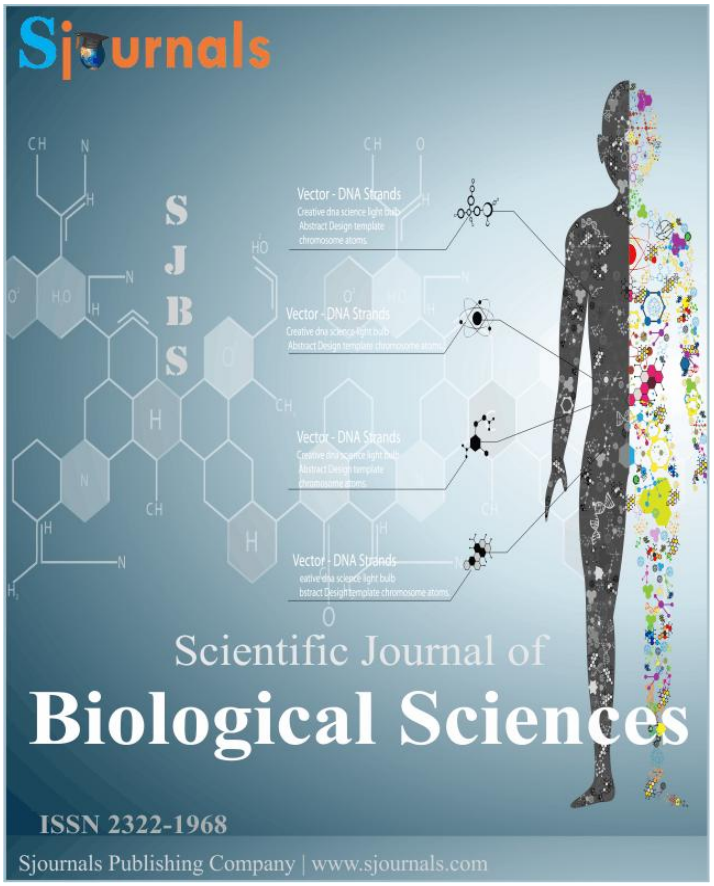

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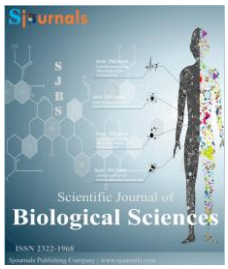

Original article

Reproductive biology and histological characteristics of female little tunny *Euthynnus alletteratus* (Rafinesque, 1810) caught on continental shelf of Côte d'Ivoire

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ABSTRACT

Some females little tunny (n=395) caught in gillnets and measuring in size from 35 to 76 cm FL (centimetre Fork Length) were sampled from January to December 2004 to study some biological features (length-weight relationship, size at first sexual maturity, eggs variation in diameter, gonado-somatic index, hepato-somatic index, somatic condition, and fecundity) along with histological characteristics of the reproduction process in this species. Female *E. alletteratus* reached maturity at 42.54 cm FL. Maturity stage distribution and gonado-somatic index (GSI) revealed that spawning period extended from May to October, with a peak value of GSI attained in August. There is a direct correlation between GSI and hepato-somatic index (HSI), and an inverse correlation of these factors to the somatic condition (K_c). The absolute fecundity has linear relationship with the weights of specimens and weights of ovaries. Yet, curvilinear relationship was found between the absolute fecundity and sizes of females. Eggs count in ovaries at spawning (IV) and post spawning (V) stages

revealed bimodal size classes, while ovaries at maturing stage III showed unique modal-egg-frequency distribution.

1. Introduction

Reproduction can be defined as mixed physiological and biological events and processes guided by behaviour as a result of inner and/or outer interacting phenomena in both females and males of a given population in order for them to give birth (in some species) or lay eggs (in others) whenever the young are to await. In various animals including fishes, reproduction occurs in due time without delay as it involves all individuals of the population. In tunas, species such as yellowfin (*Thunnus albacares*) and Atlantic bluefin tuna (*Thunnus thynnus*) are known for exhibiting serial spawning over broad areas of the Atlantic Ocean (Albaret, 1976) or the Pacific (Compeán-Jimenez and Bard, 1983), freely swimming in large-scale movements in favourable water temperature. Such movements, known as migrations associated with spawning, do not occur in little tunny because they are scarcely migratory fish (Valeiras and Abad, 2010). It seems that differences in behavioural specialization for reproduction are typical of each migratory or non migratory species. However, whether migratory or not, reproduction in fishes is almost always associated with facts that are of frequent occurrence. Some years before we carried out this study, as we examined the stomach contents of larger specimens from June to October, we observed various prey, of which some juveniles *Euthynnus alletteratus* along with juveniles *Auxis spp*. Measurements of ingested prey showed increasing sizes of those juveniles from 15 to 23 cm FL at that time. Additionally, various observations regarding the gonads of captured little tunny specimens revealed that almost all stages (from stage I, immature, to stage V, post spawning) were observed, suggesting that little tunny could possibly reproduce during that period.

Little tunny are epipelagic and neritic species typically occurring in inshore waters as well as tropical and subtropical waters of the Atlantic Ocean. They are also known to be fished worldwide in seas such as the Mediterranean, Black Sea, Caribbean Sea, and Gulf of Mexico (Collette and Nauen, 1983). In Côte d'Ivoire, West Africa, they heavily occur during the cooler period known as main upwelling season (Bahou, 2001; Bahou et al., 2007), when the Sea Surface Temperature (SST) are the lowest between June and October (Varlet, 1958; Verstraète, 1970; Morlière and Rébert, 1972). Though several studies on tunas in West Africa exist (See Fonteneau and Marcille, 1988), the reproductive biology of little tunny in those studies has not been addressed in relation with the Ivorio-Ghanian main upwelling season that occurs annually, especially in Côte d'Ivoire. Regarding the histology of gonads, studies on it, if any, are scarce in the region. The overall objective of the current work was therefore to study the characteristics of the reproductive biology of *Euthynnus alletteratus*. A specific goal was to investigate peculiarities of gonads and tell whether they support the high fecundity little tunny are credited with.

2. Materials and methods

Temperature plays a key role in the occurrence of tunas in a given area. For that reason, the SST was measured daily using an accurate thermometer whose readings are consisted of a tenth the degrees. Data were recorded daily at 7 am, 11 am, and 15 pm after 10 mn immersion of the thermometer in seawater collected in a 5 to 10-liter capacity container. The procedure permitted using of an average SST-value. Temperature measurements were made at the suitable site of Port-Bouët, in Abidjan, for data collection. *Euthynnus alletteratus* specimens were collected in the manner described by Bahou et al. (2007). Briefly, tuna were caught in gillnets of 25 mm and 35 mm mesh size by a fishery which operated at night with canoes powered by 40-hp motors, at the edge of the continental shelf of Côte d'Ivoire (Figure 1).

Fish were selected randomly as often as landings occurred in the morning at Abidjan fishing port and samples were taken to the laboratory for processing. Data were obtained from freshly caught specimens (i. e. samples were neither frozen nor fixed in any solution) and included determination of fork length, weighing of specimens as well as gonad and liver weighing. Individuals were measured to the nearest centimetre fork length and weighed to the nearest 0.1 g. Sex and maturity stage were assigned following the maturity data of Chur (1972) and as reported by Diouf (1980) for this species, and enhanced by our own observation of the gonads of dissected specimens.

Maturity stages were determined macroscopically basing on external features (morphological appearance, colour, consistency, resistance to pressing) and microscopically by histological examination.

Two sections each of 1 cm width (the former from the central part and the later from the upper extremity of ovaries at stages III, IV, and V) were taken from one single ovary and stored in 10% formalin. Intra-ovarian egg diameter was measured using an ocular micrometer. Additionally, the other gonad pair isolated from the same specimen was immersed in Bouin's fixative for two weeks and used for histological processing. Prior to sectioning, gonads had been dehydrated in ascending ethanol concentrations (70, 85, and 95°). Sections were cleared in Xylene, impregnated in liquid paraffin wax and poured into metal rectangular Lucas moulds. The moulds were placed under running tap water to harden and positioned in the microtome for trimming. The samples were sectioned at approximately 7 µm width with a microtome. Hardened wax trimmings housing parts of the gonads were stretched out properly. With the help of a clean slide, the stretched films of gonads were picked and placed on hot plate for about 30 minutes to dry up so as to properly attach to the slide. Each slide was passed through Xylene (for about 10 minutes) and through descending ethanol concentrations (95, 90, and 70°). Then, the preparations were stained with hematoxylin-eosin (H and E) and mounted using Distrene Platicizal Xylene (DPX). Sections were observed under a light microscope at various magnifications (X200, X250, and X400), when necessary, and photographed.

Furthermore, fecundity was investigated. Portions of 1 g, each taken from the central part of ovaries at stage IV (ripe ovaries), were immersed in Gilson fluid for two weeks to harden. Those ripe ovaries were taken from forty-five gravid females harvested at various months in the year. After the Gilson fluid had been filled up as to reach 50 ml, it was shaken vigorously for a while to make it homogeneous and to separate the connective ovarian tissues. Then 1 ml was taken as a sample with a Pasteur pipette and put in a tinny receptacle. Thereafter, eggs were manually enumerated and recorded. That procedure was repeated three times to enable choosing of mean values attributed to each individual fish. Absolute fecundity (AF) was taken as the number of ripe eggs in the female gonad prior to spawning. Relative fecundity (RF) was the number of eggs per gram of fish body weight (Wootton, 1979). Relationship between absolute fecundity and fork length was estimated through the commonly used equation $F=a\times L^b$, where "F" represents the number of eggs, "a" is a constant, "b" represents the regression co-efficient, while "L" is the fork length in centimetre. Absolute fecundity was calculated as follows:

AF=Number of eggs (NE)×50×Total weight of ovaries (TW)

Gonado-somatic index, Hepato-somatic index and Somatic condition were calculated using the formulae:

$$GSI = \frac{Ovary\ weight\ (OW)\times 100}{Weight\ of\ eviscerated\ \ fish\ (WE)},$$

$$HSI = \frac{Liver\ weight\ (LW)\times 100}{Weight\ of\ eviscerated\ \ fish\ (WE)}$$

$$K_C = \frac{Total\ body\ weight\ (TW)\times 100}{Fork\ length\ (FL)^3}$$

Length-weight relationship was computed through the equation $W=a\times L^b$ according to Ricker (1980), using the linear version of that equation as log W=log a + b×log L, where W= weight of fish in kilogram, L=fork length (FL) of fish in centimetre, "a" is a proportionality constant while the exponent "b" that represents the allometric co-efficient was tested for departure from isometric value (3) using Student's "t" statistics.

Size at first sexual maturity (FL_{50}) was defined as the size at which 50% of fish reached maturity (Diouf, 1980). Females at stages IV and V were chosen to determine the size at first sexual maturity. These individuals were ranged into 1 cm size classes and their percentages were calculated. The Statistica 7.1 software (Statsoft, Inc.) made it possible to obtain the curve that enabled determination of the size at first sexual maturity by fitting it to the logistic function of a non-linear regression (Barbiéri et al., 1994; Lowère-Barbiéri et al., 1996; Duponchelle et al., 1998). Such a function fits in with logistic regression and the probability associated with it satisfies the following equation:

$$\log it\ [p(X)] = \log\left[\frac{p(X)}{1-p(X)}\right] = \alpha + \beta X$$

Another option to the logistic regression is found through the utilization of the exponential function as follows:

$$p(X) = \frac{e^{(\alpha+\beta X)}}{1+e^{(\alpha+\beta X)}}$$, where α and β are two constants.

Applying such a model to our data was equivalent to attributing to mature females the probability for p (X) and to X the values in middle of the considered size classes. In such option, mature individuals count 50% when FL_{50}=-α/β. Linear regression was used to determine relationships between any given pair of variables. Statistical analyses were performed using Statistica 7.1 software and a significance level of 0.05 was adopted.

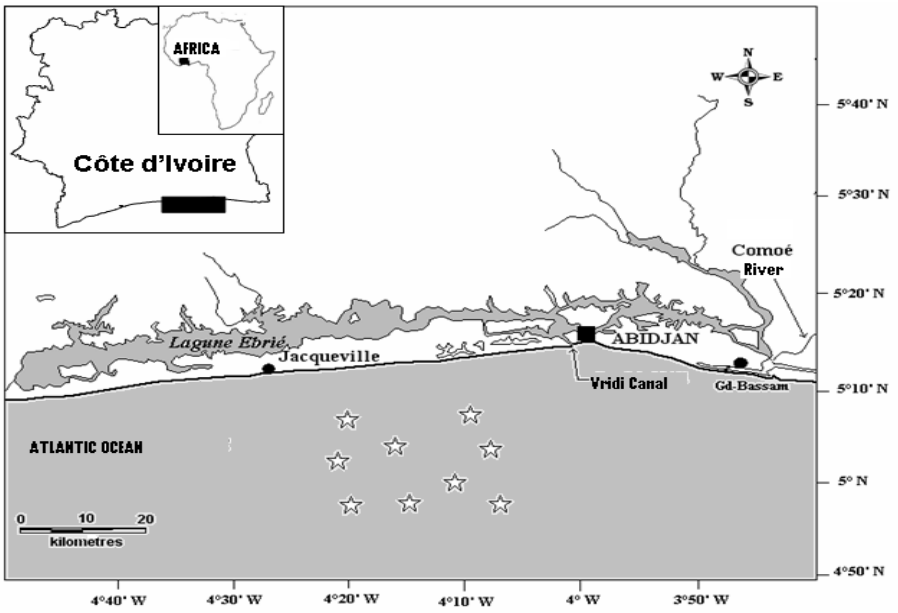


Fig. 1. Map of the fishing area (the centre of the fishing area is approximately 4°80'N - 5°10'N and 4°30'W – 4°W).

3. Results

3.1. Biological features

The length-weight relationship was $W=1.387\times10^{-5}(FL)^{3.025}$; r^2=0.98 for females, suggesting isometric growth, for the value of "b" (3.025) is statistically identical to the commonly referred isometric value "3" ("t" statistics, F=3.07; t=1.309). Additionally, first sexual maturity is attained at 42.54 cm FL (FL_{50}=137.26/3.22643), according to the equation for the curve that led to the calculations [y=exp(-137.26+(3.22643)*x)/(1+exp(-137.26+(3.22643)*x)), where "y" represents the percentage for mature individuals and "x" the size of those individuals. All females measuring in size 42.54 cm FL and over are mature individuals.

Monthly variation of the maturity stages is shown in Figure 2. The immature individuals (stage I) and those of onset of maturation (stage II) were present throughout the year though they fluctuated from one month to another, reaching higher percentages from July to September, especially for the former. Females at maturing or developing stage (III) occurred in March as they numbered 66.67% and lessened in September (11.36%). Spawning started in May while females at stage IV numbered 60% but it reached minimum value in October (16.13%). Post spawners (females at stage V) gradually increased in number from June (10%), with a peak value attained in November (57.58%). Females at resting stage culminated in December (66.67%) though being present from November (12.12%) to February (21.74%).

Variations of the GSI, HIS, and K_c are shown in full Figure 3. GSI was not that higher from January (0.89±0.21%) to April (1.91±0.28%) (Fig. 3A). It increased gradually, as the ovaries started to increase in weight, and reached greater values from May (3.55±0.73%) to July (4.55±1.18%), attaining an approximately greater value in August (4.53±1.78%). GSI thereafter decreased from August to December (0.86±0.26%), due to spawning and

post spawning. Overall, greater values of the GSI were observed between May and October. A closer observation of the GSI curve simultaneously with the occurrence of females at stage IV (from May to October) led us to conclude that reproduction did take place from May to October. Four periods – resting period, maturation period, spawning period, and post spawning period – were also noted. HSI seemed to exhibit the same trend, compared to that of GSI (Fig. 3B). Hence, increase in HSI was observed from January (HSI=0.421±0.001%) with its peak attained in August (HSI=0.422±0.001%). Decrease in HSI occurred till November (HSI=0.421±0.001%). The somatic condition showed a tendency to decrease from February (K_c=1.56±0.02%) to August (K_c=1.54±0.02%) (Fig. 3C). The somatic condition thereafter increased from September (K_c=1.55±0.02%) to December (K_c=1.56±0.02%). Temperature slightly increased from January (27.44±1.48°C) to May (28.53±1.48°C) and thereafter decreased till August (22.14±1.49°C) (Fig. 4). Yet SST increased when cooling of water masses weakened from September (23.06±1.51°C) to November (27.71±1.46°C), followed by decrease in temperature in December (27.49±1.52°C). SST thus featured four hydro climatic periods. These are the minor cool season (mCS), the main warm water season (MHS), the main cool season (MCS) also known as the main upwelling season (MUS), and the minor warm water season (mHS).

Ovaries at stage III predominantly contained eggs that measured 0.5 mm (Fig. 5A), although eggs diameter ranged from 0.3 to 0.6 mm (mean size=0.49±0.12 mm). Ovaries at stage IV were characterized by bimodal distribution of eggs (Fig. 5B). Eggs measuring 0.5 mm (mean size=0.53±0.10 mm) dominated in the first modal class, whereas the second modal class was featured by abundance of eggs measuring 0.9 mm (mean size=0.93±0.15 mm). As we can see in that figure, ovaries at stage IV are characterized by abundance of eggs whose size ranged from 0.7 to 1.1mm. The first modal class in ovaries at stage V was due to abundance of eggs whose size was 0.5 mm (mean size=0.49±0.13 mm) (Fig. 5C). In the second modal class, eggs diameter ranged from 0.7 mm to 1.1 mm (mean size=0.91±0.14 mm). In terms of abundance of eggs, the first modal class in the ovaries at stage V prevailed over the other one. There was seemingly decrease in number of eggs measuring in size 0.9 mm and over, probably due to release out of those eggs during the spawning. Overall, eggs frequency distribution showed a growth pattern indicative of progressive increase in size from 0.3 mm (in ovaries at maturing stage III) to a maximum size (1.1 mm in ovaries at spawning stage IV); which is likely to result in setting in for modes of various eggs groups. Such a type of ovaries is an attribute of batch spawning fishes.

Absolute fecundity was estimated to fluctuate between 342000 and 2127000 eggs (mean value=718024±428 eggs) in females measuring in size between 42.0 and 76.0 cm FL (52.8±8.8 cm). Relative fecundity was estimated to be 179-419 eggs/g (299±49 eggs/g). Relationship was found between absolute fecundity and the size of specimens (Fig. 6A). Therefore, egg count increased with increasing fork length as a curvilinear relationship. Absolute fecundity was positively correlated with body weight of specimens (Fig. 6B), which suggests that fecundity is likely to be more important in larger females. Absolute fecundity was also found to correlate with ovary weight. Therefore, greater eggs producers are likely to be specimens whose ovaries are relatively larger (Fig. 6C).

Macroscopically observation of gonads revealed six kinds of ovaries (Figure 7 to Figure 13). 1. The immature stage (I): Ovaries were thin, thread-like and cylindrical, with two tapering ends. 2. The onset of maturation stage or early maturing stage (II): Ovaries increased in size and were pinkish in colour. 3. The maturing stage or developing stage (III): Ovaries were orange yellow in colour. Eggs were distinguishable with the naked eye when looking through the ovarian membrane. 4. The spawning stage (IV): At this stage, the ovaries showed maximum development in thickness and width, and occupied the entire length of the body cavity, almost leaving little space for the viscera to display. With the ovary membrane becoming thinner, eggs were more distinguishable with the naked eye. The belly of females seemed too swollen and a slight pressing on the belly generally made eggs release out. 5. The post spawning and spent stage (V): The discharge of several ripe ovaries during the course of spawning caused a decrease in the weight of the ovaries, which resulted in them being severely flaccid and collapsed. Surface blood vessels were prominent, which caused the ovaries to become reddish in colour. 6. The recovery and resting adult stage (VI): The ovaries were much darker, yet less flaccid.

3.2. Histology of the ovary of little tunny

Gradual changes that occurred throughout the reproduction process were divided into six stages as follows (See Figure 7 to Figure 13): (i) Immature stage was characterized by small and spherical cells (oogonia) showing thin and indistinct peripheral cytoplasm. Pre vitellogenic oocytes could be seen (Fig. 7). (ii) The onset of maturing period primarily showed pre vitellogenic oocytes whose thin cytoplasm around the nucleus is conspicuous. Primary vitellogenic oocytes were also present (Fig. 8). (iii) The maturing stage or vacuolization period was characterized by appearance of the zona radiata as constituent of the oocyte wall. Cytoplasmic vacuoles also appeared. These

vacuoles were at first few in number, small in size and occupied the periphery of the cytoplasm. Oocytes of the primary yolk stage are generally characterized by the appearance of the yolk granules at the periphery of the cytoplasm. Those oocytes nearing onset of secondary vitellogenic division ranged in diameter between 300 and 635 µm across their long axis (Fig. 9). (iv) The spawning period corresponded to yolk deposition and maturation stage. The secondary yolk stage follicles or secondary vitellogenic division eggs increased in diameter and reached maximum size, 985 µm (mean size). The vacuoles increased in size and intermixed with the yolk granules that scattered within the cytoplasm (Fig. 10 and Fig. 11). (v) The post spawning and spent period was characterized chiefly by the presence of empty follicles. At the early stage of this period, the ovary closely resembled the ripe ovaries in having mature follicles that are not yet released. Besides atretic oocytes, empty follicles could be observed. The discharge of numerous ripe ovaries during the spawning process resulted in there being few ripe follicles (Fig. 12). (vi). The recovery and resting period was characterized by the appearance of different stages of cells, which made this stage different from the preceding stage V, since atretic oocytes and empty follicles could be observed. New generation of small oocytes were noticeable as constituent of this stage (Fig. 13).

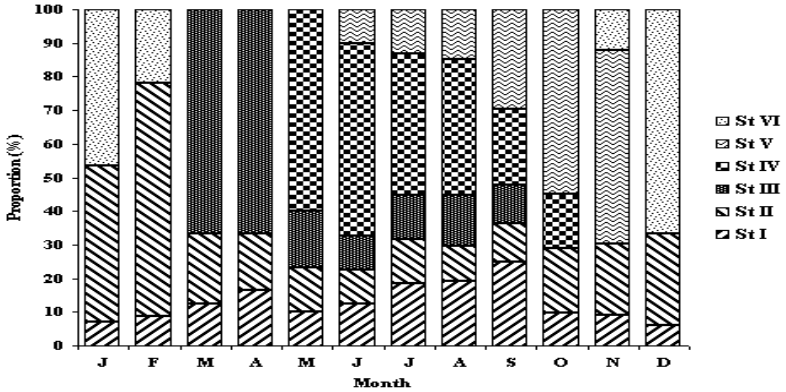
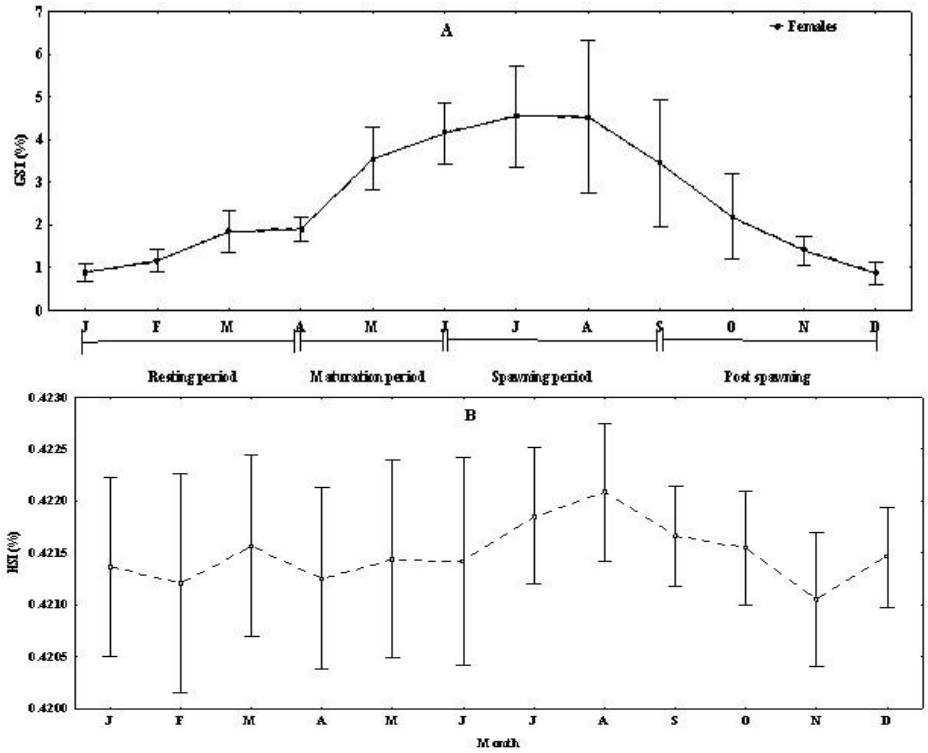


Fig. 2. Proportion of females little tunny *Euthynnus alletteratus* by maturity stage and month. St = stage; St I (immature); St II (early maturing); St III (maturing); St IV (spawning); St V (post spawning and spent); St VI (recovery and resting adult).



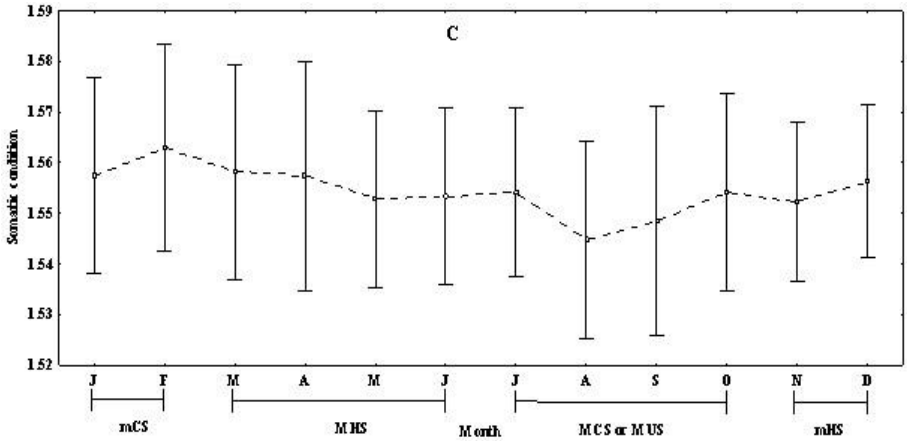


Fig. 3. Monthly variation of GSI, HSI, and K_c in female little tunny caught in gillnets in Ivorian shelf waters from January to December 2004. mCS = minor cool season; MHS = main warm water season; MUS = main upwelling season; mHS = minor warm water season.

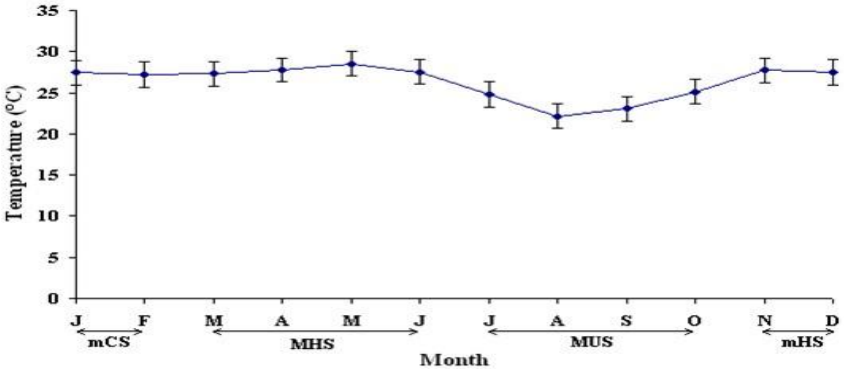


Fig. 4. SST variation on continental shelf of Côte d'Ivoire throughout the study period from January to December 2004. mCS = minor cool season; MHS = main warm water season; MUS = main upwelling season; mHS = minor warm water season.

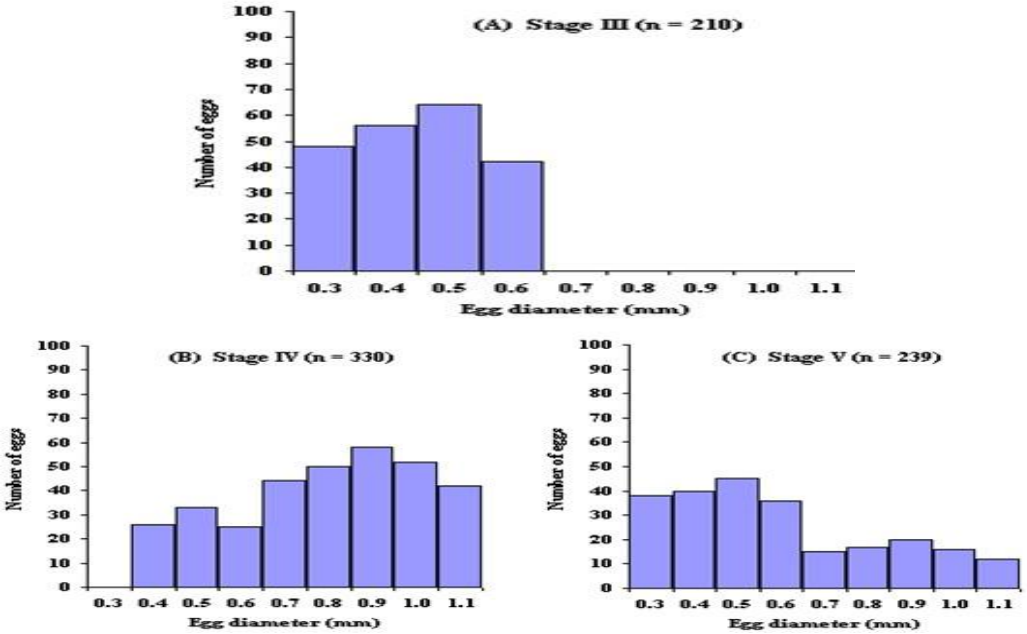


Fig. 5. Frequency distribution of eggs diameter in the ovaries of little tunny *E. alletteratus* at stages III, IV, and V.

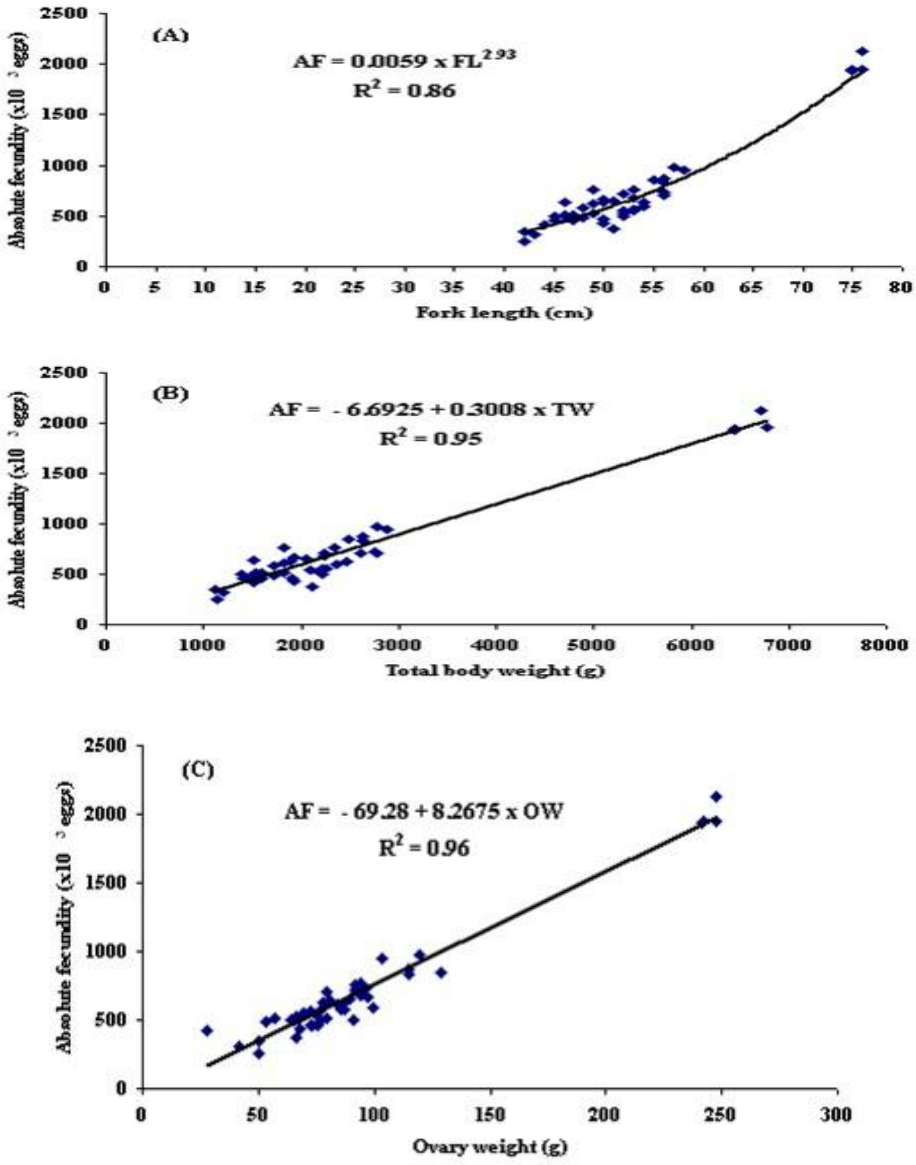
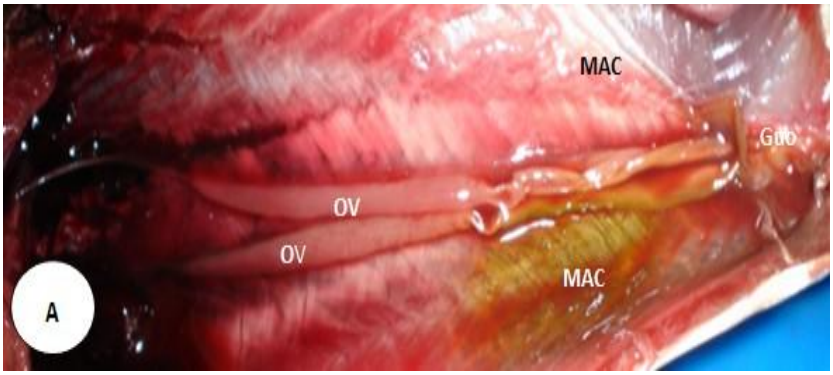


Fig. 6. Relationships between AF and FL (A), AF and TW (B), AF and OW (C) in female little tunny sampled from January to December 2004 at Abidjan fishing port.



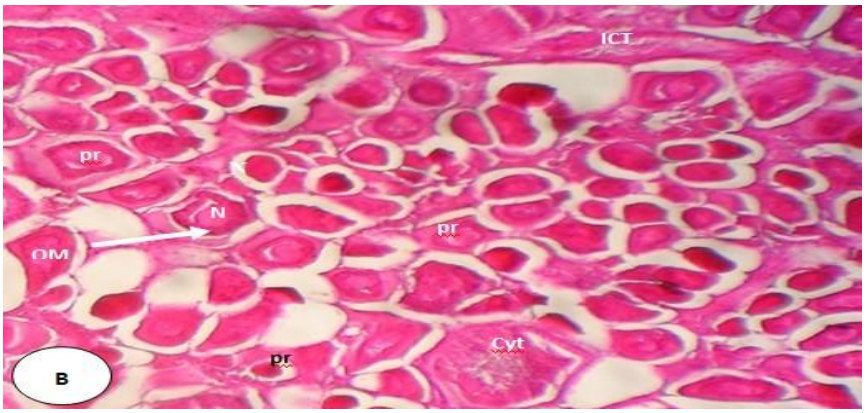


Fig. 7. (A) Overall appearance and localization of the two-thread-like immature ovaries of a female little tunny *Euthynnus alletteratus* at stage I. The ovaries (OV) show no surface blood vessels. They are surrounded with muscles of abdominal cavity (MAC), though separate from each other on the anterior side and joined in the oviduct, mixed with the combined genital and urinary orifice (Guo). (B) Cross-section of an immature ovary showing two lobes of germ cells, with an interstitial conjunctive tissue (ICT) keeping them apart (M × 200). We can see pre vitellogenic oocytes (pr) with their nuclei (N), cytoplasm (Cyt), and oocyte membrane (OM). (Hematoxylin and Eosin).

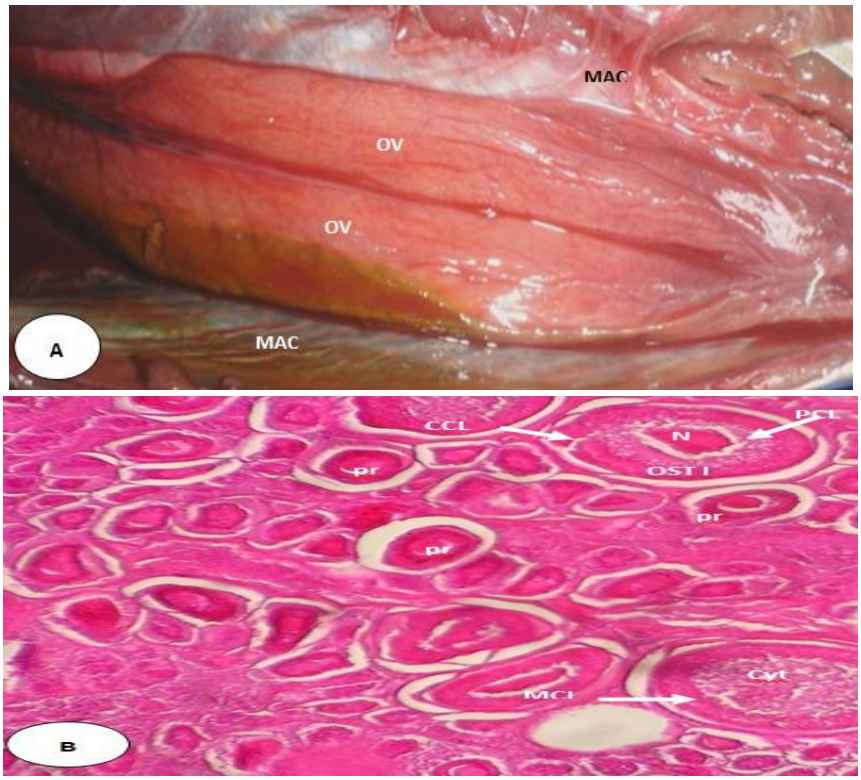


Fig. 8. (A) Overall appearance of the ovaries of a female little tunny *E. alletteratus* at Stage II (Onset of maturation) showing a few surface blood vessels that are not conspicuous. The ovaries (OV) are relatively larger, compared to their size at the preceding stage I. (B) Cross-section showing details of the observation of ovaries of little tunny at Stage II. Appearance of primary vitellogenic oocytes (O_{ST1}), though fewer in number comparably to the numerous pre vitellogenic oocytes (pr). These oocytes (O_{ST1} and pr) have nuclei (N) located in the center. Primary vitellogenic oocytes (O_{ST1}) show conspicuous cytoplasmic growth, which results in three cytoplasmic layers of which the outermost or cortical cytoplasmic layer (CCL) seems to be thinner and homogeneous. The middle cytoplasmic layer (MCL) is the thickest and it opens on the perinuclear inner cytoplasmic layer (PCL). (M × 200) (Hematoxylin and Eosin).

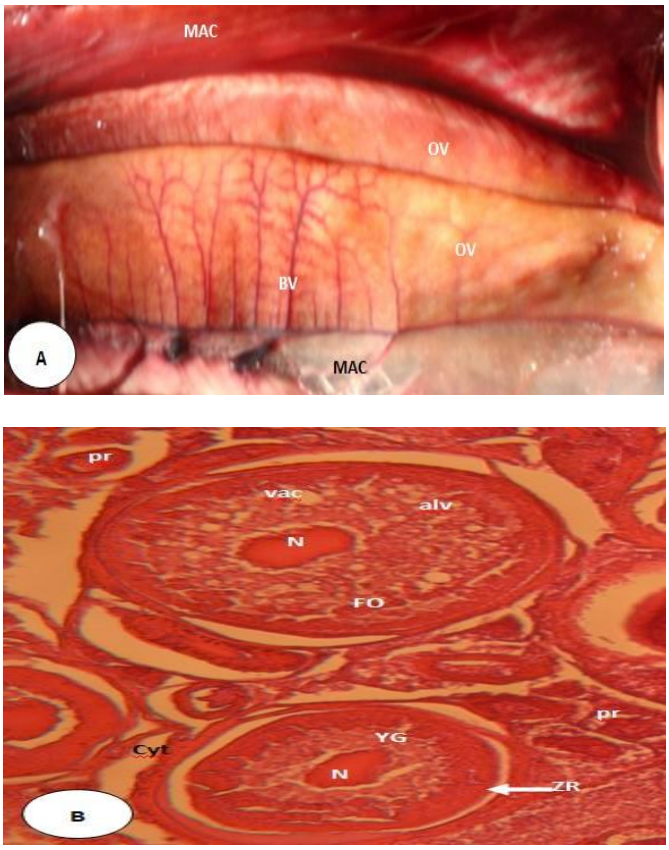
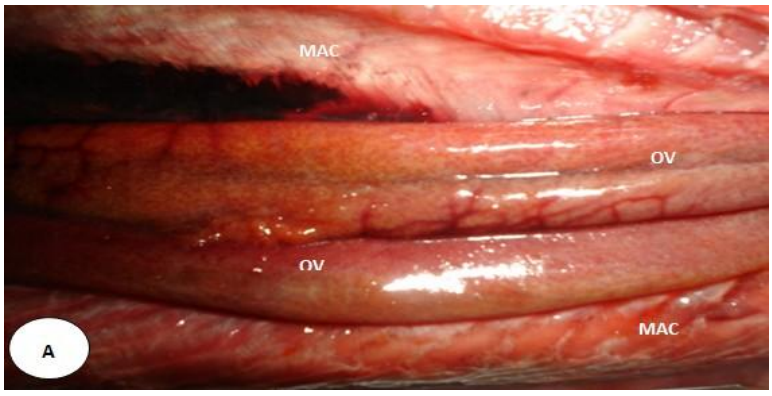


Fig. 9. (A) Characteristics of the ovaries of a specimen *E. alletteratus* at Stage III (Maturation). The ovaries (OV) are orange-yellow, with conspicuous surface blood vessels (BV). These ovaries are much larger than the preceding ones. The eggs they contain are visible through the ovarian membrane. (B) Cross-section of an ovary of little tunny at Stage III showing eggs nearing onset of secondary vitellogenic division (FO). Appearance of the zona radiata (ZR), vacuoles (vac), and yolk granules (YG). Numerous alveoli (alv) can be seen in the cytoplasm (Cyt). N = nucleus ; pr = pre vitellogenic oocytes. (M × 250) (Hematoxylin and Eosin).



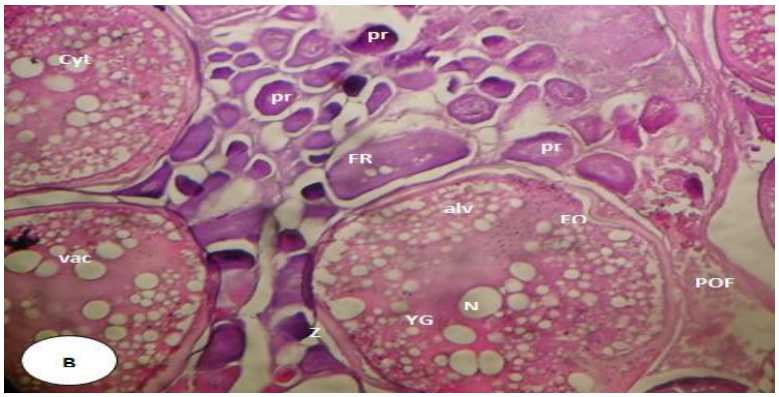


Fig. 10. (A) Overall appearance of the ovaries in a mature specimen *E. alletteratus* at spawning stage IV showing much more visible eggs through the ovarian membrane. (B) Cross-section of the ripe ovary of a specimen little tunny at spawning stage showing, besides oocytes at different stages, three secondary yolk stage follicles (FO). Pre vitellogenic oocytes (pr), post ovulatory follicles (POF), and follicles in resorption state (FR) can be seen. Vacuoles (vac), alveoli (alv), and yolk granules (YG) are mixed up and they scattered within the cytoplasm (Cyt). The nucleus (N) occupies a central position. (M × 200) (Hematoxylin and Eosin).

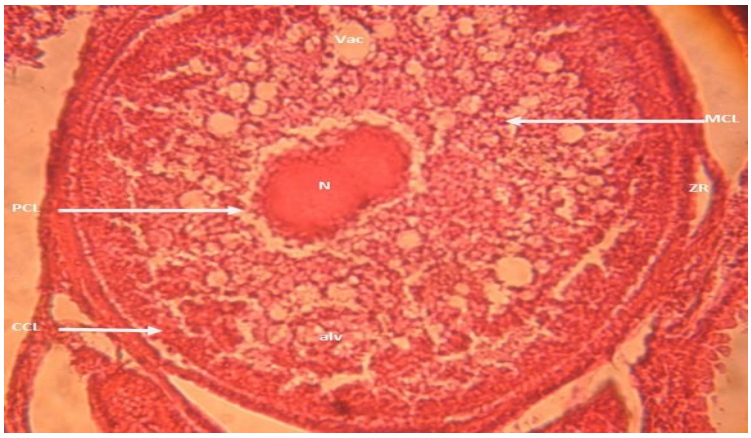
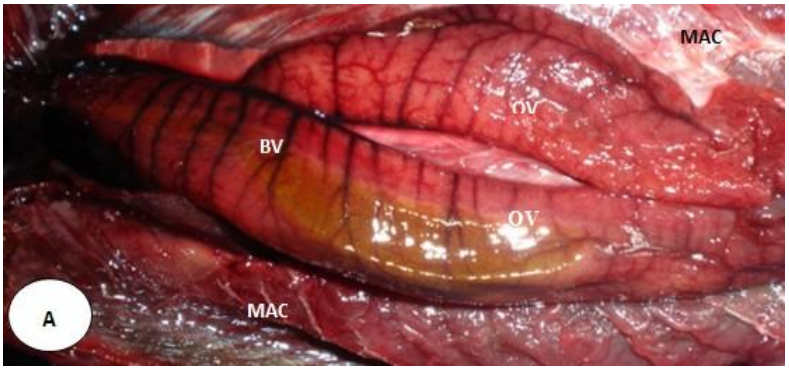


Fig. 11. Details of a ripe ovary showing a secondary yolk stage follicle. We can see in central position the nucleus (N) surrounded with three cytoplasmic layers. We notice that the vacuoles (vac), alveoli (alv), and yolk granules scattered within the middle cytoplasmic layer. A thin portion of the cortical cytoplasmic layer beneath the zona radiata (ZR) can be seen. CCL = cortical cytoplasmic layer ; MCL = middle cytoplasmic layer ; PCL = perinuclear inner cytoplasmic layer. (M × 400) (Hematoxylin and Eosin).



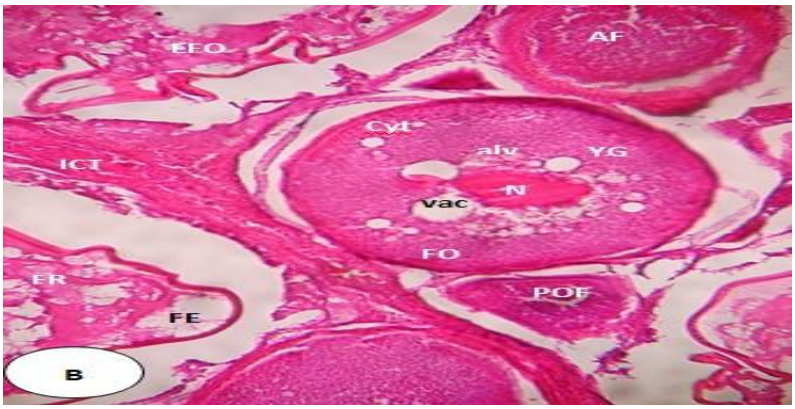
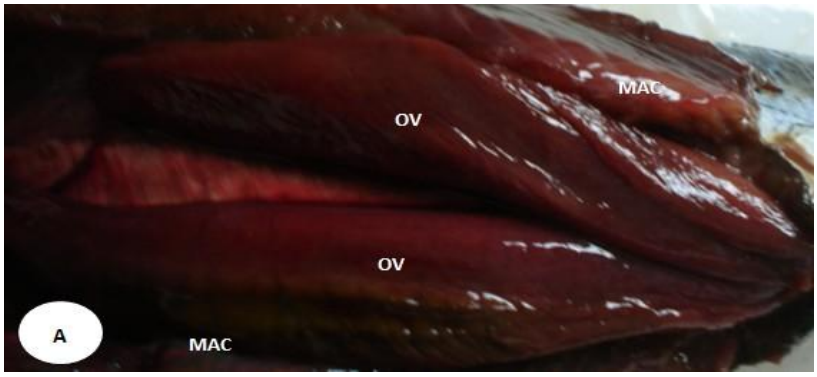


Fig. 12. (A) Overall appearance of the ovary of a specimen *E. alletteratus* at post spawning stage V. Surface blood vessels conspicuous. Ovaries reddish, not yet completely flaccid, which means further serial spawning is to occur. OV = ovaries ; BV = blood vessels ; MAC = muscles of abdominal cavity. (B) Cross-section of the ovary of a post spawner showing in central position a secondary yolk stage follicle (FO) with its nucleus (N). We notice that the ovary is subject to profound modifications, looking as if upside down. The follicular epithelium (FE) underwent invagination after spawning. Atretic follicles (AF), follicles in resorption state (FR), empty follicles (EFO), and post-ovulatory follicles (POF) can be seen. (M × 200) (Hematoxylin and Eosin).



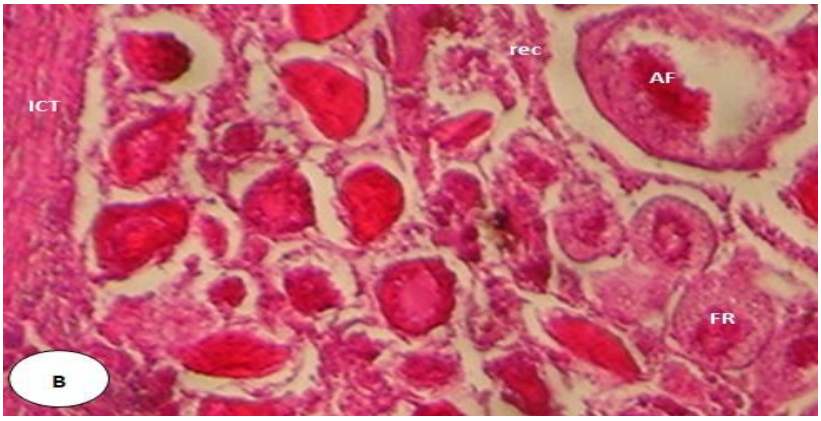


Fig. 13. (A) Overall appearance and characteristics of the ovaries of a resting adult *E. alletteratus*. These ovaries are relatively flaccid, red yet black-colored, showing no apparent surface blood vessels. (B) Cross-section of the ovary of a specimen little tunny at resting stage. We can see atretic follicles (AF), follicles in resorption state (FR), and various small cells at different developmental stages. The interstitial conjunctive tissue (ICT) is partially interrupted, probably due to reconstitution (rec). (M × 200) (Hematoxylin and Eosin).

4. Discussion

Length-weight relationship showed isometry. Diouf (1980) also found isometry for female little tunny. Yet, the size at first sexual maturity he reported for this species was 43.0 cm FL. Still, maturity size was reported to be 39.7 cm FL (Postel, 1955) or 42.8 cm FL (Chur, 1977). The maturity size we found in this study (42.54 cm FL) is in variance with that of several authors, possibly due to differences in habitat and type of specimens. However, it confirms the maturity size (42 cm FL) reported for little tunny by the International Commission for the Conservation of Atlantic Tunas, ICCAT (2003).

GSI and HSI displayed inverse trends compared to that of the Somatic condition, which supports the results of Kahraman et al. (2010) reported for the Bullet tuna *Auxis rochei* from the Turkish Mediterranean coast. These authors admitted that there was an inverse correlation between Somatic condition and ovarian development as is the case for little tunny. We think that availability of higher food resources possibly contributed to lessen reserves transfer from liver for the disposal of gonads, which, to some extent, resulted in weak variation of HSI. The later assertion needs be confirmed by future studies.

Macroscopically and histological examinations of gonads revealed six distinctive maturity stages, which confirms results of Chur (1972) and those of Diouf (1980). The measure of eggs diameter at stages III and IV showed that eggs could be arranged in at least two groups – the former consisting of small and transparent eggs and the later of yolky eggs – as a result of several modes of eggs sizes shortly before the spawning. Such results are indicative of long spawning season as well as fractional spawning characteristic (Zaki et al., 1995). Therefore, little tunny may spawn more than once along the spawning period as indicated by Cayré et al. (1988) for yellowfin tuna (*Thunnus albacares*), for bigeye tuna (*Thunnus obesus*) and for Skipjack (*Katsuwonus pelamis*). Yet, the spawning period found in the current study, occurring from May to October and covering a long cool season, conflicts with preceding results, namely that of Bakun (1996) which indicated 26 °C as the minimum suitable temperature for spawning of tropical tunas. Assuredly, temperature range in the study corresponds to those (20-31°C) commonly reported for the Eastern part of the Tropical Atlantic Ocean (Stretta, 1988), of which Ivorian waters are a part. Additionally, these temperature variations were in accordance with the results found by several authors (Colin et al., 1993; Golé-Bi et al., 2005). Various spawning seasons have been reported for little tunny, from May to November in Senegal (Diouf, 1980), from October to December in Sao Tome and Principe (Frade and Postel, 1955), and from June to July off the White Cape (Chur, 1972), indicating that the reproductive period could likely be extended, depending on the study area. Additionally, we think that there is no way for temperature to set any limitation to spawning as long as little tunny can live in an area because they are equipped with natural ability to regulate their body temperature. We also think that availability of higher food resources during the long cool season undoubtedly played a significant role during the reproductive period, which enabled little tunny to take advantage of the bloom of the planktonic foodweb that ensures food supply for both spawners and the young. Nutrient concentration during the main cooler period is high and comparable to what is found in other upwelling areas (Roy, 1995). Food availability improves fish health (Oboh, 2002) and by extension enhances reproduction (Offem et al., 2007).

Diouf (1980) reported fecundity variation between 70000 and 2200000 eggs in female little tunny. The relationship between the absolute fecundity and fork length as well as the relationships between fecundity and the fish body weight as well as fecundity and ovary weight were found to be highly expressive as Diouf (1980) did. Some authors associate fecundity with qualities that are typical of certain spawners. For instance, in fishes other than tuna, low fecundity was viewed as peculiarity of species exhibiting either parental care (Anon, 2002) and/or prolonged breeding habits (Fawole and Arawomo, 2000).

The progressive changes observed in the gonads of female little tunny revealed varied sizes of eggs indicating the presence of immature eggs in the midst of matured ones. The fecundity rate found in the study could likely be in the line with the prolific nature of this tuna species. The reproductive period of little tunny in Côte d'Ivoire occurs from May to October and covers half the main warm water season and the main cool season or main upwelling season (MUS) throughout. The latter season is characterized by abundance of food, enabling the young to become distributed to areas where food could easily be found by them. This could be viewed as a strategy for little tunny to compensate for the lack of parental care.

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