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Reproductive biology of *Trichiurus lepturus* (Perciformes: Trichiuridea) in the coastal waters of Cote d'Ivoire

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Abstract

Trichiurus lepturus remains a highly exploited species by the industrial and artisanal fisheries in Cote d'Ivoire. But there is no formally established fishery, in addition to the limited information on aspects of its biology in this area. This work was carried out to determine its reproductive aspects for fishery management. The whole sample consisted in 876 specimens with size ranging from 38-104 cm in total length were taken at the harbour of Abidjan between January 2018 and December 2018. The sex was determined for all specimens. The sizes at first sexual maturity (L_{50}) were estimated by means of logistic function that was fitted to the proportion of the mature individuals using a nonlinear regression. The reproductive period was established by analysing the temporal evolution in the frequency of the maturity stages and monthly variations in the gonadosomatic index (GSI). The sex ratio (F: M) of 1:0.93 was not significantly different between sexes (χ^2= 0.89, p> 0.05). The length at first maturity was 45.81 cm for females and 50.23 cm for males. The higher values of GSI occurred in March-June and August-November. The absolute fecundity ranged from 3408 to89975 oocytes. The frequency distribution of oocytes diameters was unimodal (stage 4 and 5) and three mode (stage 3).

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Introduction

The largehead ribbonfish, *Trichiurus lepturus* Linnaeus, 1758 is a coastal species of cosmopolitan distribution, with commercial importance in different regions of the world (De la Cruz *et al*., 2014). It is a benthopelagic and amphidromous found from shallow inshore waters to 350 m depth, occurring in dense schools and reaching approximately 120 cm in length (Randall, 1995). *Trichiurus lepturus* plays an important role as a top predator in the ecosystem in controlling populations of mid and lower trophic level fishes, cephalopod species and crustaceans (Chiou *et al*., 2006; Yan *et al.,* 2011).This species is caught by artisanal fisheries using drift gillnets, fixed nets and hand-line, and by industrial trawlers. Commercial capture of this species is ranked in the sixth place of landing volume worldwide and represents the largest volumes of capture, with 85% of the global statistics (Martins and Haimovici, 1997; FAO, 2005). In Cote d'Ivoire, although this species does not represent a good commercial value for local populations, it remains a highly exploited species by the industrial and artisanal fisheries. According to Claro (1994), species of this genus are characterised by a rapid growth and a very long longevity which naturally make them vulnerable to exploitation.

Comprehensible studies on aspects of the reproduction of *T. lepturus* have been carried out in China Seas (Kwok and Ni, 1999), in the South-West Atlantic (Martins and Haimovici, 2000) and in the Arabian sea coast of Oman (Al-Nahdi *et al*., 2009).

The studies revealed a flexible reproductive strategy, depending on latitude. Females of ten spawn more than once in a reproductive season with group-synchronous spawning behaviour (Kwok and Ni, 1999). However, despite its abundance in the landing sites of industrial and artisanal fisheries, no study has been conducted on reproductive biology in central eastern Atlantic in generally and in particular in Cote d'Ivoire. Therefore, the present work was conducted to study the population composition, the sex ratio, the first sexual maturity size, the spawning period and the fecundity of *T. lepturus* in the coastal waters of Cote d'Ivoire.

Material and methods

Data collection

Samples of *T. lepturus* were collected weekly from the industrial trawlers which operated between latitudes 4°N and 5°N and longitudes 2.30°W and 8°W (Fig. 1).

Fig. 1. Fishing areas of fishing location (⬬) of different fisheries in the coastal of Cote d'Ivoire (West Africa).

The whole sample consisted in 876 specimens with size ranging from 38-104 cm in total length were taken between January and December 2018 at the fishing harbour of Abidjan. The specimens were identified using the keys of FAO (FAO, 1992). The total length (TL) was recorded individually to the nearest 1 mm, and total body weight (TW) and eviscerated body weight (EW) to the nearest 0.1g.After dissection of individuals to determine the sex by macroscopic investigations, the gonads and the liver were removed and then weighed to the nearest 0.001 g.

The maturity stages were determined macroscopically following Li (1982) with minor modifications from laboratory observations. In females, I= immature, II = Developing, III = Maturing, IV = ripe, V = spent; and in males, I= Immature, II= Developing, III= maturing, IV= ripe, V= spent.

Data analysis

Average length at maturity was defined as the 10 cm length class at which 50% of the individuals reached maturity. The percentage of sexual maturity was described by the logistic function (Amenzoui *et al.*, 2005):

$$P = 1 \Big/ \left[1 + e^{-(\alpha + \beta X)} \right]$$

Where P= proportion of mature fish, X= total length, and α, β are coefficients.

The value of L_{50} was estimated from the negative ratio $-\frac{\alpha}{\beta}$ by substituting P = 0.5.

The gonadosomatic index (GSI), which represents the gonad weight expressed as a percentage of the wet body mass, was estimated according to the method of West (1990) and Vazzoler (1996) as follows:

$$GSI = \frac{\text{Gonad weight (g)}}{\text{Eviscerate weight (g)}} \times 100$$

Fecundity which is the number of ripe oocytes in the female prior to the next spawning season was estimated according to Bagenal (1978). The absolute fecundity (AF) was determined by counting the oocytes of the ovaries in advanced stages III and IV. The relative fecundity (RF) was also determined by the number of eggs per gram.

Statistical analysis

The Shapiro-Wilk normality test for homoscedasticity were applied to the data, to determine whether the assumptions of the parametric and nonparametric analyses for GSI and K factor. The Chi-square test was performed for sex ratio contrasts. The GSI and K factor were tested by one-way analyses of variance, followed by Tukey multiple comparison tests for significant differences among months and seasons in relation to sexes. Significant differences were established at 0.05 level. All analyses were carried out with the software Statistical 7.1 version.

Results

Sex ratio

A total of 876 specimens (452 females and 424 males) with size ranging from 38-104 cm in total length were caught during the study period (Table 1). The sex ratio of 1 F: 0.93 M was not significantly different from the theoretical sex ratio 1:1 ($\chi^2 = 0.89$; $P < 0.05$, N = 876).However, males outnumbered females during January-March, July, September and November with a significant difference in January ($\chi^2 = 19.92$, $p < 0.05$) and March ($\chi^2 = 13.63$, $p < 0.05$) and females dominated the catches in April-June, August, October and December with a significant difference in May ($\chi^2 = 23.51$, $p < 0.05$), August ($\chi^2 = 6.85$, $p < 0.05$) and October ($\chi^2 = 21.05$, $p < 0.05$).Following fish sizes, males dominated between 45-59 cm whereas females outnumbered males in catches from 66 cm to108 cm. On other hand, the proportion of males and females was equal at 38-66 cm (Table 2).

Size at sexual maturity

The sizes at sexual maturity (L_{50}) were 50.23 cm TL for malesand45.81cm females (Fig. 2). The smallest male with mature gonads was 44 cm TL and weighed 49 g, while the smallest mature female was 45.5 cm

TL and weighed 100 g.

Variation of maturity stages

The monthly percentage of maturity stages is summarized in Fig. 3. In females, the immatures (stage 1) appeared throughout the year with a significant proportion observed in January, February, July, August and December. The developing (stage 2) and maturing (stage 3) females were recorded throughout the year.

Table 1. Number of females and males of *T. lepturus* per months and results of the Chi-square test for a sex ratio from January to December 2018 from Cote d'Ivoire. *= significant difference.

Months	No. of males	No. of females	F : M	χ^2
J	50	24	1: 2.08	19.92*
F	40	26	1: 1.53	2.96
M	48	18	1: 2.7	13.63*
A	28	34	1: 0.8	0.58
M	22	68	1: 0.3	23.51*
J	34	42	1: 0.8	12.37
J	44	34	1: 1.4	1.28
A	30	54	1: 0.6	6.85*
S	42	26	1: 1.6	3.76
O	18	58	1: 0.3	21.05*
N	42	32	1: 1.3	1.35
D	26	36	1: 0.8	1.61
Total	424	452	1: 0.93	0.89

Table 2. Number of females and males of *T. lepturus* per total length classes and results of the Chi-square test for a sex ratio from January 2018 to December 2018 from Cote d'Ivoire. *= significant difference.

Tl (cm)	No. of females	No. of males	Total	F: M	χ^2
[38-45[	8	10	18	1:1.3	0.22
[45-52[	52	78	130	1:1.5	5.20 *
[52-59[	82	130	212	1:1.6	10.86 *
[59-66[	100	106	206	1:1.1	0.17
[66-73[	104	52	156	1:0.5	17.33 *
[73-80[	38	26	64	1:0.8	2.25
[80-87[	34	20	54	1:0.5	3.62
[87-94[	22	2	24	1:0.1	16.67*
[94-101[	8	0	8	-	8.00*
[101-108[	4	0	4	-	4.00*
Total	452	424	876	1:0.93	0.89

Their proportions were high in January and September. The number of ripe females (stage 4) increased gradually in early January to March, peaked in April-May and decreased thereafter in June.

A second increase occurred from August to October before declining till December. In April-May and October, they constitute more than half of the landed fish. Spent individuals (stage 5) were found throughout the year with the highest proportion occurring in June-July and November-December (Fig. 3A). In males, Immature and developing individuals (stages 1 and 2) were found throughout the year with the highest percentages were observed in January, February, August and December.

The proportion of mature males (stage 3) was higher in February, May and September. The proportion of the ripe males (stage 4) increased from January to

April-May and from August to October before declining respectively in July and November. Spent males (stage 5) were found throughout the year with the highest proportion in June-July and November-December (Fig. 3B).

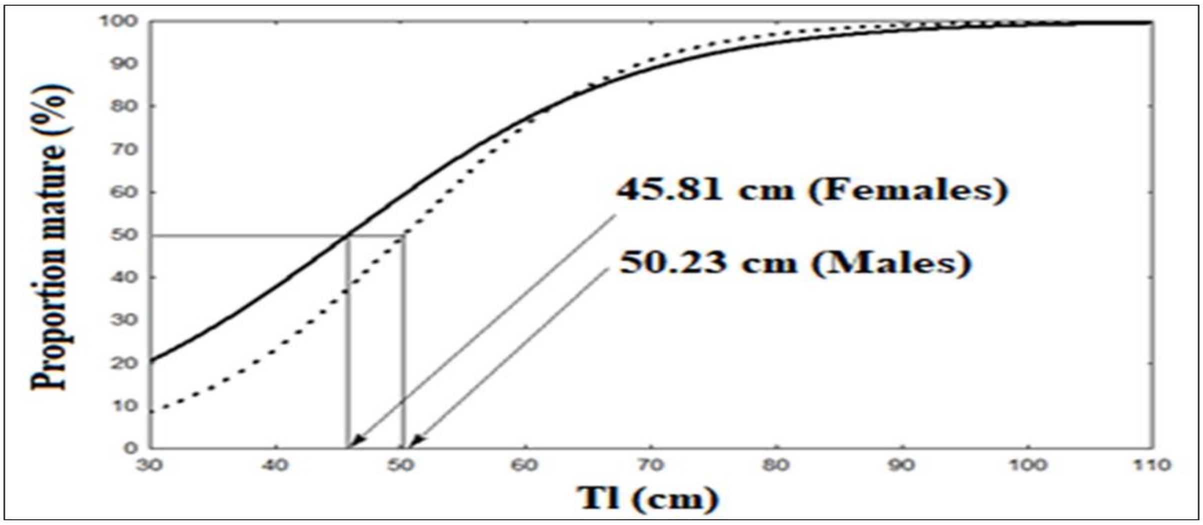

Fig. 2. Logistic curve for determining size (Total length) at first sexual maturity (L_{50}) of *T. lepturus* from January 2018 to December 2018 in Cote d'Ivoire Coast.

GSI variation and spawning period

The monthly changes of males and females GSI index showed the same trend (Fig. 4). But with significant differences between the different values of each month of female ($F_{11,\ 0.05}$ = 3.79, p = 0.0006) and male ($F_{11,\ 0.05}$ = 3.18, p= 0.0001).

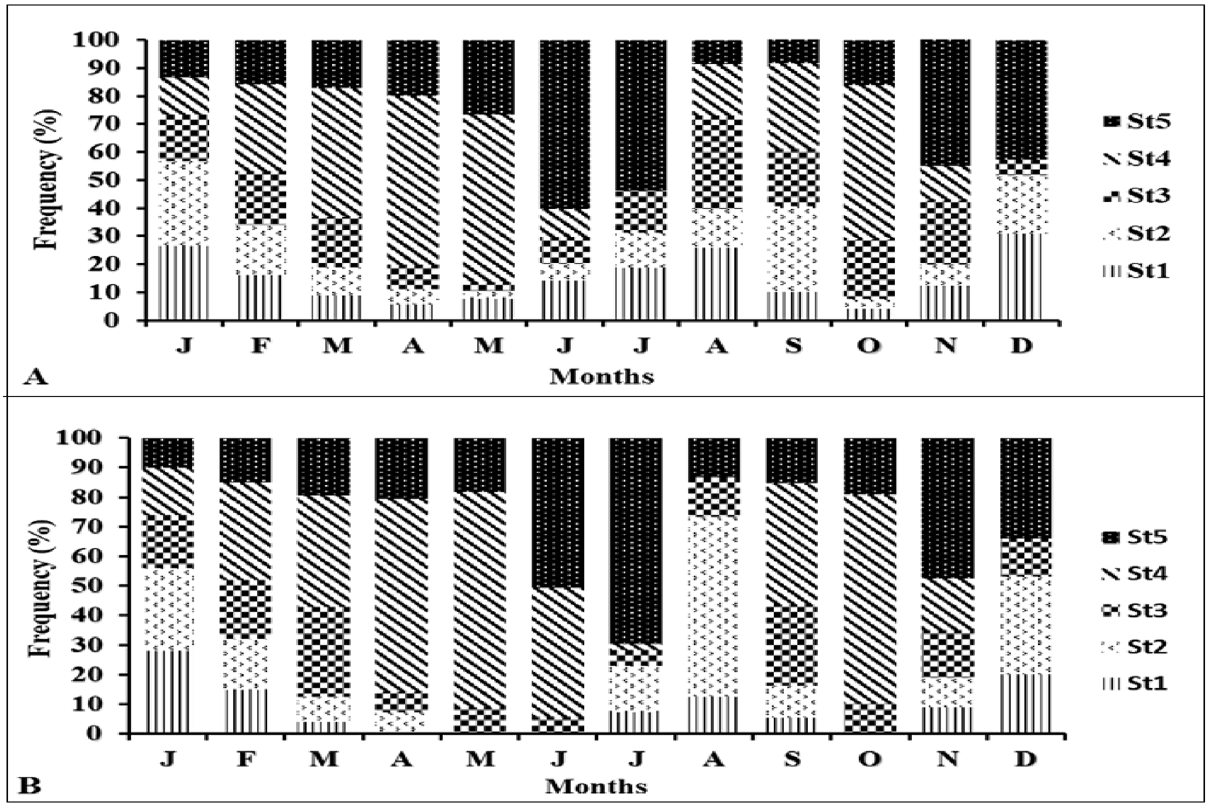

Fig. 3. Percentage of different maturation stages for females (A) and males (B) of *T. lepturus* from January 2018 to December 2018; St: Stage.

The monthly GSI of both sexes increased from February, peaked in May (2.30 ± 2.17) and decreased between June and August. A second increase occurred from September to October (0.82 ± 0.19) and declined thereafter from November to December. The lowest values of GSI for males (0.29 ± 0.08) and females (0.30 ± 0.65) were reported in December. The majority of spent individuals occurred in June-July and November-December, corresponding to the peak of ripe individuals respectively in April-May and October. The spawning occurs mainly from March to July and from September to December.

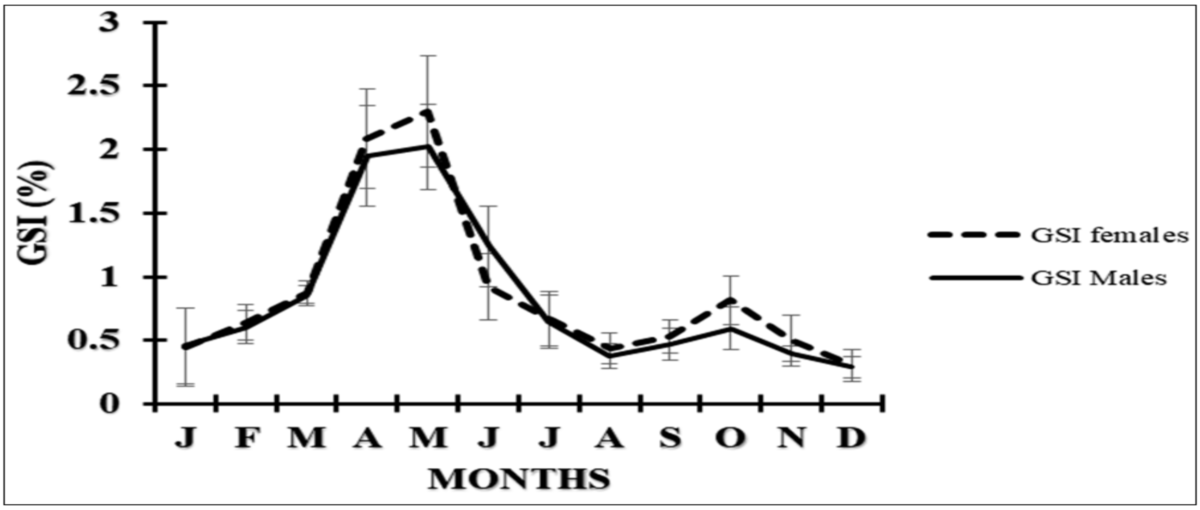

Fig. 4. Monthly variation of the gonadosomatic index (GSI), for females and males of *T. lepturus* from January 2018 to December 2018.

Fecundity and oocyte diameter

The absolute fecundity ranged from 3408.08 to89975.33oocytes for females with size varying from 46.9 to 87 cm.

The mean relative fecundity was 268 ± 212 oocytes g^{-1} of body weight.There was a positive correlation between the absolute fecundity and the body length (r^2 = 0.61) (Fig. 5).The distribution of oocytes was three-modal in maturing females (stage 3) with size ranging from 0.2-0.40 mm, 0.45-0.55 mm and 0.60-0.66 mm. In ripe (stage 4) and spent (stage 5) females, the distribution was unimodal and the diameters ranged between 0.1-1.2 mm and 0.2-1.8 mm respectively (Fig. 6). The mean oocyte diameter was 0.59 mm ± 0.28 mm at spawning.

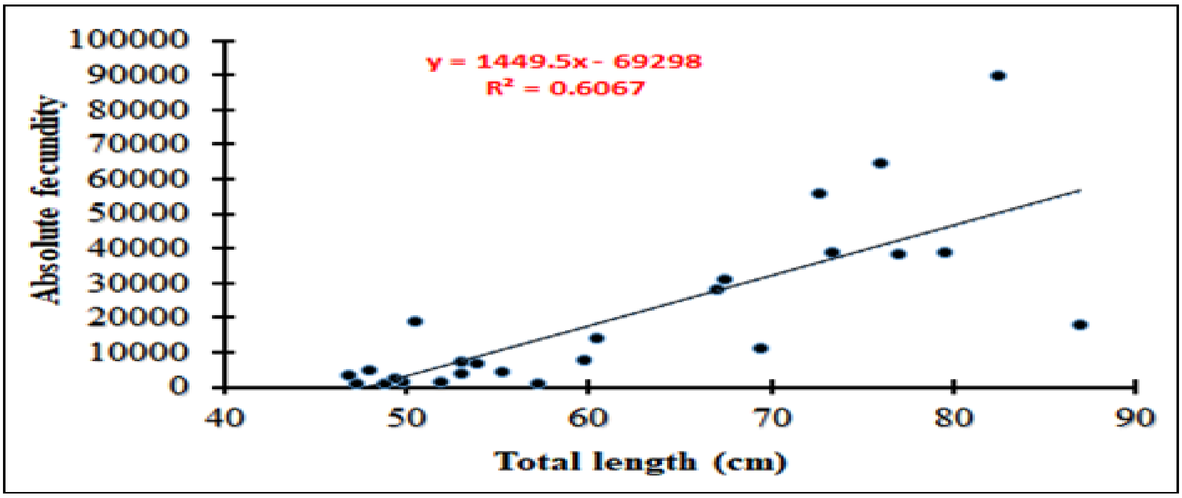

Fig. 5. Relationship between absolute fecundity and body length for females of *T. lepturus* from January 2018 to December 2018.

Discussion

The sex ratio of *T. lepturus* was slightly in favour of females in the coastal waters of Cote d'Ivoire. However, the difference was not significantly different ($p > 0.05$) from the expected 1:1 distribution. Males outnumbered females during January-March, July, September and November while females dominated the catches in April-June, August, October and December.

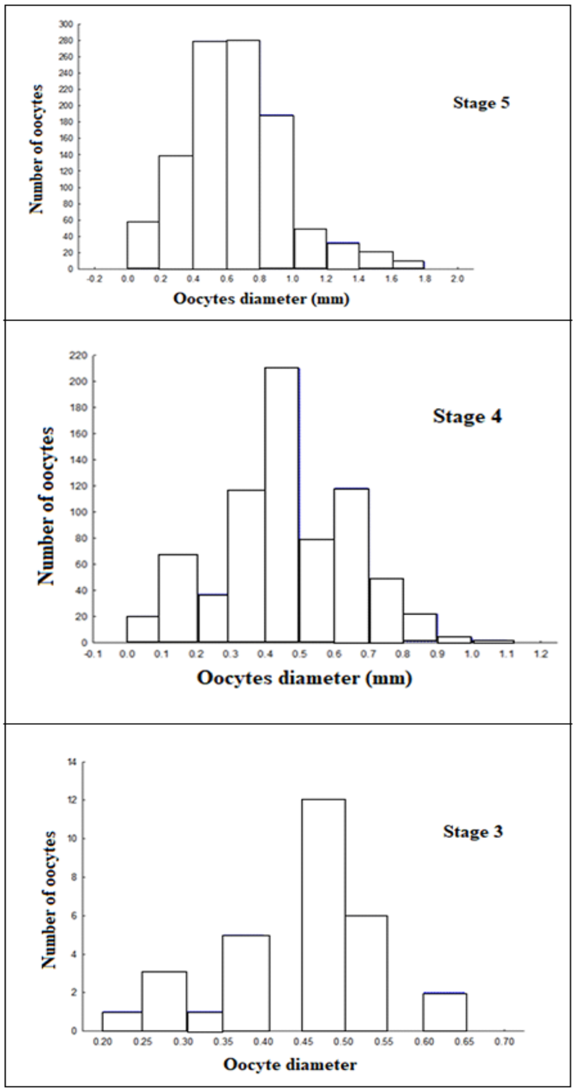

Fig. 6. Frequency distribution of oocyte diameter in the gonads at macroscopic stages of *T. lepturus* from January 2018 to December 2018.

The differences in sex ratio is related to the changes in the pattern of migration of sexes. Dulce and Guillena (2017) and Bryan and Gill (2007) noted similar observation in localities of South India and South Brazil coasts, where the sex proportion mentioned is favourable for females. For Kwok and Ni (1999), the predominance of one sex is a natural phenomenon in most species, especially in *T. lepturus*. Several hypotheses such as the mortality rate by sexes, the difference of growth rate between sexes, environmental conditions and the capture intensity (Mellinger, 2002; Pavlov *et al.*, 2014) could also explain these results. Yamada (1971) and Narasimham (1994) found that in *T. lepturus*, males are dominant in fish below 25 cm snout-vent length; beyond this length female's outnumbered male. In the present study also female dominance in the larger size groups was observed. The size at first maturity was slightly lower in females (45.81 cm) than in males (50.23 cm). The size at maturity for females and males was lower to that reported by Martins and Haimovici (2000), of 69.26 cm for females and 63.96 cm for males in the South of Brazil.

In Japanese Sea, this size is 59 cm for both sexes (Munekiyo and Kuwahara, 1988). This is considered important because the information obtained shows that most individuals caught in this area had small sizes, which could affect fishery yield and maintaining adequate populations of this species. Al-Nahdi *et al.* (2009), noted that estimates of length at first maturity from regions with marked temperature cycles and lower annual mean temperatures have been substantially higher than that of subtropical areas where there are no marked temperature cycles. In regards to this assumption and the sizes obtained in this study, *T. lepturus* of Ivorian waters could be lightly overexploited, compared to South of Brazil and Japanese Sea stocks. Nevertheless, our result should be interpreted with some caution as the data came from a short period. Numerous authors reported that the reproductive strategy of *T. lepturus* can be characterised by its flexibility, depending on latitude (Kwok and Ni, 1999; Martins and Haimovici, 2000; Al-Nahdi *et al.*, 2009). According to Al-Nahdi *et al.* (2009), the highest values of the GSI registered in the Oman coast was close to 3, a value that set the breeding season between May-June. In the South of China Sea, spawning of this species peaked during March-June (Kwok and Ni, 1999). For Kwok and Ni (1999), the females often spawn more than once in a reproductive season with group-synchronous spawning behaviour. The distribution of oocytes in ripe (stage 4) and spent (stage 5) females of this study confirms this hypothesis. In our study, the monthly percentage of maturity stages and GSI support a peak spawning during March-July and September-December and the presence of ripe gonads in all months indicates spawning throughout the year.

In this study, the fecundity of females with size ranging from 46.9 to 87 cm is about 3408.08 to 89975.33 oocytes, thus indicating a higher fecundity in this area. In larger fish measuring 74.3 to 87.2 cm, Tampi *et al.* (1971) estimated the fecundity at 24288 to 61595 oocytes from India. James *et al.* (1983) observed that the fecundity ranged from 1000 to 134000 oocytes in fishes measuring 42.4 to 92.3 cm. Guillena *et al.* (2017) estimated the fecundity about 69915 oocytes per fish of 60-80 cm size along the Zamboanga Norte Coast. This variation may occur due to the variations in environmental conditions and food intake by the individual. Doha and Hye (1970) reported that the variation of fecundity is very common and observed in fishes and the number of eggs produced by an individual female is dependent on several factors like size, age, environmental conditions. According to Patrick *et al.* (2010), fish with an average fecundity above 10000 oocytes can be classified as have a well fecundity. So, the fecundity range of 3408 to 89975 oocytes obtained in this study is well within the range given by the above authors. The fecundity increased with the increase of fish length as reported by the above studies.

Conclusion

The reproductive biology of *Trichiurus lepturus* in the coastal waters of Cote d'Ivoire was studied. The result showed that the sex ratio (F: M) of 1:0.93 was not significantly different between sexes. The length at first maturity was 45.81 cm for females and 50.23 cm for males. This species exhibited two spawning peaks annually along the coastal waters of Cote d'Ivoire from March to July and from September to December. The absolute fecundity ranged from 3408 to 89975 oocytes. There was a positive correlation between the absolute fecundity and the body length.

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