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POPULATION STRUCTURE AND REPRODUCTIVE PARAMETERS OF THE CASSAVA CROAKER, *PSEUDOTOLITHUS SENEGALENSIS* (PISCES, VALENCIENNES, 1833) IN NEARSHORE WATERS OF BENIN (WEST AFRICA) AND THEIR IMPLICATIONS FOR MANAGEMENT

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ABSTRACT

The production of the common commercially Sciaenids species, *Pseudotolithus senegalensis* off Benin nearshore waters, has been decreasing since 1994, and increasingly more small-sized fishes are regularly harvested, while very little information exist about the species' population structure and life history. Therefore, population structure, probability of capture and size at first capture were investigated using length-frequency data of 865 specimens sampled from beach seine hauls over a period of 18 months. A total of 51.23% of this population were immature, confirming the domination of small-sized fishes in the catches. Gonad maturation stages were also examined. Histological structure of ovaries and frequency distribution of oocyte size exhibited two cohorts of mature oocytes suggesting two spawning periods per year. Monthly averages of gonado-somatic index confirmed that *P. senegalensis* spawned twice a year during the major warm season (March – May) and during the transition minor warm to minor cold season in October –December. Length at first capture was greater than the length at first sexual maturation indicating minimal pressure of the beach seine gear on this resource. Innovative and precautionary management measures involving all relevant stakeholders in a community-based management effort to reduce fishing pressure during the reproductive periods from March to May and from October to December yearly.

INTRODUCTION

Theoretical and empirical work has shown that an unmanaged fishery will almost certainly become overexploited (both biologically and economically). However, it is also understood that success in fisheries management is difficult to achieve. In addition, the conventional approach to fisheries management - which has emphasised fish stock management, fishing effort regulation and production maximisation - has been a partial solution to the challenges and opportunities represented by fisheries. For example, there has been a tendency to ignore non-biological issues such as the management of resource rent (with severe implications for wealth generation and usage). Apart from being a cheap source of highly nutritive protein, fish contain essential nutrients required by the body (Sikoki *et al*., 1999). The fisheries sub-sector is important to Benin on many fronts. For example, as a source of foreign income, the sub-sector contributed US $ 12 million to Benin's total receipts of agricultural non traditional export products in 2008 (INSAE, 2009). Fish is also a preferred source of animal protein in the Beninese diet (approximately 55%), with a consumption of approximately 14.4 kg per person per annum (Direction des Pêches, 2011). The fish requirement for the population (8 millions, INSAE, 2003) was estimated to be approximately 96,000 metric tons. The fishery sector supports an informal workforce of 1.5 million people (approximately 18% of the population), which includes fishermen, fish processors and traders, most of whom are women (Anato, 1999). The dependence of the Beninese on fish has resulted in a demand that far outstrips the total local production from capture fisheries (both marine and inland waters). In 2011, for example, the total production was 37,784 metric tons, while the demand was approximately 120,000 metric tons (Direction des Pêches, 2011). In 2005, the total value of fish imports into Benin was US $ 80 million. Approximately 33% of the local fish production is from marine waters. The marine fisheries sector in Benin is dominated by artisanal fisheries, which contribute approximately three-quarters of the total marine

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production (Gbaguidi, 2000). The species of high market value caught by artisanal fisheries are *Sciaenids* (21.75%), *Polynemids* (08.77%), *Lutjanids* (05.52%) and *Sparids* (04.07%) (Anato, 1996). Sciaenids constitute a large and varied family of fishes that are closely related to snappers, but differ in that the spinous dorsal fin is short, and the adipose tissue is much longer than the anal fin, which has only one or two spines (Edwards *et al*., 2001). This family comprises croakers, drums, meagres and weakfishes. Approximately 70 genera and 270 species are known, with 14 species occurring along the Gulf of Guinea on the coast of West Africa (Edwards *et al*., 2001). The genus *Pseudotolithus* (Family: Sciaenidae) (croakers) constitutes an abundant and commercially-important fish group in Benin's nearshore waters (Gbaguidi, 2000, 2001, Sossoukpe, 2011) and throughout the Atlantic coast of West Africa (Bayagbona, 1969). *Pseudotolithus senegalensis* and *P. typus* are widely distributed along the coast of tropical West Africa from Senegal to Angola (Edwards, *et al*., 2001). These two Sciaenids are easily mistaken. Number of spines at dorsal fin and Inter-Orbital length were the two discriminative morpho-meristic factors that could be used to reinforce macroscopically the difference between *P. senegalensis* and *P. typus* even at post juvenile stage (Sossoukpe, 2011).

Unfortunately, since 1994, the production of *Pseudotolithus* species has been decreasing, and increasingly more small-sized fishes are regularly harvested (Gbaguidi 1999, 2000, Sossoukpe, 2013a). Larger specimens do not exceed 80 cm total length (TL) (Gbaguidi 1999, 2000). In spite that *P. senegalensis* is widely studied (Longhurt, 1966; Troadec, 1971; N'Jock, 1990; Domain *et al*., 2000; Sidibé, 2003, Nunoo *et al*., 2013), there is a dearth of information on the management of this species. However, information on sex ratio, size at first sexual maturation, spawning seasons and fecundity could be a useful input in deciding on sustainable management measures. For example, the fluctuations of the sex ratio according to fish size provide a useful tool to examine the biological characteristics of the fish species, such as sexual inversion, longevity in relation to sex, vulnerability to fishing gear and the spatial, seasonal and even daily distribution of species (Aboussouan and Lahaye, 1979). Fecundity regulates the numerical abundance of the fish population and affects fish stocks. The current study presents this information for *Pseudotolithus senegalensis* to contribute to management and conservation policies for further development of this fishery in Benin.

MATERIALS AND METHODS

Study area, fish sampling and data collection

Coastal waters serve as an important spawning area as well as a nursery zone for juveniles (Blaber *et al*., 1995). For this reason, the study of population structure and reproduction of *P. senegalensis* was performed in the nearshore waters of Benin (West Africa) (Fig 1). Samples were taken weekly from commercial beach seine hauls for 18 months (March 2008 to August 2009) along Benin coast from Djako at Cotonou city (06°20'51''N, 2°21'58''E) to the village of Djègbadji at Ouidah city (06°20'36''N, 02°14'56''E). A total number of 941 fish specimens were sampled from the catches and 865 specimens were sexed. The samples were conveyed in thermos cool boxes to the laboratory. Specimens were measured [total length (TL) and standard length (SL)] to the nearest 1.0 millimetre with a fish measuring board then weighed to the nearest 0.1 gram with an electronic balance. Pressure was applied to the ventral abdominal wall to determine if gonads were fully matured (indicated by expulsion of oocytes). Specimens were dissected and gonads were removed for weight measurements. Sex was determined by macroscopic examination of gonads. Gonad maturation were estimated using a scale of gonad maturation stages described by King (1995).

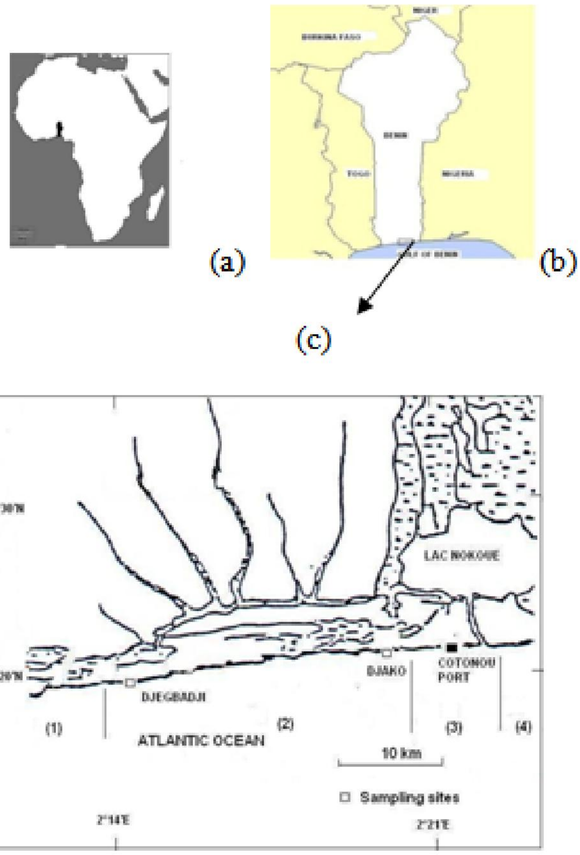


Fig 1. Maps showing Benin in Africa (a) Republic of Benin (b) and sampling sites (c)

Fig 2. Removed internal organs showing ovary at maturation stage IV

Female stages were: (1) resting (juvenile) – ovary undeveloped, small and translucent with oocytes invisible to naked eye; (2) developing – ovary opaque, orange colour with oocytes opaque and visible to naked eye; (3) ripe – fully developed ovary fills ventral region of the abdominal cavity with translucent, large and round postvitellogenic eggs; (4) spawning - ovary releases eggs when pressed with large, translucent oocytes; some are free in the ovary (diameter 0.65-0.97 mm); (5) spent (postspawning)– shrinking or slack ovary with some residual eggs. Male maturation stages were: (1) immature (juveniles) – undeveloped testis consisting of a translucent filament; (2) early maturation – intermediate size testis having a very light yellow or tan colour; (3) advanced maturation – large testis, opaque white or light tan colour; (4) ripe testis – fully developed testis, pressure applied to ventrum expulses white milt; and (5) post spawning- flaccid testis without milt. For histological preparation, tissue samples were fixed in 10% neutrally buffered formalin for 24 hours, soaked in water another 24 hours, and stored in 70% ethanol. Samples were embedded in paraffin, sectioned to 5-6 µm thickness and stained with Harris' Haematoxylin and Eosin Y. Subsequent to staging, gonads were fixed in 5% formalin. After 7 days, preserved gonads were removed from formalin and stored in 75% ethanol to avoid shrinking of oocytes with reduction of egg diameter. Fecundity was determined from 22 late-ripening ovaries (stage IV) collected from February to March. Batch fecundity was estimated as a total number of mature oocytes extrapolated from three 0.1 g samples taken from each ovary (samples from anterior, middle and posterior portions of the ovary). After at least two weeks the specimen tubes were shaken vigorously to liberate the eggs from the ovarian tissue. Pooled oocytes from all three areas were counted in a Petri dish under a binocular microscope (10 x 1.6). Oocytes having yellow-orange colour and range 0.45-0.97 mm in diameter were considered large (mature) and then counted. Diameters of 10 mature oocytes from each of 22 gonads were measured using an ocular micrometer attached to a dissecting stereomicroscope. The diameters of ova from representative ovaries of the five maturity stages were also measured.

Data analysis

The size frequency distribution was analyzed using 2 cm class intervals (standard length) to plot a histogram to determine the type of distribution, which characterizes the fish population. Sex ratio was calculated for different months and size groups of fish. The sex ratio was tested for equality for different months using Chi-square test. The Gonadosomatic Index (GSI) was used to determine the spawning period using the formula:

$$\mathrm{GSI} = 100\,\frac{\text{Gonad weight}}{\text{Gutted body weight}}\ (\text{Anato}, 1999)$$

The reproduction or spawning period was determined by the changes in the monthly GSI. The period between the beginning of the increase of the GSI and its decrease corresponds to the reproduction period. The egg-laying time corresponds to the maximum value of the GSI. Fishes belonging to maturity stage II and above were considered as matured fish and used for calculating the size at first sexual maturation (L_{50}). The L_{50} was estimated as the size at which 50% of individuals were classified as "mature" or "advanced maturation" stage (Albaret, 1977). The L_{50} was estimated from a sigmoid curve constructed with the percentage of mature individuals and associated size class categories. A frequency distribution was plotted for oocytes diameter based on ovaries in the top 10^{th} percentile of GSI values. Fecundity was estimated for mature ovaries as:

$$F = \mathrm{Wg}\,\frac{\mathrm{n}}{\mathrm{p}}\ (\text{Anato}, 1999)$$

where Wg is the gonad weight, "n" is mean number of oocytes in the sample ovary, "p" is mean weight of the sample ovary. The linear relationship of fecundity with gonad weight was examined as: Log(F) = bLog(Wg) + Log(a), where F is the fecundity, Wg is the gonad weight, "a" is the intercept and "b" is the slope. The probability of capture provides a clear indication of the estimated real size of fish in the fishing area that are being caught by specific gear. Probability of capture is also an important tool for fishery managers who, by regulating the minimum mesh size of a fishing fleet, can mostly determine what should be the minimum size of the target species of a fishery. The probability of capture was estimated by backward extrapolation of the descending limb of the length converted catch curve. A selectivity curve was generated using linear regression fitted to the ascending data points from the plot of probability of capture against length, which was used to estimate the final value of L_{25}, L_{50} and L_{75} (i.e., lengths at which 25%, 50% and 75% of the fish will be vulnerable to the gear, respectively). Estimates of length-at-first capture (L_{50}) were derived from the probabilities of capture generated from the catch curve analysis output by FiSAT II (version 1.2.2., 2005).

RESULTS AND DISCUSSION

Population structure and sex ratio

The population was distributed as indicated in Table 1. Only 48.77% of this population was mature. The distribution of population size structure was unimodal (Fig 9) with a modal class interval of 24.0 cm. A total of 51.23% of individuals sampled were immature (sexed and unsexed). Gbaguidi (1999) reported that 72% of individuals of *Pseudotolithus* species caught by beach seine from Benin nearshore waters were also juveniles. Nunoo (2003) reported that 90% of individuals of fish assemblages were juveniles in the beach seine hauls at Sakumono in Ghana throughout the year indicating the dependence on the nearshore as a nursery for juveniles. These finding agrees with that of Ashong (1999) for Sakumono between 1998 and 1999. However, juvenile fishes formed about 53% of individuals in beach seine hauls at False Bay, South Africa (Clark *et al*., 1996). These results imply that the nearshore waters of Benin serve as an important spawning area as well as a nursery zone for *P. senegalensis.* The data on sex ratio is presented in Table 2. The ratio of males to females was found to be 0.90:1. Test of significance of difference revealed that in March and October 2008 and in February and March 2009 the number of males and females differ significantly meaning that females were more numerous than males in these months ($X^2 = 10.72$ $P < 0.001$; $X^2 = 6.48$ $P < 0.01$; $X^2 = 9.54$ $P < 0.01$; $X^2 = 10.38$ $P < 0.001$ respectively). In the other months, the difference was insignificant. The Chi-square test of pooled data did not show any significant difference ($X^2 = 0.32$, $P < 0.05$). The sex-ratio (males to females) was widely variable from one month to another. During the reproduction period, the number of females outstrips those of males. For the pooled data, it was about 0.90:1. In Côte d'Ivoire and in Congo, Troadec (1971) found that females of *P. senegalensis* were more numerous than males up to 40 cm (TL) and beyond 48 cm (TL) there were only females. In Guinea there was equivalence between males and females of *P. senegalensis* at length (TL) range 22 cm - 46 cm and females were more numerous from 46 cm (TL) (Sidibé 2003). Caverivière (1982) reported that, the dominance of females at the advanced age could be explained by: an availability or a high vulnerability of females; or a higher natural mortality of males; a sexual inversion; a differential growth or a mere differential sexual migration. Variations of the sex-ratio according to the size, which are observed, can have a considerable influence on the fertility of stocks depending on whether majority of the adult individuals captured were females or males. Finally, it is necessary to note that the sex-ratio of the population is calculated from catches and that the observed variations can be an indication of catch ability between the two sexes. However, sex ratio is influenced by many factors. According to Bertin (1958) and Lissia Frau (1966), the difficulties determining the sex of immature and hermaphroditic individuals could greatly affect the proportion of males and females obtained.

Table 1: Classification of different maturity stages in *P. senegalensis*

Maturity stage	Description	Mode of ova diameter (mm)	Maximum diameter of ova (mm)
Stage I	Immature	0.15 – 0.18 0.18 – 0.27	0.29
Stage II	Maturing	0.18 – 0.21 0.27 – 0.30 0.39 – 0.42	0.46
Stage III	Mature	0.24 – 0.27 0.33 – 0.36 0.39 – 0.42 0.45 – 0.48	0.58
Stage IV	Mature	0.27 – 0.30 0.33 – 0.36 0.36 – 0.48 0.74 – 0.97	0.99
Stage V	Spent	0.15 – 0.18 0.27 – 0.30	0.44

Table 2 Sampling distribution by gender of *P. senegalensis* from Benin nearshore waters between March 2008 and August 2009

SL class (cm)	TL class (cm)	Un sexed	Males	Females	Total	%
< 18 (Unsexed)	< 20	76	---	---	76	8.16
18 – 23 (Immature)	20 - 30	---	198	214	401	43.07
23 – 32 (mature)	30 – 39	---	225	229	454	48.77
	Total	76	412	453	931	100

SL: standard length, TL: total length

Development of ova to maturity

The size frequency distribution of ova in stages I – V of maturity are shown in Table 1 and Figs 10-12. The frequency histograms of diameters of various maturity stages showed that in stage I (immature ovary, Fig 3), majority of the ova were 0.18 – 0.21 mm (representing the immature stock of ova), and a few ones measured upto 0.30 mm. The immature stock of ova was found in all the subsequent stages. In stage II (maturing ovary), a batch of ova separated from the general stock forming a mode at 0.18 – 0.21 mm, another distinct mode at 0.27 – 0.30 mm forming the first batch of maturing ova was also formed. In stage III, (mature ovary, Fig 4), the first batch of maturing ova which appeared in stage II, developed further and formed a mode at 0.0.30 – 0.0.33. In addition a new batch of maturing ova with mode at 0.24 – 0.27 mm contributed to its appearance. At this stage the mature group of ova was well demarcated from maturing and immature ones by mode a mode 0.74 – 0.87 mm. Stage IV (ripe ovary, Figs 5-6), contained all the four stages of ova. The mature group of ova with mode at 0.35 – 0.38 mm, which was found in stage III, developed further and reached a mode at 0.74 – 0.97 mm, these ova were ripe and were ready for spawning. In addition to this group, modes at 0.32 – 0.35 mm representing the mature ova, 0.17 – 0.20 mm and a fraction at 0.23 – 0.26 mm also took place. In stage V (spent ovary), the ripe ova that had been at 0.74 – 0.97 mm in stage IV were already extruded, and there were only immature, maturing and few residual of mature ova (Fig 7). Generally, the maturing and mature ova passed in succession to advanced maturity stages and fresh batches of maturing ova separated from the immature stock.

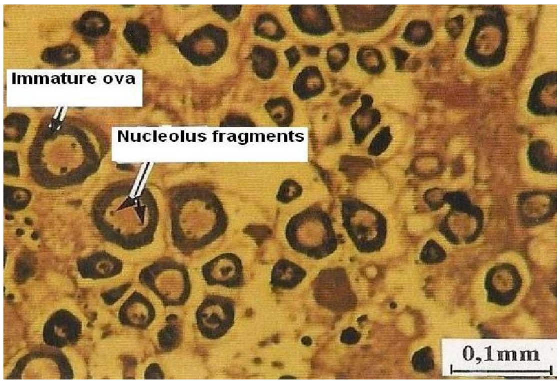


Fig 3. Immature ovary (Stage I, Jul. 2009)

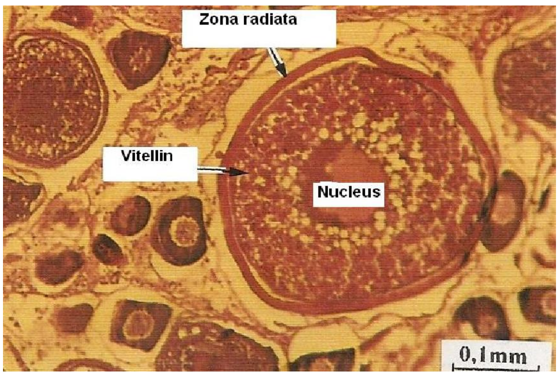


Fig 4. Maturing ovary (Stage III, Sept. 2008)

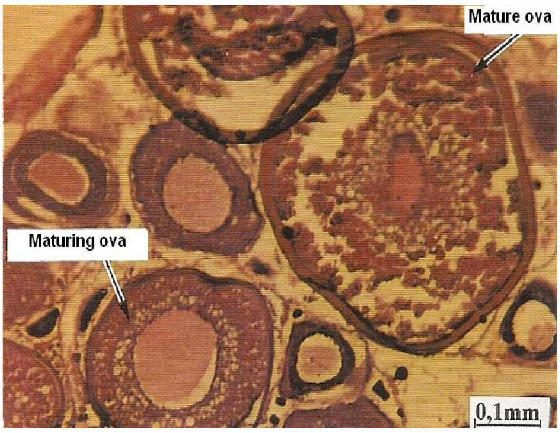


Fig 5. Spawning ovary (Stage IV, first spawning period, Nov. 2008)

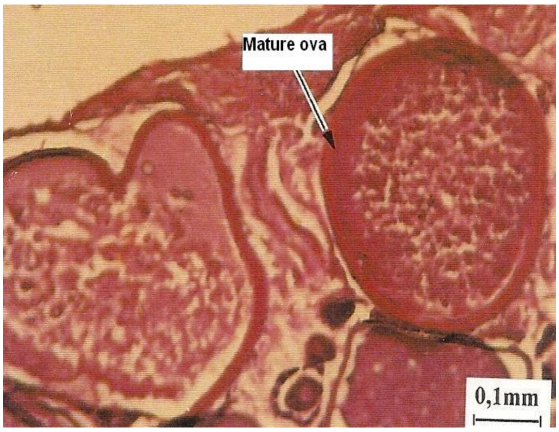


Fig 6. Spawning ovary (Stage IV, second spawning period, Mar. 2009

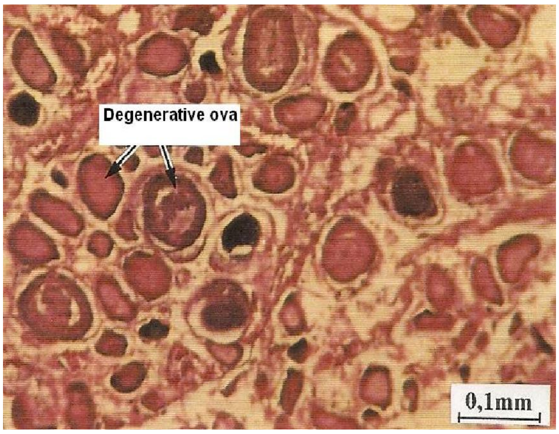


Fig 7. Post-spawning ovary (Stage V, June 2009)

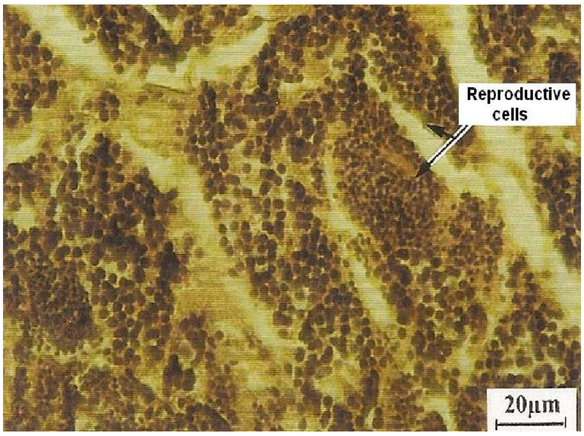
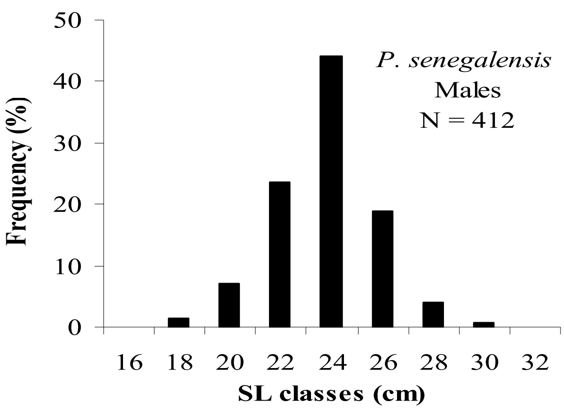


Fig 8. Mature testis (Stage IV, Oct. 2008)



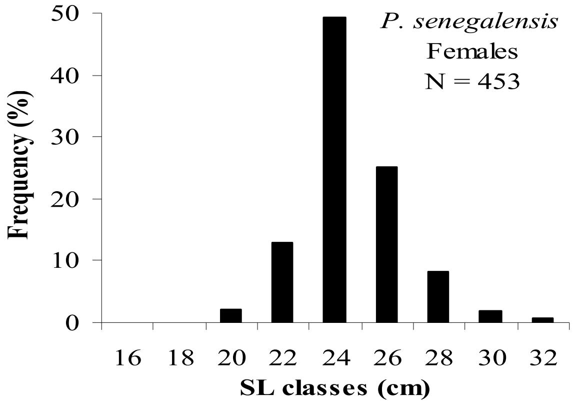


Fig 9. Size structure of males and females of *P. senegalensis* sampled from Benin nearshore waters between March 2008 and August 2009

Spawning frequency

As can be seen from Figs 10-12, in an advanced stage of ovary three distinct groups of maturing and mature ova at 0.21 – 0.32, 0.32 – 0.35 and 0.74 – 0.97 mm are separated from the immature ones (0.18 – 0.21). As the fish approaches the spawning season, the most advanced group of ova at 0.74 – 0.97 mm (75% of total oocytes in mature ovary, Fig 13) was separated distinctly and released from the follicular chamber. By the time the next group at 0.45 – 0.48 mm (18% of total oocytes in mature ovary, Fig 11) is approaching the ripe stage suggests a second spawning season. Monthly averages for GSI (Fig 14) peaked twice a year, in March and in October, suggesting two spawning periods per year. The first one occurred from March to May (range 3.252±0.22 - 1.779±0.13) and the second, from October to December (range 3.885±0.19 - 2.103±0.01). Proportions of ripe males and females in each month were correlated ($r^2 = 0.57$; $P < 0.01$). The percentage of individuals with mature gonads (stages III and V) and mean monthly GSI were correlated for both males ($r^2 = 0.45$; $P < 0.05$) and females ($r^2 = 0.72$; $P < 0.01$), providing confirmation that *P. senegalensis* spawned twice a year. The first spawning occurs during the major hydrological warm season in Benin (February-May) and the second including the minor hydrological warm season (in November). Similar results were reported for *P. typus* (Sossoukpe *et al*., 2013b). These findings confirm those of Longhurst (1966) who reported that *P. senegalensis* in Nigeria spawn mainly during the warm season in waters where temperature is high or equal to 27.5°C. In Congo, using percentages of mature females, Poinsard and Troadec (1966) fixed the spawning during the minor and major warm seasons. Several observations by the different authors, and summed up well by Troadec (1971), indicated that spawning would take place at shallow depths and probably at the neighborhood of stream mouths, rivers or lagoons.

Size at first sexual maturation

The proportion of mature individuals increased rapidly between 23 and 28 cm SL for both males and females (Fig 15). The size at which 50% of individuals were mature was 24.0 cm (SL, males) and 24.6 cm (SL, females). The smallest size at which mature specimens were found was 19.2 cm (Stage II, 149.4 g ungutted weight) and 20.5 cm (stage II, 205.6 g ungutted weight) in male and female, respectively. The total length at which 50% of *P. senegalensis* individuals (males and

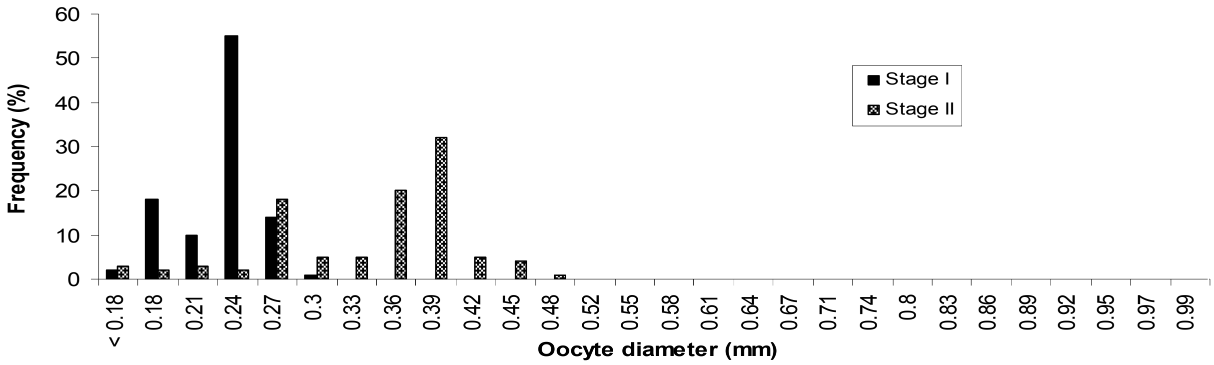


Fig 10. Size frequency distribution of oocytes in ovaries at maturation stage I and II of *P. senegalensis* from Benin nearshore waters sampled between March 2008 and August 2009

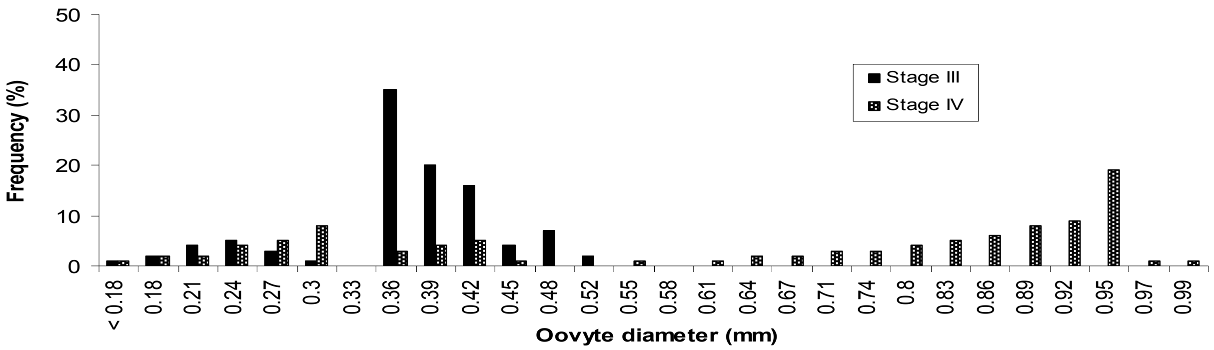


Fig 11. Size frequency distribution of oocytes in ovaries at maturation stage III and IV of *P. senegalensis* from Benin nearshore waters sampled between March 2008 and August 2009

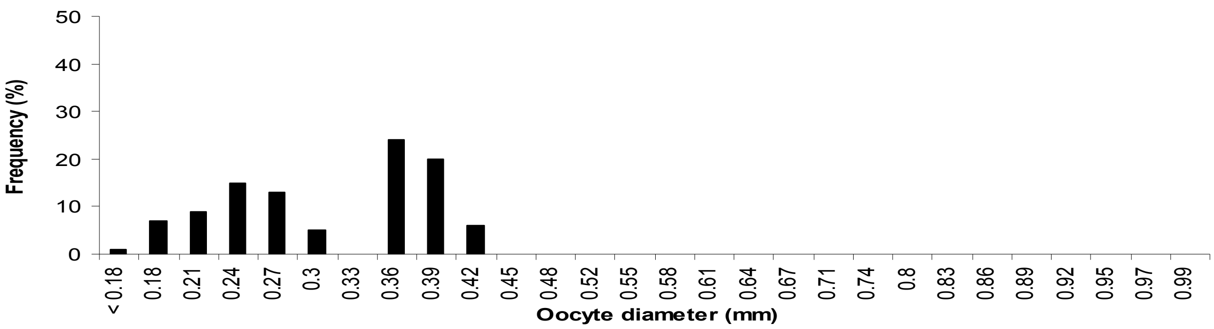


Fig 12. Size frequency distribution of oocytes in ovaries at maturation stage V of *P. senegalensis* from Benin nearshore waters sampled between March 2008 and August 2009

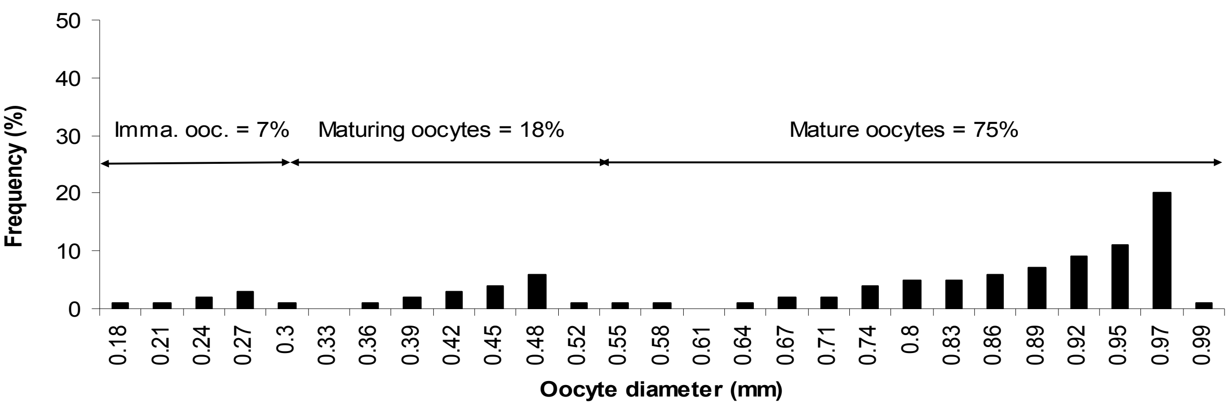


Fig 13. Size frequency distribution of oocytes in mature ovaries of *P. senegalensis* from Benin nearshore waters sampled between March 2008 and August 2009

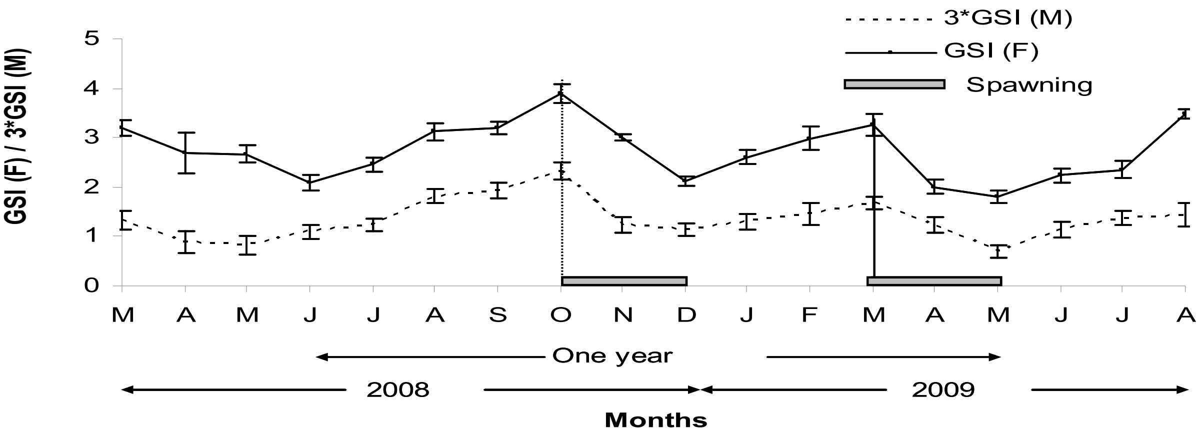


Fig 14. Variation of monthly averages of GSI (means ± SE, standard error bars) of males and females of *P. senegalensis* from Benin nearshore waters with indication of spawning seasons

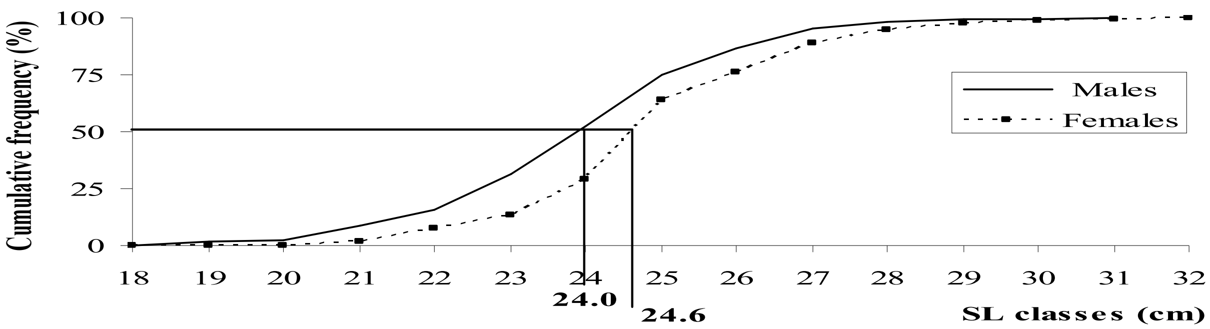


Fig 15. Graphs showing the size at first sexual maturation for both genders of *P. senegalensis* from Benin nearshore waters sampled between March 2008 and August 2009

females) became mature (TL_{50}) was 30.4 cm. This value was found to be close to what was reported in Guinea (Domain *et al*., 2000 (31.0 cm) and Sidibé, 2003 (29.0 cm)) but different from what was reported in Cameroon (N'Jock, 1990, (26.5 cm) and the neighboring Nigeria (Longhurst *in* Troadec, 1971 (35.0 cm)). In conclusion, the size at first sexual maturation is relatively variable with the species and its bio-geographical zone.

Probability and length of first capture

The length of first capture of 50% and 75% of the fish individuals was 25.76 and 26.5 cm, respectively (Fig 16). In the present investigation, the length at first capture of 50% of *P. senegalensis* species (L_{50} = 25.76 cm) was greater than the length of first sexual maturation ($L_{50\%}$ = 24.6 cm, Fig 15) indicating theoretically that it was given each fish the chance of reproducing at least once in its lifetime to replenish the stock. The predominance of small-sized fishes in the catches could be explained by the non selectivity of the gear beach seine and the fact that the fishing zone is the nursery zone of juveniles. Several studies on recruitment show that the number of recruits per year would depend on abundance as well as the strategy of reproduction of the stock and the variability of their environment (Blaxter, 1973; Cushing, 1975; Beyer and Laurence, 1980; Walters, 1986, Sinclair, 1988; Cury, 1989). Conditions of the area could play a fundamental role in the regulation of recruitment by their influence on the survival of eggs, larvae and juvenile as well as on the fertility of the reproductive stock probably based on trophic relationships.

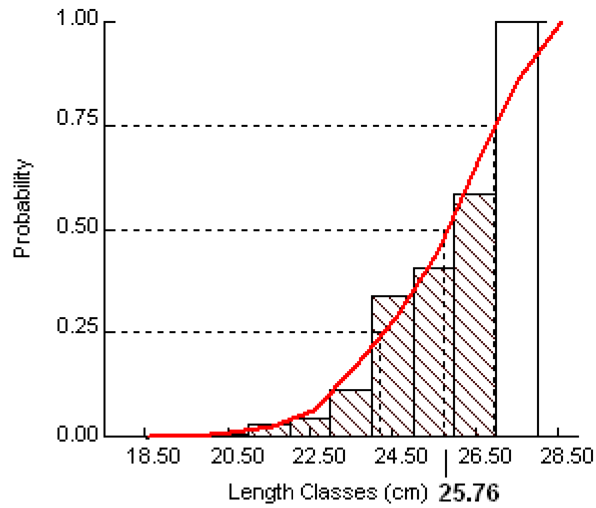


Fig. 16. Probability and size at first capture of *P. senegalensis* individuals (output from FISAT) L_{50} = 25.76 cm

Fecundity

Overall, fecundity (measured as the number of mature oocytes in the ovary) was strongly correlated with gonad weight (r^2 = 0.93; $p < 0.05$) (Fig 17). Body length was correlated with fecundity but the body weight revealed no general association with fecundity (Fa = 2.4539LogSL + 1.8365, r^2 = 0.0.02 P > 0.05; Fa = 1.8056LogWe + 0.5196, r^2 = 0.08 P > 0.05). The Lowest and highest fecundities recorded for individual fish were 22,527 oocytes (24.2 cm SL, 204.6 g We) and 214,267 oocytes (24.3 cm SL, 226 g We), respectively. The mean fecundity of *P. senegalensis* of Benin nearshore waters was about 6.85 x 10^4±2,070 (P < 0.05).

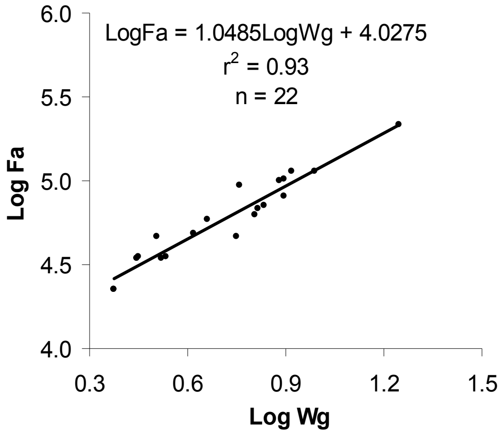


Fig.17 Best fit relationships between fecundity (Fa) and gonad weight (Wg) of *P. Senegalensis*

Conclusion

In theory, equilibrium life history strategies should be associated with significant density-dependent recruitment, such that minimum or optimal densities of spawners could be estimated. Maintenance of a healthy population of spawners is essential for sustainable fisheries. The fact that females are more numerous than males at the beginning of each spawning season was identified as one of the life history strategies of this species. The nearshore waters of Benin serve as well as spawning areas as well as nursery zone of juveniles of *P. senegalensis*. To improve chances for a sustainable Cassava croaker fishery in the nearshore waters of Benin, better enforcement of fishing regulations governing the open access coastal fishery established. Innovative and precautionary management measures involving all relevant stakeholders in a community-based management effort to reduce fishing pressure during the reproductive periods from March to May and from October to December yearly will be beneficial.

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