Iranian Journal of Fisheries Sciences
http:doi.org/ 10.22092/ijfs.2025.134243 2025, 24(5) 1081-1091

Research Article

Population dynamics of deepwater rose shrimp (*Parapenaeus longirostris*, Lucas 1846) along the coast of Ghana

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Keywords

Exploitation rate,
Growth,
Mortality rates,
Population structure,
Sustainability monitoring

Article info

Received: October 2024
Accepted: February 2025
Published: September 2025

Abstract

This study provides detailed information on the population structure, growth, mortality, probability of capture, and longevity of the Deep-water rose shrimp (*Parapenaeus longirostris*, Lucas 1984) along the coast of Ghana. A total of 1,164 specimens were collected monthly from July 2020 to June 2021. The mean total length of the species was 9.72±2.22 cm. The length-weight relationship, in log-transformed format, was Log BW=2.841 Log TL–2.109, indicating a negative allometric growth pattern. The Von Bertalanffy growth parameters for total length were estimated as L_∞=17.85 cm TL, t_0=-0.21, and K=0.87 year^{-1}. The critical length at capture ratio was 0.56, suggesting potential growth overfishing due to intensified fishing efforts. Natural and fishing mortality rates were 1.84 per year and 1.98 per year, respectively. The exploitation rate was 0.52, indicating relatively optimal exploitation of the stock along the coast of Ghana. Continuous monitoring and extended closed seasons are some of the recommended management measures required to enhance the sustainability of the sampled species in the coast of Ghana.

Introduction

The deep-water rose shrimp, (*Parapenaeus longirostris*, Lucas 1846), is a demersal decapod crustacean with an extensive geographic distribution, spanning from the northern Iberian Peninsula to southern Angola, including Ghana (Holthuis, 1987). This species predominantly inhabits depths ranging from 20 m to 750 m along the Mediterranean and Atlantic, with the highest concentrations found between 100 m and 400 m (Fischer *et al.,* 1987). Adult individuals migrate to shallower waters during the spawning period (Ardizzone *et al.,* 1990; Kapiris *et al.,* 2007).

In Ghana, five penaeid species have been documented: *Holthuispenaeopsis* (*Parapenaeopsis*) *atlantica* (Balss, 1914), *Penaeus* (*Farfantepenaeus*) *notialis* (Perez Farfante, 1967), *Penaeus* (Melicertus) *kerathurus* (Forskal, 1775), *Parapenaeus longirostris* (Lucas, 1846), and *Penaeus monodon* (Fabricius, 1798) (Kwei and Ofori-Adu, 2005). Annual landings of penaeid shrimps in Ghana peaked between 2008 and 2015, with catches ranging from 800 to 8,048 metric tonnes. These penaeids are crucial crustacean fishery resources and significantly contribute to the socio-economic development of the country (Opkei *et al.,* 2020a). However, the observed reduction in shrimp landings in Ghana demands immediate attention to ensure the sustainability of these resources.

Unfortunately, few studies including Opkei *et al.* (2020a; 2020b), have focused on the distribution and biology of shrimp in the coastal waters of Ghana. Notably, there are no prior records on the population dynamics of *P. longirostris* in this region, despite its biological and economic significance. This study would be the first comprehensive examination of population dynamics of *P. longirostris* in the coast of Ghana. The findings will be pivotal for the development of effective fishery management strategies, optimizing resource use, and preventing overfishing of the sampled species.

Material and methods

Study area

This research was conducted in the coastal waters of Apam, Keta, Sakumono, and Sekondi along the coast of Ghana (Fig. 1). Apam, located in the Central Region of Ghana, is the capital of Gomoa West District, situated at 5°17’5" N latitude and 0°44’13" W longitude, with a population of 23,588 (Ghana Statistical Service, 2014). The primary occupations in Apam are subsistence agriculture and fishing. Apam has landing beaches, 216 canoes, and 2,694 fishermen (GSS, 2014). Semi-industrial fishing vessels use trawling gears to target demersal species like seabreams and groupers, while purse seine gears, notably the ‘Ali-Poli-Watsa’ (APW), capture pelagic species such as sardines and mackerels (MoFAD, 2022). Artisanal fishers use dug-out canoes, some motorized with outboard engines, employing gillnets, drift gill nets (DGN), set nets, and beach seines to catch various pelagic and demersal species, including *Sardinella aurita, Pseudotolithus senegalensis*, and *Caranx crysos* (Nunoo *et al.,* 2009).

Keta, located in the Volta Region of Ghana at coordinates 5°55’04.5" N latitude and 0°59’16.4" E longitude, has a population of 147,618, comprising 68,556 males and 59,062 females (Ghana

Statistical Service, 2014). The Keta Municipality spans 1,086 km² and relies heavily on fishing and salt mining as its primary economic activities (GSS, 2014). About 30% of the municipality is covered by water bodies, with the Keta Lagoon being a significant resource for fishing (Ghana Statistical Service, 2014). The main fish species caught in Keta include *Engraulis encrasicolus, Brachydeuterus auritus, Chloroscombrus chrysurus, Sardinella maderensis* and *Sardinella aurita*, and *Trachurus trecae*. MoFAD, 2022 Keta has seven fishing villages, nine landing beaches, and supports 358 canoes and 3,442 fishermen, who use various fishing gears such as purse seines, beach seines, lobster nets, and drift gill nets (MoFAD, 2022).

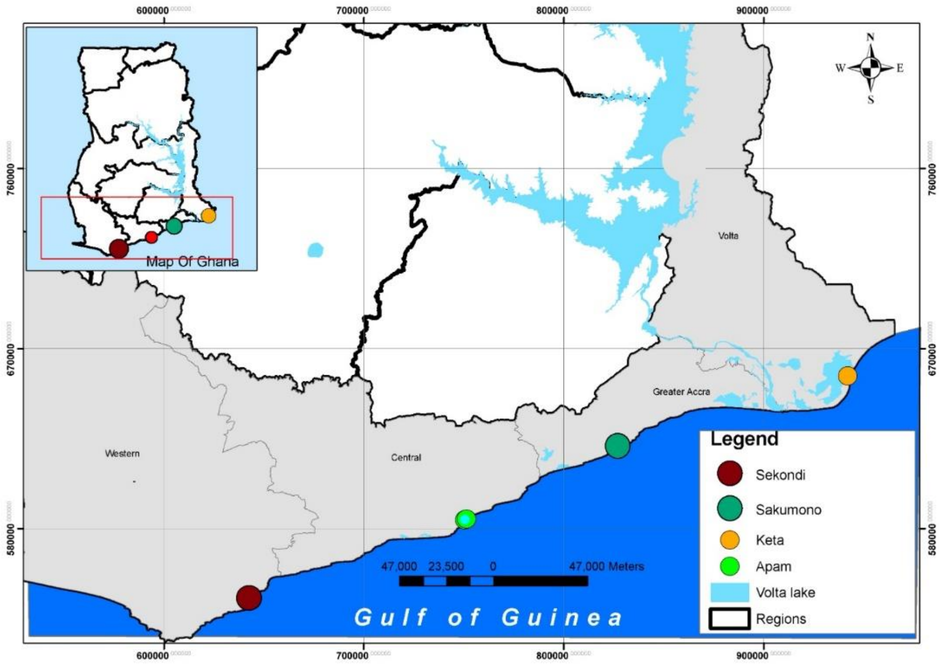

Figure 1: Sampling stations in the coast of Ghana.

Sakumono, a peri-urban village along the Accra-Tema highway, is located 3 km west of Tema and 18 km east of Accra at coordinates 05°37′00″ N and 00°03′00″ W. The village is flanked by two lagoons, Mukwe and Sakumo II (Nunoo and Ameka, 2005). Fishing is a vital livelihood in Sakumono, with 245 fishermen operating 31 canoes. The primary fishing gears used include purse seines, hook and line, and lobster nets (MoFAD, 2022).

Sekondi, the administrative capital of the Sekondi-Takoradi twin city in the Western Region of Ghana, is located at coordinates 4.92° N latitude and 1.77° W longitude. It is part of a larger urban area with a population of 445,205. The economy of the city is largely industrial, with fishing playing a major role alongside timber, plywood, shipbuilding, and railroad repair industries. The main fish species caught in the Sekondi area include *Sardinella aurita, Auxis thazard*, and *Ilisha africana* (Dovlo *et al.,* 2016). Sekondi has six fishing villages and six landing sites, with primary fishing gears consisting of purse seines, beach seines, lobster nets, drift gill nets, and the 'Ali-Poli-Watsa' (APW) (MoFAD, 2022).

Data collection
Over twelve months, from July 2020 to June 2021, samples of Deep-water rose shrimp were randomly collected from fishermen along the four fish landing sites. The samples were identified on-site and transported to the Department of Marine and Fisheries Sciences Laboratory at the University of Ghana for further analysis. In the laboratory, specimens were sorted and identified to the species level using fish identification keys (Kwei and Ofori-Adu, 2005). Morphometric measurements including total length (TL/cm) from the rostral extremity to the telson extremity, and total body weight (BW/g) were recorded using fish measuring board and electronic balance respectively.

Length -weight relationship
A linear equation (log W=log a+b log TL) was fitted for log-transformed data. Parameters a and b were estimated using power regression and the coefficient of determination (R^2) to show the total length–weight relationship (Sparre *et al.,* 1989). The parameter b is a shape parameter for the body form of the shrimp species.

Growth parameters
Von Bertalanffy's growth parameters were calculated as below:
$Lt = L\infty (1-e^{-K(t-t0)})$,
Where, Lt is the size at age t, L∞ is asymptotic length (cm), K is the growth coefficient (per year) and t0 is the hypothetical age at which the size is zero.

Growth parameters (L∞ and K) analyses were performed on the monthly length distributions using the ELEFAN I routine, of the FISAT II automatic calculation program (Gayanilo *et al.,* 2002).

The t0 was computed by the equation of Pauly (1984):

$$\text{Log}(-t0) = (-0.3932) - 0.2752 * \log TL\infty - 1.038 * \log k.$$

The index of overall growth performance Φ, was calculated by Pauly and Munro (1984):
$\Phi = \log K + 2\log TL\infty$

Mortality parameters
The natural mortality (M) was obtained using Pauly's empirical formula (Pauly, 1984):

$$\ln M = -0.0152 - 0.279 \times \ln L\infty + 0.6543 \times \ln K + 0.463 \times \ln T$$

Where, T is the annual average of water temperature (°C) of 26.7°C.

Total mortality (Z) was found using the length converted catch equation (Pauly, 1984). Fishing mortality (F) was calculated by the subtraction of the estimates of M from Z: F=Z-M (Pauly, 1983).

Exploitation rate was calculated as follows: E=F/Z (Pauly, 1983).

Probability of capture

The probabilities of capture (Lc_{25}, Lc_{50}, and Lc_{75}) were estimated using the gear selection curve generated from the length converted catch curve.

Exploitation parameters

The relative yield per recruit (Y/R) and relative biomass per recruit (B/R) were computed from the ogive selection using the procedure in the FISAT II program (Gayanilo *et al.,* 2002).

Results

Length frequency distribution

From a total of 1,164 individuals of the sampled species, the mean body length was 9.72±2.22 cm (Fig. 2).

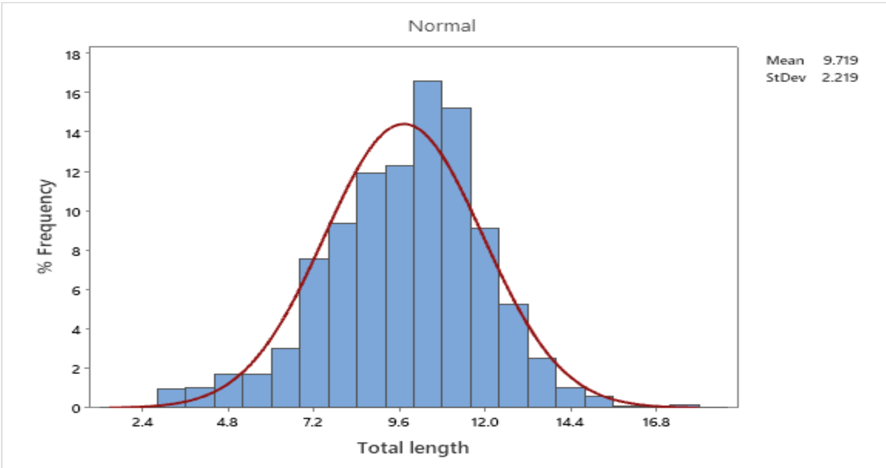

Figure 2: Length frequency distribution of *P. longirostris* in the coast of Ghana.

Length weight relationship

The length-weight relationship equation was calculated as Log BW=2.841 Log TL–2.109. The growth pattern was estimated as 'b'=2.84 (Fig. 3).

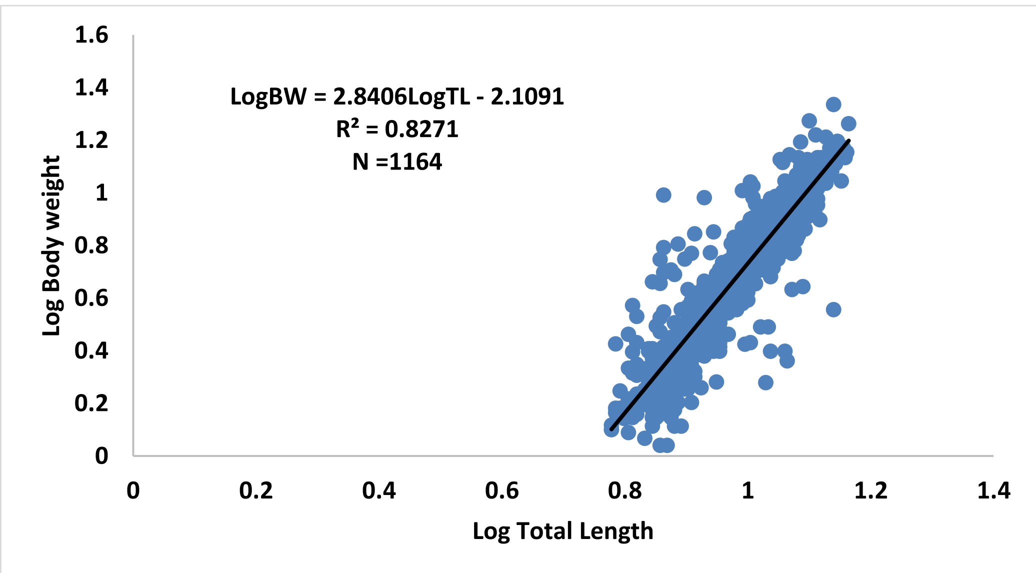

Figure 3: Length weight relationship of *P. longirostris* in the coast of Ghana.

Growth parameters

The estimated VBGF parameters for *P. longirostris* from the coast of Ghana was: $TL\infty$=17.85 cm, t_0= -0.21 and K=0.87 per year (Fig. 4). The estimated growth performance index (φ) and Tmax were 2.44 and 3.44 years, respectively.

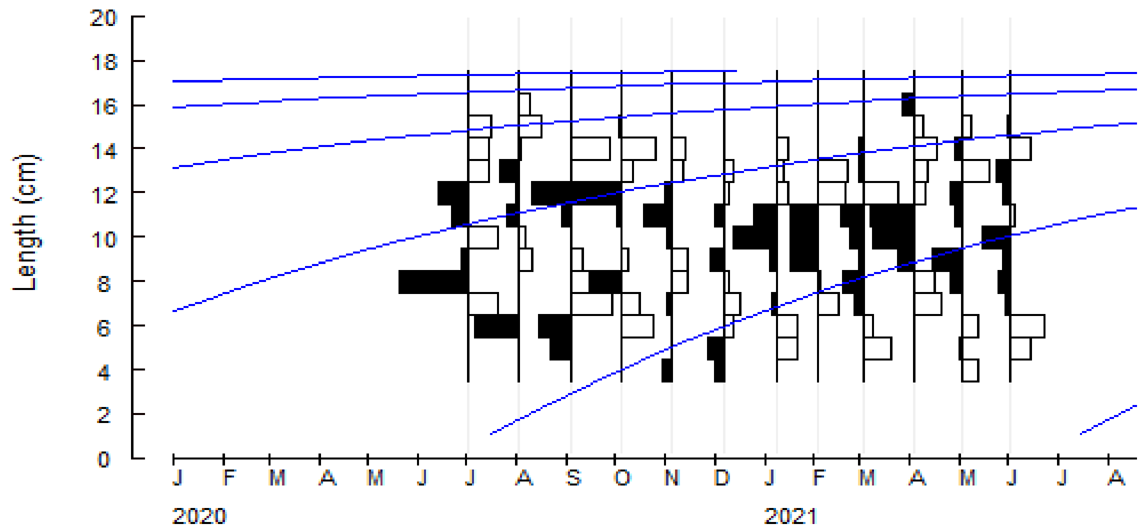

Figure 4: Von Bertalanffy growth curves for *P. longirostris* from the coast of Ghana. The black and white bars of three length groups represent pseudo-cohorts.

Mortality and exploitation rate

The total, natural and fishing mortality coefficient for the sampled fish species was 3.82 per year, 1.84 per year and 1.98 per year respectively (Fig. 5). The current exploitation rate ($E_{current}$) was 0.52.

Length at first capture

The lengths at first capture (the length at which 50% of the fish are vulnerable to capture) were estimated as $Lc_{50\%}$=9.8 cm TL. The lengths at 25% and 75% capture were 8.89 cm and 10.7 cm respectively (Fig. 6).

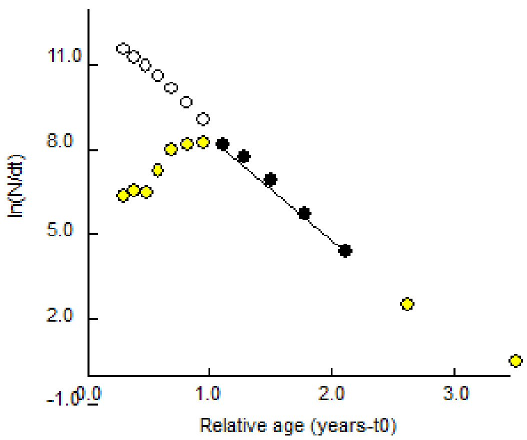

Figure 5: Length converted catch curve for *P. longirostris* from the coast of Ghana.

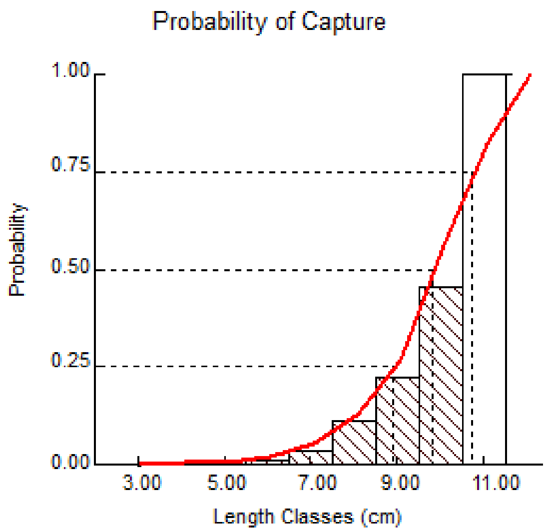

Figure 6: Length at first capture for *P. longirostris* from the coast of Ghana.

Exploitation parameters

The plot of relative yield per recruit (Y'/R) and biomass per recruit (B'/R) against exploitation rate (E) for the *species* showed that the maximum (Y'/R) was obtained at 0.749. Both $E_{0.1}$ and B'/R were estimated to be 0.607 and 0.370 (Fig. 7).

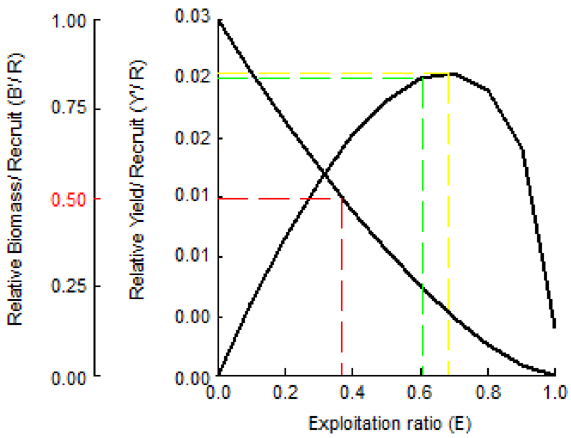

Figure 7: Relative Y/R and B/R using selection Ogive for *P. longirostris* from the coast of Ghana.

Discussion

The growth pattern (b) of *P. longirostris* in this study was 2.84, indicating a negative allometric growth where the species' body length increases faster than its body weight. Garcia-Rodriguez *et al.* (2009) and Arslan Ihsanoglu and Ismen (2020) reported similar growth patterns (b=2.61 and 2.52, respectively) from the coastal waters of Spain and Turkey, though their b values were slightly lower. Likewise, Dereli (2010) and Fellah *et al.* (2021) observed negative allometric growth for *P. longirostris* in Sığacık Bay, Turkey, and Algeria, with slightly lower growth coefficients (b=2.70 and 2.37-2.60, respectively) than in the present study (Table 1). This variation in 'b' values could be attributed to differences in locality and season, as noted by Lawal-Are and Akinjogunla (2012).

Table 1: Length -weight relationship parameters recorded by other researchers.

References	Location	a	b	R^2
Garcia – Rodriguez *et al.* (2009)	Spain	0.0020	2.61	0.96
Dereli (2010)	Turkey	0.0012	2.70	0.95
Arslan Ihsanoglu and Ismen (2020)	Turkey	0.0022	2.52	0.94
Fellah *et al.* (2021)	Algeria	0.449 0.562	2.60 2.37	0.91 0.87
Present study	Ghana	0.0078	2.84	0.83

Growth parameters

The growth constant of *P. longirostris* in this study (K=0.87 per year) was higher than estimates from other geographic locations (Table 2), indicating a fast growth rate for the sampled species from the coast of Ghana. This fast growth trait has also been observed by Fellah *et al*. (2021) and Tosunoglu *et al.* (2009) in Algeria and Turkey, respectively. Short-lived species like shrimps typically reach their asymptotic length within the first or second year of life, characterized by a high K-value. The phi prime value from this study aligns with findings by Arslan Ihsanoglu and Ismen (2020) and Garcia-Rodriguez *et al.* (2009), as shown in Table 2. The phi prime values are generally consistent within related taxa and exhibit narrow normal distributions (Sparre and Venema, 1992).

The ratio of the length at first capture to the length at infinity (Lc/L∞) was 0.56, indicating that the catches were predominantly composed of smaller individuals rather than adults. This suggests the onset of growth overfishing due to intensified fishing efforts (Arslan Ihsanoglu and Ismen, 2020).

Table 2: Growth parameters obtained by other researchers for *P. longirostris.*

References	Location	L∞	K (per year)	Phi	t_0
Garcia-Rodriguez *et al.* (2009)	Spain	-	0.39	2.90	-
Tosunoglu *et al.* (2009)	Turkey	-	0.50	2.95	-
Baran and Ozturk (1990)	Turkey	147 mm	-	-	-
Arslan Ihsanoglu and Ismen (2020)	Turkey	-	0.35	2.79	-
Awadh and Aksissou (2020)	Morocco	-	0.39	-	-
Fellah *et al.* (2021)	Algeria	-	0.60 (F) 0.62 (M)	-	-
Present study	Ghana	17.85 cm	0.87	2.44	- 0.21

The natural (M) and total (Z) mortality rates observed were higher than estimates reported in other geographical studies. This variation may be attributed to differences in environmental parameters. Abiotic factors such as temperature, hypoxia, and salinity, along with biotic factors like predation, disease, and food supply restrictions, influence the natural mortality of penaeid shrimp across regions. Additionally, the fishing mortality rate (F) exceeded findings from other researchers (Table 3). This variation could be due to the size of the individuals, fishing activity levels (Fella *et al.,* 2021), and high consumer demand. The high fishing mortality from the study aligned with intense global fishing pressure on penaeid fisheries (Garcia and Le Reste, 1981). Increased fishing efforts have undoubtedly elevated the total mortality rate. According to Moshen (2017), most penaeid fisheries worldwide exhibit high fishing mortality rates, resulting in high Z values (Mohsen, 2017).

Table 3: Mortality parameters from other studies for *P. longirostris*.

References	Location	M	F	Z	E
Deval *et al.* (2006)		0.56	0.60	1.16	0.38
Tosunoglu *et al.* (2009)		0.77	1.18	1.95	0.60
Arslan Ihsanoglu and Ismen (2020)	Turkey	0.61	0.99	1.60	0.62
Awadh and Aksissou (2020)	Morocco	1.98	1.51	3.49	0.43
Fellah *et al.* (2021)	Algerian	0.89 1.04	1.77 0.99	2.66 2.03	0.67 0.49
Present study	Ghana	1.84	1.98	3.82	0.52

In the present study, the $E_{current}$ was marginally higher than the values of E_{opt} given by Gulland (1971), indicating the optimal level of exploitation of the *P. longirostris* stock in the coast of Ghana. The result of the relative Y/R and B/R analysis for the stock of *P. longirostris* showed that exploitation of the sampled species was within the safe limit ($E_{current} < E_{max}$). For resource management purposes, it is suggested that the exploitation rate should be reduced to the conservative limit such as an exploitation rate at 0.1 (Gayanilo and Pauly, 1997).

Conclusions

The study provided preliminary insights into the population parameters of *P. longirostris* from the coast of Ghana. It indicated fast growth and optimal exploitation level for the sampled species residing in the coast of Ghana. However, individuals of the sampled species were faced with intense fishing pressure. Based on the findings from the study, urgent management measures in Ghana are needed for sustainable management of the sampled species. Some management measures may include extended closed fishing seasons, protection of spawning and nursery grounds through the establishment of marine protected areas (MPAs), and mesh size regulations.

Acknowledgments

The authors would like to thank fisherfolks from Apam, Keta, Sakumono, and Sekondi who helped during the fieldwork.

Conflicts of interest

The authors declare that for this article they have no actual, potential, or perceived conflict of interests.

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