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POPULATION DYNAMICS OF SHARK SPECIES IN THE COAST OF GHANA, WEST AFRICA

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ABSTRACT

This study aimed at assessing the growth and mortality parameters of the *Prionace gluaca* and *Sphyrna lewini* shark species from the coast of Ghana. Data was taken for nine (9) months from April 2021 to December 2021. The length data taken from the shark species was analyzed for the estimation of population parameters using the FiSAT II tool. From the results, the estimated asymptotic length ($L\infty$) and the growth rate (K) of *P. glauca* and *S. lewini* were 396.4 cm and 0.27 yr^{-1} and 349.1 cm and 0.24 yr^{-1} respectively, indicating that these species exhibited slow growing characteristics, evinced by a longevity of approximately 11 – 12 years. The length at first capture (Lc_{50}) for *P. gluaca* was 128.6 cm and that for *S. lewini* was 169.0 cm. The length at first maturity (Lm_{50}) for *P. gluaca* and *S. lewini* was 179.74 cm and 160.4 cm respectively. By comparing the Lc_{50} and Lm_{50}, it implies that individuals of *P. gluaca* were vulnerable to fishing gears before having the chance to mature and even spawn once. The total mortality (Z), natural mortality (M), fishing mortality (F) and the exploitation rates for *P. glauca* and *S. lewini* were 0.82 yr^{-1} , 0.22 yr^{-1} , 0.60 yr^{-1} and 0.73 and 0.76 yr^{-1}, 0.21 yr^{-1}, 0.55 yr^{-1} and 0.72, respectively. This suggests that fishing activities are the main cause of decline in the abundance of these shark species. The exploitation rate (E > 0.5) revealed that these species are overexploited in Ghana's marine waters. Based on these findings, it is recommended that fishing effort be reduced through appropriate measures by relevant authorities.

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INTRODUCTION

Sharks play a crucial functional role as the apex predators in marine ecosystem and being in the top of food chain, are usually found in lower biomass compared to those occupying lower trophic levels (Bonfil et al. 2014; Camhi, 2018). Sharks play a major function in conserving the marine ecosystem. Therefore, monitoring their population is key in their conservation. Sharks also are of interest to humans because they represent one of only a few groups of animals that negatively interact with Homo sapiens on a regular, albeit uncommon, basis through the phenomenon commonly referred to as “shark attack (Midway et al. 2019). They create significant job opportunities and millions of dollars in revenue, but true ecotourism requires that education and conservation be incorporated into activities that benefit local communities socially, economically, and environmentally.

Shark species are often targeted by fisherfolks due to rising demand for their meat, fins, liver and other products, and this has led to indiscriminate fishing of the resource and ultimately decline in their population. The global shark landings has reduced from 893,000 tons in 2000 to 766,000 tons in 2018, registering a 15% decline in a decade (Seidu et al. 2022).

In Ghana, shark landings increased from 27,400 tons in 2012 to the highest of 75,000 tons in 2018, since then, the trend in landings has been highly fluctuating, showing an overall decrease (Fathima et al. 2013). The shark landings in Ghana was about 22,479 tons in 2015, which is about 70 % lower than the historic highest landings of sharks. The contribution of shark landings to the total marine fish landings has also decreased from 3.4 % in 2015 to 0.6 % in 2020 (Seidu et al. 2022). Although many scientific works have been carried out on sharks in Ghana, many of these studies have centred on the socio-economic aspects of shark trade (e.g., Seidu et al. 2022; Agyeman et al. 2020) with little attention to the population dynamics of the stocks, including information on the growth and mortality parameters. Therefore, this study aimed to examine the growth, mortality, and exploitation parameters of some key shark species, limited to *Sphyrna lewini* and *Prionace glauca* in the coastal waters of Ghana. Findings from this study will aid in sustainable management of these key shark species in Ghana.

MATERIAL AND METHODS

Study area

The study was conducted in two coastal communities in the Western Region (i.e. Axim and Dixcove) and one community in the Greater Accra Region (i.e. Tema), Ghana (Fig.1). These three communities are the hotspots for shark fishing activities in Ghana. Dixcove is located in Ahanta West district (4°47'38.82"N, 1°56'49.56"W); Axim in the Nzema East district (4°51'26.98"N, 2°14'37.35"W) while the Tema fishing community (5°38'41.27"N, 0° 1'1.67"E) is situated in Tema Newtown within the Tema Metropolitan Assembly.

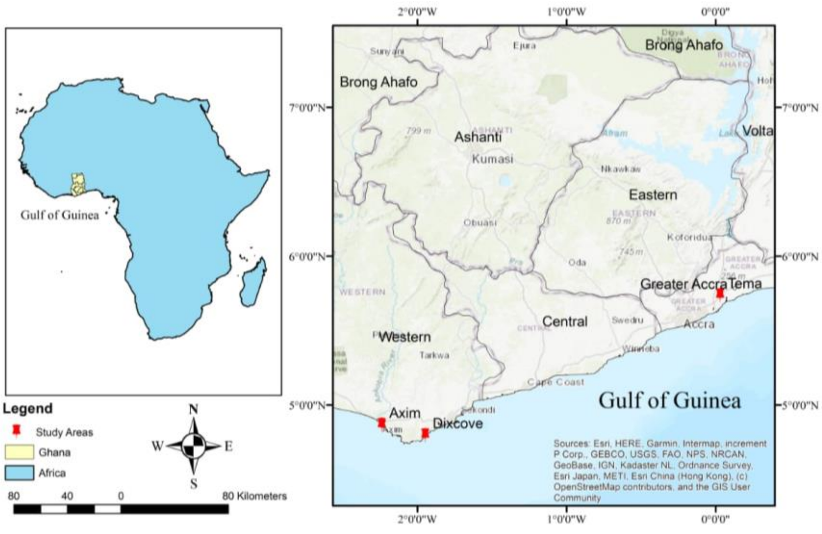

Figure 1. Map showing the study sites

Data collection

Morphometric measurement of shark species including total lengths were taken daily from April 2021 to December 2021 using a measuring tape. Species were identified in-situ using a combination of local and scientific names according to the Schneider et al. (1995) identification keys.

Length frequency distribution

Length data from monthly sampling were grouped into length classes of 15 cm interval for plotting the length frequency distribution chart.

Growth parameters

Growth parameters that followed the Von Bertalanffy Growth Function (VBGF) including growth rate (K) and asymptotic length (L∞) were estimated using the Electronic Length Frequency Analysis (ELEFAN) option. Von Bertalanffy Growth Function (VBGF) was given as follows:

$$L_t = L_\infty\left(1 - e^{-K(t - t_o)}\right)$$

Lt is the expected or average length at time (or age) t,
L_∞ is the asymptotic average length
K is the so-called Brody growth rate coefficient (units are yr−1), and
t_o represents the time or age when the average length was zero.

Estimation of longevity (t_{max}) of the species was done using the method: t_{max} = 3/K (Anato, 1999)

The growth performance index (phi) was calculated using the formula: Φ′ = 2logL∞ + log K (Munro and Pauly, 1984)

The theoretical age at length zero (t_0) followed the equation: $\log_{10}(-t_0) = -0.3922 - 0.2752 \log_{10} L_\infty - 1.038 \log_{10} K$ (Pauly, 1979)

Length at First Capture (Lc_{50})

The ascending left part of the length converted catch curve was used in estimating the probability of length at first capture (Lc_{50}) in addition to the length at both 25 and 75 percent capture which correlates with the cumulative probability at 25% and 75%, respectively (Pauly, 1984).

Mortality rates

Total mortality (Z) was computed using Linearized length converted catch curve (Spare and Venema 1992) as-

Z = M + F

Where, Z is the instantaneous rate of total mortality
M is the instantaneous rate of natural mortality, and
F is the instantaneous rate of fishing mortality.

The natural mortality rate (M) was calculated using the procedure: $M = 4.118K^{0.73}L_\infty^{-0.333}$ (Then et al. 2015).

Fishing mortality (F) was calculated as: Z – M (Qamar et al. 2016).

The exploitation rate (E) was computed using F/Z (Georgiev and Kolarov 1962)

Length at first maturity

The length at first maturity (Lm_{50}) was estimated as: $\log_{10} Lm_{50} = 0.8979 * \log_{10}(L_\infty) - 0.0782$ (Froese and Binohlan 2000)

Data analysis

The length data were pooled together with an interval of 15 cm for the estimation of population parameters using the FiSAT II tool. Results were displayed in the form of charts and tables for easy understanding.

RESULTS

Length frequency distribution

From Table 1, the mid-length (ML) of *S. lewini* individuals ranged from 77.5 cm – 332.5 cm with August recording the highest number of samples (i.e. 24 samples) followed by October and November (i.e. 15 and 12 samples respectively).

Table 1. Length distribution of *S. lewini* obtained during the study period

ML/cm	April	May	June	August	September	October	November	December
77.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
92.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
107.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
122.5	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
137.5	0.0	0.0	1.0	1.0	0.0	3.0	0.0	1.0
152.5	0.0	0.0	0.0	1.0	0.0	1.0	4.0	0.0
167.5	0.0	0.0	0.0	0.0	0.0	2.0	2.0	0.0
182.5	0.0	0.0	0.0	0.0	0.0	1.0	3.0	0.0
197.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
212.5	0.0	0.0	1.0	1.0	1.0	2.0	2.0	0.0
227.5	1.0	0.0	0.0	4.0	1.0	1.0	0.0	0.0
242.5	0.0	0.0	0.0	8.0	1.0	1.0	0.0	0.0
257.5	0.0	0.0	0.0	2.0	3.0	0.0	1.0	0.0
272.5	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0
287.5	0.0	1.0	1.0	2.0	0.0	0.0	0.0	0.0
302.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
317.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
332.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
Total	1.0	1.0	4.0	24.0	6.0	15.0	12.0	1.0

From Figure 4.2, with a total of 64 specimens of *S. lewini* collected during the study period, the mean length of the individuals was 203.1 ± 54.2 cm.

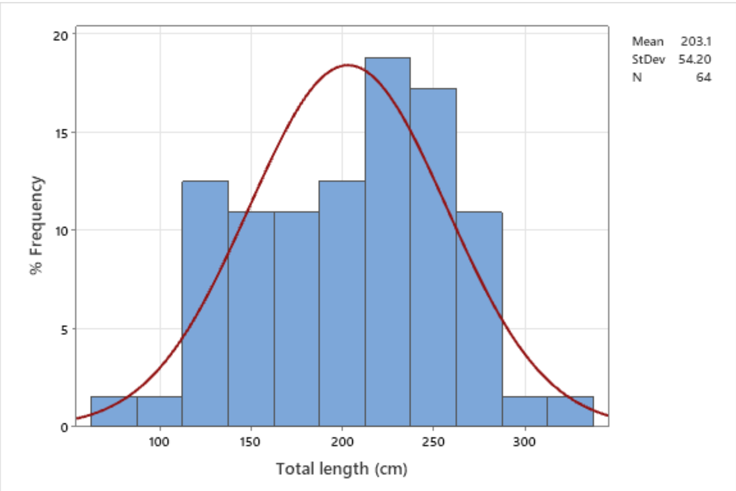

Figure. 4.2 Length structure of *S. lewini* obtained from the study

From Table 2, the mid length of *P. gluaca* individuals ranged from 32.5 to 377.5 cm with August recording the highest number of samples (i.e. 276 samples) and May exhibiting the lowest number of samples (i.e. 26 samples).

Table 2. Length distribution of the *P. gluaca* specimen obtained during the study period

ML	April	May	June	August	September	October	November	December
32.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
47.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
62.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
77.5	0.0	0.0	0.0	5.0	3.0	1.0	0.0	0.0
92.5	0.0	0.0	1.0	2.0	2.0	2.0	0.0	2.0
107.5	0.0	0.0	2.0	6.0	0.0	6.0	2.0	4.0
122.5	0.0	0.0	4.0	16.0	4.0	19.0	10.0	11.0
137.5	0.0	0.0	3.0	7.0	9.0	14.0	10.0	6.0
152.5	0.0	0.0	1.0	3.0	6.0	8.0	18.0	13.0
167.5	0.0	0.0	3.0	20.0	2.0	12.0	16.0	8.0
182.5	0.0	1.0	4.0	18.0	8.0	15.0	23.0	11.0
197.5	1.0	0.0	14.0	15.0	9.0	17.0	19.0	13.0
212.5	5.0	0.0	19.0	32.0	5.0	4.0	10.0	6.0
227.5	1.0	5.0	17.0	28.0	11.0	11.0	3.0	4.0
242.5	3.0	7.0	14.0	18.0	4.0	6.0	4.0	1.0
257.5	0.0	4.0	10.0	19.0	5.0	5.0	2.0	1.0
272.5	1.0	4.0	17.0	21.0	8.0	3.0	2.0	0.0
287.5	0.0	3.0	10.0	18.0	11.0	9.0	1.0	1.0
302.5	0.0	2.0	2.0	17.0	15.0	6.0	0.0	1.0
317.5	0.0	0.0	0.0	15.0	5.0	2.0	1.0	0.0
332.5	0.0	0.0	0.0	6.0	1.0	1.0	0.0	0.0
347.5	0.0	0.0	0.0	4.0	0.0	1.0	0.0	0.0
362.5	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0
377.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Total	**11.0**	**26.0**	**121.0**	**276.0**	**108.0**	**142.0**	**121.0**	**83.0**

From Fig. 4.3, with a total of 888 specimens of *P. gluaca* collected during the study period, the mean length of the individuals was 201.8 ± 61.41 cm.

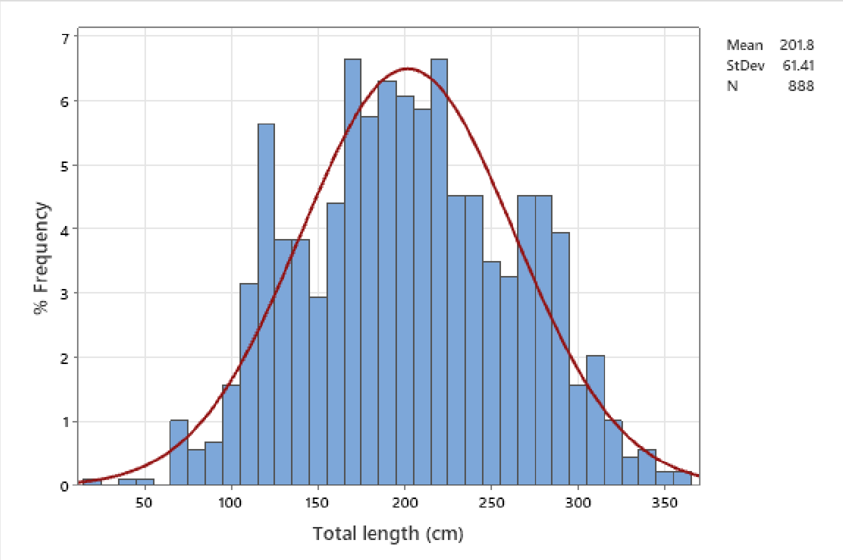

Figure 4.3. Length structure of *P. gluaca* obtained from the study

Growth parameters

Fig. 4.4 and 4.5 show the restructured length frequency with superimposed growth curves for both *P. gluaca* and *S. lewini*.

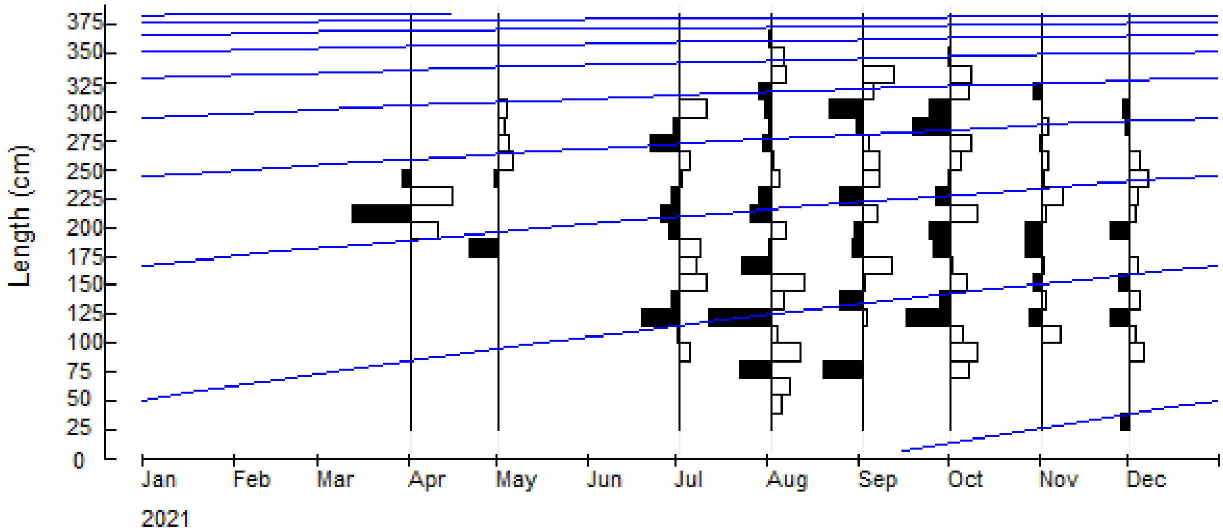

Figure 4.4 Plot of von Bertalanffy growth function for *P. gluaca*

From the Fig. 4.4, the asymptotic length (L∞) and the growth rate (K) of *P. gluaca* was 396.4 cm and 0.27 yr^{-1} respectively. The growth performance index (Φ′) was 4.628. The theoretical age at length zero was -0.30. The longevity of the assessed fish species was 11 years.

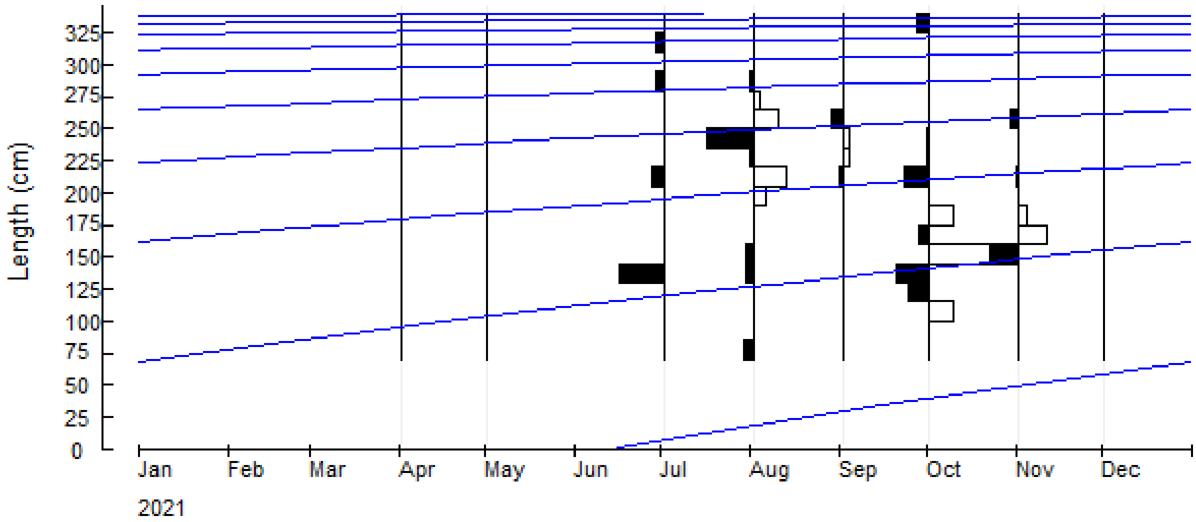

Figure 4.5 Plot of von Bertalanffy growth function for *S. lewini*

From the Fig. 4.5, the asymptotic length (L∞) and the growth rate (K) of *S. lewini* was 349.1 cm and 0.24 yr^{-1} respectively. The growth performance index (Φ′) was 4.466. The theoretical age at length zero was -0.36. The longevity of the assessed fish species was 12 years.

Length at first capture

Figure 4.6 and 4.7 shows the probability of capture of *P. gluaca* and *S. lewini* respectively.

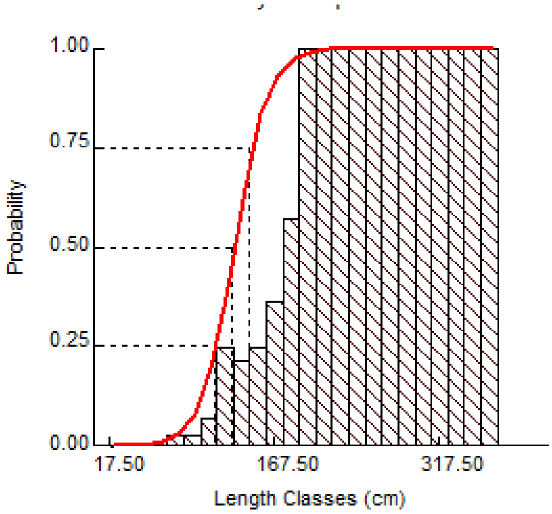

Figure 4.6 Probability of capture for *P. gluaca*

From Figure 4.6, the probability of capture for *P. gluaca* was estimated as Lc_{25} = 112.3 cm, Lc_{50} = 128.6 cm and Lc_{75}= 144.93 cm. Therefore, the length at first capture (Lc_{50}) was 128.6 cm. Approximately 14.1 % of the total individuals were below the estimated length at first capture.

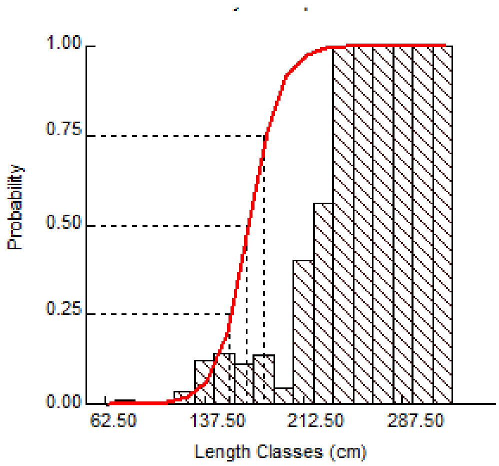

Figure 4.7 Probability of capture for *S. lewini*

From Figure 4.7, the probability of capture for *S. lewini* was estimated as Lc_{25} = 156.0 cm, Lc_{50} = 169.0 cm and Lc_{75}= 182.1 cm. Therefore, the length at first capture (Lc_{50}) was 169.0 cm. Approximately 31.3 % of the total individuals were below the estimated length at first capture.

Length at first maturity

The length at first maturity (Lm_{50}) for *P. glauca* was 179.74 cm with about 44% of the total catch being less than the estimated length at first maturity. For the *S. lewini*, the length at first maturity (Lm_{50}) was 160.4 cm with about 26.6 % of the total catch being less than the estimated length at first maturity.

Mortality rate

The Linearized length-converted catch curve was used for the estimation of instantaneous total mortality (Z) for *P. gluaca* and *S. lewini* (Figures 4.8 and 4.9).

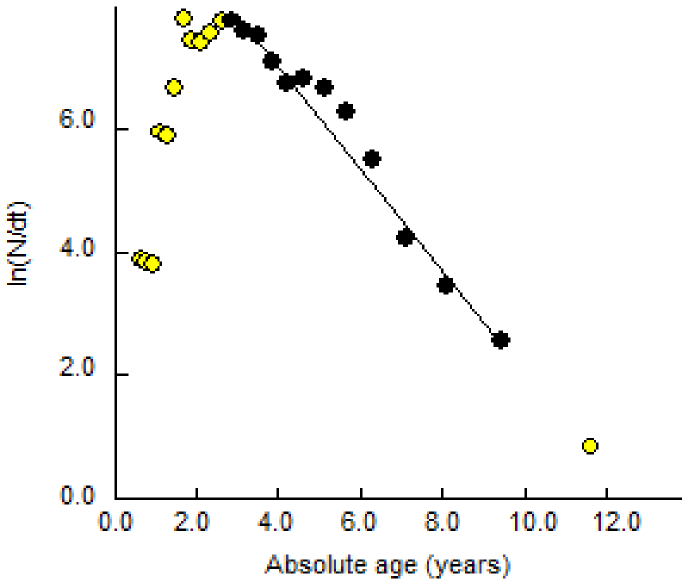

Figure 4.8 Length converted catch curve for *P. gluaca*

From Figure 4.8, the total mortality rate (Z) was as 0.82 yr^{-1} for *P. gluaca.* The natural mortality (M) and fishing mortality (F) rates were estimated at M = 0.22 yr^{-1} and F = 0.60 yr^{-1} respectively. The current exploitation rate (E) was obtained at 0.73.

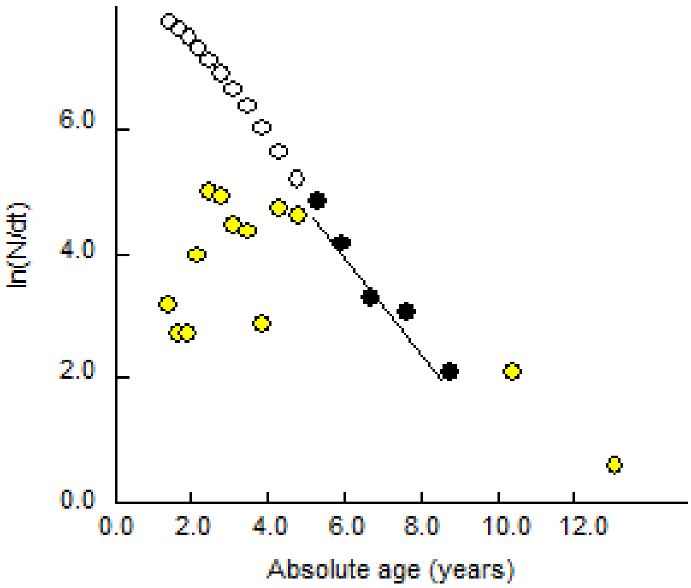

Figure 4.9 Length converted catch curve for *S. lewini*

From Figure 4.9, the total mortality rate (Z) was 0.76 yr^{-1} for *S. lewini*. The corresponding natural mortality (M) and fishing mortality (F) rates were estimated at M = 0.21 yr^{-1} and F = 0.55 yr^{-1} respectively. The current exploitation rate (E) was obtained at 0.72.

Yield per recruit analysis

From Fig. 4.10, the E_{max}, $E_{0.5}$ and $E_{0.1}$ for *P. gluaca* was 0.54, 0.33 and 0.47 respectively while for the *S. lewini*, 0.62, 0.36 and 0.55 were the values recorded for E_{max}, $E_{0.5}$ and $E_{0.1}$ (Figure 4.11).

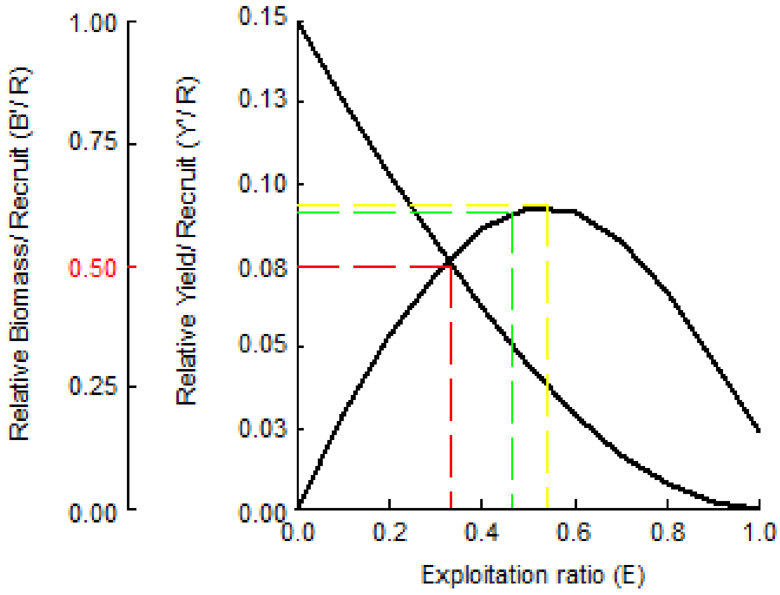

Figure 4.10 Yield per recruit diagram of *P. gluaca*

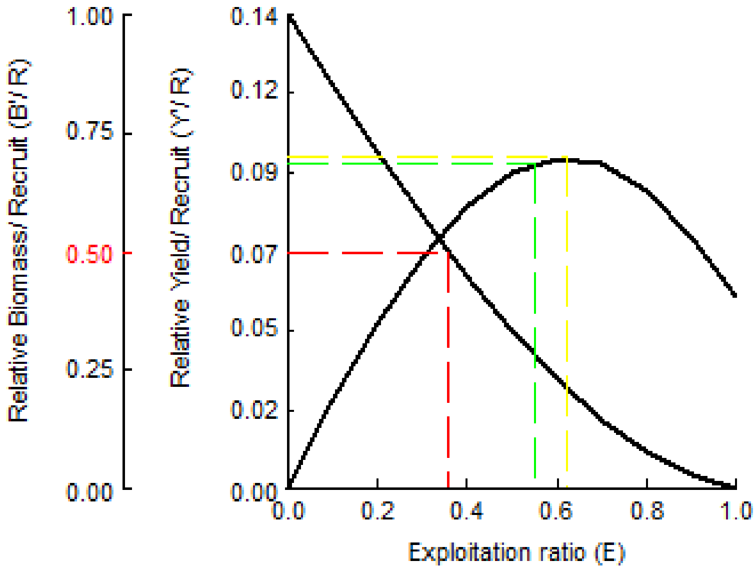

Figure 4.11 Yield per recruit diagram of *S. lewini*

From the isopleth diagrams (i.e. Figures 4.12 and 4.13), both species were recorded in the Quadrant 4 which indicates fishing at high intensity for small-sized fishes.

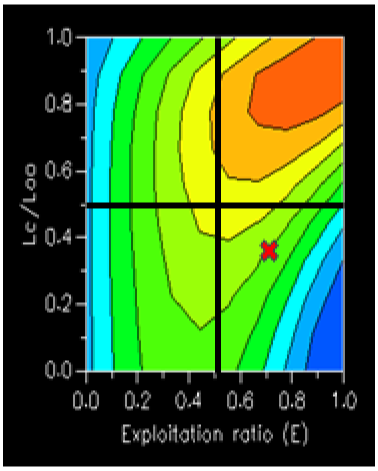

Figure 4.11 Isopleth diagram of *P. gluaca*

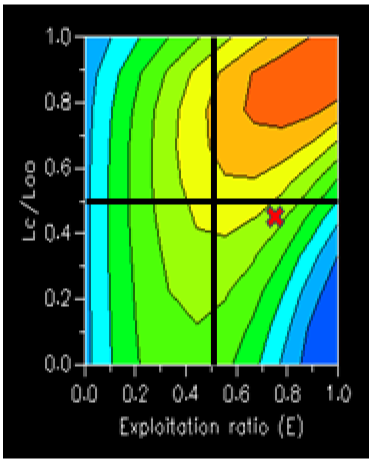

Figure 4.12 Yield per recruit diagram of *S. lewini*

Table 3. Population parameters for *Prionace gluaca* and *Sphyrna lewini*

Parameters	*S. lewini*	*P. gluaca*
L_∞	349.1	396.4
K	0.24	0.27
t_o	-0.36	-0.30
t_{max}	12	11
M	0.21	0.22
Z	0.76	0.82
F	0.55	0.60
E	0.72	0.73
E_{max}	0.62	0.54
$E_{0.5}$	0.36	0.33
$E_{0.1}$	0.55	0.47
Lc_{50}	169.0	128.6
Lm_{50}	160.4	179.7
M/K	0.88	0.80
Lc_{50}/L_{inf}	0.46	0.32
Lm_{50}/L_{inf}	0.46	0.45
Phi	4.466	4.628

DISCUSSION

There is currently little information on the growth parameters of *P. gluaca* and *S. lewini* in Ghana. Therefore, findings from this study will provide additional information in managing sustainably these important shark species. From the study, the growth rate (K) of *P. gluaca* was 0.27 yr^{-1}. Studies by other researchers from different coastal habitats recorded lower growth rates for the *P. gluaca*. Blanco et al (2008) recorded a growth rate of 0.10 yr^{-1} from Eastern North pacific. Manning et al (2005) from the southwest Pacific Ocean documented a growth rate of 0.08 yr^{-1} while Nuraneni et al (2020) from the Indonesian coast recorded 0.16 yr^{-1} for the *P. gluaca*. The asymptotic length (L_∞) from the study recorded a length of 396.4 cm. This was higher than values recorded by Huang et al (2006) and Blanco et al. (2008) who reported L_∞ as 332.7

cm and 299.9 cm respectively. Nonetheless, values recorded by Manning et al (2005) and Nuraeni et al. (2020) were higher than the estimate from the current study. Both researchers recorded 411.1 cm and 407 cm respectively. The growth performance index (phi) recorded from the current study was 4.628 for *P. gluaca*.

From the current study, the growth rate (K) of *S. lewini* was 0.24 yr^{-1}, relatively higher than estimates provided by other researchers from different coastal habitats. Sayd et al. (2011), Kotas et al. (2011), Percy et al. (2010), Harry et al. (2011), Chondrijah and Faizah (2021) and Coelho et al. (2011) documented 0.23 yr^{-1}, 0.05 yr^{-1}, 0.11 – 0.16 yr^{-1}, 0.076 yr^{-1}, 0.17 – 0.27 yr^{-1} and 0.06 – 0.07 yr^{-1} from Indian, Brazilian coast, Gulf of Mexico, Australia, Eastern Indian Ocean and Gulf Mexico and Eastern equatorial ocean respectively. Regarding the asymptotic length (L_∞) of *S. lewini*, findings from the study recorded a length of 349.1 cm. This was higher than values recorded by Gaza et al. (2004), Coehlo et al. 2011), Kotas et al. (2011), Percy et al. (2010) and Harry et al. (2011) who reported L_∞ as 301.6 cm, 272 - 285 cm, 266 – 300 cm, 204 – 307.8 cm and 331.2 cm respectively. Nonetheless, values recorded by Sayd et al. (2011), Anisleads and Tolensto (2008) as well as Chondrijah and Faizah (2011) were higher than the L_∞ estimated from the current study. The growth performance index recorded from the current study was 4.666 for *S. lewini*, and was higher than the values provided by other researchers such as Coelho et al. (2011) who reported 4.20. The possible factors accounting for the variation in growth rate (K), growth performance index and asymptotic length (L_∞) in relation to other studies could be due to changes in the climatic conditions of the respective geographical locations, the data analysis method used and the size classes obtained (Amponsah et al. 2016). However, the growth rate (K) obtained from the current study for both species were lower than 0.5 which is an indication that these species exhibit slow growing characteristics, evinced by a longevity of approximately 11 – 12 years (Kienzle, 2005). In terms of implications, the impact of heavy exploitation on these species could be more of biological than economical because rebuilding of these species is likely to be at a slower pace.

For *P. gluaca* and *S. lewini*, the length at first capture estimated from the study was lower than the estimates recorded by other researchers. Chondryit and Faizah (2021) and Ami et al. (2022) reported a length at first capture of 250.98 – 267.76 cm and 156.1 cm respectively. Similarly, Chondryit and Faizah (2021) also recorded a higher length at first capture for *S. lewini* (Lc_{50} = 192.3 cm) than obtained from the study (i.e. Lc_{50} = 169.02 cm). The variation in the length at first capture could be due to the fishing method employed by fisherfolks, length classes obtained and the species growth rate. The ratio of the length at first capture to the asymptotic length is known as the critical length at fist capture (Lc). Pauly and Soriano (1986) documented when Lc is less than 0.5, it implies the presence of more juveniles while Lc above 0.5 suggest the presence of more adult specimen. From the study, the Lc for both species was slightly less than 0.5, indicative of the presence of few juveniles. This finding also shows that any increase in the landings of more juvenile specimen could trigger growth overfishing in the fishery of the assessed fish stocks. Compared to the length at first capture estimated from the study, the length at first maturity was higher than the length at first capture for *P. gluaca*. This reveals that the individuals of *P. gluaca* in Ghana's coastal waters become vulnerable to fishing gears before having the chance to mature and probably spawn. Furthermore, majority of the landed catch for both species were adults (i.e., 56 % and 73 % for *P. gluaca* and *S. lewini* respectively). Continuous landings of adult individuals of these shark species could have serious implications on their recruitment potential, and with the slow growth rate, such impact could affect the stability of the ecosystems in the future as well as economic wellbeing of dependent fishing households.

The natural mortality (M = 0.21 yr^{-1} and 0.22 yr^{-1}) was found to be lower than the fishing mortality (F = 0.60 yr^{-1} and 0.55 yr^{-1}) for both species (*S. lewini* and *P. gluaca* respectively). This suggests that fishing activities are the main cause of decline in the abundance of these species. In addition, these species are facing high fishing mortality rate due to the fact that the estimated exploitation rate for both species were above the optimal level of 0.5 (Pauly, 1980). To buttress these findings, the exploitation at the maximum sustainable yield (E_{max}) for both species was lower than the current rate of exploitation (E) as shown in Table 3. Furthermore, it was observed from the isopleth yield plot that the fishery of the both species fell in the fourth quadrant where small-sized individuals are caught at high fishing pressure which signifies the existence of overfishing (Pauly and Soriano, 1986). This condition could affect the economic returns of fisheries and lead to the possible collapse of the assessed species in the future. As a management option, there is the urgent need to reduce fishing efforts through measures such as reducing the number of active canoes and institutionalization of closed season. Also, enforcement of the fisheries law for shark conservation should be enhanced and executed by the appropriate authorities.

CONCLUSION

This study sought to assess the population parameters of *P. gluaca* and *S. lewini* from the coastal waters of Ghana. Overall, both species with asymptotic length (L∞) of 396.4 and 349.1 cm respectively are slow-growing with a growth rate (K) of 0.27 $yr^{-1}$and 0.24 yr^{-1} respectively. The length at first maturity for *P. gluaca* was higher than the length at first capture, which suggests the presence of potential recruitment overfishing. The exploitation rate for both species (E = 0.73 and 0.72 respectively) was higher than the exploitation at the maximum sustainable level (E_{max}) which indicates that these species in Ghana's marine waters are overexploited. To sustainably manage these shark species, fishing effort should be greatly reduced.

COMPETING INTEREST

The authors declare that they have no competing interests.

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REFERENCES

1. Agyeman NA, Blanco-Fernandez C, Steinhaussen SL, Garcia-Vazquez E and G Machado-Schiaffino, 2021. Illegal, unreported, and unregulated fisheries threatening shark conservation in African waters are revealed by high levels of shark mislabelling in Ghana. Genes, 12(7). https://doi.org/10.3390/genes12071002
2. Amir F, Mallawa A and J Tresnati, 2022. Population dynamics of Prionace glauca, using length frequency in the waters of Makassar Strait, Indonesia. Aquaculture, Aquarium, Conservation and Legislation, 15(2), 978-987.
3. Amponsah SKK, Ofori-Danson PK, Nunoo FKE and GA Ameyaw, 2016. Aspects of population dynamics of Red Pandora, Pagellus bellottii (Steindachner, 1882) from the coastal waters of Ghana. Journal of Scientific and Innovative Research, 5(6), 215–224. https://doi.org/10.31254/jsir.2016.5604
4. Anato CB, 1999. Les Sparidae des côtesbéninoises: Milieu de vie, pêche, présentation des espècesetbiologie de Dentexangolensis Poll et. Maul, 1953. Thèse de Doctoratd'Etat es Sciences, Faculty of Science, 1060 Tunis, p 277.
5. Blanco-Parra, MDP, 2008. Line: Ecological effects of fishing on socio-environmental ecosystems (Project: functional structure and trophic ecology of fish) View project. https://www.researchgate.net/publication/299077044
6. Bonfil R, 2014. Overview of world elasmobranch fisheries, FAO Fisheries Technical Paper, 341 (FAO, Rome, Italy) 2014, pp. 119. 2
7. Camhi MD, Valenti SV, Fordham SV, Fowler SL and C Gibson, 2007. The conservation status of pelagic sharks and rays. Newbury: IUCN Species Survival Commission Shark Specialist Group. p 78.
8. Chodrijah U and R Faizah, 2021. Biology aspect and parameter population the scalloped hammerhead (Sphyrna lewini Griffith & Smith, 1834) caught from coastal fisheries in the eastern Indian Ocean. In IOP Conference Series: Earth and Environmental Science (Vol. 777, No. 1, p. 012009). IOP Publishing.
9. Coelho R, Mejuto J, Domingo A, Yokawa K, Liu KM, Cortés E, Romanov EV, da Silva C, Hazin F, Arocha F, Mwilima AM, Bach P, Ortiz de Zárate V, Roche W, Lino PG, García-Cortés B, Ramos-Cartelle AM, Forselledo R, Mas F and MN Santos, 2018. Distribution patterns and population structure of the blue shark (*Prionace glauca*) in the Atlantic and Indian Oceans. Fish and Fisheries, 19(1), 90–106.
10. Froese R and C Binohlan, 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. Journal of Fish Biology 56 (4): 758–773.

11. Georgiev ZM and P Kolarov, 1962. On the migration and distribution of horse mackerel (Trachurus ponticus Aleev) in the western part of Black Sea. Arbeiten des Zentrolen Forschungsinstitutes fur Fishzught und Fisherei - Varna, 2: 148-172.
12. Harry AV, Macbeth WG, Gutteridge AN and CA Simpfendorfer, 2011. The life histories of endangered hammerhead sharks (Carcharhiniformes, Sphyrnidae) from the east coast of Australia. Journal of Fish Biology, 78(7): 2026-2051.
13. Huang CC, 2006. Age and growth of the Blue Shark, Prionace glauca, in the northwestern Pacific Ocean. Master's thesis. National Taiwan Ocean University, Keelung, Taiwan. (In Chinese.)
14. Kienzle MO, 2005. Estimation of the population parameters of the Von Bertalanffy Growth Function for the main commercial species of the North Sea. Rome: FAO Fisheries Department, Rome, pp. 34.
15. Kotas JE, Mastrochirico V and M Petrere Junior, 2011. Age and growth of the Scalloped Hammerhead shark, Sphyrna lewini (Griffith and Smith, 1834), from the southern Brazilian coast. Brazilian Journal of Biology, 71: 755-761.
16. Kouame AC, Sylla S, Yao SS, Tia CB and GA Loukou, 2020. Stock Assessment of Red Pandora *Pagellus bellottii* (Steindachner, 1882) in The Ivorian Continental Shelf (West Africa). Agronomie Africaine, 423-438.
17. Manning MJ and MP Francis, 2005. Age and growth of blue shark (Prionace glauca) from the New Zealand Exclusive Economic Zone. New Zealand Fisheries Assessment Report, 26(2005): 52.
18. Midway SR, Wagner T and GH Burgess, 2019. Trends in global shark attacks. PloS one, 14(2), e0211049.
19. Munro JL and D Pauly, 1984. Once more on the comparison of growth in fish and invertebrates. ICLARM Fishbyte, 2: 21 p.
20. Pauly D, 1979. Gill size and temperature as governing factors in fish growth: a generalization of von Bertalanffy's growth formula.
21. Pauly D, 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. ICES journal of Marine Science, 39(2): 175-192.
22. Pauly D and ML Soriano, 1986. May. Some practical extensions to Beverton and Holt's relative yield-per-recruit model. In The first Asian fisheries forum (pp. 491-496). Manila: Asian Fisheries Society.
23. Qamar N, Panhwar SK and S Brouwer, 2016. Population Characteristics and Biological Reference Point Estimates for Two Carangid Fishes, *Megalaspis cordyla* and *Scomberoides tol*, in the Northern Arabian Sea Coast of Pakistan. Pakistan Journal of Zoology, 48(3).
24. Schneider W, 1990. FAO species identification sheets for fishery purposes. Field guide to the commercial marine resources of the Gulf of Guinea. Prepared and published with the support of the FAO Regional Office for Africa. FAO, Rome, 268 p
25. Seidu I, Brobbey LK, Danquah E, Oppong SK, van Beuningen D, Seidu M and NK Dulvy, 2022. Fishing for survival: Importance of shark fisheries for the livelihoods of coastal communities in Western Ghana. Fisheries Research, 246: 106157.
26. Then AY, Hoenig JM, Hall NG and DA Hewitt, 2015. Handling editor: Ernesto Jardim. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science, 72(1): 82-92.