Population parameters of two commercially important species belonging to the Family Sciaenidae encountered in the Coast of Ghana

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Authors' contributions

This work was carried out in collaboration with all authors. Author SKKA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SYA and KFA managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Population parameters for two commercially important fishes of Sciaenidae from the coastal waters of Ghana were assessed using length-frequency data obtained from August 2017 to June 2019. Samples of the assessed fish species were obtained through experimental fish trawl along the coast of Greater Accra, Ghana. Trawling was performed every quarter for an average of one hour at an average speed of 3.0 km/hr. In all, a total of 399 samples were measured and the obtained data were analyzed with FiSAT II. The assessed fish species included Pteroscion peli (165 samples) and Pseudotolithus senegalensis (234 samples). The asymptotic length (L∞) was 19.4 cm and 41.5 cm for Pteroscion peli and Pseudotolithus senegalensis. Pteroscion peli and Pseudotolithus senegalensis recorded growth rate (K) of 0.48 and 0.50 per year respectively. Both assessed fish species exhibited continuous recruitment pattern with minor and major recruitment peaks. The total mortality rate (Z) was 1.86 and 1.63 per year for Pteroscion peli and
**Keywords:** Fisheries management; Ghana; *Pteroscion peli*; *Pseudotolithus senegalensis*; stock assessment.

### 1. INTRODUCTION

In the shallow warm seas and estuaries of the world, Sciaenid fishes which include croakers and drums, are the most essential fisheries resources. The Sciaenidae is the seventh-largest family among the 150 families of Perciformes (perches) and includes about 90 genera and 280 species [1]. Many croakers use river mouth and estuarine environments seasonally as nursery grounds for juveniles and as seasonal feeding grounds for adults [2]. Chen [3] reported that species in the Sciaenidae family occur in the warm water above the base of the thermocline and are primarily marine but also occur seasonally in brackish water areas. They inhabit mud, sandy and rocky bottoms from the shoreline to 70-m depth. Smaller and younger individuals prefer shallow waters and move to mid-waters when the bottom temperature falls below 18°C [4]. They occur throughout the coast of West Africa including Ghana [5].

Similarly, species in the Sciaenidae family also form part of the important demersal fish in Ghana’s coastal waters and, are largely caught with bottom trawl, set net, and beach seine fishing gears, especially on muddy and sandy bottoms [6]. In Ghana, about twelve (12) different species in the Sciaenidae family are harvested, however, the commercially important species include *Pseudotolithus senegalensis*, *Pseudotolithus typus* and *Pteroscion peli* [7]. The big-sized individuals of Sciaenid species are harvested for their excellent flesh and high market price in either fresh or smoked form whereas the small-sized individual of species like *Pteroscion peli* is often sold dried or salted [7].

To buttress the usefulness of these finfish species to the economy and nutrition of dependent households and indirect consumers, these species have been enshrined in Ghana’s Fisheries legal framework as one of the commercially important finfish species [8]. Despite the high utilization of species in the Sciaenidae family for economic and nutrition security, there is a paucity of information regarding population parameters of the major fish species in this family, making policies centred on sustainable management of these species (if any) less productive. Thus, the present study focused on some population parameters for major fish belonging to the Sciaenidae family.

### 2. METHODS

#### 2.1 Study Area

Fishing communities in Greater Accra, Ghana are inhabited mainly by the Ga-Adangbe tribe, with an appreciable number of other tribes in the district, which includes the Akans, Ewes, Guans and others [9]. Fishing is the main occupation in communities along the coast of Greater Accra where men usually engage directly in fishing (weave the nets, build the boats, and sail all night to catch and land the fish), with the women mostly involved in all forms of fish processing (drying, smoking, salting and marketing) [10]. The study focused on five (5) offshore stations off the coast of Greater Accra, Ghana (Fig. 1). The coordinates of these five (5) offshore sites are presented in Table 1.

#### Table 1. Sampling sites and their coordinates

| Offshore sampling sites | GPS coordinates       |
|------------------------|-----------------------|
| A                      | 05°42'34.65"N, 000°12'46.90"E |
| B                      | 05°40'32.91"N, 000°09'57.94"E |
| C                      | 05°35'32.78"N, 000°04'12.38"E |
| D                      | 05°35'58.37"N, 000°01'59.51"W  |
| E                      | 05°34'54.59"N, 000°02'31.64"W  |
2.2 Data Collection

Fish samples were obtained on quarterly basis from experimental fishing activities using inshore trawling vessel from August, 2017 to June, 2019. Trawling was performed for one (1) hour at an average speed of 3.2 km per hour at each of the five offshore sampling locations. Obtained fish samples were preserved on ice blocks and transported in an ice chest to the laboratory at the Department of Marine and Fisheries Sciences, University of Ghana. At the laboratory, fish samples were weighed using the electronic weighing balance to the nearest 0.01g, with the standard lengths measured to the nearest 0.1 cm using the 100cm measuring board. Fish samples were identified to the species level using fish identification keys by [7] and [11]. In all, three hundred and ninety-nine (399) samples were assessed including 165 specimens of *Pteroscion peli* and 234 specimens of *Pseudotolithus senegalensis*.

2.3 Growth Parameters

Growth parameters including growth rate (K), asymptotic length (L∞) and the growth performance index (ϕ) were obtained using the Von Bertalanffy Growth Function (VBGF) fitted in FISAT II. The growth of individual fish on the average towards the asymptotic length based on instantaneous growth rate (K) and length at any time (t) was identified using the Von Bertalanffy Growth Function(VBGF): \( L_t = L_\infty \left(1 - e^{-K(t-t_0)}\right) \) [12]. The theoretical age at zero length \( (t_0) \) was estimated independently, using the equation: \( \log_{10}(-t_0) = -0.3922 - 0.2751 \log_{10}L_\infty - 1.038 \log_{10}K \) [12]. The longevity of individuals \( (t_{max}) \) was estimated using the expression: \( t_{max} = 3/K + t_0 \) [13]. The growth performance index was generated using the formula: \( \phi = 2 \log L_\infty + \log K \) [14].

2.4 Mortality Parameters

The Length converted catch curve [15] was used in determining the total annual instantaneous mortality rate \( (Z) \). The instantaneous natural mortality rate \( (M) \) was computed using the empirical equation of [16] at a mean surface temperature \( (T) \) of 25.7°C: \( \log_{10}M = -0.0066 - 0.279 \log_{10}L_\infty + 0.6543 \log_{10}K + 0.4634 \log_{10}T \) [16], where \( M \) is the instantaneous natural mortality rate, \( L_\infty \) is the asymptotic length, \( T \) is the mean surface temperature (25.7°C) and \( K \) refers to the growth rate of the VBGF. Instantaneous fishing mortality rate \( (F) \) was estimated as \( F = Z - M \) [17], where \( Z \) is the instantaneous total mortality rate, \( F \) is the instantaneous fishing mortality rate, and \( M \) is the instantaneous natural mortality rate. The exploitation level \( (E) \) was estimated by the relationship of Gull and (1971): \( E = Z - M \) [18]. The precautionary limit reference point \( (F_{lim}) \) was computed as \( F_{lim} = (2/3) M \) [19]. The precautionary target reference point \( (F_{opt}) \) was calculated as \( F_{opt} = 0.4M \) [20].

2.5 Recruitment Pattern

The recruitment pattern was obtained as described in the FISAT routine [21]. The length at
first recruitment (Lr\textsubscript{50}) was estimated as the mid-
length of the smallest length interval [22].

2.6 Probability of Capture

By plotting the cumulative probability of capture
against mid-length, a resultant curve was
obtained, from which the length at first capture
(Lc\textsubscript{50}) was taken as corresponding to the
cumulative probability at 50%. Additionally, the
lengths at which 25% and 75% of the stock is
captured were taken as corresponding to the
cumulative probability at 25% and 75%
respectively [21].

2.7 Relative Yield per Recruit (Y/R) and
Relative Biomass per Recruit (B/R)

Relative yield per recruit (Y/R) and relative
biomass per recruit (B/R) values as a function of
E were calculated from the estimated growth
parameters and the probability of capture by
length [23]. As a result, the maximum exploitation
rate (E\textsubscript{max}), exploitation rate at 10% and 50% of
its virgin stock (E\textsubscript{0.1} and E\textsubscript{0.5}, respectively) were
computed using the Knife-edge option
incorporated in the FiSATII Tool.

2.8 Data Analysis

The length-frequency data were pooled into size
groups with a 1 cm length interval. The resultant
data was analyzed using the FiSATII (FAO-
ICLARM Stock Assessment Tools) software as
explained in detailed by [21].

3. RESULTS

3.1 Growth Parameters

The estimated growth rate (K) for \textit{Pteroscion peli}
and \textit{Pseudotolithus senegalensis} was 0.48 and
0.50 per year respectively. \textit{Pteroscion peli}
and \textit{Pseudotolithus senegalensis} recorded
asymptotic length (L\textsubscript{∞}) of 19.4 cm and 41.5 cm
respectively. Growth performance index (ø) for
\textit{Pteroscion peli} and \textit{Pseudotolithus senegalensis}
was estimated at 2.257 and 2.935 respectively.
Estimated longevity (t\textsubscript{max}) for \textit{Pteroscion peli}
and \textit{Pseudotolithus senegalensis} was 6.3 years
and 6.0 years respectively.

3.2 Mortality Rates

The instantaneous natural mortality rate (M) for
\textit{Pteroscion peli} and \textit{Pseudotolithus senegalensis}
was 1.20 per year and 1.00 per year respectively
(Fig. 4). \textit{Pteroscion peli} and \textit{Pseudotolithus senegalensis}
recorded the instantaneous fishing mortality rate (F)
to be 0.66 per year and 0.63 per year respectively
(Fig. 2). The instantaneous total mortality rate (Z)
for \textit{Pteroscion peli} and \textit{Pseudotolithus senegalensis}
was 1.86 per year and 1.63 per year respectively
(Fig. 2). The exploitation ratio (E) was 0.36 and 0.39
for \textit{Pteroscion peli} and \textit{Pseudotolithus senegalensis}
respectively.

Fig. 2. Length-converted catch curve for A) \textit{Pteroscion peli} B) \textit{Pseudotolithus senegalensis}
3.3 Recruitment Pattern

The recruitment pattern outlined two recruitment peaks (major and minor) for *Pteroscion peli* and *Pseudotolithus senegalensis* (Fig. 3). Having estimated the theoretical age at zero length \( t_0 \), the major recruitment peak occurred in September and April for *Pteroscion peli* and *Pseudotolithus senegalensis* (Fig. 3). The minor peak for *Pteroscion peli* and *Pseudotolithus senegalensis* was recorded in July and August (Fig. 3). The length at first recruitment \( L_{50} \) for *Pteroscion peli* and *Pseudotolithus senegalensis* was 5.5 cm and 8.5 cm respectively.

3.4 Probability of Capture

The calculated length at first capture \( L_{c50} \) was 7.4 cm and 10.7 cm for *Pteroscion peli* and *Pseudotolithus senegalensis* respectively (Fig. 4). The lengths at capture at 25% \( L_{c25} \) and 75% \( L_{c75} \) of the fish captured were estimated at 6.4 cm & 8.4 cm and 8.5 cm & 12.9 cm for *Pteroscion peli* and *Pseudotolithus senegalensis* respectively (Fig. 4).
Fig. 5. Relative yield and biomass per recruit plot for A) Pteroscion peli and B) Pseudotolithus senegalensis

3.5 Relative Yield and Biomass per Recruit

Using the Knife-edge option in FISAT tool II, the maximum exploitation rate ($E_{max}$) was found to be 0.58 and 0.50 for *Pteroscion peli* and *Pseudotolithus senegalensis* respectively (Fig. 5). The exploitation rates ($E_{0.1}$) and ($E_{0.5}$) were estimated as 0.50 & 0.32 and 0.41 & 0.29 for *Pteroscion peli* and *Pseudotolithus senegalensis* respectively (Fig. 5).

4. DISCUSSION

*Pteroscion peli* and *Pseudotolithus senegalensis* exhibited intermediate growing characteristics with a growth rate which is sandwiched between 0.34 and 0.67 [24]. The intermediate growing nature could suggest that the rebuilding of the fishery could take a longer period, particularly in the presence of heavy fishing leading to an eventual collapse. The growth rate estimated for *P. senegalensis* from the present study was relatively higher than estimates by [25,26,27]. Comparatively, the growth performance of the assessed fish species was favourable, suggesting that these fish are of the same family. The growth performance index for *P. senegalensis* from the current study was similar to estimates by [25,26, and 27]. As such, the growth parameters estimated for *P. senegalensis* from the current study was biologically acceptable because its growth performance index ($\phi'$) fell within the range of 2.753 – 2.970 as reported by these authors (e.g. [25]; [27]). [28] reported that the $\phi'$ values for some important fish in Africa range from 2.65- 3.32 and considered such species as showing low growth.

From the study, the growth performance of *P. senegalensis* was within the range, indicating that it is showing a low growth rate. However, the recorded growth performance of *P. peli* was close to the lower limit of the range and could be suggestive of a low growth rate. [29] assigned a low growth rate in fish species to induced changes in the physical and chemical characteristics of the aquatic environment. The asymptotic length ($L_\infty$) calculated from the study for *P. senegalensis* was lower than that documented from the Ivorian waters [25] and Liberian waters [27]. This may suggest that *P. senegalensis* from Ghana’s waters is experiencing a higher exploitation rate on relatively small-sized individuals [25]. Nonetheless, its asymptotic length compared favourably with the estimate from the Beninese waters [26] which is because [26] used standard length instead of total length (which was applied in the current study). Despite the variation in growth rates ($K$) for the assessed species, the estimated longevity was relatively similar.

The recruitment pattern of the assessed fish species agreed with the finding by [16] who documented that tropical fish species exhibit recruitment pattern with two peaks, a major and minor peak. The major recruitment peaks for both species coincided with the major and minor upwelling seasons. The conducive conditions during the upwelling seasons play a vital role in the spawning activities of mature female species. The existence of recruits throughout the year suggests that the recruitment pattern is continuous [30]. Nonetheless, the lengths at first recruitment for both species were found to be...
lower than the lengths at first capture, which supposes that these species get the opportunity to spawn and add to the stock biomass before becoming vulnerable to capture [22]. Further to this, the presence of continuous recruitment signals the absence of recruitment overfishing [31]. Wehye et al. [27] identified two peaks with major and minor peaks in May and September respectively for P. senegaleensis. [4] identified the major spawning period of P. senegaleensis to be from March to May which compared favourably with the major peak recorded from the current study. On the contrary, [25] documented one recruitment peak for P. senegaleensis from the coastal waters of the Ivory Coast. The changes in recruitment peaks may be as a result of regional variation in marine productivity and environmental parameters.

The length at first capture (Lc50) for P. senegaleensis from the present study was lower than estimates calculated by [26] and [27] which may be linked to the mesh size of fishing gear used during the trawl period. Pauly and Soriano [23] reported that fish species with critical length at capture (Lc) lower than 0.5 is an indication of more juveniles than adults. From the study, the estimated Lc fell below 0.5 which depicts that the composition of the catch was largely juveniles. Diouf [32] reported that juveniles of the Sciaenidae species are common in shallow waters (i.e. less than 50 m from the surface). For the present study, trawling was performed at depths between 0 – 50 m, thus accounting for the high number of juveniles encountered in the study. Also, the clogging of mesh sizes by large-sized species during trawling may be a contributing factor for the observed high number of juveniles than adults.

The assessed fish species exhibited a relatively higher instantaneous natural mortality rate than the instantaneous fishing mortality rate, which could be due to the presence of more juveniles than adult species as a result of the non-selectivity of the gear [5]. The instantaneous fishing mortality rate (F) was higher than the biological reference points (Fopt) which signified the presence of relatively heavy fishing pressure [27]. However, instantaneous fishing mortality rates were relatively lower than the precautionary limit (Flim). This suggests that though the fishing pressure on the stock maybe high, it is still within the sustainable range [31]. Estimated instantaneous total and natural morality rates by [26], [25] and [27] were lower compared to values obtained for P. senegaleensis from the current study. Variation in instantaneous total and natural mortality rates maybe a natural phenomenon that is largely controlled by density-dependent and independent factors as well as geographical differences. The instantaneous fishing mortality rate of both species from the present study were comparable, an indication that both species are vulnerable to the fishing gear at the same rate. The instantaneous fishing mortality rate from the present study was higher than estimated by [27] and [25] for P. senegaleensis, which confirms the earlier claim that fishing pressure on assessed fish stocks is relatively higher than observed in other coastal regions.

The exploitation rate (E) for the assessed fish species was lower than the optimum categorization of 0.5 by [16], thus portraying the under-exploitation of the assessed species in Ghana’s coastal waters. Similar circumstance regarding E (0.28) was observed by [25]. On the contrary, studies [27] and [26] recorded E to be 0.60 and 0.81 for P. senegaleensis respectively, showing that these species are over-exploited in the waters of Liberia and Benin respectively. Therefore, it can be assumed that changes in the E are largely related to regional interest such as economic gains. [25] reported that fish stocks are preserved from over-exploitation in terms of yield per recruit when the E is highly below Emax and E0.5. Therefore, measures should be put in place to harness the exploitation and utilization of these major species in Ghana’s coastal waters belonging to the Sciaenidae family.

5. CONCLUSION

P. senegaleensis and P. peli occurring in the coastal waters of Ghana are not fast-growing species. Recruits overfishing was found to be absent because the lengths at first recruitment were lower than lengths at first capture coupled with continuous recruitment throughout the year. The exploitation ratio revealed that there is the potential for increasing the exploitation of these major species belonging to the Sciaenidae family within Ghana’s coastal waters. The availability of small-sized individuals for exploitation can facilitate the rate of growth overfishing in the coastal waters of Ghana if proper management measures are not implemented.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is no conflict
of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by the personal efforts of the authors.

ETHICAL APPROVAL

As per international standard written ethical permission has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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