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Population Dynamics of *Pseudotolithus Senegalensis* and *Pseudotolithus Typus* and Their Implications for Management and Conservation within the Coastal Waters of Liberia

Austin Saye Wehye[1*], **Patrick K Ofori-Danson**[2] **and Angela Manekuor Lamptey**[2]

[1]*Bureau of National Fisheries, Ministry of Agriculture, Liberia*

[2]*Department of Marine and Fisheries Sciences, University of Ghana*

***Corresponding author:** Austin Saye Wehye, Bureau of National Fisheries, Ministry of Agriculture, Liberia, Tel: +231775717273; E-mail: austinwehye@yahoo.com

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Abstract

The study evaluated some aspect of population parameters of *Pseudotolithus senegalensis* and *Pseudotolithus typus* within Liberia's coastal waters. A total of 177 and 152 samples of *P. senegalensis* and *P. typus* respectively were collected from July to December, 2016. Individual fish samples was measured for standard length and analysed using FiSAT II software. From the results, *P. senegalensis* growth parameter were estimated at asymptotic length (L_∞)=66.68 cm, growth rate (K)=0.13 yr^{-1}, the longevity (t_{max})=21.49 years, theoretical age at birth (t_0)=-1.586 years and growth performance index (φ')=2.762. While *P. typus* growth parameters asymptotic length (L_∞)=66.68 cm, growth rate (K)=0.14 yr^{-1}, the longevity (t_{max})=19.3 years, theoretical age at birth (t_0)=-2.126 years and growth performance index (φ')=2.294. Mortality parameters for *P. senegalensis* and *P. typus* were calculated as total mortality rate (Z)=0.93 yr^{-1} and 0.70 yr^{-1}, natural mortality rate (M)=0.37 $yr^{-1}$and 0.39 yr^{-1} and fishing mortality rate (F)=0.56 yr^{-1} and 0.31 yr^{-1} respectively. The calculated fishing mortality rates (F) compared to F_{opt}=0.4M were beyond the limit for sustainable fishing. The exploitation rate (E) of *P. senegalensis* (E=0.60) was higher than the E_{opt}=0.5 criterion. It implies that *P. senegalensis* is overexploited while *P. typus* was at the peak of exploitation (E=0.45). Results from the study revealed that the *P. senegalensis* fishery in Liberia is slightly overexploited while *P. typus* is at the optimal level of exploitation; as well as the presence of growth overfishing within the two species population within Liberian coastal waters. Thus, to avert the consequences of growth overfishing, sustainable fisheries measures including monitoring of fishing efforts, and increase in mesh size should be implemented and enforced.

Keywords: Liberia; *Pseudotolithus senegalensis; Pseudotolithus typus;* Growth; Mortality; Exploitation rate

Introduction

The world per capita fish consumption is reported to have increased from an average of 9.9 kg in the 1960s to 19.2 kg in 2012 [1]. On the other hand, the proportion of assessed marine fish stocks fished within biologically sustainable levels declined from 90% in 1974 to 71.2% in 2011, with 28.8% of fish stocks estimated to be overfished [1]. Although fish are renewable resources, this huge irremediable depletion of marine biodiversity by location and depth partly due to intense fishing activities has led to decline of marine capture fisheries [2,3]. The declining trend in global marine catches has led some fisheries scientists to forecast the collapse of ocean fisheries [4]. More so, the trends in catches forecast that more stocks will become overexploited and collapsed [5].

The total marine landed catch for Liberia was estimated at 1,570.82 tons in 2013 excluding artisanal catch and drop speedily to 204 tons in 2014 (BNF unpublished data, 2016). This drastic decline may be due to the reduction in fishing fleets from four (4) vessels in 2013 to two (2) vessels in 2014. The family *Sciaenidae* was among the species targeted. There was a new development in 2016 that increased the fishing intensities on this family. It was the main focus of export by local exporters to Asian markets. This has enticed local artisanal fishers to target *Pseudotolithus senegalensis* and *Pseudotolithus typus* by doubling the price per pound from one United States dollar to two United States dollars and providing outboard motors. This has exacerbated the already existing tension on these species that are mostly consumed by Liberian.

In Liberia, factors such as poor fisheries data collection, limited resources, conflicts and illegal, unregulated and unreported (IUU) do not only make it difficult to estimate the status of almost all of the marine biodiversity but also presents a great challenge to fisheries managers [6,7]. However, Togba [8] reported that Sardinella, Barracudas, Croakers (*P. senegalensis* and *P. typus*), Sharks and Ilisha africana constituted 83% and 59.06% of local fish supply in 2004 and 2005 respectively; indicating that there has been a declined in fish catches.

Furthermore, the paucity of information on population parameters and biology pertaining to commercially important fish species within Liberian coastal waters cripples any management interventions geared towards sustainable fisheries in Liberia. It is against this backdrop that the present study sought to estimate some population parameters of the family *Sciaenidae* residing in Liberian coastal waters to enhance already existing management interventions.

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Methodology

Study area

Liberia is a relatively small coastal state located in West Africa with geographical coordinates as 6.4281 °N, 9.4295 °W. The coastline of Liberia is 570 kilometers comprising of relatively warm waters and low nutrient contents [9]. However, the study focused on two fish landing sampling stations (ELWA, N 06.23355° and W 010.69365°; and Marshall, N 06.13833° and W 010.38171°) within two coastal counties along the coastline of Liberia (Figure 1).

The main source of livelihood for the majority of the inhabitants residing within the selected two fish landing sampling stations is fishing and its related activities such as fish processing and fish trade. However, a few of the indigenes are engaged in alternative forms of livelihoods including farming, driving, and others.

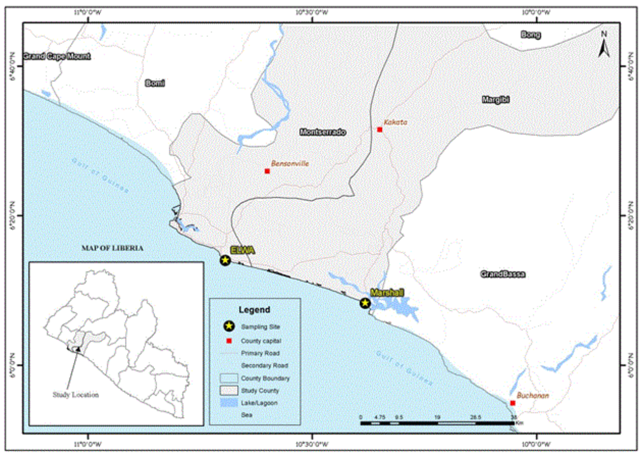

Figure 1: Map showing the sampling sites and Liberia map.

Data collection

Monthly fish samples were collected from artisanal fishermen who operated with multifilament gears from the selected fish landing stations. Fish sample collection was performed from July, 2016 to December, 2016 (six months). According to Pauly [10] analysis of the structure of fish population requires at least data collected over a period of six months. Morphometric measurements of the obtained fish samples including standard length and weights were recorded in the lab at the Bureau of National Fisheries. The standard length was measured using the 100 cm Measuring Board to the nearest 0.1 cm, whereas the weight was measured using the electronic weighing scale to the nearest 0.01 g. Fish samples were identified to the species level using fish identification keys by Schneider [11]. In all, a total of 177 and 152 specimens of *Pseudotolithus senegalensis* and *Pseudotolithus typus* respectively were sampled.

Growth and mortality parameters

The growth of the fish was assumed to follow the von Bertalanffy's growth function (VBGF) which has the basic form $L_t=L_\infty(1-e^{-K(t-t_0)})$. Where, L∞ is the asymptotic length that is the mean length the fish of a given stock would reach if they were to grow indefinitely, K is a growth constant, t0 is the age of the fish at zero length, Lt is the length at age and t is age at length. These parameters were fitted in FISAT II [12] for estimation. Pauly's [13] empirical equation for the theoretical age at length zero (t0) was used to obtain this parameter as$\log_{10}(-t_0)=-0.392 - 0.275\log_{10} L_\infty - 1.038\log_{10}K$.

In order to compare different estimations of growth parameters, the empirical equation of growth performance,

$\varphi=\log_{10}k + 2\log_{10}(L_\infty)$, of Pauly and Munro [14] was used.

The total instantaneous mortality rate (Z) was estimated using length converted catch curve method as implemented in FiSAT II. Natural mortality rate (M) was estimated using Pauly's empirical relationship using a mean surface temperature (T) of 27°C:

$\text{Log } M=- 0.0066 - 0.279 \log L_\infty + 0.6543 \log K + 0.4634 \log T$ [15],

Where M is the instantaneous natural mortality, L∞ is the asymptotic length, T is the mean surface temperature and K refers to the growth rate coefficient of the VBGF. Fishing mortality (F) was calculated using the relationship: F=Z–M [16], where Z is the total mortality, F the fishing mortality and M is the natural mortality. The exploitation level (E) was obtained using the relationship: E=F/Z [16],

Optimum fishing (F_{opt}) which is directly related to the natural mortality (M) was calculated for the selected fish species using the expression below:

$F_{opt}=0.4M$ ....[14].

Length at first capture (L_{C50})

The ascending left arm of the length converted catch curve incorporated in FiSAT II tool was used to estimate the probability of length at first capture (L_{c50}) in addition to the length at both 25 and 75 captures which corresponded to the cumulative probability at 25% and 75% respectively. The probability of capture gives clear idea about the estimate of the real size of the fish in the fishing area that is being caught by specific gear. It is an important tool for fisheries managers in sustainably managing a target fishery, because it helps would be managers determining the minimum mesh size of a fishing fleet.

Length at first maturity (L_m)

To estimate the length at first maturity (L_m) for the assessed species, the procedure by Hoggarth et al. [17] below was used. The input parameters for the model included asymptotic length only (L_∞).

Length at first maturity $(L_m)=L_\infty * 2/3$..............................[17].

Recruitment pattern and yield per recruit

The recruitment pattern of the stock was determined by backward projection on the length axis of the set of available length-frequency data as described in FiSAT. This routine reconstructs the recruitment pulse from a time series of length–frequency data to determine the number of pulses per year and the relative strength of each pulse. Input parameters included L_∞ and K. Normal distribution of the recruitment pattern was determined by NORMSEP (Separation of the normally distributed components of size-frequency samples) [18] in FiSAT. The midpoint of the smallest length group in the catch was estimated as the length at recruitment (Lr) length at recruitment [19].

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The relative biomass per recruit (B'/R) was estimated as B'/R=(Y'/R)/F. E_{max} which depicts exploitation rate producing maximum yield, $E_{0.1}$ highlighting exploitation rate at which the marginal increase of Y'/R is 10% of its virgin stock with $E_{0.5}$ implying exploitation rate under which the stock is reduced to half its virgin biomass were computed using the procedure incorporated using the Knife-edge option fitted in the FiSAT II Tool.

Data Analysis

The length frequency data were pooled into groups with 1cm length intervals. Then the data were analyzed using the FiSAT II (FAO-ICLARM Population Assessment Tools) software [12].

Results

Growth parameters

Figure 2 show the restructured length frequency with superimposed growth curves. The observed curves of growth portrayed the existence of six cohorts within the population of both targeted species.

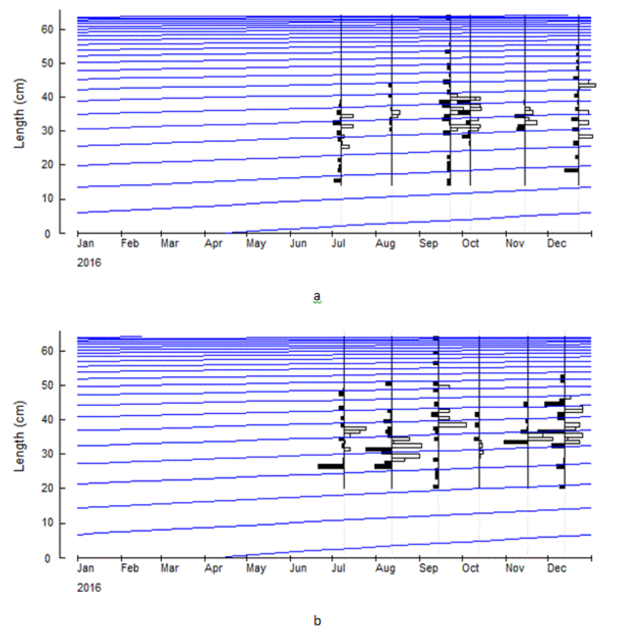

Figure 2: a. Restructured frequency distribution output from FiSAT II with superimposed growth curves for *P. senegalensis*. b. Restructured frequency distribution output from FiSAT II with superimposed growth curves for *P. typus*.

The asymptotic length (L_∞) and growth rate/ constant (K) for the two targeted species were estimated at 66.68 cm SL and 0.13 yr^{-1} respectively with its longevity (t_{max}) as 21.49 years for *P. senegalensis*, while the asymptotic length (L_∞) and growth rate/constant (K) for *P. typus* were 66.68 cm SL and 0.14 yr^{-1} correspondingly, with its longevity as 19.3 years. The growth performance index (φ') and theoretical age at birth (t_0) were estimated at 2.762 and -1.686 years for *P. senegalensis* whereas *P. typus* recorded 2.294 and -2.126 years for growth performance index (φ') and theoretical age at birth (t0) respectively. Using the estimated growth parameters (L_∞, K and t_0), the VBGF for length at time (t) for the two targeted species were expressed as:

P. senegalensis

$$SL_t=66.68\ (1-e^{-0.13\ (t-(-1.586)})$$

P. typus

$$SL_t=66.68\ (1-e^{-0.14\ (t-(-2.126))})$$

Estimated growth parameters of *P. senegalensis* and *P. typus* in the current study were compared to what other authors reported in different localities (Table 1).

Species	Authors	Country	SL_∞	K	φ'	t_0
P. senegalensis	Sidibe [20]	Guinea	60.8 (TL)	0.35	3.112	-0.329
	Sossoukpe [21]	Benin (Site 1)	42.98	0.24	2.753	-0.60
	Sossoukpe [21]	Benin (site 2)	42.98	0.16	2.549	-0.90
	Current study	Liberia	66.68	0.13	2.762	-1.586
P. typus	Sidibe [20]	Guinea	73.8 (TL)	0.35	3.280	-0.149
	Sossoukpe [21]	Benin (Site 1)	48.6	0.19	2.652	-0.73
	Sossoukpe [21]	Benin (site 2)	48.6	0.15	2.549	-0.92
	Current study	Liberia	66.68	0.14	2.294	-2.126

Table 1: Estimated growth parameters of *P. senegalensis* and *P. typus* from the current study compared to other authors.

The above equations were used to estimate the lengths of the two species of *Sciaenidae* at various ages (Table 2). *P. senegalensis* attain at least 50% of the asymptotic length when at the fourth class, while *P. typus* attain at least 50% of the asymptotic length when at the third class.; both indicating less rapid growth in length at the early age class (Table 2).

Age class (yr)	*Pseudotolithus senegalensis*		*Pseudotolithus typus*	
	SL (TL) (cm)	% of L_∞	SL (TL) (cm)	% of L_∞
1	19.04 (21.14)	29	23.63 (26.24)	35
2	24.85 (27.58)	37	29.26 (32.48)	44
3	29.95 (33.25)	45	34.15 (37.91)	51
4	34.42 (38.22)	52	38.4 (42.63)	58
5	38.36 (42.58)	58	42.09 (46.73)	63

Table 2: Calculated age-length data for the two-sciaenid based on their respective von Bertalanffy growth equation.

In doing a comparative analysis of the calculated age-length data of both species for the current study, the estimated values were compared with what other authors reported in different countries (Table 3).

Species	Authors	Country	1yr	2yrs	3yrs	4yrs	5yrs
P. senegalensis	Troadec [22]	Congo	23.12	31.85	38.01	42.35	45.41
	Sun [23]	Senegal	9.77	18.01	24.97	30.84	35.79
	Coutin and Payne [24]	Sierra Leone	13.81	24.45	32.66	38.99	43.87
	Njock [25]	Cameroon	11.16	19.94	26.84	32.27	36.55
	Sidibe [20]	Guinea	23.15	36.67	44.71	49.49	52.23
	Sossoukpe [21]	Benin (Site 1)	18.3	25.68	31.34	35.72	39.13
	Sossoukpe [21]	Benin (site 2)	15.31	20.98	25.7	29.61	32.92
	Current study	Liberia	21.14	27.58	33.25	38.22	42.58
P. typus	Bayagbona [26]	Nigeria	29.21	47.79	61.68	72.09	79.87
	Poinsard [27]	Congo	26.86	36.96	45.43	52.54	58.51
	Njock [25]	Cameroon	14.26	25.24	33.69	40.19	45.19
	Sidibe [20]	Guinea	24.44	36.97	46.07	52.68	57.48
	Sossoukpe [21]	Benin (Site 1)	18.12	25.14	30.77	35.33	39.04
	Sossoukpe [21]	Benin (site 2)	17.11	22.35	27.34	31.54	35.10
	Current study [28]	Liberia	26.24	32.48	37.91	42.63	46.73

Table 3: Calculated age-length data of *P. senegalensis* and *P. typus* of the fisheries waters of Liberia compared with what others reported.

Mortality coefficients and current exploitation rate

Figure 3 shows the calculated mortalities from the length converted catch curve fitted in the FiSAT II (Table 4). From Figure 3, mortality parameters for *P. senegalensis* were estimated as: Z=0.93 yr^{-1}, M=0.37 yr^{-1} and F=0.56 yr^{-1} whereas the estimates for *P. typus* were Z=0.70 yr^{-1}, M=0.39 yr^{-1} and F=0.31 yr^{-1} (Table 5). However, the dark circles in the figure represent the points used in calculating (Z) through least squares regression lines. The yellow circles represent frequencies of fishes either not fully recruited or approaching (L_∞), and hence discarded from the calculation. The estimated optimum fishing mortality rate for *P. senegalensis* and *P. typus* were F_{opt}=0.37 yr^{-1} and F_{opt}=0.28 yr^{-1} respectively. The values of M/K ratio were 2.85 and 2.79 for *P. senegalensis* and *P. typus*, respectively (Table 6).

Species	Authors	Country	Z (yr^{-1})	M (yr^{-1})	F (yr^{-1})	E
P. senegalensis	Sidibe	Guinea	1.20	0.97	0.51	0.64
	Sossoukpe (2011)	Benin (Site 1)	3.26	0.63	2.63	0.81
	Sossoukpe (2011)	Benin (site 2)	0.91	0.49	0.42	0.47
	Current study	Liberia	0.93	0.37	0.56	0.60
P. typus	Sidibe (2003)	Guinea	1.26	0.66	0.60	0.65
	Sossoukpe (2011)	Benin (Site 1)	2.65	0.52	2.13	0.80
	Sossoukpe (2011)	Benin (site 2)	1.60	0.45	1.15	0.72
	Current study	Liberia	0.70	0.39	0.31	0.45

Table 4: Estimated mortality parameters of *P. senegalensis* and *P. typus* of the fisheries waters of Liberia compared to those off other regions.

From Table 6, the current exploitation rate of the two species were estimated as follow: for *P. senegalensis* it was estimated $E_{current}$=0.60 and $E_{current}$=0.45 for *P. typus*. The Z/K ratio were estimated as 7.15 and 5.00 for *P. senegalensis* and *P. typus* respectively. The reliability of the estimated natural mortality rate, M, was ascertained using the M/K ratios because this ratio has been reported to be within the range 1.12-2.5 for most of the fish [28].

Species	TL_{m50} (cm)	TL_{c50} (cm)	Authors	Localities
P. senegalensis	44.5 (SL)	33.84 (SL)	Current study	Liberia
	30.4	25.5	Sossoukpe [21]	Benin
	29.0	-	Sidibe [20]	Guinea
	31.0	-	Domain et al. [29]	Guinea
	26.5	-	Jock [25]	Cameroon
	26.4- 28.0	-	Troaddec [22]	Congo
P. typus	44.5 (SL)	30.23	Current study	Liberia
	30.1	22.76	Sossoukpe [21]	Benin
	40.0	-	Sidibe [20]	Guinea
	37.0	-	Domain et al [29]	Guinea
	26.5	-	Jock [25]	Cameroon
	33.0	-	Fontana [30]	Congo

Table 5: Estimated length at first capture and length at first maturity of *P. senegalensis* and *P. typus* of the fisheries waters of Liberia compared to those off other regions.

Parameters	*P. senegalensis*	*P. typus*
SL_∞ (cm)	66.68 (TL_∞=74.03)	66.8 (TL_∞=74.03)
K (yr^{-1})	0.13	0.14
φ'	2.762	2.294
t_0 (yr^{-1})	-1.586	-2.126
t_{max} (yrs)	21.49	19.3
Z (yr^{-1})	0.93	0.70
M (yr^{-1})	0.37	0.39
F (yr^{-1})	0.56	0.31
M/K	2.85	2.79
Z/K	7.15	5.00
F_{opt} (yr^{-1})	0.37	0.28
$E_{current}$	0.60	0.45
L_{c25}(cm)	30.57	28.46
L_{c50}(cm)	33.84	30.23
L_{c75}(cm)	37.11	32.00
L_{m50}(cm)	44.45	44.45
L_c/L_∞	0.51	0.45
$E_{0.1}$	0.807	0.704
$E_{0.5}$	0.376	0.357
E_{max}	0.963	0.829

Table 6: Summary of estimated growth and other derived fish population parameters for the two species of concern from July 2016 to December 2016.

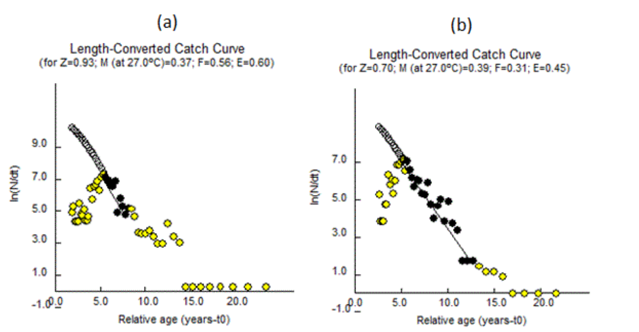

Figure 3: FISAT II output of linearized length-converted catch curve for *P. senegalensis* and *P. typus* (a for *P. senegalensis* and b for *P. typus*).

Estimated mortality parameters of both species were compared with what other authors reported from different regions in Africa (Table 4).

Length at first capture (L_{c50}) and Length at first maturity (L_{m50})

Figure 4 shows the probability of capture and length at first maturity for the two targeted fish species. The probability of capture for *P. senegalensis* and *P. typus* at 25%, 50% and 75% were estimated as: 30.57 cm, 33.84 cm and 37.11 cm for *P. senegalensis* and 28.46 cm,

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30.23 cm and 32 cm for *P. typus* respectively. The length at first maturity (Lm50) was estimated at 44.5 cm for both species (Table 6). Figure 4 below shows FiSAT II output of the probability of capture. The estimated Lc/L∞ ratios using the relationship between the Length at first maturity (L_{c50}) and the asymptotic length (L∞) for the two-treated species were 0.51 and 0.45 for *P. senegalensis* and *P. typus* correspondingly (Table 6).

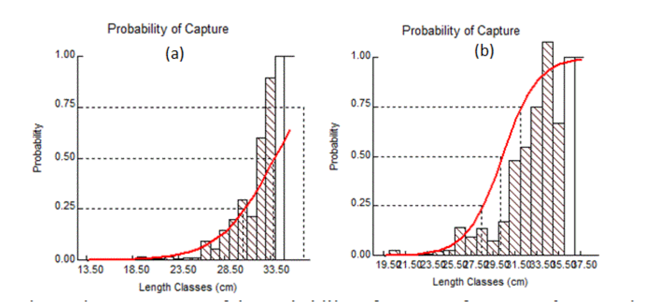

Figure 4: FiSAT II output of the probability of capture of *P. senegalensis* and *P. typus* respectively in the fisheries waters of Liberia (0.2, 0.50 and 0.75 relates to 25%, 50% and 75% respectively).

Estimated length at first capture and length at first maturity of *P. senegalensis* and *P. typus* of the present study compared with those of other authors from different localities (Table 5).

Recruitment pattern

Figure 5 shows the recruitment pattern of the two targeted fish species *P. typus* and *P. senegalensis*. The recruitment pattern for the two targeted fish species was continuous throughout the period of study with two recruitment peaks-major and minor (Figure 5). Using macro inspection, the months for the major and minor recruitment peaks were May and September for *P. senegalensis*, and October and May for *P. typus* correspondingly. The calculated length at recruitment were 8.52 cm and 9.53 cm for *P. senegalensis* and *P. typus* respectively (Figure 5).

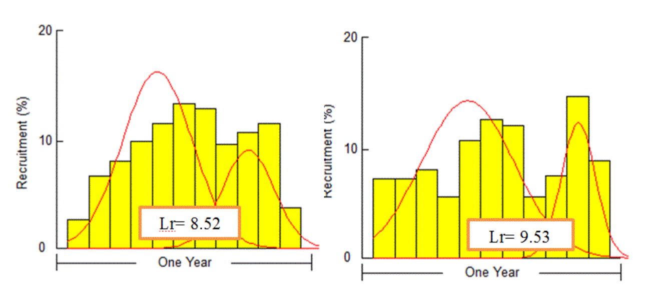

Figure 5: FiSAT II output of recruitment patterns of *P. senegalensis* and *P. typus* respectively.

Relative yield per recruit (Y'/R)

Figure 6 shows the various exploitation rates based on the Beverton and Holt relative yield per recruit model. E_{max} which implies exploitation rate producing maximum yield (yellow dashes), $E_{0.1}$ suggesting exploitation rate at which the marginal increase of Y'/R is 10% of its virgin stock (green dashes) and $E_{0.5}$ indicating exploitation rate under which the stock is reduced to half its virgin biomass (red dashes) of *P. senegalensis* and *P. typus* were estimated as $E_{0.1}$=0.807, $E_{0.5}$=0.376 and E_{max}=0.963; and $E_{0.1}$=0.704, $E_{0.5}$=0.357 and E_{max}=0.829 respectively (Figure 6). Table 5 showed the actual values of $E_{0.1}$, $E_{0.5}$ and E_{max} by sexes of the targeted fish species.

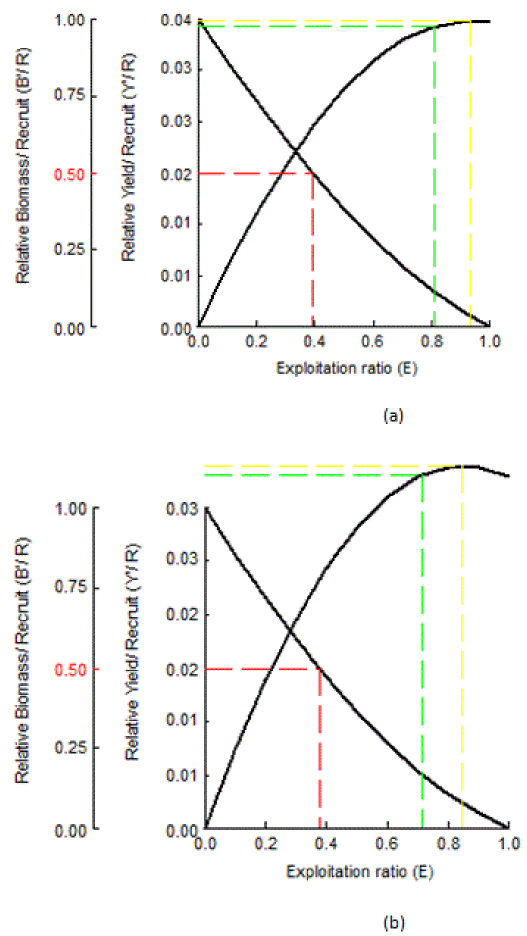

Figure 6: (a) Beverton and Holt's relative yield per recruit and average biomass per recruit models, showing levels of yield indices for *P. senegalensis* in the Coastal waters of Liberia. (b) Beverton and Holt's relative yield per recruit and average biomass per recruit models, showing levels of yield indices for *P. typus* in the Coastal waters of Liberia.

Discussion

Growth parameters

The asymptotic length (L_∞) for *P. senegalensis* in the present study is higher than what were reported by other authors but similar to estimate by Sidibe (Table 1) [20]. While the value of asymptotic length for *P. typus* in the current study is close to what was reported by Sidibe [20] and higher than what were reported by other authors (Table 1). The difference in values could be linked to the diversity of methods used for the assessment of growth parameters, length of largest species, time and period of sampling as well as the nature of the length distribution The asymptotic length estimated for the two-species in the present study is lower than the highest length recorded by Sidibe [20] from Guinea (100 cm *P. senegalensis*) and 108 cm *P. typus*). This assertion suggests that the stock being exploited in Liberian fisheries waters is relatively small. The K (yr^{-1}) for the both species from the study were lower and t0 higher than what were reported from Benin and Guinea respectively, indicating that maximum size is rapidly attained for both species in Benin and Guinea than for those of Liberia (Table 1). The φ' mean values for *P. senegalensis* and *P. typus* were close to what were reported by other authors (Table 1). In this study the φ' mean values estimates of *P. senegalensis* fall within range estimated by Baijot et al. [31] for some important fishes in Africa range of 2.65-3.32 which were considered as low; moreover, *P. typus* φ' mean values estimates slightly fall below 2.65; so these species are regarded as showing slow growth performance in Liberian fisheries water. The growth performance index of the two-species in the current study appeared to be in line with estimates from other studies (Table 1). This finding demonstrates that they are of similar taxonomic family. Further, the growth performance index indicates the important availability of food and other favorable environmental conditions [32]. Moreover, the growth rate (K) was found to be lower than 0.34, demonstrating that, *P. senegalensis* and *P. typus* are slow growing fish species, evinced by the long lifespan of 21.49 and 19.3 years respectively [33]. This slow growth rate might be induced by changes in the physical and chemical characteristics of the water amplified by the persistent climate change problems [34].

The calculated age-length data result show that for *P. senegalensis* growth was similar to what were reported in Congo and Guinea; but the growth was slower in other countries (Table 3). The linear growth of *P. typus* was closer to what were reported in Congo, Guinea and Nigeria and by far higher than what was reported in other localities (Table 3). This observation show that *P. senegalensis* and *P. typus* in Liberian waters are fast growing than some countries in Table 3 and are growing almost at the same rate with others countries (Table 3). Evidently, this affirmed the first assertion that these two-species within the Liberian coastal waters are physiologically healthy.

Mortality coefficients and current exploitation rate

The fishing mortality (0.56 yr^{-1}) for *P. senegalensis* from the current study was relatively greater than the natural mortality (F=0.37 yr^{-1}). This estimate agrees with estimates from Benin from site 1, but contradicts what where reported from Guinea and Benin site 2 (Table 4). Additionally, the obtained fishing mortality was found to be higher than the optimum fishing rate (Fopt=0.37 yr^{-1}), which is an indication of over-fishing. Beverton et al. [28] suggested that when the natural mortality and fishing mortality are equal (that is; exploitation rate (E)=0.5), then the stock is in a healthy state and optimally exploited. The estimated current exploitation rate (E) was 0.60, which indicated heavy exploitation. Further, the estimated Z/K ratios for *P. senegalensis* which was greater than 1 (Z/K=7.15) as in Table 6 also strengthen the presence of heavy exploitation as a result of increased fishing mortality [35]. The estimated Ecurrent compared favourably with [28] but lower than [32] from Site 1 (Table 4). This variation could be due to the high rate of fishing pressure on stock in Benin than in Liberia. However, the calculated exploitation rate was not intense because it (Ecurrent=0.60) was much lower than the maximum allowable limit based on the yield-per-recruit calculation (Emax=0.963). Nonetheless, the exploitation of this stock could soon approach the maximum sustainable yield if the current level of exploitation is not monitored accordingly with subsequent negative consequences on the stock biomass and food security for fishing households. Therefore, the present level of fishing mortality (in terms of number of fishing vessels, especially artisanal canoes) should be of urgent concern for fisheries managers in Liberia.

The natural mortality (M=0.39 yr^{-1}) for *P. typus* was concurrent to estimate by Sossoukpe et al. [21] from Benin site 2 (Table 6), and relatively lower than estimates reported by Sossoukpe et al. [21] from Benin site 1 and [20] from Guinea in Table 4. This observation could be due to the fact that *P. typus* stock in Liberian coastal waters is less susceptible to natural mortality conditions than the *P. typus* in Benin and Guinea waters. Further, it shows that environmental conditions in Liberian waters are more favourable than in Benin coastal waters.

Fishing mortality (F) is mostly reported to cause changes in population parameters such as size ratio, growth rate, size composition and size at first maturity [36]. The estimated fishing mortality for *P. typus* compared to other studies was relatively lower; this could be due to the low numbers of industrial fishing vessels resulting in low fishing pressure. For instance, industrial fishing vessels in Liberia in 2013 was 7 vessels and has decreased drastically to 2 vessels in 2016, although there has been an increased in artisanal fleets 2,986 canoes in 2013 to 3,250 canoes in 2016; thou their capacity still remain low. *P. senegalensis* fishing mortality in the current study was similar to estimates by Sidibe et al. [20,21] in Table 4.

The exploitation rate (Ecurrent=0.45) from the present study was lower than 0.5, depicting that the *P. typus* stock is currently underexploited. In comparison with studies done elsewhere (Table 4), the Ecurrent reported were more than 0.5, which is an indication that *P. typus* is overexploited in Guinea and Benin.

Length at first capture (Lc_{50}) and Length at first maturity (Lm50)

The length at first maturity (L_{m50}=44.5 cm for both species) was relatively higher than the length at first capture for both targeted fish species (L_{c50}=33.84 cm for *P. senegalensis* and L_{c50}=30.23 cm for *P. typus*). This signifies that the stocks of the two species are harvested before they could reach the matured stage, a characteristic feature of growth overfishing [37]. Growth overfishing is mostly characterized by small size fish species within the harvested catch. From the two-assessed fish species *P. typus* recorded L_c/L_∞ ratios (0.45) was less than 0.5 which indicated that majority of the catch landed constituted juvenile fish species [31]. This assertion affirmed the evidence of growth overfishing. The abundance of small-sized fishes in the catches could be explained by the indiscriminate use of small mesh sized gears and the non-selectivity of fishing gears mostly deployed within the nursery zone of juvenile fishes.

In comparison of the length at first capture of the two assessed species are slightly higher than what was reported by Sossoukpe et al. [21] from Benin (Table 5). The length at first maturity in the current study of *P. typus* was close to what was reported by Sidibe et al. [20,29] both from Guinea respectively, and greater than what were reported by Sossoukpe et al. [21,25] from Cameroon (Table 5). And also the length at first maturity for *P. senegalensis* in the current study was higher than what were reported by other authors in Table 5. This confirmed the early assertion that *P. senegalensis* and *P. typus* in the Liberian fisheries waters are fast growing than those of Benin. Sossoukpe et al. [38] concluded that the size at first sexual maturity is relatively variable with the species and its bio-geographical zone.

Recruitment pattern and relative yield per recruit (Y'/R)

The population structure of *P. senegalensis* and *P. typus* was bimodal indicating probably two spawning periods for this species per year. The presence of two recruitment peaks (one major and one minor) from the study was in line with the description of the recruitment pattern for tropical fishes put forward by Pauly [39]. The observed small length at first recruitment (L_r) for *P. senegalensis* was L_r=8.52 cm and for *P. typus* was L_r=9.53 cm (Figure 5) supports the use of small mesh sized fishing gears by fishermen in Liberian coastal fishing operations with no regards to the damage they cause to the fishery [40]. The presence of recruit throughout the year indicated that recruitment within the targeted species is continuous [41]. Thus, this observation suggests the absence of recruitment overfishing within the fishery of the targeted fish species; there spite the use of small mesh sized fishing gears. For instance, the length at first recruitment was lower than the length at first capture, indicating that species get recruited before been captured by any fishing gear. This finding confirms the assertion that recruitment overfishing is absent within the population of the assessed stock.

However, the continual use of small mesh sized fishing gears in addition to high fishing effort can result in diminished economic benefits, reduced catch per effort, and the collapse of the fisheries for the current target species [42]. Therefore, it is mandatory for fisheries managers to appropriately increase the mesh sizes after careful scientific research, while ensuring that fishers comply with the use of the approved appropriate mesh sized fishing gear in order to avert the occurrence of recruitment overfishing. This is because larger mesh sized gears catch large sized fishes, while allowing juvenile fish to spawn at least once before they are harvested [43-45].

Conclusion

The study has revealed that *P. senegalensis* population within Liberia's coastal waters is currently overexploited while the population of *P. typus* is experiencing exploitation rate close to the maximum sustainable yield amidst the presence of heavy fishing pressure. However, *P. senegalensis* and *P. typus* fisheries in Liberia are currently exhibiting growth overfishing signs which could lead to severe implications on the population size and food security within vulnerable fishing households in the future. Therefore, urgent management interventions in form of monitoring fishing efforts and mesh size regulation (to increase length at first capture) are needed to safeguard these commercially important fish species from possible collapse in the future.

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