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Population dynamics of the Brown mussel *Perna perna* at a Rocky beach near Cape Coast, Ghana

Eric A. Krampah | **Kobina Yankson** | **John Blay**

Department of Fisheries and Aquatic Sciences, University of Cape Coast, Cape Coast, Ghana

Correspondence
Eric A. Krampah, Department of Fisheries and Aquatic Sciences, University of Cape Coast, Cape Coast, Ghana.
Email: eakrampah@gmail.com

Abstract

The brown mussel, *Perna perna*, is an ecologically important species which has a great potential for aquaculture in Ghana. Though it is harvested from the wild for consumption locally, there is no information on its population parameters to guide its management and subsequent culturing. The species inhabiting Iture rocky beach near Cape Coast (Ghana) was therefore investigated to elucidate its growth and other population parameters. Specimens had shell length ranging from 5.00 to 78.0 mm, a modal shell length class of 35.0–39.9 mm, and exhibited negative allometric growth. The asymptotic length ($L\infty$), growth coefficient (K), and growth performance index (Φ') were 80.10 mm, 0.49 per year, and 3.49, respectively. The recruitment pattern showed that *P. perna* has year-round recruitment with a single peak between April and July. Total mortality (Z) was estimated at 2.79 per year, while natural mortality (M) and fishing mortality (F) were 0.87 and 1.92 per year, respectively. The calculated exploitation level of the population (E = 0.69) suggests possible overfishing of the mussels at Iture rocky beach. These results could serve as baseline information for management of the mussel population in Ghana.

KEYWORDS
exploitation, mortality, *Perna perna*, recruitment, von Bertalanffy growth function

1 | INTRODUCTION

The brown mussel *Perna perna* is among the popular edible bivalves in Ghana which are collected from the wild for consumption. A study by Intsiful (2002) reported that an estimated 68.6 tonnes of *P. perna* was exploited from the Iture rocky beach in Ghana. However, increased exploitation of this bivalve by coastal dwellers in recent times, particularly in the Cape Coast and Elmina areas, has led to population decline. *P. perna* is also considered as one of the bivalves with a high culture potential in the country, the others being *Crassostrea tulipa*, *Anadara senilis*, and *Galatea paradoxa* (Yankson, 2004).

Aside its importance as a fishery resource, *P. perna* is relevant species in terms of its role in the distribution and composition of the macro-invertebrate community of rocky beaches in Ghana (Intsiful, 2002; Yankson & Akpabey, 2001) and also as indicator of heavy metal contamination (Otchere, 2003). Mussels are generally recognized as key species in determining the community structure of intertidal rocky shores worldwide (Harris et al., 1998; Suchanek, 1986). Mussel beds have been considered as microhabitats enhancing assemblage and harboring a large number of invertebrate animal species (Alvarado & Castilla, 1996; Griffiths, Hockey, Erkom Schurink, & Le Roux, 1992; Ndzipa, 2002; Suchanek, 1986), presumably because of their great structural complexity, which results from their extensive shell surface and the byssus threads (Ndzipa, 2002). The current level of exploitation of the mussel at Iture rocky beach, if not regulated, could lead to decimation of the population and ultimately affect the ecological conditions of their biotopes.

Generally, studies on population dynamics of bivalves are usually conducted with the objective of sustainable management and conservation (Adjei-Boateng & Wilson, 2012). Management of molluscan resources requires knowledge of various population parameters and exploitation level of populations (Adjei-Boateng & Wilson, 2012; Al-Barwani et al., 2007). There are many tools for assessing exploitation levels and population dynamics of a stock. The FAO-ICLARM computer software, Fish Stock Assessment Tools (FiSAT), has been most frequently used for estimating population parameters of fin-fish and shell-fish (Al-Barwani et al., 2007; Tuaycharden, Vakily, Saelow, & McCoy, 1988; Vakily, 1992) because it needs only length–frequencies as input data to generate growth and mortality parameters.

The objective of the present study was to estimate the population parameters such as population density, length–frequency distribution, length–weight relationship, asymptotic length ($L\infty$), growth coefficient (K), growth performance index (Φ'), recruitment pattern, mortality rates, and exploitation level of *P. perna* at Iture rocky beach near Cape Coast, Ghana. The aim is to generate baseline information, which will be essential for future studies and also crucial for sustainable management of the mussel population. Also, possible ecological implications of the mussel exploitation are discussed.

2 | MATERIALS AND METHODS

2.1 | Study area

The study was carried out at Iture rocky beach near Cape Coast in the Central Region of Ghana. The beach, as described by Yankson and Akpabey (2001), is about 6 km west of Cape Coast and 3 km east of Elmina (5°N, 1°10'W). It is relatively narrow and is about 60 m long from the low water mark (MLWM) to the uppermost limit. The site may be described as a moderately sheltered rocky shore (Krampah, Yankson, & Blay, 2016; Lawson, 1956) with a gentle slope of about 9°.

2.2 | Growth parameters

Mussel sampling was carried out at monthly intervals, from September 2014 to August 2015. Sampling was done at the lowest daytime low tide, using a 0.25 m^2 quadrat placed randomly on the mussel beds. Four quadrat samples were taken during each sampling period. The number of mussels in each quadrat throw was counted for the determination of population density. Population density was estimated by dividing the number of mussels enclosed in the quadrat by the area of the quadrat. Mean population density was computed from the four quadrat throws. Subsamples of 30–40 mussels were taken to the laboratory within one hour after sampling for analyses of population parameters. Shells of mussels were washed and scrubbed clean of fouling organisms (seaweeds, barnacles, etc.) and debris, and the byssus threads removed. They were then blotted dry with an absorbent paper before the shell dimensions and the weight were determined. The shell length (maximum anterior–posterior axis) of each specimen was measured with a pair of vernier calipers to the nearest 0.01 mm. The shells were carefully opened and the “meat” (soft body) was extracted, blotted to remove excess moisture, and weighed to the nearest 0.01 g, with an electronic balance. The shells were also blotted dry and weighed to the nearest 0.01 g. The total weight was determined by adding the meat weight and the shell weight. The length–weight relationship of the mussels was established using the commonly used equation $W = aL^b$ (Ricker, 1975), where W is the total weight (g), L the shell length (mm), a is the intercept, and b is the slope (growth coefficient). The parameters a and b were estimated by least squares linear regression on log–log transformed data: $\log_{10} W = \log_{10} a + b \log_{10} L$. The coefficient of determination (r^2) was used as an indicator of the quality of the linear regression (Scherrer, 1984), and 95% confidence limit of b and the statistical significance level of r^2 were estimated.

Length data obtained from the monthly samples were grouped at 5.0 mm class intervals and analysed using the electronic length frequency analysis (ELEFAN I) computer program incorporated in the FiSAT II software (Gayanilo, Sparre, & Pauly, 2005) to estimate asymptotic length (L_∞) and growth coefficient (K) of the von Bertalanffy growth function (VBGF), mortality parameters, and exploitation level of the mussels. Preliminary estimates of the asymptotic length (L_∞) and growth coefficient (K) were obtained from the Powell-Wetherall Plot to guide the final estimates by the ELEFAN I routine (Sparre & Venema, 1992).

The growth performance index (Φ') (Pauly & Munro, 1984) was estimated using the equation:

$$\Phi' = \mathrm{Log}_{10}K + 2\,\mathrm{Log}_{10}L$$

The theoretical age at zero length (t_o) (Pauly, 1979) was calculated as:

$$\mathrm{Log}_{10}(t_0) = 0.392 - 0.275\mathrm{Log}_{10}L_\infty - 1.038\mathrm{Log}_{10}K$$

Longevity (t_{max}) (Pauly, 1984) of the population was estimated according to the equation:

$$t_{max} = 3/K$$

The growth parameter estimates were used to fit the VBGF, $L_t = L_\infty\,[1-(\exp - K\,(t - t_o))]$, for the Iture population.

2.3 | Recruitment pattern

The recruitment pattern which describes how new individuals are added onto the population was determined by the backward projection onto the length axis of the length–frequency data as described in FiSAT. This routine reconstructs the recruitment peak pulses from a time series of length–frequency data to determine the number of peak pulses per year and relative strength of each peak pulse (Al-Barwani et al., 2007). Input parameters are L_∞, K, and t_o, and the normal distribution of the recruitment pattern was determined by NORMSEP in FiSAT (Al-Barwani et al., 2007; Pauly & Caddy, 1985).

2.4 | Mortality and exploitation rate

The total mortality (Z) of the mussels was estimated from the slope of the descending right arm of the linearized length-converted catch curve (Pauly, 1984; Sparre & Venema, 1992). Natural mortality (M) (Pauly, 1980) was estimated using the empirical relationship:

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_{\infty} + 0.6543 \log_{10} K + 0.4634 \log_{10} T$$

where T is the mean annual water temperature of the study site.

Fishing mortality (F) (Gulland, 1971) was obtained from the relationship: $F = Z - M$. The level of exploitation (E) (Gulland, 1969) of the mussels was calculated by the relationship:

$$E = F/Z = F/(F+M)$$

3 | RESULTS

3.1 | Growth parameters estimates

Mean population densities of *P. perna* at Iture rocky beach varied from 56 ± 16.1 individuals/m^2 to 466 ± 68.3 individuals/m^2. A total of 1,229 *P. perna* was analysed for their size–frequency distribution, and the mussel population had a shell length range of 5 mm to 78 mm. The overall size–frequency distribution (Figure 1) showed a modal shell length of 35–39.9 mm. The monthly length–frequency distribution of the mussels fitted with the growth curve obtained by ELEFAN I routine from September 2014 to August 2015 is shown in Figure 2. The length–weight relationship of the population is presented in Figure 3. The relationship was described by the equation $W = 0.0006L^{2.448}$ in mussels of shell length 10.5 to 78.0 mm weighing 0.15 to 35.9 g. There was a significant strong relationship ($r^2 = 0.88$; $p < 0.01$) between the length and weight, and the exponent ($b = 2.448 \pm 0.03$) suggests a negative allometric growth ($t = 19.29$; $p > 0.05$) of the brown mussels at the Iture rocky beach.

Table 1 indicates the final estimates of growth parameters of the mussels. The maximum observed length (L_{max}) of *P. perna* was 78 mm and the asymptotic length ($L\infty$) was 80.1 mm. A growth constant (K) of 0.49 per year and longevity (t_{max}) of approximately 6 years were estimated for the Iture mussel population. The hypothetical age at

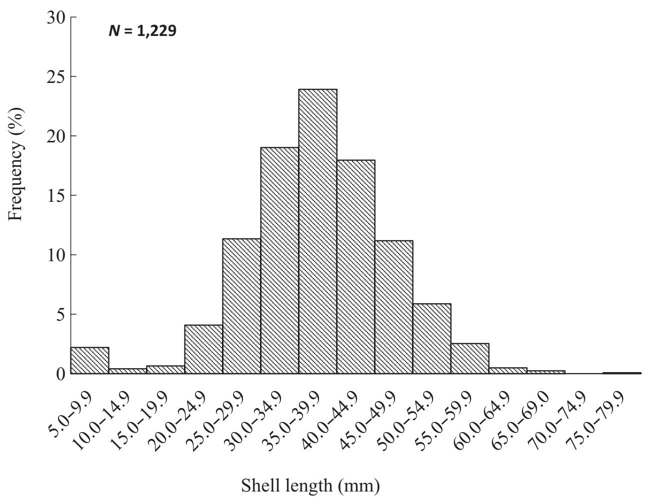

FIGURE 1 Length–frequency distribution of *Perna perna* from Iture Rocky beach (Ghana)

zero length (t_o) was computed as −1.66 years. Hence, the VBGF describing the growth of the *P. perna* population at Iture rocky beach was as follows:

$$L_t = 80.10 \{1 - \exp[-0.49 (t + 1.66)]\}$$

The derived growth curve of *P. perna* at Iture rocky beach is shown in Figure 4. Hence, the sizes attained by *P. perna* at year 1, 2, 3, 4, 5, and 6 were 58.34, 66.77, 71.93, 75.10, 77.04, and 78.22 mm, respectively.

3.2 | Recruitment pattern

The recruitment pattern of *P. perna* generated from FiSAT II software for the population at Iture rocky beach is shown in Figure 5. Recruitment of *P. perna* at Iture rocky beach occurred throughout the year with a single peak pulse, which occurred between April and July.

3.3 | Mortality and exploitation

Figure 6 illustrates the length-converted catch curve of *P. perna* which estimated the total mortality rate (Z) of the populations based on mussels that were fully exploited. The annual mean sea surface temperature during the sampling period was 29.0°C. The total mortality (Z), natural mortality (M), and fishing mortality (F) of the mussels were estimated as 2.78, 0.87, and 1.92 per year respectively. The current exploitation rate (E) was estimated to be 0.69 suggesting that the *P. perna* population at Iture was overexploited.

4 | DISCUSSION

Naturally, *Perna* species reproduce profusely with individuals of various sizes settling on rocks, and it has been reported by Abada-Boudjema and Dauvin (1995) that *Perna perna* could have a density of over 10,000 individuals/m^2. According to Hicks and Tunnell (1995), densities up to 27,000 individuals/m^2 have been recorded on jetty rocks from Port Aransas to Brazos Santiago Passes in Texas, U.S.A; 5,216 individuals/m^2 were recorded at the shores of Punta Boca Andrea and 120,000 individuals/m^2 were recorded on algal substratum at the Playa Escondida site, all around the Gulf of Mexico. High population densities could probably obscure the possible danger which the mussel fishery may face at an uncontrolled level of exploitation (Abada-Boudjema & Dauvin, 1995). However, this scenario cannot be said of *P. perna* population at Iture rocky shore, as the densities (56–466 individuals/m^2) recorded in the present study are relatively low compared with densities recorded in studies elsewhere. The low densities could be attributed to overexploitation of the mussels, which is so intense that the mussel populations virtually disappear at some period of the year. This observation reaffirms an earlier observation made by Intsiful (2002) that some exploited species of the rocky beaches are not normally available in

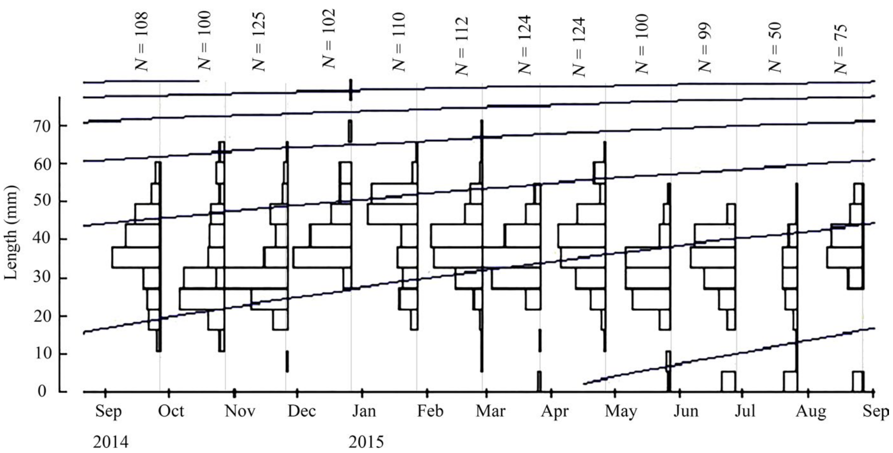

FIGURE 2 Monthly length–frequency distributions of *Perna perna* fitted with a growth curve obtained by ELEFAN I routine from September 2014 to August, 2015 ($L\infty$ = 80.10 mm, K = 0.49 per year and N = sample size)

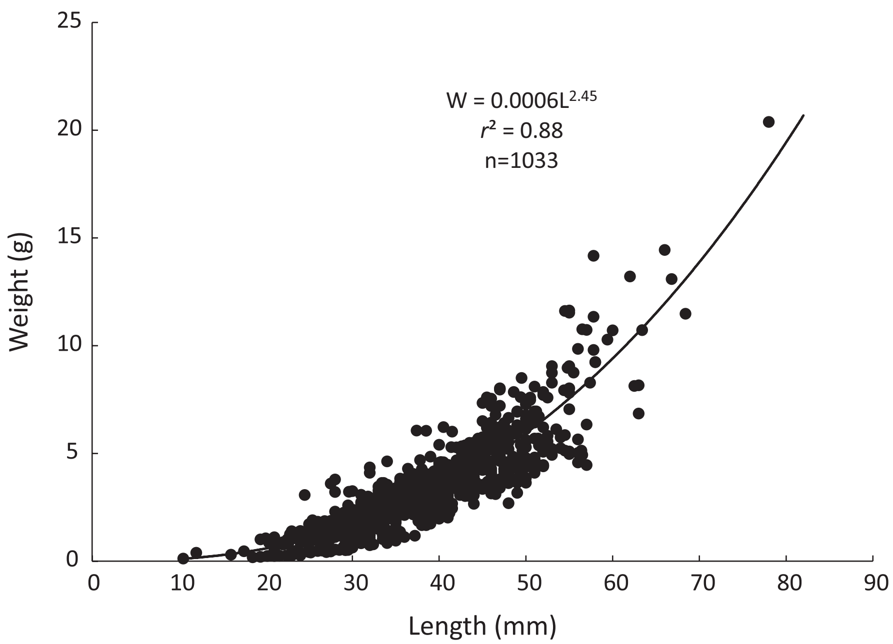

FIGURE 3 Length–weight relationship of *Perna perna* from Iture Rocky beach (Ghana)

TABLE 1 Estimates of growth parameters of *P. perna* population at Iture Rocky beach

Growth parameters	Values
Asymptotic length ($L\infty$)	80.10 mm
Maximum observed length (Lmax)	78 mm
Growth constant (K)	0.49per year
Longevity (t_{max})	6 years
Theoretical age at zero length (t_o)	−1.66 year
Growth performance index (Φ')	3.49

large quantities in their habitats throughout the year, especially from April/May to August/September.

The size of *P. perna* population at Iture rocky shore may be summarized by the shell length–frequency distribution, which is the size structure of the underlying populations. Based on the length–frequency data, the size of brown mussels ranged from 5 to 78 mm and the majority of shell lengths (modal length) ranged from 35.5 to 39.9 mm. This finding is similar to an earlier finding by Intsiful (2002), who reported a length range of 5 to 80 mm for the same population. The monthly length–frequency distributions showed inconsistent shifts in the modes (see Figure 2); however, there was a modal progression from October 2014 to January 2015, which appeared that the brown mussel grew by 20 mm in 4 months, with an average growth rate of 5.0 mm per month. *Perna species* from other locations in Africa exhibited differences in growth rates (Table 2). These differences in growth rates according to Vakily (1989) could be as a result of the combined effects of a number of prevailing environmental factors, such as water temperature, availability of food, settling density, currents, exposure, and pollution. These apparently existing relationships between growth and environmental factors are difficult to quantify because of the obvious complexity of the influence of the multiple factors (Wilbur & Owen 1964; Vakily, 1992).

The objective of length–weight relationship analysis is to obtain the necessary constants that allow the transformation of length into weight, a dimension that is usually more difficult to measure in growth experiments (Vakily, 1992). In length–weight growth studies,

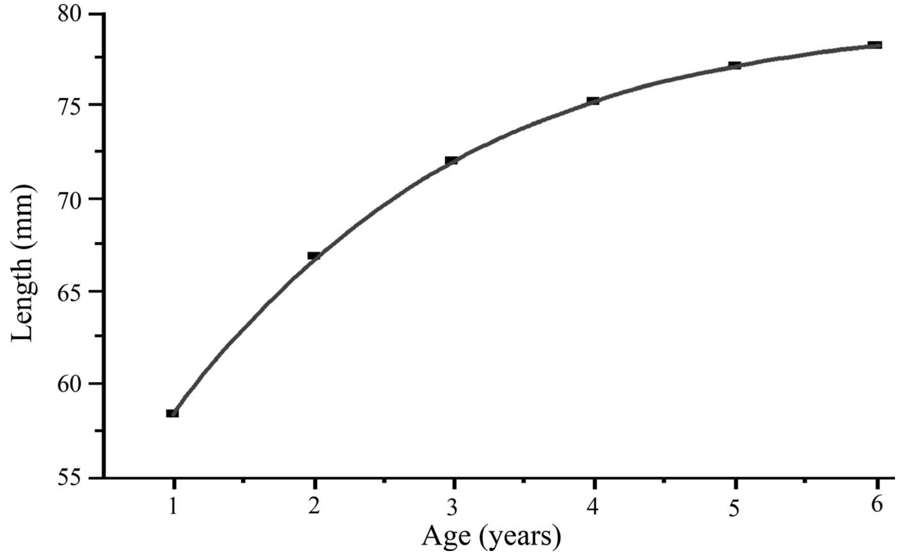

FIGURE 4 Derived growth curve of *Perna perna* from Iture Rocky beach

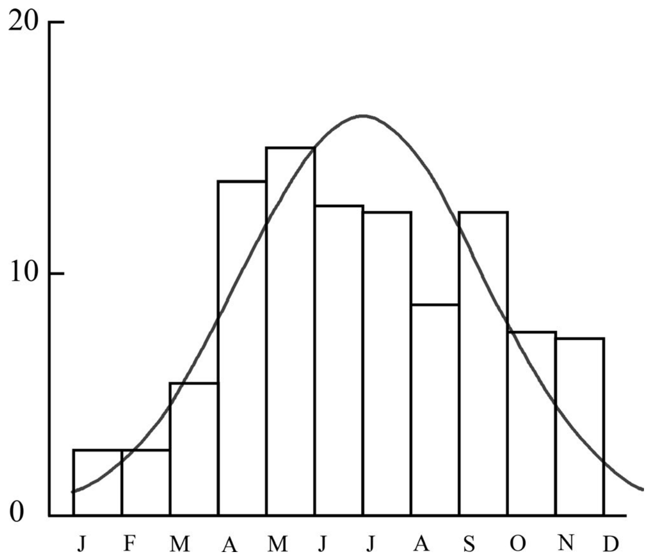

FIGURE 5 Recruitment pattern of *Perna perna* obtained by backward projection, along a trajectory defined by the VBGF, of the restructured length–frequency data onto a one-year timescale. The months on the *x*-axis were located exactly by providing the theoretical age at zero length (*to*= −1.66) of the population at Iture rocky beach

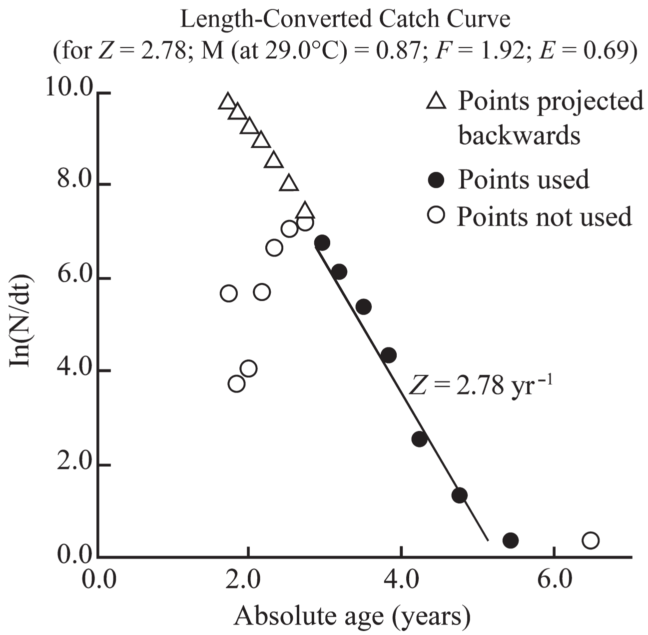

FIGURE 6 Length-converted catch curve of *P. perna* from Iture Rocky beach based on pooled monthly length–frequency data

the constant *b*, also known as the coefficient of allometry, expresses the rate of change of the relative animal body shape during the growth process (Winberg, 1971; Thejasvi et al., 2013). The growth coefficient *b* generally lies between 2.4 and 4.5 in most bivalves (Wilbur & Owen 1964), and the relation is said to be isometric when it is equal to 3 (Carlender, 1977). Unlike *P. viridis*, growth data for *P. perna* are lacking hence an attempt to compare growth and VBGF estimates from this study to other closely related species of the same genus. Table 3 summarizes values of the coefficients "*a*" and "*b*" for *Perna* species around the world. The values of "*b*" show considerable variation, ranging from 2.37 (Lee, 1985) to 2.86 (Narasimham, 1981). The exponent "*b*" of the length–weight relationship in the genus *Perna* is generally different from 3 as shown in Table 3. This might partly be explained through the influence of ecological factors such as mussel density and shore level (Al-Barwani et al., 2007).

The VBGF estimates of the *P. perna* population at Iture differ from those of the same genus from other areas in the world (see Table 4). The $L\infty$ (80.10 mm) of *P. perna* from Iture was relatively smaller than that recorded for *P. viridis* (184.60 mm) from Indian waters (Narasimham, 1981). *P. perna* in the present study has a higher growth constant than *P. viridis* in Hong Kong (Lee, 1985) and India (Narasimham, 1981), but lower than those observed in Malaysia (Choo & Speiser, 1979) and Bangladesh (Khan, Assim, & Ismail, 2010). It could be inferred that the *P. perna* population at Iture rocky beach approaches its hypothetical maximum length at a faster rate than *P. viridis* at Hong Kong and India, but much slower than the *P. viridis* population at Malaysia and Bangladesh. The growth performance index (Φ') allows inter- and

TABLE 2 Size range and growth rates of genus *Perna* from different locations

Species	Location	Investigated size range (mm)	Average growth per month (mm)	Temperature (°C)	Source
P. perna	Ghana	5.0–78.0	5.0	29.0	Present study
P. viridis	Malaysia	11.02–98.97	9.0	29.4	Al-Barwani et al.(2007)
P. perna	Ghana	5.0–80.0	-	27.3	Intsiful (2002)
P. perna	Mozambique	-	7.0	-	Ribeiro (1984)
P. perna	South Africa	0–75.0	6.3	-	Berry (1978)

TABLE 3 Values of the coefficients "*a*" and "*b*" for *Perna* from various locations

Species	Location	*a*	*b*	Length units	Temperature (°C)	Source
P. perna	Ghana, Cape Coast	0.0006	2.448	mm	29	Present study
P. viridis	Malaysia, Malacca	0.0002	2.603	mm	29.4	Al-Barwani et al., (2007)
P. viridis	Hong Kong	1.12E−03	2.37	mm	-	Lee (1985)
P. viridis	India, Goa	5.13E−04	2.50	mm	26–30	Parulekar, Dalal, Ansari, and Harkantra (1982)
P. viridis	India, Kankinada Bay	1.63E−04	2.88	mm	-	Narasimham (1981)
P. viridis	Malaysia, Penang	2.22E−04	2.76	mm	-	Choo and Speiser (1979)
P. viridis	Singapore	9.18E−02	2.79	cm	-	Cheong and Chen (1980)
P. viridis	Thailand, Upper Gulf	7.07E−02	2.78	cm	28–33	Chonchuenchob, Chalayondeja, and Mutarasint (1980)
P. canaliculus	New Zealand, Ahipira	2.14E−04	2.80	mm	18.1	Hickman (1979)

TABLE 4 Parameters of von Bertalanffy growth function of some species of genus *Perna* from different locations

Location	Species	L_∞(mm)	*K*(per year)	Φ'	Temperature (°C)	Source
Ghana	*P. perna*	80.10	0.49	3.49	29.0	Present study
Malaysia	*P. viridis*	102.38	1.5	-	29.4	Al-Barwani et al. (2007)
Malaysia	*P. viridis*	89.4	2.14	-	-	Choo and Speiser (1979)
Hong Kong	*P. viridis*	101.9	0.30	-	24.0–29.0	Lee (1985)
India	*P. viridis*	184.6	0.25	-	-	Narasimham (1981)
Bangladesh	*P. viridis*	136.5	1.30	2.38	30.2	Khan et al. (2010)

intra-specific comparison of growth performance in bivalve species of different stocks (Abohweyere & Falaye, 2008; Adjei-Boateng & Wilson, 2012). The growth performance index of *P. perna* (Φ'= 3.49) at Iture rocky shore of Ghana was higher than *P. viridis* population (Φ'= 2.38) in Bangladesh (Khan et al., 2010), but lower than that of *P. viridis* (Φ'= 4.197) population in coastal waters of Malacca, Peninsular Malaysia (Al-Barwani et al., 2007). Growth performance of bivalves could be as a result of influences of environmental factors, and thus, bivalves found at different geographical locations may have different growth performance indices which could be as a result of the prevailing environmental conditions. From the von Bertalanffy growth equation, the length of *P. perna* from Iture at age 1 was 58.34 mm, which suggests that the mussel grows at an average length of 4.9 mm (approximately 5 mm) per month, which corroborates the inferences made from the monthly length–frequency analysis. *P. perna* in the current study was observed to have a relatively longer lifespan (6 years) compared with findings for other mussels by previous authors. For example, Lee (1985) concluded from his data, that the observed average life span of three years for *P. viridis* in Hong Kong was delimited by ecological factors (mainly pollution). Berry and Schlerrer (1983) described *P. perna* as being very short-lived since only 0.1% of the population investigated off Durban (South Africa) survived into their third year. Also, *P. viridis* from the offshore waters of Naf River Coast, Bangladesh (Khan et al., 2010) and coastal waters of Malacca, Peninsular Malaysia (Al-Barwani et al., 2007) both have life span of approximately 2 years and have L_∞ of 136.5 mm and 102.38 mm respectively, which are higher than L_∞ (80.10 mm) of *P. perna* at Iture. The intense fishing pressure on the Iture *P. perna* could account for their general smaller sizes in spite of the estimated long life span of 6 years.

Gayanilo, Soriano, and Pauly, (1989) defined recruitment as a fully metamorphosed young fish whose growth is described adequately by the VBGF and occurs at the fishing ground(s) with the instantaneous rate of natural mortality similar to that of the adults. Recruitment has been described as a continuous phenomenon for tropical species because of the relatively stable and elevated water temperatures allowing year-round breeding (Adjei-Boateng & Wilson, 2012; Qasim, 1973; Weber, 1976). The recruitment pattern exhibited by *P. perna* suggested a year-round recruitment with a single seasonal peak from April to June (see Figure 5), which coincided with the major spawning period of the species (Krampah et al., 2016) and the period of low densities. This observation is similar to the finding by Al-Barwani et al. (2007) who also observed one seasonal peak (July–August) in the recruitment pattern of *P. viridis* in the coastal waters of Malacca, Peninsular Malaysia. Khan et al. (2010), however, observed two seasonal pulses in recruitment pattern of *P. viridis* in Bangladesh.

Bivalves in the larval, juvenile, and adult stages can die from a variety of causes, which can be environmental or biological in origin (Helm, Bourne, & Lovatelli, 2004). They serve as food for a wide range of other organisms from groups such as fish, birds, mammals, crustaceans, echinoderms, flatworms, and even other molluscs. These predators constitute important sources of natural mortality in bivalve molluscs (Gosling, 2003; Seed & Suchanek, 1992). Higher fishing mortality (1.92 per year) was observed than natural mortality (0.87 per year) (Figure 6) for the *P. perna* population in the present study, which suggests that mortality based on exploitation was relatively higher than that based on natural causes. On the other hand, higher natural mortality was observed than fishing mortality for *P. viridis* in Malaysia (Al-Barwani et al., 2007) and in Bangladesh (Khan et al., 2010), indicating that mortality as a result of natural causes was higher than that of exploitation of the mussels in those areas. As a general rule, if Z/K ratio is < 1, the population is growth dominated; if it is > 1, then it is mortality dominated; and if it is equal to 1, then the population is in an equilibrium state where mortality balances growth (Abohweyere & Falaye, 2008; Uneke, Nwani, Okogwu, & Okoh, 2010). In the present study, Z/K ratio was estimated as 5.67 for *P. perna*. This implies that the mussel population is highly mortality dominated.

The higher value of E (0.69) indicates “over-fishing” of the *P. perna* stock at Iture rocky beach. According to Gulland (1969), the yield is optimized when $F = M$; therefore, when E is more than 0.5, the stock is overfished. In other parts of the world, heavy exploitation of the mussels has been reported to have adverse implications for rocky shore community structure, and thus mussels are significant in the conservation of biodiversity in these biotopes (Tomalin, 1997). Disturbance of mussel beds may also impact negatively on mussel bed-associated fauna (Ndzipa, 2002). Experimental analyses of the ecological impact of exploitation have shown that algae usually replace mussels following disturbance from heavy exploitation and that recovery may take more than eight years (Dye, Lasiak, & Gabula, 1997; Lasiak & Dye, 1989). As mussels tend to recruit preferentially into already existing mussel beds, heavy exploitation not only affects reproductive output but also reduces the preferred settlement habitat (Lasiak & Barnard, 1995; Dye et al., 1997; Tomalin, 1997). To this end, it is thus important that proper management strategies are implemented for conservation and sustainable exploitation of the *P. perna* at the Iture rocky beach to minimize the negative impacts associated with mussel overploitations that have been observed elsewhere.

5 | CONCLUSION

The high fishing pressure on the *P. perna* population at Iture rocky beach could account for their general low densities and smaller sizes in spite of the estimated relatively high growth rate, long life span, and high growth performance index. The Iture rocky beach *P. perna* population is overfished and would require immediate action to manage this valuable fishery and ecological resource.

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ORCID

Eric A. Krampah https://orcid.org/0000-0003-0659-704X

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