology of *Arius latiscutatus* Günther, 1864 and *A.~~rius~~ gigas* Boulenger, 1911was studied through monthly sampling~~,~~ from January to December 2016.

Methodology. Fish~~es~~ were caught using gill nets in several sampling sites. Five gonadal stages were described, based on macroscopic observation~~s~~ of gonad formation, size, weight, color and oocyte diameter.

Results. The population was dominated by males (61%) in *A. latiscutatus* and females (53%) in A. gigas, showing a sex-ratio of 1:1.54 (Chi-square, *P* <0.05) and 1:0.88 (*P* >0.05), respectively. The length-weight relationship ~~had~~ wasa positive allometry for *A. latiscutatus and A. gigas*, and ~~and~~ males (35.37 and 35.47 cm, respectively) reached first maturity earlier than females (39.7 ~~cm~~ and 40.8 cm, respectively). Changes in the gonadosomatic index (GSI) and in stages of gonadal development showed ~~what~~ that *A. latiscutatus* spawned between April and October, while *A. gigas* spawned in May-November. The peak of condition factor was observed in June (0.68±0.05) and July (0,55±0.04) in females of *A. latiscutatus* and *A. gigas*, respectively.

Conclusion. Both species, having only one annual breeding season, *A. latiscutatus* spawns earlier than *A. gigas*. The reproductive traits depicted in the bays are useful for fisheries management and species conservation.

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Keywords: reproduction, spawning, bay, Ariidae, GSI, ~~matrurity~~maturity size.

1. INTRODUCTION

Determining the lifecycle strategies of fish allows a better understanding of how species adapt to different environments. Studies of reproduction, such as duration of spawning season and size at first maturity, require knowledge of the stage of gonad development in individual fish [1,2].

Catfish constitute a group of fish of great importance in terms of biodiversity, biogeographic and economic [3,4] and includes several families. The majority species of Ariidae family, which are known as marine catfish, inhabit shallow coastal areas, estuaries and ~~brackfish~~brackish lagoon in tropical and temperate regions [5]. Indeed, *Arius latiscutatus* is a marine species whereas *A. gigas* occurs in coastal waters and brackish water of estuaries and lagoons, also ascending rivers and entering freshwater [6].

A number of researchers have studied various aspects of biology and ecology of African catfishes such as growth parameters [7], reproductive strategies [8,9,10] and feeding ecology [11,12] but little is known ~~of~~ aboutthe reproductive biology of Ariid fish~~es~~ in the bays of Tabounsou and Sangareah, despite of their wide distribution and abundance along the Guinean coast and their economic importance in Republic of Guinea [13]. Even if data exist on the reproductive parameters of *A. latiscutatus* in the Saloum Delta [14], the knowledge on reproductive strategies of *A. gigas* remains unavailable. However, several authors have reported the variation in reproductive parameters as a function of several factors such as environmental parameters, availability of food resources, seasons variation [15,16].The present study ~~is~~ wasaimed to know the population structure and reproductive parameters of the two Ariidae species, *A. Latiscutatus* and *A. Gigas* for proper management and conservation of the bays of Tabounsou and Sangareahin Republic of Guinea.

2. MATERIAL AND METHODS

2.1. Study area

Bays of Tabounsou and Sangareah are located to southwest of Conakry in Guinea (9° to 10° N and 13° to 14° W) (Figure 1). Tabounsou bay receives several rivers such as two permanent rivers Kitema and Sarinka, three temporary rivers, Katembé, Tombolia and Dabonvi. Most of the river flow in Sangareah Bay comes from Konkouré and Soumba rivers. Tidal waves travel long distances and rise upstream from rivers. Depth of the area near the river's mouth vari~~y~~es between 2 and 4 m, and range 12~~-~~ to 16 m towards the ocean [17]. These bays are mainly dominated by mangrove forests composed of several trees such as *Rhizophora racemosa*, *R. harrisonii*, *R. mangle*, *Avicennia nitida*, *Laguncularia racemosa* and *Conocarpus erectus*[18].

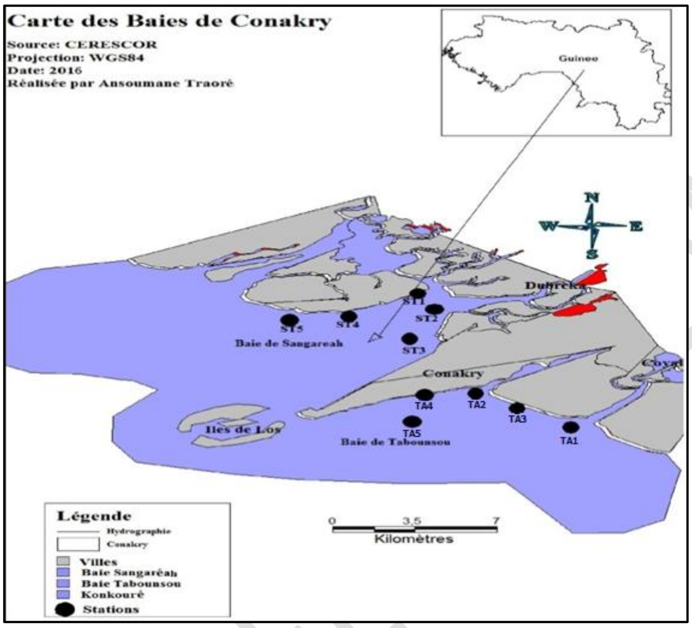

Fig. 1. Map of Tabounsou and Sangareah bays showing sampling sites (Republic of Guinea)

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2.2. Data collection and analysis

Samples of both species were collected in several sampling sites in Tabounsou and Sangareah bays (Fig~~ure.~~ 1).A total of 261 and 448 specimens of *A. gigas* and *A. latiscutatus*, respectively were ~~monthly~~ collected monthly from January to December 2016 using gill nets and then specimens were identified using species identification guide of FAO [13]. The ~~F~~fork length (FL) (nearest 0.01 cm) and different weights (W, nearest 0.01 g) of each individual were recorded: W_t - body weight, W_{ev} - eviscerated fish weight and W_g ~~–~~- gonad weight. All specimens were sexed and sexual maturity was determined through the macroscopic observation of the gonads. Five stages were identified: I - immature, II - sexual resting, III - gonadal maturation, IV - mature gonads and spawning, V - post-spawning [19,20].

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Length frequency distribution and Length-weight relationship: The size structure of both species population was examined by constructing the frequency histograms of ~~F~~fork ~~L~~length (FL) intervals.The ~~L~~length-weight relationship was performed by this formula $W=aFL^b$ logarithm-transformed and expressed as following equation: LogW = Loga+bLogFL, where a isthescaling constant and b is the allometry coefficient [21]. The student's t-tests were used to verify whether the coefficient b was significantly different from the expected or theoretical value of 3 (i.e b=3, p<0.05). Thus, ts= (b-3)/sb[21,22], where t =student's t test, b=slope, sb=standard error of the slope.

Condition factor: During reproduction fish undergoes physiological changes due to the mobilization of its energetic reserves. Thus, the allometric condition factor (K) was calculated to determine the health of the fish throughout the year, using the formula $K=W_t x100/aFL^b$, where W_t is body weight measured and a et b are the regression coefficients between W and FL (Fork Length)[23].

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Size at first maturity: The size at first maturity is the size at which 50% of individuals are mature (FL_{50}). During the reproduction season, the collected individuals were classified as mature and immature individuals. Mature individuals with gonads in stages III, IV and V were classified by size class at an interval of 2 cm. The proportions of mature individuals (Pr) and their corresponding size classes (FL) were adjusted to a logistic curve [24] such as: $Pr= 1/(1 + e^{-r(FL-FL50)})$.

Sex-ratio: The sex of each specimen was identified by examination of the gonads. The proportion of the two sexes relative to one another was used to calculate the sex ratio. SR=F/M, where F=number of females, M=number of males.

Gonadosomatic index (GSI): In order to monitor the sexual cycle and determine the spawning period, the percentage of different stages of sexual maturity and the average of the gonadosomatic index (GSI) were calculated monthly for both females and males:GSI = Wg/Wev x 100 in which W_g is gonad weight and W_{ev} is the eviscerated weight (total weight minus gonad weight) of the individual.

2.3 Statistical analysis

~~:~~ The sex ratio was determined on monthly basis and the chi-square test (χ^2) with a 5% significance level was used to evaluate if sex ratio differed from 1:1. Comparisons of monthly GSI and K values were performed using one-way ANOVA ~~one-way~~. The ~~S~~statistica 7.1.software package was used and all analysis were considered significant at *p*<0.05.

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3. RESULTS

3.1. Population structure and length-weight relationship

Overall, the fish assemblages showed Fork Lengths (FL) of *A. latiscutatus* varying from 20 ~~cm~~ to 50 cm and individual total Weight (W_t) ranged between 148~~-~~ to 1492 g. Length of *A. gigas* varied between 32.90 ~~cm~~ and 49.20 cm and weight ranged between 210~~-~~ to 1644g (Table1). The mean size of *A. gigas* was longer than *A. latiscutatus* but no significant difference was observed (ANOVA, $P<0.05$). Among Both species, the individuals ranging in size 38 to 39.99 cm are the most abundant in catches. This proportion was 29~~%~~ and 32% in *A. latisculatus* and *A. gigas*, respectively. The allometric coefficient b was 3.38 and 3.47 for *A. latiscutatus* and *A. gigas*, respectively, indicating that both species exhibited a positive allometric growth pattern (Table 1).Length (FL) frequency histogram established for the whole population showed unimodal size distributions (~~Figure~~ Fig. 2). A size comparison of nine classes between 32 and 50 cm showed that the differences were not significant (Chi-square, $P<0.05$).

Table 1. Mean, range and length-weight ~~relashionship~~relationship of *A. latiscutatus* and *A. gigas*in Tabounsou and Sangareah bays from January ~~and~~ toDecember 2016.

Species	n	Length (cm) min-max	Length (cm) mean±SD	Weight (g) min-max	Weight (g) mean±SD	Parameters of LWR b	r^2	ts	Growth
A. latiscutatus	448	26.28 - 49.87	37.96±3.7	148 - 1492	877.80±231	3.38	0.89	8,88	A+
A. gigas	258	32.89 - 49.18	38.19±3.1	210 - 1644	931.72±235	3.47	0.96	11,78	A+

Note: n: sample size; Min: minimum; Max: maximum; b: allometric coefficient; r^2: determination coefficient; ts: ~~=~~ t de Student; A+: positive allometric growth, LWR: ??.

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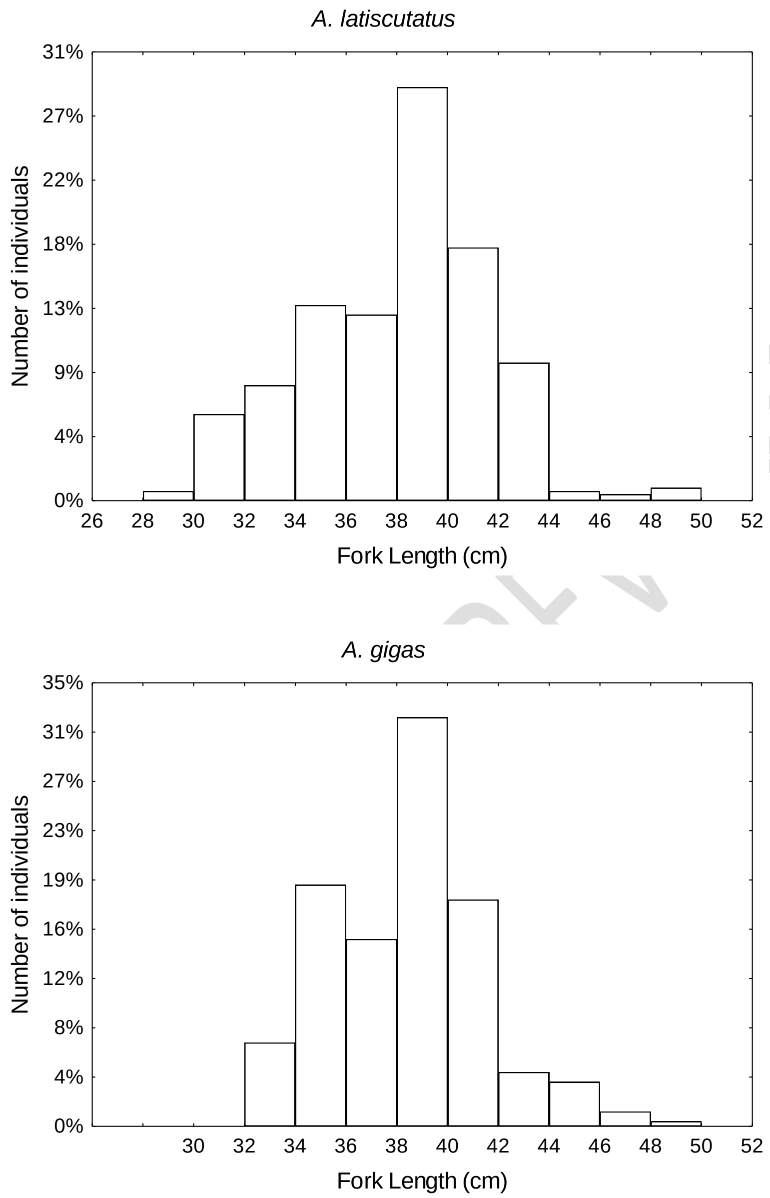

Fig. 2. Length frequency distributions of *A. latiscutatus*~~et —~~and*A. gigas* in Tabounsouand Sangareahbays ~~(Republic of Guinea)~~ from January ~~and~~ toDecember 2016.

3.2. Sex-ratio

Of specimens of *A. latiscutatus*, 176 (39%) were females and 272 (61%) were males, an overall sex-ratio of 1:1.54 which is significantly different from the theoretical value (χ^2, P<0.05), suggesting that males consistently dominated the population. For *A. gigas* 261 individuals were collected from the bays, including 139 females (53.26%) and 122 males (46.74%). The overall sex ratio is 1: 0.88 and is not significantly different from the theoretical 1: 1 sex ratio (χ^2; *P*>0.05). The monthly sex ratio showed significant differences in both species during two periods of December~~-~~toFebruary and July~~-~~toSeptember (Table 2).

Table 2. Monthly variations of sex ratio (SR) of *A. latiscutatus* and *A. gigas* in Tabounsou and Sangareah bays from January ~~and~~ toDecember 2016.

Month	***A. latiscutatus***			***A. gigas***		
	n♀ (%)	**n♂ (%)**	**SR (M:F)**	**n♀ (%)**	**n♂ (%)**	**SR (M:F)**
Jan	39	61	1:1.58*	59	41	1:0.69*
Feb	33	67	1:2.08*	64	36	1:0.57*
Mar	32	68	1:2.13*	45	55	1:1.20
Apr	35	65	1:1.83*	50	50	1:1.00
May	39	61	1:1.56*	55	45	1:0.82
Jun	55	45	1:0.82	71	29	1:0.40*
Jul	30	70	1:2.33*	65	35	1:0.54*
Aug	40	60	1:1.50*	58	42	1:0.73*
Sep	42	58	1:1.38*	39	61	1:1.56*
Oct	52	48	1:0.94*	52	48	1:0.92
Nov	45	55	1:1.21	52	48	1:0.92
Dec	39	61	1:1.58*	32	68	1:2.14*

Note: n: ~~=~~ number of sample, *: ~~=~~ statistically significant difference at *P*< .05.

3.3. Spawning season

The monthly values of GSI were ranged from 5.84 to 8.25 in females and from 2.28 to 2.90 in males of *A. latiscutatus*. In *A. gigas*, GSI was ranged from 2.84~~-~~to 6.33 and 1,87~~-~~to 2,30 in females and males, respectively (~~Figure~~ Fig.3)**.** The comparison of the mean values of GSI between females of both species and between males indicated no significant differences (ANOVA, *P*>0.05). However,

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differences are significant between male and female of the same species (ANOVA, *P*<0.05). Monthly variations of GSI showed distinct phases of reproductive cycle (~~Figure~~ Fig.3):

(1) The gonadal growth phase: in *A. latiscutatus*, the average GSI increased between March and May (5.84~~-~~to 8.25 in females and 2.28~~-~~to 2.90 in males) corresponding to maturation period of gonads; In *A. gigas*, this period extends from February to July (4.0~~-~~to 6.33) in females and from March to June (2.25~~-~~to 2.10) in males. The ~~C~~comparison of the March~~-~~toApril GSI in both sexes of *A. latiscutatus* and females of *A. gigas* indicated significant differences (ANOVA, *P*<0.05).

(2) The gonadal decline phase: in *A. latiscutatus*, GSIs were reduced from May to October (7.28~~-~~to 6.35) in females and from May to August in males (2.88~~-~~to 2.23), corresponding to stages spent. In *A. gigas*, this spawning period starts from July to October in females (6,33~~-~~to 2,84). In males (2.25~~-~~to 1.87), the changes in GSI were similar to those in females and therefore there appears to be ~~a simultaneity~~simultaneity in the chronology of the different gonadal stages. The May~~-~~toJune GSI of both sexes of *A. latisctutatus* indicated significant differences (ANOVA, *P*<0.05), as well as the June~~-~~toJuly and July~~-~~toAugust GSI, respectively in males and females of *A. gigas*.

(3)~~t~~Thesexual resting phase: ~~I~~in *A. latiscutatus*, this period is between October and March then the period November-February in *A. gigas*. During this period, GSIs were low and remained nearly stable (5.84~~-~~to 6.35 in *A. latiscutatus* and 3.50~~-~~to 3.70 in *A. gigas*). The comparison of mean values ~~didn't~~ were not indicated any significant differences (ANOVA, *P*<0.05).

The evolution of gonadal and spawning maturation stages in Tabounsou and Sangareah bays was similar to monthly percentages of maturation stages in females (~~Figure~~ Fig.4). In *A. latiscutatus*, the stage IV showed very high proportions between January and March and these proportions started to decrease from the appearance of the stage V from April to September (Figure 5). Between November and December, stage III reaches proportions of more than 60%. In *A. gigas*, the stage V appeared later between June and November, with high proportions in September and October (more than 26%) and the stage is observed throughout the year with variable proportions. In both species, the period of onset of the post-oviposition stage (V) coincides with the period of decline phase of GSI.

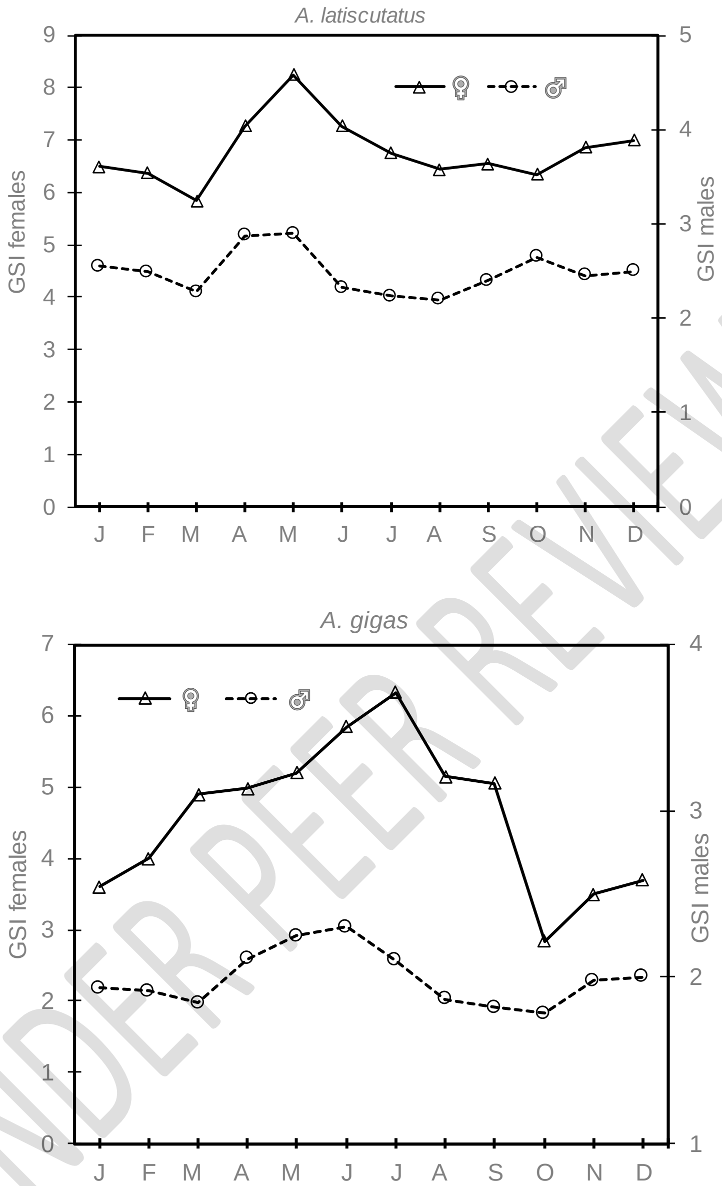


Fig. 3. Monthly variations of gonadosomatic index (GSI) of both sexes of *A. latiscutatus* and *A. gigas*in Tabounsou and Sangareah bays from January to December 2016.

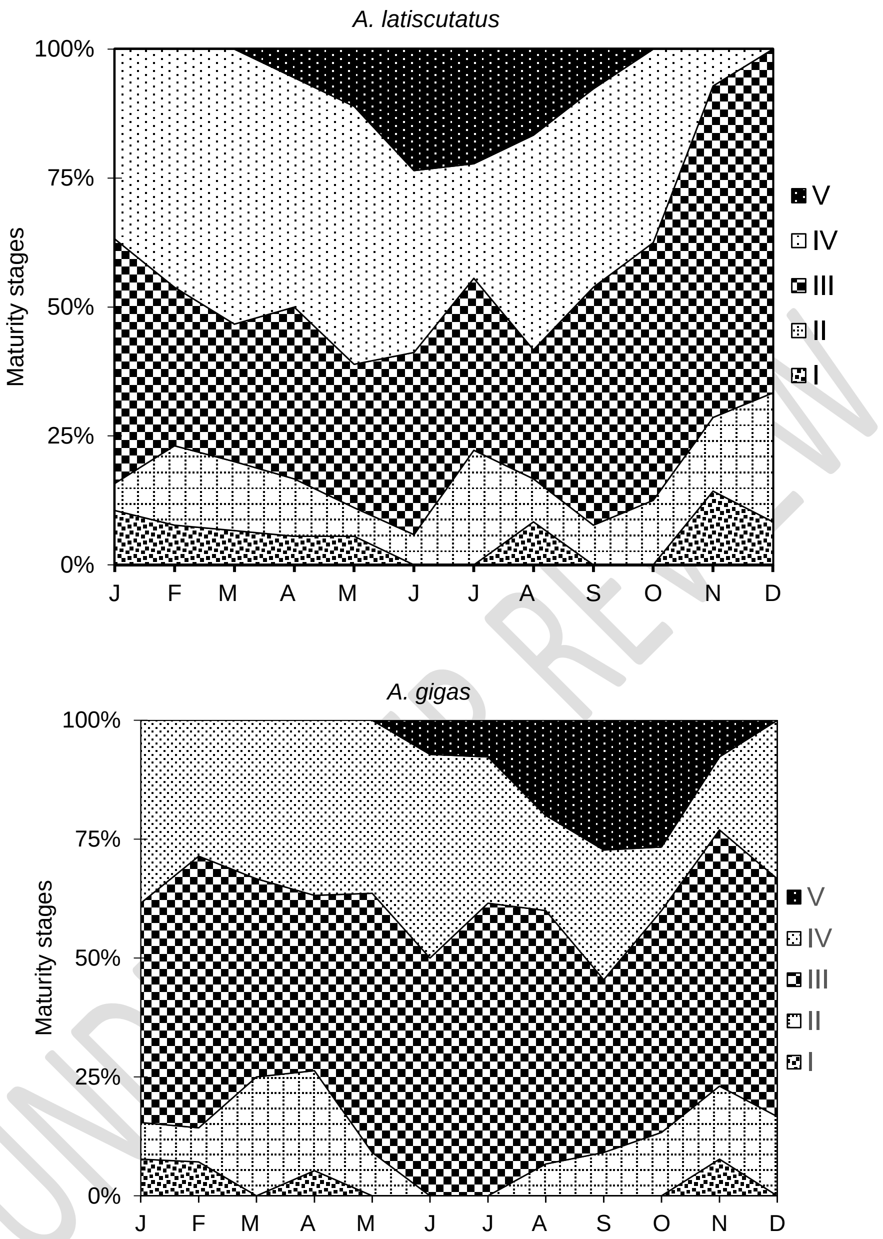


Fig. 4. Monthly evolutions of gonadal maturity stages of females of *A. latiscutatus* and *A. gigas* in Tabounsou and Sangareah bays from January to ~~Decemver~~December 2016.*Maturity stages I=immature; II=sexual resting; III=gonadal maturation; IV= mature gonads and spawning; V=post-spawning*.

3.4. Size at first sexual maturity

Lengths at first sexual maturity (FL_{50}) for females of *A. latiscutatus* and *A. gigas* were about 39.7 cm and 40.8 cm FL, respectively. In males, LF_{50} is low and about 35.37 and 35.47 cm in the first and second species (Figure Fig. 5).

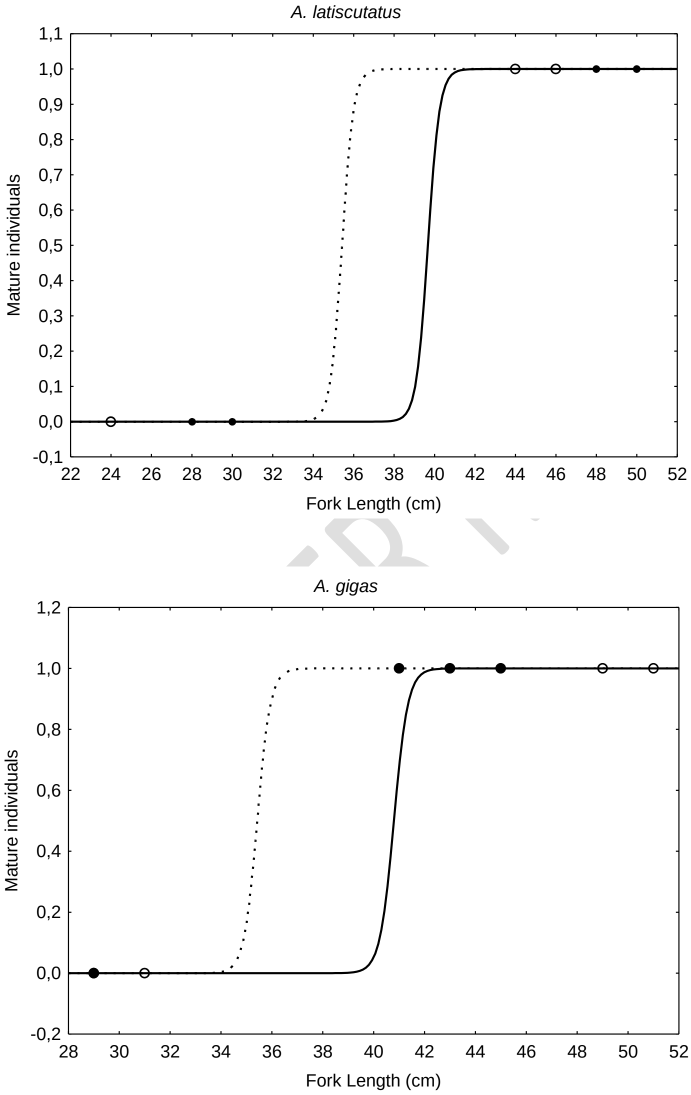
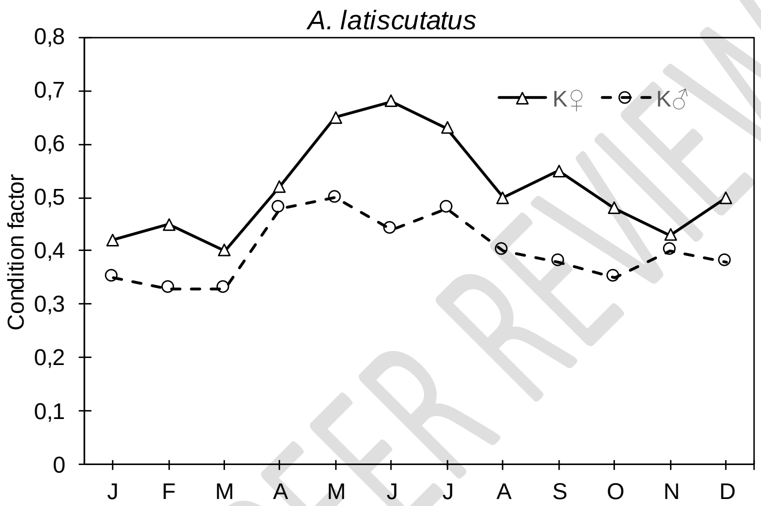


Fig. 5. Logistic curves for estimation of the size at first sexual maturity (L_{50}) of *A. latiscutatus* and *A. gigas* female and male in Tabounsou and Sangareah bays from January and to December 2016.

3.5. Condition factor

Condition factor (K) presented slight monthly variations: 0.35±0.03 ≤ K♀ ≤ 0.55±0.04; 0.32±0.02 ≤ K♂ ≤ 0.52±0.03 for *A. latiscutatus*, 0.40±0.04 ≤ K♀ ≤ 0.68±0.05; 0.33±0.04 ≤ K♂ ≤ 0.50±0.06 for *A. gigas* (~~Figure~~ Fig.6). Monthly variations curve of K generally showed the same pattern for both sexes. In *A. latiscutatus*, the highest values were recorded between March-toJuly for both sexes, while values of K were higher between March-toJune for males and April-toJuly for females. Statistically, K values didn't show significant differences in both species (ANOVA, $P<0.05$).



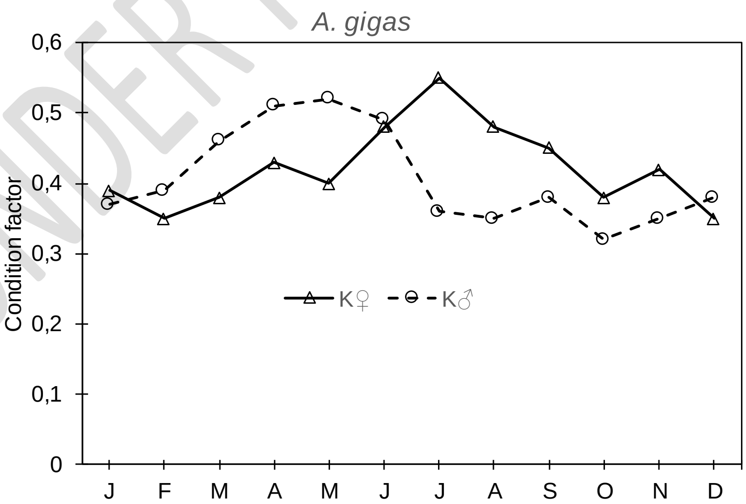


Fig.6. Monthly variations of the condition factor (K) of *A. latiscutatus* and *A. gigas* female and male in Tabounsou and Sangareah bays from January ~~and~~ to December 2016.

4. DISCUSSION

Length frequency distributions observed in this study provides snapshots of the size structure of *A. latiscutatus* and *A. gigas* in the bays of Tabounsou and Sangareah.Large number of catches were recorded between 38 and 40 cm fork length where more than half of males of both species and females of *A. latiscutatus* had reached the size of first sexual maturity. The results of the present study indicated positive allometric growth for both species. Similar results were found by Diop et al. [14] of *A. latiscutatus* from the Saloum Delta. However, the comparison of growth pattern with other studies indicated some differences. The value of b obtained for *A. latiscutatus* from Grand-Lahou lagoon (3.11) and *A. gigas* from Odi river (2.94) indicated isometric growth for both species [25,26]. The values for slope b~~are~~ werewithin the range of 2.5~~-~~to 3.5 as defined by Calander [27] and the disparity in previous findings could be attributed to environmental parameters differences in living environment. In fact, also factors like water temperature, salinity, food availability, health and habitat, stage of maturity and length ranges of the specimen caught ~~are~~ wereresponsible for variations in the length weight relationship [28,29].

Monthly variations of GSI showed that the reproduction season occurred from April to October with a peak in June for males and females in *A. latiscutaus*. This period is confirmed by the appearance of post-spawning females in samples between April and September. In *A. gigas*, the spawning season begins later in May and extends ~~until~~ uptoNovember, the same period of 7 months. The peak is in June for males and July for females but the post-spawning stage indicated intense reproductive activity between September and October. These differences in reproductive period may be related to the maturation period of the eggs. Indeed, in *A. latiscutatus*, the maturation period of eggs takes place earlier between March and May while it extends from March to July in *A. gigas*. This period was reported by other authors who investigated the marine areas. Diop et al. [14]~~noted~~ reportedthat *A. latiscutatus*spawns between March and July in the Delta Saloum (Senegal). In other species of Ariidae family such as *Arius argyropleuron*, the fish matured throughout the year with major spawning peak for females occurred in April and minor peak in July [8]. The similarity between these reproductive periods ~~is~~ wasthat it coincideds~~s~~ with rainy season (May to October) in the bays of Tabounsou and Sangareah in Republic of Guinea. The appearance of mature gonads stage throughout the year suggests that *A. latiscutatus* and *A. gigas* may have an extended spawning period. Therefore, females of stage V observed during the rainy seasons may mean that eggs laying is favored by environmental parameters. According to several authors, temperature acts on gonads maturity stages and spawning of marine fishes [30]. Indeed, Yoneda and Wright [31]indicated that the temperature and food availability resulted in higher sperm production in Atlantic cod, *Gadus morhua*. For the two Carangidae species from the Gabès golf course, *Caranx crysos* and *C. rhonchus*, the spawning was favored by the decreasing of water temperature [32]. However, the spawning period of *A. latiscutatus* and *A. gigas* in flooded seasons from the bays of Tabounsou and Sangareah seems to be linked to the decreasing of temperature. According to several researchers, many tropical fishes ~~are~~ werereported to breed at the beginning of the rainy season [33,34]. The reason for this pattern may be due to the large varieties of food items which is an advantage for gonadal material production and egg or milt production. This fact suggested~~s~~ that the reproductive activity of *A. latiscutatus and A. gigas* follows the general pattern seen in tropical catfishes, which reproduced in the rainy season [35,36].Furthermore, the presence of mangrove forests in the study area could justify the migration of *A. gigas* spawners due to the habitat heterogeneity, abundance of organic matter and food resources availability [37].

Males dominated the population of *A. latiscutatus*~~and~~ during the spawning period (except June). This predominance of males in the catches may result from behavioral differences between the sexes [38]. According to several authors, females of several catfishes migrate to areas less accessible to fishermen for the incubation of eggs and larvae care [39,40], unlike males. Consequently, *A. latiscutatus* could have this behaviour in Tabounsou and Sangareah bays. However, in *A. gigas*the sex ratio revealed an absence of predominance of one gender over the other when assessing the total catch but unequal occurrences were found in monthly assessments (from December to February and June to September). The spawning season ~~is~~ wasnot dominated by one sex over the other, which would indicated different behavior compared to the spawners of *A.latiscutatus*.Opposite results ~~have been~~were obtained by Diop et al. [14] where the sex ratio was largely in favor of females (about 70%) in *A. latiscutatus*, indicating that this parameter can vary in the same species based on study area [38].

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In both species, females matured at relatively higher sizes than males and lengths at first sexual maturation (FL50) in the bays were estimated at 39.7-to 35.37 cm and 40.8-to 35.47 cm in *A. latiscutatus* and *A. gigas*, respectively. A delayed maturation was also reported in catfish *Clarias buettikoferi* by Konan [41] in Tanoe-Ehy swampy forest, with LS_{50} estimated to 13.0 and 14.8 cm in females and males, respectively. According to Wootton [42], the variation in size of first maturity depends on several factors such as living environment, abiotic parameters andfishing pressure. For example,Size size at first sexual maturity of *A. latiscutatus* varied by gender and site: $TL_{50♀}$ =40 cm, $TL_{50♂}$= 44.8 cm inside the Mmarine Pprotected Aarea, and $TL_{50♀}$ =41.9 cm, $TL_{50♂}$ = 37.5 mm outside this area [14].*A. latiscutatus* reached LF_{50} early in the present study compared to results of Diop et al. [14]. Indeed, differences in the lengths of sexual maturity of both sexes were probably due to the stochasticity of the environmental condition and the variability in food resources availability of these habitats [43,44]. Differences of size at first sexual maturity results can also be related to the choice of parameter, e.g. standard length, fork length or total length of specimens.

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The condition factor (K) of *A. latiscutatus* et *A. gigas* ranged between 0.35 and 0.68 and variations don't show significant differences. Lower K values in females were found between January and April, corresponding to gonad maturation phases, and indicating the mobilization of energy reserves for egg laying [45]. In *A. latiscutatus*, the fluctuations in K were synchronous and the peak was observed in May and June, respectively in females and males, at the beginning of spawning phases and it would indicate the energy use for the spawning activity. The same observation was made in *A. gigas* where the decreasing of condition factor occurred during the spawning phase.The similarity observed in the different phases of males and females in both species would indicate the simultaneousness in the energy investments spent on reproduction [46].

Conclusion

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The reproductive parameters analysis of the two Ariidae species showed that gonad maturation phase occurred in hot seasons and the egg-laying phase coincided with the cold season. Both species, having only one breeding season, *A. latiscutatus* spawns earlier than *A. gigas* during the year. The sex disparity in catches tends to show the parental control behavior in *A. latiscutatus* in contrast to *A. gigas*. The reproductive traits of both species depicted in Tabounsou and Sangareah bays are useful for fisheries management and species conservation.

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