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Growth and mortality parameters of *P. senegalensis* and *P. typus* (Sciaenidae) in nearshore waters of Benin (West Africa) and their implications for management and conservation

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ABSTRACT

Most fisheries in Africa are overexploited or are at the peak of exploitation. A key contributor to this overfishing is poor data on fisheries, inefficient management strategies and unenforced policies. *Pseudotolithus* species off Benin nearshore waters are mainly fished by beach seining. Unfortunately, since 1994, the production of these species has been decreasing, with more small-sized fishes appearing in catches, and little is known about the species' population dynamics. Therefore, the growth and mortality parameters of two commercially important Sciaenids (*Pseudotolithus senegalensis* and *Pseudotolithus typus*) off Benin's nearshore waters were investigated using length–frequency data of 2019 specimens sampled from beach seine hauls over a period of 18 months. The length–weight relationship was computed from linear regression analysis. *P. senegalensis* exhibited isometric growth while *P. typus* exhibited negative allometric growth. The von Bertalanffy growth constants for *P. senegalensis* were $TL\infty = 51.4$ cm, $K = 0.24\ yr^{-1}$, and $t_0 = -0.60$ yr with a derived growth performance index of $\varphi' = 2.753$. The corresponding estimates for *P. typus* were $TL\infty = 56.2$ cm, $K = 0.19\ yr^{-1}$, $t_0 = -0.73$ yr and $\varphi' = 2.652$. The growth patterns determined by the growth performance index (φ') were higher for *P. senegalensis* than for *P. typus* of similar sizes. The total mortality rate, *Z*, for *P. senegalensis* was estimated as $4.39\ yr^{-1}$, with the fishing mortality, *F*, being calculated as $3.70\ yr^{-1}$. The mortality estimates for *P. typus* were $Z = 4.12\ yr^{-1}$ and $F = 3.70\ yr^{-1}$. The exploitation rate of the two fish species was higher than the optimum exploitation criterion, which is indicative of over-fishing. Several immediate management actions, such as size-limit regulation by gradually increasing beach seine mesh size and time-limit regulation by restricting fishing outside the spawning season, are considered necessary for sustainable exploitation of these stocks.

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1. Introduction

Many of the world's fish populations are overexploited, probably to meet the fish consumption requirements of the human population (Milton et al., 2002; Nunoo et al., 2006; Fazli et al., 2007; Narges et al., 2011). Apart from being a cheap source of highly nutritive protein, fish contain essential nutrients required by the body (Sikoki and Otobotekere, 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 are also a preferred source of animal protein in the Beninese diet (approximately 55%), with a consumption of approximately 12 kg per person per annum (FAOSTAT, 2005). 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 2008, for example, the total production was 43,000 metric tons, while the demand was approximately 80,000 metric tons (Direction des Pêches, 2009). In 2005, the total value of fish imports into Benin was US$80 million. Approximately 33% of the local fish production is from a marine source. The marine fisheries in Benin are dominated by artisanal fisheries, which contribute approximately three-quarters of the total marine production (Gbaguidi, 2000). The species of high

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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 *Pseudotolithus typus* are widely distributed along the coast of tropical West Africa from Senegal to Angola (Edwards et al., 2001). These two species are the dominant *Sciaenid* species collected by beach seining in Benin (*P. senegalensis* (87.64%) and *P. typus* (10.96%)) (Gbaguidi, 2001).

Pseudotolithus species are preferred by consumers for their landed size and the quality of their flesh (Kebe et al., 1997). Unfortunately, since 1994, the production of *Pseudotolithus* has been decreasing, and increasingly more small-sized fishes are regularly harvested (Gbaguidi, 1999, 2000). Larger specimens do not exceed 80 cm total length (TL) (Gbaguidi, 1999, 2000).

Due to the high demand for these species, it is necessary to evaluate their population parameters to ensure the proper management of this fishery.

Morphometric parameters form the basis for fishery management decisions (Sissenwine et al., 1979). The fundamental tools are the length–weight relationship, the length–breath relationship, growth at age, growth increment, mortality, exploitation and condition (Ricker, 1975). Age and growth information are particularly important for describing the status of a fish population and for predicting the potential yield of the fishery. This information also facilitates the assessment of production, stock size, recruitment to adult stock and mortality (Lowe-McConnel, 1987). Aging studies of *P. senegalensis* using otoliths and scales are well-described in Troadec (1971). The two fish species occur in Guinea at a temperature range of 15.75–29.58 °C and a salinity range of 27.72–36.10%.

Fish mortality is caused by several factors, including, age (King, 1991), fish predation (Otobo, 1993), environmental stress (Chapman and Van Well, 1978), parasites and diseases (Landau, 1979) and fishing activity (King, 1991). The exploitation rate is an index that estimates the level of utilization of a fishery. The value of the exploitation rate is based on the fact that sustainable yield is optimized when the fishing mortality coefficient is roughly equal to natural mortality (Pauly, 1983).

Significant contributions from growth studies have been made by Schaefer (1954), Beverton and Holt (1957), Ricker (1975) and Gulland (1969), among many other scientists, but these studies have focused primarily on temperate stocks. Studies examining the population dynamics of tropical fish stocks have been limited by the difficulty of aging tropical fish species, which, from the ecological perspective, inhabit a steady-state environment.

Following the adoption of Peterson's length frequency distribution method for aging tropical fishes, there have been notable contributions by Longhurst (1964), Gulland (1969) and Pauly (1980) in this area of fishery research. Despite these efforts, length–weight, length–breadth, growth, mortality and exploitation rate data are still lacking for many tropical fish species.

The current study presents this information for *Pseudotolithus* species to contribute to management and conservation policies for the further development of this fishery in Benin. The data of this study were compared with those reported in Guinea for further regional management and conservation policies, as Benin and Guinea share the same fishery resources.

2. Materials and methods

2.1. Study area, fish sampling and data collection

The study was performed in the nearshore waters of Benin (West Africa) (Fig. 1). Two sampling sites were considered. Site 1 (06°20′51″N, 2°21′58″E) is located in the fishing camp of Djako at Cotonou city. Site 1 is situated 500 m from the International Airport of Cotonou and approximately 2 km from the Port of Cotonou, which can present risks of chemical pollution because of tar released from oil tankers and phosphate residues. Site 2 (06°20′36″N, 02°14′56″E), which has no apparent risk of pollution, is located in the fishing village of Djègbadji at Ouidah city, approximately 30 km from Site 1.

Sampling was performed biweekly at both sites using commercial beach seine hauls for 18 months (March 2008–August 2009). Approximately 40% of the total biomass of *Pseudotolithus* species (2239 specimens) was sampled in the catch. A total of 2019 specimens were sexed. The samples were conveyed in thermos cool boxes to the laboratory.

The total length (TL) of the fish was measured from the tip of the anterior or part of the mouth to the extremity of the caudal fin. The standard length (SL) was measured from the tip of the mouth to the base or the articulation of the caudal fin. The fish were measured to the nearest millimeter with a fish measuring board. Fish weight was measured after blot drying with a clean hand towel. The total weight (W) was measured to the nearest 0.1 g with an electronic balance. The specimens were dissected and the internal organs were removed. The gender was determined by macroscopic examination of gonads (King, 1995). The gutted body weight (We) was determined to the nearest 0.1 g. Length data were pooled monthly from different sites and converted into length frequencies with a constant class interval of 1 cm. The mean lengths and weights of the classes were used for data analysis using the format accepted by FiSAT (Gayanilo and Pauly, 1997).

2.2. Population structure and sex ratio

The size frequency was analyzed at a 2 cm interval standard length class using a histogram to determine the type of distribution, which characterizes the fish population.

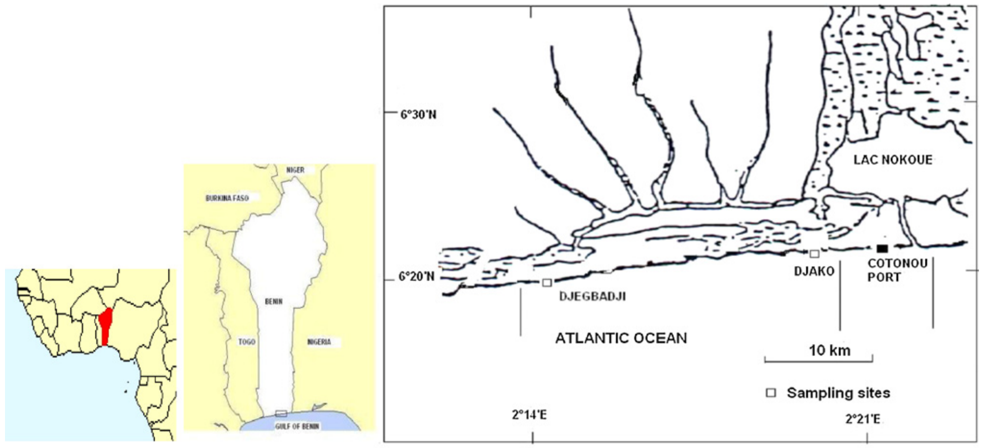
The fluctuations of the sex ratio according to fish size provide a useful tool to examine the biological characteristics of the fish species, such as sexual inversion, longevity in relation to sex, vulnerability to fishing gear and the spatial, seasonal and even daily distribution of species. With the numerical abundance by sex, the following ratio was computed (Anato, 1999):

$$\text{Sex-ratio S-R} = \frac{\text{number of males}}{\text{number of females}} \times 100$$

2.3. Length–weight relationship

The commonly used relationship $W = aL^b$ was applied (Ricker, 1975) to establish the length–weight relationship by sex, where W is the gutted weight (We, g), L is the standard length (SL, cm) and "a" and "b" are intercept and slope of the regression curve of the length and weight of the fish, respectively. Tests for differences between sexes were performed to consider the whole population together.

The correlation (r^2), which is the degree of association between the length and weight, was computed from the linear analysis.



(a) (b) (c)

Fig. 1. Maps showing Benin in Africa (a), Republic of Benin (b) and the two sampling sites (Site 1 (Djako) and Site 2 (Djègbadji)) (c).

Paired sample *t*-test within SPSS software version 16.0 was used to compare "*b*" to 3, and a Pearson correlation was used to test the significance of all regressions.

2.4. Growth and mortality parameters

The asymptotic length ($L\infty$) is the theoretical maximum length that the species would reach if it lived indefinitely, and the growth coefficient (K) is a measure of the rate at which the maximum size is attained (King, 1995).

Monthly length frequency distribution data were used to estimate $L\infty$ (cm) and growth coefficient K (yr^{-1}), which can be calculated following from (von Bertalanffy, 1938):

$$Lt = L\infty[-\exp(-K(t - t_0))].$$

The ELEFAN I and ELEFAN II routines incorporated in the FiSAT software (Gayanilo and Pauly, 1997) were used to determine $L\infty$ and K following the Powell–Wetherall method (Wetherall et al., 1987). This method was used to provide an initial estimate of $L\infty$. This initial estimate of $L\infty$ was later used as a seed value to determine the value of K (Silvestre and Garces, 2004). Minor adjustments to $L\infty$ and K were made to maximize the "goodness of fit" criterion built into ELEFAN I (Pauly, 1987).

The theoretical age at length zero (t_0) was estimated using Pauly's empirical equation (Pauly, 1979):

$$\text{Log}_{10}(-t_0) = -0.392 - 0.275\,\text{Log}_{10}L\infty - 1.038\text{Log}_{10}K.$$

The inverse von Bertalanffy growth equation (Sparre and Venema, 1992) was used to find the lengths of the fish at various ages.

To compare the growth of *P. senegalensis* and *P. typus* from the study area with those from other studies, the growth performance index (φ') was calculated. The estimates of $L\infty$ and K were used to compute the φ' (in terms of length) of the species (Munro and Pauly, 1983; Pauly and Munro, 1984):

$$\varphi' = \text{Log}_{10}K + 2\text{Log}_{10}L\infty.$$

The fitting of the best growth curve was based on ELEFAN I (Pauly and David, 1981), which allows the fitted curve through the maximum number of peaks of the length–frequency distribution.

The annual instantaneous rate of total mortality, Z, was estimated by constructing linearized length-converted catch curves (Sparre and Venema, 1992). Instantaneous natural mortality rates, M, were computed using the empirical equation of Pauly (1980) using a mean annual surface temperature (T) of 27.7 °C at Site 1 and 27.9 °C at Site 2, as described below:

$$\text{Log}_{10}M = -0.0066 - 0.279\,\text{Log}_{10}L_\infty + 0.6543\,\text{Log}_{10}K + 0.463\,\text{Log}_{10}T.$$

The instantaneous fishing mortality rate, F, was calculated as $Z–M$, and the exploitation ratio (E) was $E = F/Z$ (Pauly, 1980).

2.5. Probability of capture and length at first capture (LC or $L_{50\%}$)

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.

2.6. Exploitation rate

The exploitation rate (E) was derived by FiSAT from the linearized length-converted catch curve of each species.

3. Results

3.1. Population structure and sex ratio

The population size structure of *P. senegalensis* and *P. typus* was very similar in the two sampling sites (Fig. 2). The distribution was unimodal with a modal class interval of 24.0–26.0 cm. The body size ranges of the males and females of each species were not significantly different in each site (Table 1).

Females were more numerous than males for both species sampled at the two sites (Table 1).

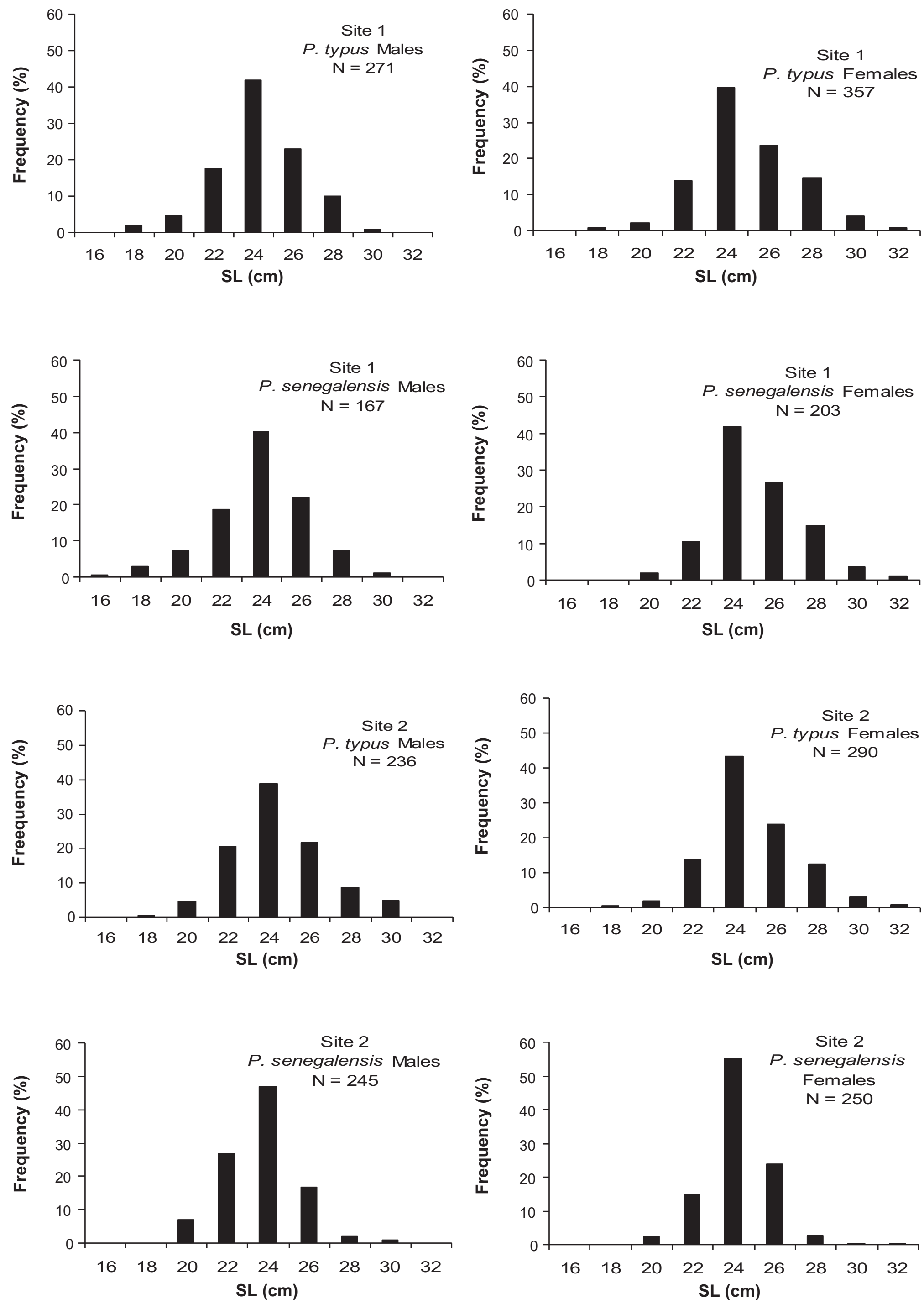


Fig. 2. Size structure of males and females of *P. typus* and *P. senegalensis* from the two sampling sites.

3.2. Length–weight relationship

The length–weight regressions for *P. typus* and *P. senegalensis* by gender are reported in Table 2. There is no significant difference between males and females in the length–weight regressions ($p > 0.05$).

The respective length–weight relationships for *P. typus* and *P. senegalensis* are presented in Fig. 3.

The body gutted weight (We) was strongly correlated with standard length (SL) ($r^2 = 0.92$) for *P. typus* (both genders) from Site 1. The correlation was strong ($r^2 = 0.85$) for *P. typus* from Site 2 and was similar for *P. senegalensis* from the two sampling sites (r^2 range 0.87–0.83).

The length exponent, or slope "*b*", for *P. typus*, with a range of 2.392–2.598 was significantly different from "3" (*t*-test, $p < 0.05$). This result implies an allometric growth of this species in both sampling sites, while *P. senegalensis* shows isometric growth because there was no significant difference between the "*b*" values and "3" (*t*-test, $p > 0.05$).

Table 1
Mean standard length (SL), mean gutted weight (We), number of specimens (N) and sex ratio (S-R) of *P. typus* and *P. senegalensis* collected at both sites.

		P. typus			*P. senegalensis*		
		N (S-R)	Mean SL (cm) (range)	Mean We (g) (range)	*N* (S-R)	Mean SL (cm) (range)	Mean We (g) (range)
Site 1	Males	271	24.5	227.3	167	23.3	233.9
			(18.2–30.9)	(75.0–379.7)		(17.5–29.1)	(72.9–394.9)
			24	227.5		25.8	263.6
	Females	357	(17.2–30.8)	(82.9–372.1)	203	(20.1–31.6)	(130.0–397.3)
	Males + Females	628	24	227.5	370	24.5	233.9
		(**75.9%**)	(17.2–30.8)	(82.9–372.1)	(**82.2%**)	(17.5–31.6)	(72.9–397.3)
Site 2	Males	236	25.0	183.0	245	25.3	256.5
			(19.7–30.4)	(96.9–369.1)		(20.4–30.2)	(128.7–384.3)
			25.6	239.1		25.8	259.7
	Females	290	(19.8–31.4)	(135.0–343.3)	250	(20.5–31.2)	(120.7–398.8)
	Males + Females	526	25.5	220.1	495	25.8	263.7
		(**81.3%**)	(19.7–31.4)	(96.9–343.3)	(**98%**)	(20.4–31.2)	(128.7–398.8)

Table 2
Length–weight relationships parameters of males and females *P. typus* and *P. senegalensis* off Benin nearshore waters.

		Gender	df	Slope	95% CI	r^2	Intercept	95% CI
Site 1	*P. typus*	Males	270	2.74	2.71–2.76	0.91	0.02	0.01–0.04
		Females	356	2.42	2.40–2.44	0.91	0.08	0.06–0.09
	P. senegalensis	Males	166	2.91	2.88–2.94	0.86	0.02	0.01–0.03
		Females	202	2.67	2.65–2.70	0.88	0.04	0.03–0.05
Site 2	*P. typus*	Males	235	2.51	2.48–2.53	0.84	0.06	0.07–0.09
		Females	289	2.39	2.37–2.41	0.87	0.09	0.08–0.11
	P. senegalensis	Males	244	2.82	2.80–2.85	0.85	0.03	0.01–0.04
		Females	249	2.86	2.88–2.93	0.81	0.02	0.01–0.03

$p < 0.001$ for all regression slopes.

3.3. *Estimation of growth parameters ($L\infty$, K, t_0) from length frequency data*

The length frequency distribution with the superimposed growth curve output for the eighteen successive months from the FiSAT analyses is shown for *P. typus* and *P. senegalensis* in Fig. 4.

A summary of the estimated parameters that describe growth in length (K, $L\infty$, t_0) and derived growth performance index (φ') is presented in Table 3.

The overall growth performance as determined by growth performance index (Fig. 4) was higher ($\varphi' = 2.753$) for *P. senegalensis* than that for *P. typus* at Site 1. However, φ' is higher for *P. typus* at Site 2 than for *P. senegalensis*.

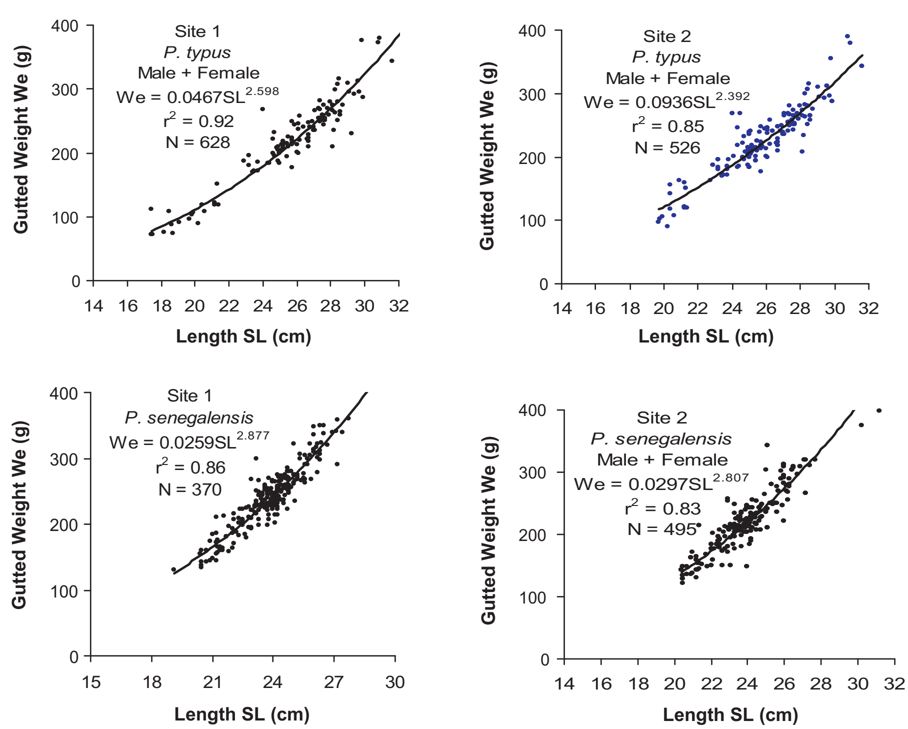


Fig. 3. Length–weight relationship of *P. typus* and *P. senegalensis* from the two sampling sites.

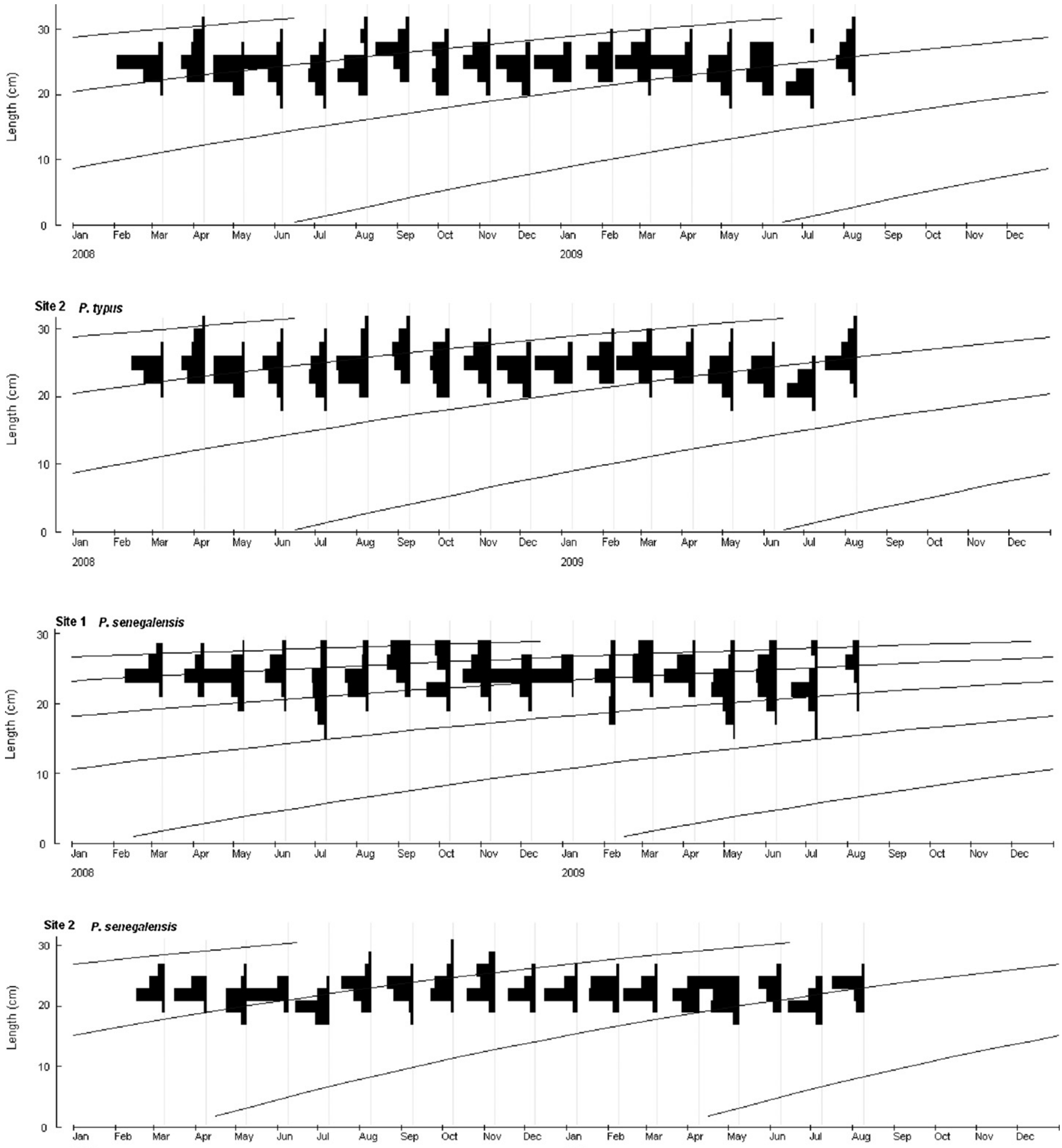


Fig. 4. Length frequency distribution output from FiSAT with superimposed growth curves for *P. typus* and *P. senegalensis* from the two sampling sites.

The lengths of the fish at various ages are presented in Tables 4 and 5. The two fish species attain at least 50% of the asymptotic length in the third year class, indicating rapid growth in length at the early age class. The growth was more rapid for individual fish from Site 1 than those from Site 2.

3.4. Estimation of mortality parameters (M, F and Z)

Fig. 5 shows the linearized length-converted catch curve which enabled estimation of the average annual instantaneous total mortality rate, Z (for fish ranging from 16.0 to 30.0 cm in standard length), as 2.65 (Site 1) and 1.60 yr^{-1} (Site

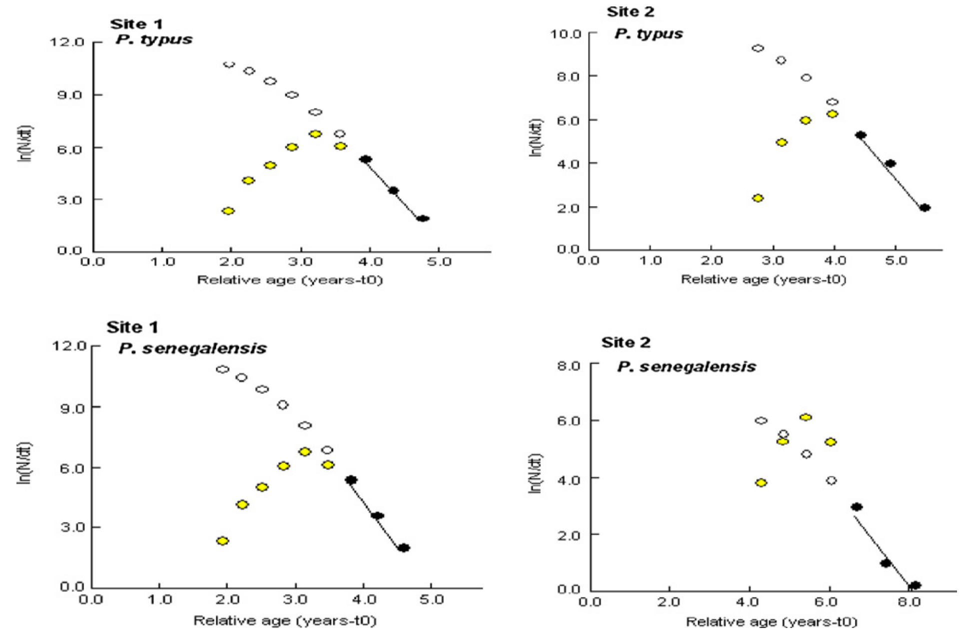


Fig. 5. FISAT output of linearized length-converted catch curve for *P. typus* and *P. senegalensis* from the two sampling sites.

Table 3
Estimated growth parameters of *P. typus* and *P. senegalensis* off Benin nearshore waters.

Sites	Species	$SL\infty$ ($TL\infty$) (cm)	K (yr^{-1})	t_0 (yr)	φ'
Site 1	*P. typus*	48.6 (56.2)	0.19	−0.73	2.652
	P. senegalensis	42.9 (51.4)	0.24	−0.60	2.753
Site 2	*P. typus*	48.6 (56.2)	0.15	−0.92	2.549
	P. senegalensis	42.9 (51.4)	0.16	−0.90	2.471

Table 4
Calculated age-length data for *P. typus* from Site 1 and Site 2 on their von Bertalanffy growth equation.

Year class (yr)	Site 1		Site 2	
	SL (TL) (cm)	%$SL\infty$	SL (TL) (cm)	%$SL\infty$
1	13.6 (18.1)	28.0	12.7 (17.1)	26.2
2	19.6 (25.1)	40.4	17.2 (22.3)	35.4
3	24.6 (30.7)	50.7	21.6 (27.3)	44.4
4	28.8 (35.3)	59.2	25.3 (31.5)	52.1
5	32.2 (39.0)	61.1	28.6 (35.1)	58.8

2) for *P. typus* and as 3.26 and 0.91 yr^{-1}, respectively, for *P. senegalensis*.

The estimated instantaneous fishing mortality rate F = 0.42 yr^{-1}, for *P. senegalensis* at Site 2 seemed to be close to the estimate of the rate of natural mortality of 0.49 yr^{-1} and could be a life history strategy at Site 2 as this mortality was reflected in its near optimal level of exploitation.

Table 5
Calculated age-length data for *P. senegalensis* from Site 1 and Site 2 on their von Bertalanffy growth equation.

Year class (yr)	Site 1		Site 2	
	SL (TL) (cm)	%$SL\infty$	SL (TL) (cm)	%$SL\infty$
1	13.7 (18.3)	31.8	11.2 (15.3)	26.1
2	19.9 (25.6)	46.4	15.9 (20.9)	37.1
3	24.8 (31.3)	57.8	19.9 (25.7)	46.4
4	28.7 (35.7)	66.8	23.3(29.6)	54.3
5	31.7 (39.1)	73.9	26.2 (32.9)	61.0

3.5. Probability of capture and length at first capture (LC or $L_{50\%}$)

Fig. 6 shows the probability of fish capture and give the length at first capture, as reported below:

P. typus: (Site 1): $L_{50\%}$ = 22.76 cm; (Site 2): $L_{50\%}$ = 21.59 cm.
P. senegalensis: (Site 1): $L_{50\%}$ = 25.76 cm; (Site 2): $L_{50\%}$ = 19.84 cm.

In comparison with the length at first sexual maturation (L_{50} falls within the range of 23.8–24.0 cm for both species, Sossoukpe, 2011), it appeared that only *P. senegalensis* at Site 1 reached first sexual maturation before first capture. A total of 75% of *P. typus* species could be captured ($L_{75\%}$ range 22.05–23.36 cm) without reaching sexual maturity, indicating a high catching probability of juveniles of *P. typus* by beach seine.

3.6. Exploitation rate

According to Fig. 5, the exploitation rate was 0.90 (Site 1) and 0.86 (Site 2) for *P. typus and* 0.91 (Site 1) and 0.82 (Site 2) for *P. senegalensis*. Using the E_{opt} = 0.5 criterion (Pauly and Munro, 1984), this result implies that *P. typus* and *P. senegalensis* at both sites were over exploited.

4. Discussion

4.1. Population structure and sex ratio

The estimated theoretical maximum length for *P. typus* ($TL\infty$ = 56.3 cm at both sites) suggests that the *P. typus* stock being exploited at the two sites consists of relatively smaller-sized individuals; the same applies to *P. senegalensis* ($TL\infty$ = 51.4 cm). Larger specimens reaching TL 108 cm (*P. typus*) and TL 100 cm (*P. senegalensis*) have been reported in Guinea by Sidibé (2003), where the size distribution parameters of modal length were 24.44 cm (range 12–76 cm) for *P. typus* and 23.15 cm (range 13–54 cm) for *P. senegalensis*. These modal lengths are notably close to those reported in the current study, indicating the dominance of juveniles in these catches.

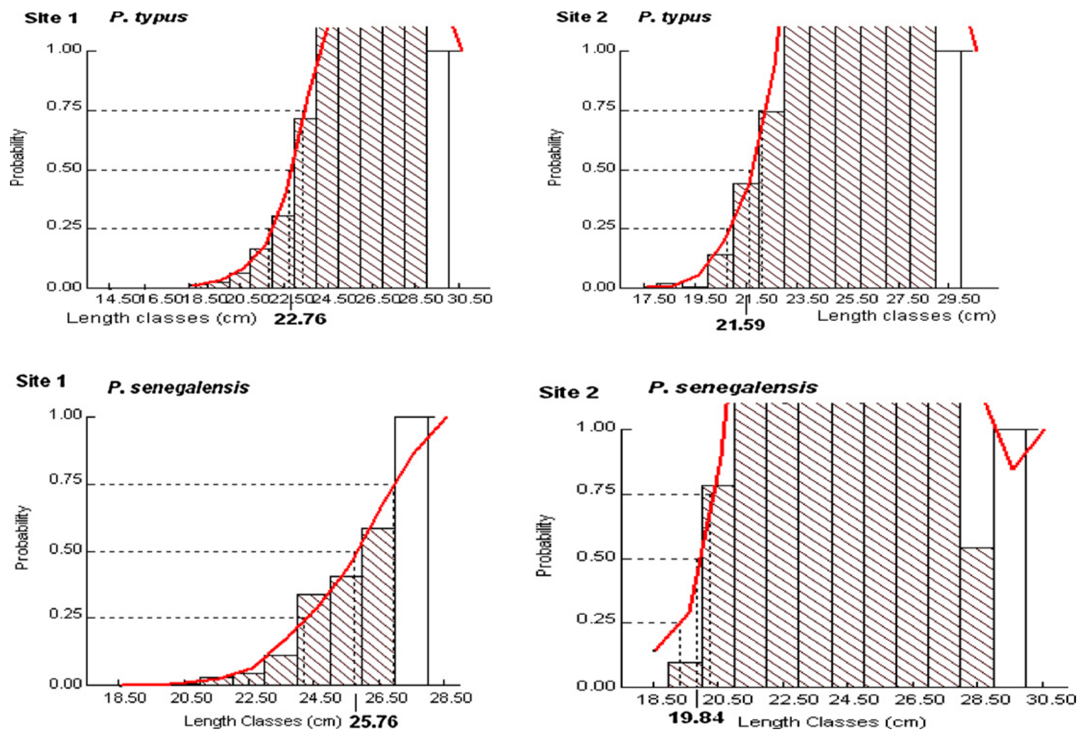


Fig. 6. FISAT output of probability of capture for *P. typus* and *P. senegalensis* from the two sampling sites.

The population structure of both species was unimodal, and females were more numerous than males. Variations of the sex ratio according to size have a considerable impact on the fertility of stocks according to whether the adult individual majority captured is female or male. Also, it is necessary to keep in mind that the sex ratio of the population is calculated from catches and that the observed variations can be an indication of catchability between the two sexes. However, the sex ratio is influenced by many factors. According to Bertin (1958) and Lissia Frau (1966), the difficulties of determining the sex of immature and hermaphrodite individuals could greatly affect the proportion of males and females obtained.

4.2. Length–weight relationship

Ricker (1975) noted that the value of “*b*” in the length–weight relationship should be exactly “3” if the growth is isometric. This cube law relationship is hardly expected, as most of the species change their shape (Hile, 1936). These changes are due to sex, maturity, season and even the time of day due to stomach content (Bagenal, 1978). *P. senegalensis* in the present investigation shows an isometric growth, which implies that the fish length increases in equal proportion with fish body weight for constant specific gravity. However, this isometric growth pattern does not agree with the results of Djama (1988), N'jock, 1990 and Sidibé (2003), as reported in Table 6. The “*b*” values found by these authors were higher than those in the present investigation, perhaps to the dominance of juveniles in the beach seine hauls. The growth in *P. typus* at both sites was negatively allometric, implying that the fish length increased more rapidly than the fish body weight. The coefficient of correlation between standard length and gutted body weight (Fig. 3) was found to be highly significant (Pearson correlation, $p = 0.005$ at 5% level of significance).

4.3. Growth and mortality parameters

The φ' mean values of *P. typus* and *P. senegalensis* (Table 7) were close to those Sidibé (2003) found in Guinea. However, K (yr^{-1}) was lower, and t_0 was higher, than what was reported in Guinea, indicating that the maximum size is more rapidly attained for *Pseudotolithus* species in Guinea than for those in Benin.

Baijot and Moreau (1997) estimated that the φ' mean value for some important fishes in Africa have a range of 2.65–3.32, which they considered as low. In this study, the φ' mean estimates for *P. typus* were 2.652 (Site 1) and 2.549 (Site 2). These values fall within this low range; therefore this species and *P. senegalensis* (2.753 at Site 1 and 2.471 at Site 2), may be regarded as showing a slow growth rate in Benin's nearshore waters. This slow growth rate may be induced by changes in the physical and chemical characteristics of the water (Ofori et al., 2002).

The linear growth of the two fish species was compared with that recorded by other authors in other regions in Africa (Tables 8 and 9). For *P. senegalensis*, the growth was similar to that reported in Sierra Leone, Senegal and Cameroon (Coutin and Payne, 1989; Sun, 1975; N'jock, 1990), but it was more rapid in Guinea than Benin (Sidibé, 2003). The linear growth of *P. typus* was low compared with that found in other regions.

Table 10 shows that the total instantaneous mortality Z and the fishing mortality F of *P. typus* reported in the current study were higher than what were found by Sidibé (2003). However, the

Table 6
Length–weight relationships derived by other authors.

Species	L–W relationship	Authors	Countries
P. typus	$W = 0.0036TL^{3.164}$	Djama (1988)	Cameroon
	$W = 0.0063TL^{3.030}$	N'jock (1990)	Cameroon
	$W = 0.0072TL^{2.970}$	Sidibé (2003)	Guinea
	$W = 0.0467SL^{2.598}$	Current study (Site 1)	Benin
	$W = 0.0936SL^{2.392}$	Current study (Site 2)	Benin
P. senegalensis	$W = 0.0038TL^{3.224}$	Djama and Pitcher (1989)	Cameroon
	$W = 0.0041TL^{3.206}$	N'jock (1990)	Cameroon
	$W = 0.0080TL^{3.022}$	Sidibé (2003)	Guinea
	$W = 0.0259SL^{2.877}$	Current study (Site 1)	Benin
	$W = 0.0297SL^{2.807}$	Current study (Site 2)	Benin

Table 7
Estimated growth parameters of *P. typus* and *P. senegalensis* off Benin nearshore waters compared to those off Guinea.

	Authors (year)	Country	$TL\infty$ (cm)	K (yr^{-1})	t_0 (yr)	φ'
P. typus	Current study	Benin Site 1	56.2	0.19	−0.730	2.652
		Benin Site 2	56.2	0.15	−0.920	2.549
	Sidibé (2003)	Guinea	73.8	0.35	−0.149	3.280
P. senegalensis	Current study	Benin Site 1	51.4	0.24	−0.600	2.753
		Benin Site 2	51.4	0.16	−0.900	2.471
	Sidibé (2003)	Guinea	60.8	0.35	−0.329	3.112

Table 8
Linear growth of *P. senegalensis* in comparison with what others reported.

Authors & year	Country	1 yr	2 yrs	3 yrs	4 yrs	5 yrs
Current	Benin Site 1	18.3	25.68	31.34	35.72	39.13
study	Benin Site 2	15.31	20.98	25.7	29.61	32.92
Coutin and Payne (1989)	Sierra Leone	13.81	24.45	32.66	38.99	43.87
Sun (1975)	Senegal	9.77	18.01	24.97	30.84	35.79
Troadec (1971)	Congo	23.12	31.85	38.01	42.35	45.41
N'jock (1990)	Cameroon	11.16	19.94	26.84	32.27	36.55
Sidibé (2003)	Guinea	23.15	36.67	44.71	49.49	52.23

Table 9
Linear growth of *P. typus* in comparison with what others reported.

Authors (year)	Country	1 yr	2 yrs	3 yrs	4 yrs	5 yrs
Current	Benin site 1	18.12	25.14	30.77	35.33	39.04
study	Benin site 2	17.11	22.35	27.34	31.54	35.10
Poinsard (1973)	Congo	26.86	36.96	45.43	52.54	58.51
Bayagbona (1969)	Nigeria	29.21	47.79	61.68	72.09	79.87
N'jock (1990)	Cameroon	14.26	25.24	33.69	40.19	45.19
Sidibé (2003)	Guinea	24.44	36.97	46.07	52.68	57.48

Table 10
Estimated mortality parameters of *P. typus* and *P. senegalensis* off Benin nearshore waters compared to those off Guinea.

	Authors	Regions	Z	M	F	E
P. typus	Current study	Benin Site 1	2.65	0.52	2.13	0.90
		Benin Site 2	1.60	0.45	1.15	0.86
	Sidibé (2003)	Guinea	0.84	0.66	0.60	0.65
P. senegalensis	Current study	Benin Site 1	3.26	0.63	2.63	0.91
		Benin Site 2	0.91	0.49	0.42	0.82
	Sidibé (2003)	Guinea	1.20	0.97	0.51	0.64

natural mortality, M, was similar in Benin and in Guinea. Similarly, The Z and F of *P. senegalensis* from Site 1 in the current study were higher than those reported in Guinea. At Site 2, the mortality parameters of this fish species were much lower than those in Guinea. The variation of these values in different regions may be due to ecological differences, physiological conditions of the fish, feeding variability, fishing pressure and sampling (Biswas, 1993).

4.4. Exploitation rate, probability of capture and management measures

P. typus and *P. senegalensis* are heavily over exploited in Benin if the $E_{opt} = 0.5$ criterion is considered ($E > E_{opt}$). Similar results were reported in Guinea (Sidibé, 2003). The over exploitation could impact recruitment if individuals are captured while laying eggs. This situation, reinforced by a high catching probability of juveniles (size at first sexual maturation greater than size at first capture of 50% of the individuals), may cause a greater reduction in catch in the near future.

One way to ease pressure further on these fish resources is to encourage government, fishery managers, private sectors and all relevant stakeholders to help fishers in general and beach seine fishers in particular, to strengthen their supplementary jobs and diversify their livelihoods.

Certain immediate management actions, such as size-limit regulation by gradually increasing beach seine mesh size and time-limit regulation by restricting fishing outside spawning seasons, are considered necessary to help improve the growth and exploitation of the stock of the two *Pseudotolithus* species.

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