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Population Dynamics of Mangrove Clam *Pegophysema philippiana* (Reeve, 1850) in Davao Region, Southeastern Mindanao, Philippines

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ABSTRACT

Mangrove clam is the most sought-after bivalve in the Philippines due to its taste, size, and nutrition. Due to its economic importance, this paper aims to determine the population dynamics of mangrove clam *P. philippiana* harvested in gleaning sites in the Davao region using the FAO ICLARM Stock Assessment Tool (FISAT II). A total of 2493 clams collected from December 2018-December 2020 with sizes ranging from 14-84 mm SL and 2.2-178.6 g were classified according to size classes with 5 mm intervals. The length-weight relationship was computed and showed negative allometry (a = 0.002, b = 2.6205, R^2 = 0.89). The estimated growth parameters using ELEFAN I was $L\infty$ = 98.64 mm, K = 1.33 $year^{-1}$, t_0 = -1.07. Length converted catch curve routine estimated Z = 10.27$year^{-1}$, M = 1.52 $year^{-1}$, F = 8.75 $year^{-1}$, E = 0.85, and backward extrapolation generated L_{c50} = 34.83 mm SL which is below L_m = 65.76 mm SL. Recruitment patterns were highest during July and August 2020, and VPA showed a high F at 60 mm SL. Beverton and Holt Y/R analysis showed $E_{0.5}$ = 0.328 and E_{max} = 0.551, yield isopleths derived from plotted $L_{c50}/L\infty$ = 0.353 and E = 0.85 values were within quadrant D. The result revealed that $L_m > L_{c50}$ implies that mangrove clams gleaned in the area were small and immature. Moreover, $F > F_{opt}$ and $E > E_{max}$ and $E > E_{0.5}$ suggest that mangrove clam fishery in the region was heavily exploited. The study concluded that the mangrove clam *Pegophysema philippiana* was overexploited and that a management strategy was needed in the Davao Region, Philippines.

1. Introduction

The mangrove ecosystem was very essential ecologically and economically (Bersaldo *et al.* 2023) as it provides ecological benefits to the environment like coastal protection, habitat for small fishes and invertebrates (Honda *et al.* 2013), and economic benefits such as improved fishery productivity and help increase the income of coastal communities like gleaners (Bersaldo *et al.* 2022). In the Philippines, particularly in Eastern Samar, mangroves were prone to natural threats like typhoons and sea level rise (Primavera *et al.* 2016) and anthropogenic activities such as coastal development, reclamation, and illegal settlers in Davao (Pacyao and Barail 2020). Mangroves were very common in the Philippines, such as in the Davao Region (Friess *et al.* 2020; Bersaldo *et al.* 2023). However, human-induced destruction weighs more than the naturally occurring phenomena that ravage mangrove forests (Quevedo *et al.* 2020; Abreo *et al.* 2021). In the Philippines, mangrove destruction was mainly influenced by the conversion of this area to aquaculture ponds that resulted in over 380,000 hectares loss from 1918 to 1994 (Primavera 2000). In the past few decades, mangrove rehabilitation projects in the Philippines have been widespread to mitigate the decreasing cover, but active involvement among stakeholders is required (Camacho *et al.* 2020).

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Mangrove forests support and play an important role in global marine biodiversity and have provided ecological and economic benefits to human society (Raheman *et al.* 2020). In general, these salt-tolerant trees help improve water quality and the health of aquatic organisms, as mangroves are known to be effective in filtering wastewater and serve as microbial barriers for pathogens (Dai *et al.* 2020). In addition, the canopy of mangrove forests provides shelter, habitat, and protection for terrestrial organisms such as birds, insects, mammals, and reptiles (Nagelkerken *et al.* 2008). Moreover, underneath its roots inhabits diverse marine fishes, crabs, prawns, and other infaunal and epifaunal organism like clams, sea urchins, sea cucumbers and varied species of gastropods (Nagelkerken *et al.* 2008; Bersado *et al.* 2022).

Mollusk is one of the most diverse invertebrate biota found in the mangrove forest, and the majority of these organisms are gastropods and bivalves (Kabir *et al.* 2014). The mangrove clam *Pegophysema philippiana* is a type of bivalve that was abundant in the muddy substrate of mangroves and was among the local favorites in Panay Island and Davao region (Primavera *et al.* 2002; Bersaldo *et al.* 2022). This clam is usually found in mangrove areas with dense aggregations of *Rhizophora* species, which provide high sulfide concentrations that serve as food for their bacterial symbionts (Lebata 2001). Together with other shellfish, mangrove clams support the marine food web as they connect detritus to upper trophic organisms, which makes them an important species ecologically (Myers *et al.* 2011). Mangrove clam supports coastal communities by providing livelihood, income, and food (Primavera *et al.* 2002); for example, in the Davao region in which the growing economy of mangrove clams was reported in Baganga, Davao Oriental (Bersaldo *et al.* 2022). Mangrove clams harvested in this area were sold locally and exported to nearby city markets (Bersaldo *et al.* 2022).

Given the importance of mangrove clams in the region, no research requires extensive data collection existed. Mangrove clam study in the Davao region only deals with distribution (Bersaldo *et al.* 2022), value chain (Palma Gil *et al.* 2023), and biology (Lumogdang *et al.* 2022) and no assessment of the wild population. In a population dynamic study, the estimation of growth parameters like asymptotic length (L∞), instantaneous growth (K), natural mortality (M), fishing mortality (F), and exploitation rate (E) was important for the evaluation and management of a fishery stock (Mirzaei *et al.* 2015). Estimating population dynamics provides fishery managers and scientists with insights into better stock prediction and efficient management information that would benefit coastal communities, especially in developing countries (Tesfaye and Wolff 2015). To know if the wild population of mangrove clams in the Davao region is in optimal condition, the current study was conducted to evaluate the population dynamics of *P. philippiana* in the Davao region and to provide fishery managers information regarding the current stock of mangrove clams in the area that would aid in proper management interventions for the optimum harvest of the gleaned mangrove bivalve resources.

2. Materials and Methods

2.1. Study Area

The study was conducted in the Davao region, specifically focusing on areas where the majority of the mangrove clam supply originates, namely Baganga in Davao Oriental, Sta. Cruz in Davao del Sur, and Malita in Davao Occidental. Mangrove clam *Pegophysema philippiana* specimens were collected from locations where clam harvesting was reported in each municipality (see Figure 1).

2.2. Sample Collection

A total of 2,493 mangrove clams, *P. philippiana*, were collected from December 2019 to December 2020 in the Davao region with the assistance of hired gleaners. Sampling times were determined based on their preferences for sampling locations. Shell length and total weight were measured in situ using a vernier caliper (Digital Vernier Caliper 200 mm, RS PRO, China) for length measurements and a digital weighing scale for clam weight. Before weighing, the mangrove clams were drained for a few minutes to minimize the presence of water inside the clam shells, which could influence their weight. Collection of samples was not continuous year-round due to travel restrictions imposed during the height of the Covid-19 pandemic and the request for an extension for the project. As a result, there were months where no data were available during April to October 2019 due to travel restrictions when the collection was very difficult (Table 1). Furthermore, from January to April of the following year, no sampling was conducted due to the pending request for the project extension. Despite the months with no available data, the 2,493 samples collected over 11 months during a two-year period exceeded the criterion set by Pauly (1984) of a total sample size of 1,500 samples collected for at least 6 months to be used in length frequency growth studies (Konan *et al.* 2015).

2.3. Data Analysis

2.3.1. Growth Parameters

The monthly length frequency data of mangrove clam *P. philippiana* were sorted into size classes at five (5) millimeter intervals. MS Excel was then utilized to process the data and determine the shell length frequency distribution. Throughout the study,

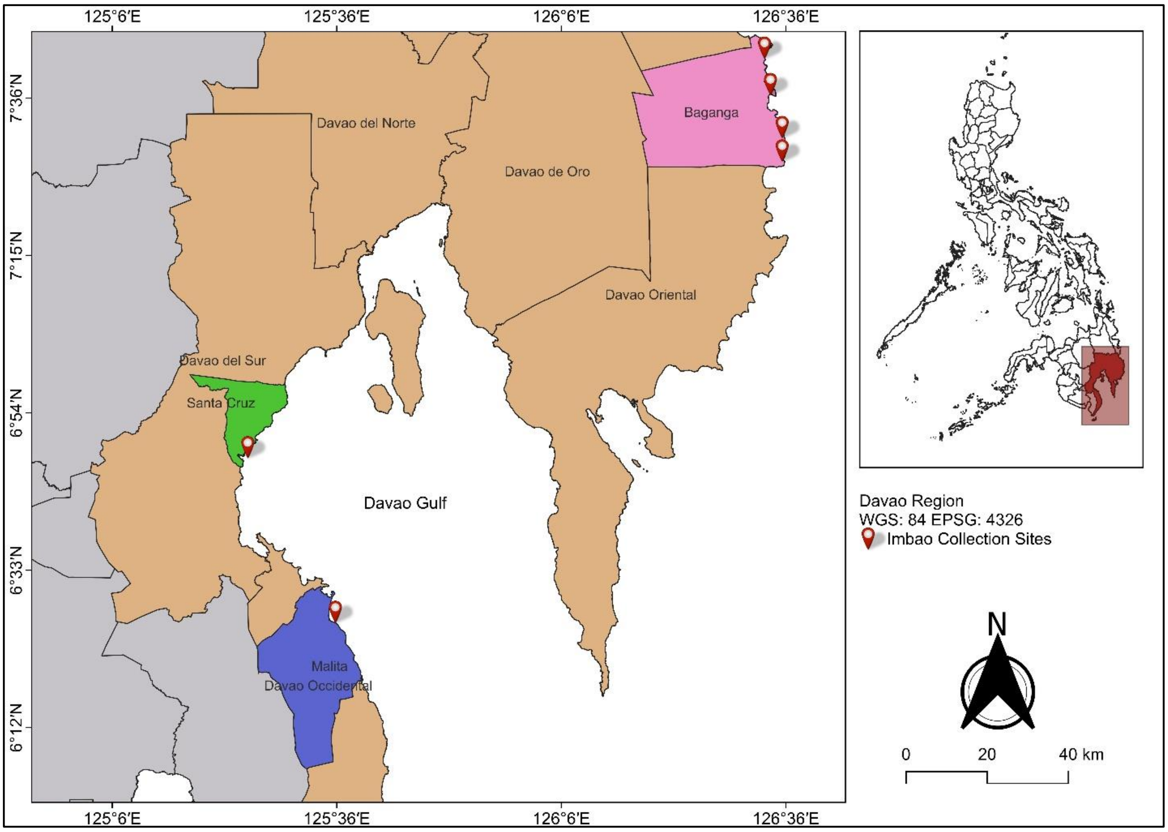

Figure 1. Map of the study sites in Davao region where mangrove clam was harvested regularly (pin indicates mangrove clam collection sites)

Table 1. Mangrove clam collection in the three study sites during the 2-year project duration. Sampling was affected during pandemic and project request for extension

Year	Months	Baganga	Sta. Cruz	Malita
2018	December	Courtesy calls		
2019	January	92	80	75
	February	75	71	78
	March	81	70	58
	April	Travel restriction due to COVID-19		
	May			
	June			
	July			
	August			
	September			
	October			
	November	63	89	75
	December	66	59	73

Table 1. Continued

Year	Months	Baganga	Sta. Cruz	Malita
2020	January			
	February		Request for project extension	
	March			
	April			
	May	86	79	80
	June	88	80	75
	July	81	80	75
	August	75	75	58
	September	88	63	75
	October	79	75	76
	November		Termination of project	
	December			

2493 samples of *P. philippiana* were collected in the Davao region for length-frequency data analysis.

The length-weight relationship (LWR) was calculated using the formula $W = aL^b$ where W represents weight, a denotes the intercept representing the initial growth coefficient, L signifies length, and b stands for the slope indicating relative growth rates and providing growth information ($b = 3$ for isometric; $b>3$ for positive allometric; $b<3$ for negative allometric). The value of the slope b was subsequently analyzed using a t-test to establish growth patterns demonstrated by *P. philippiana* (Aban *et al.* 2017; Lopez-Rocha *et al.* 2018; Sajol-Degamon and Fernandez-Gamalinda 2021). The relative condition factor was then computed according to the formula of Le Cren (1951):

$$K_n = \frac{W}{aL^b}$$

The FAO-ICLARM Stock Assessment Tool (FISAT) II software was employed to provide growth estimates using length frequency data collected throughout the study period (FAO 2020). The asymptotic length (L∞) was estimated using the Powell-Wetherall plot with a 95% confidence interval provided in the maximum length estimation support function, further determining the maximum goodness of fit (Rn) to provide an instantaneous growth (K) using ELEFAN I (Electronic Length Frequency Analysis). The Von Bertalanffy growth function equation was then computed using growth parameters (Gayanilo *et al.* 1996):

$$L_{t = L\infty}(1 - e^{-k(t - t_0)})$$

Where L_t denotes the shell length of *P. philippiana* at time t; L∞ represents the asymptotic length reached by *P. philippiana* at an infinite theoretical age; K indicates the rate at which the shell length approaches L∞; and t_0 stands for the age of *P. philippiana* when the shell length was equal to zero. The theoretical age at length zero was independently calculated based on Pauly's (1979) equation as:

$$\text{Log10}(-t_o) = -0.392 - 0.275 \text{ Log10 } L\infty - 1.038 \text{ Log10 } K$$

The Pauly and Munro (1984) equation was utilized to compute L∞ and K estimations for the growth performance index:

$$\text{Ø}' = \text{log10}K + 2\text{log10}L\infty$$

The longevity (t_{max}) of *P. philippiana* was calculated using the formula:

$$t_{max} = \frac{3}{k}$$

2.3.2. Mortality and Exploitation Rates

Total mortality (Z) was estimated using FISAT II routines in length-converted catch curves. Natural mortality (M) was calculated using Pauly's (1980) empirical equation for mortality at a mean temperature (T) of 27.1°C (Palomares and Pauly 2022):

$$\log(M) = 0.0066 - 0.279 \log(L\infty) + 0.6543 \log(K) + 0.4634 \log(T)$$

Fishing mortality (F) was determined as the difference between Z and M, and the current exploitation rate (E) was calculated using Beverton and Holt's equation (Guiland 1971):

$$E = \frac{F}{Z} = \frac{F}{F(F + M)}$$

An E value near 0.5 was considered indicative of appropriate exploitation, while E > 0.5 indicated over-exploitation (Tesfaye and Wolff 2015). The precautionary target reference point (F_{opt}) or optimum fishing mortality was calculated as $F_{opt} = 0.5 \times M$ (Patterson 1992). Furthermore, backward extrapolation of the descending limb was used to estimate the probability of capture and obtain the value of the length-at-first capture(L_{C50}). A selectivity curve was generated by fitting the logistic function to the probability of capture and size data, from which values of the sizes at capture probabilities of 25% (L_{C25}) and 75% (L_{C75}). The length at first sexual maturity(L_{m50}) was computed using the equation of Hoggarth *et al.* (2006):

$$(L_{m50}) = 2 \times \frac{L\infty}{3}$$

While the optimum length (L_{opt}) was calculated using the empirical equation proposed by Froese and Binohlan (2000):

$$3 \times \frac{L\infty}{(3 + \frac{M}{K})}$$

2.3.3. Recruitment, Virtual Population Analysis, Yield/Recruit and Biomass/Recruit

A one-year recruitment pattern was obtained using restructured data from a time series length frequency. The recruitment model was derived by projecting the length-frequency data back onto the time axis, utilizing L∞ and K as parameter inputs (Moreau and Cuende 1991). Additionally, a length-structured virtual population analysis (VPA) was conducted, incorporating the values of M, F, L∞, and K estimates to generate cohort analysis (Gayanilo *et al.* 2005). Relative yield per recruit and relative biomass per recruit were estimated using the Beverton and Holt yield-per-recruit analysis selection Ogive values as a function of E (Pauly and Soriano 1986).

The optimum exploitation (E_{max}) corresponds to yielding the maximum relative yield-per-recruit, where the exploitation rate at which the marginal increase in relative yield-per-recruit was 10% ($E_{0.1}$) of its virgin stock, and $E_{0.5}$ represented the exploitation rate corresponding to 50% of the unexploited relative biomass per-recruit (B/R). Additionally, a yield isopleth contour was generated to plot and identify *P. philippiana's* stock position based on Pauly and Soriano's (1986) quadrat rule using the values of E_{max}, $\frac{L_{c50}}{L\infty}$ and $\frac{M}{K}$.

3. Results

3.1. Population Structure and Morphometric Relationship

Mangrove clam samples collected from the study sites identified within the Davao Region varied in size from 14 to 84 mm SL, with a mean±SD size of 37.64±8.29 mm, and weights ranging from 2.2g to 178.6g, with a mean weight±SD of 30.63±19.48g. Most harvested mangrove clams (87.77%) fell within the 30-50 mm SL range (see Figure 2).

The length-weight relationship of mangrove clam *P. philippiana* harvested in the Davao region revealed a strong positive correlation, as reflected in the value of the correlation coefficient (r^2) equal to 0.89, indicating that the shell length of the mangrove clam can be used to explain its weight gain. The growth pattern shown by the collected mangrove clams in this study was negative allometry, as the value of the slope b (2.6205) was significantly less than 3, based on the t-test result (df = 2491; t = -68.95; P<0.001), suggesting that the rate of shell length increase was higher than the rate of weight increase. Moreover, the computed condition factor (kn) of mangrove clam *P. philippiana* ranged between 0.27-12.42, with a mean±SD of 1.03±0.31 (see Figure 3).

3.2. Growth Parameters

The restructured length frequency data with overlaid VBGF curves, using the values of asymptotic length L∞ = 98.64 mm and instantaneous growth rate K = 1.33 $year^{-1}$, indicated that at least three cohorts were sampled during the entire duration of the study for *P. philippiana* in the Davao region. It also revealed spawning months between July and August 2020 (see Figure 4).

The growth parameters of *P. philippiana* were determined as follows: asymptotic length (L∞) = 98.64mm, instantaneous growth (K) = 1.33 $year^{-1}$, theoretical age (t_0) = -1.07 years, growth performance index (Ø') = 4.11 and longevity (t_{max}) = 2.25 years (estimated life span). These parameters were utilized to calculate the Von Bertalanffy growth equation for *P. philippiana* in Davao region with formula L_t = 98.64 (1 – e -1.33 (t + 1.07)) which further used to plot and identify the age of mangrove clam that approached asymptotic length. Mangrove clam *P. philippiana* in Davao region exhibited rapid growth increments in first 2 years of age (more than 95 mm SL) followed

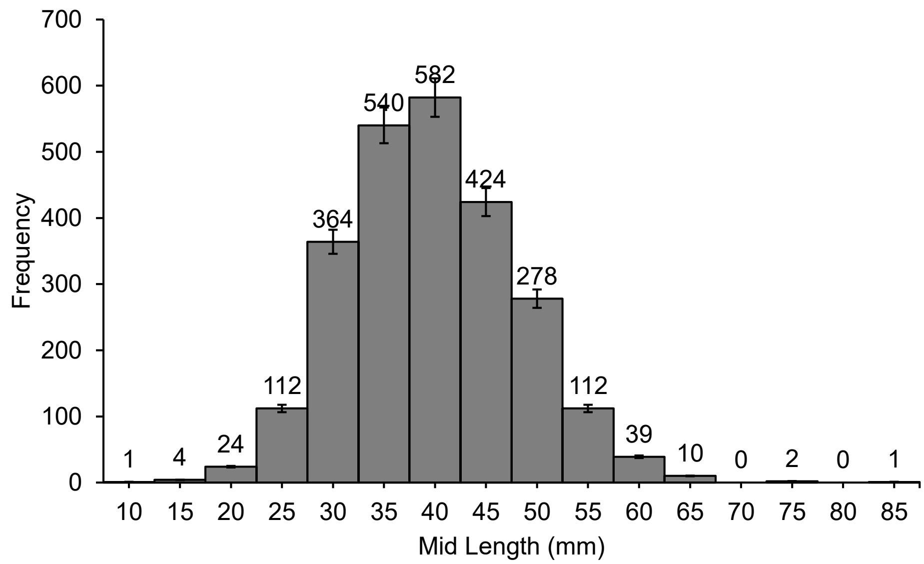

Figure 2. Distribution of shell length (mm) of *Pegophysema philippiana* in the Davao region

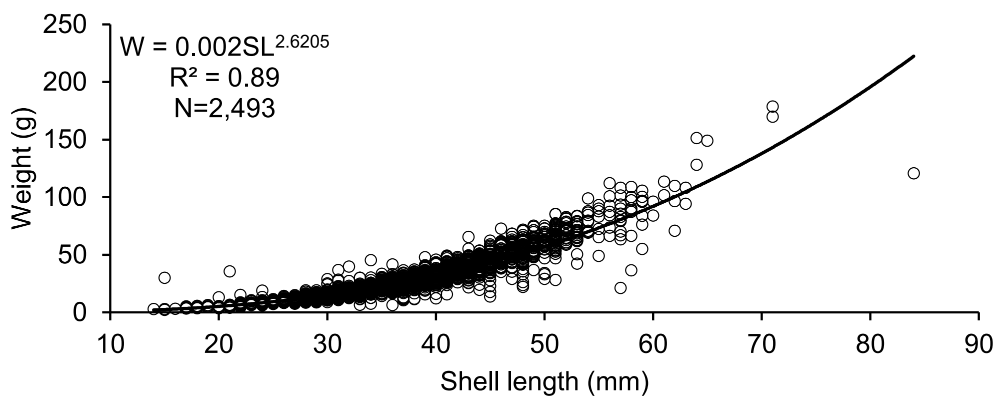

Figure 3. Length-weight relationship of mangrove clam *Pegophysema philippiana* in the Davao region

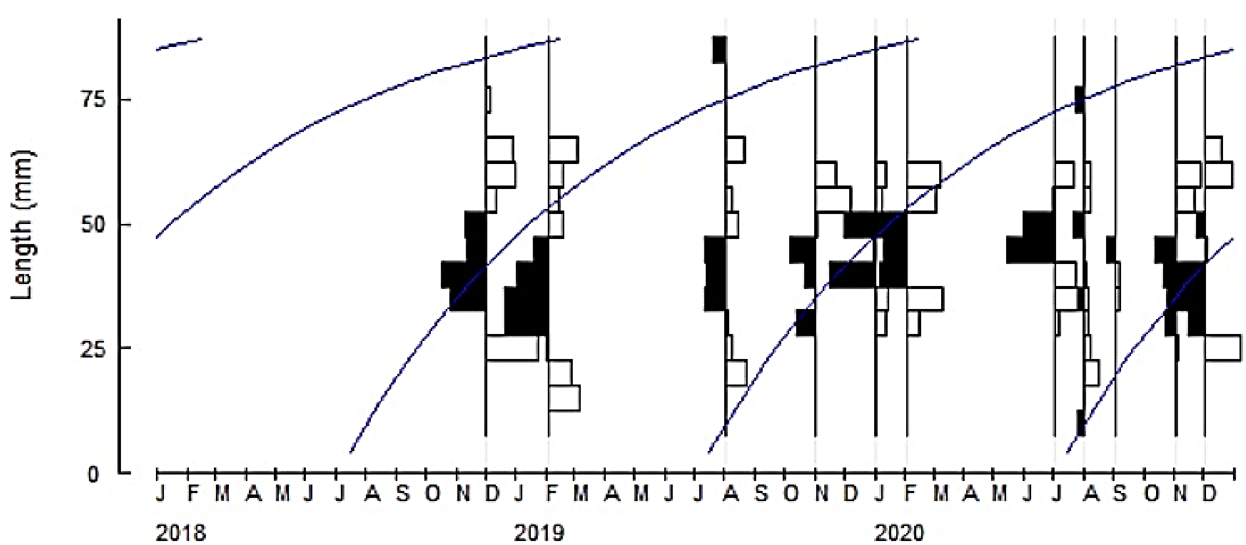

Figure 4. Restructured length frequency distribution of mangrove clam *Pegophysema philippiana* with superimposed growth curved in the Davao region

by a gradual slowing down thereafter, approaching an infinite length at 3 years old (Figure 5).

3.3. Mortality and Exploitation

Figure 6 illustrates the length converted catch curve, estimating total mortality (Z) at 10.27 year^{-1}, natural mortality (M) at 1.52 year^{-1}, fishing mortality (F) at 8.75 year^{-1}, which was higher than optimum fishing mortality (F_{opt}) of 0.76. This suggests that *P. philippiana* in the Davao region is overfished, as supported by the estimated current exploitation rate (E) of 0.85, exceeding the optimum exploitation rate of 0.5 and well beyond the suggested conservative exploitation rate of 0.3.

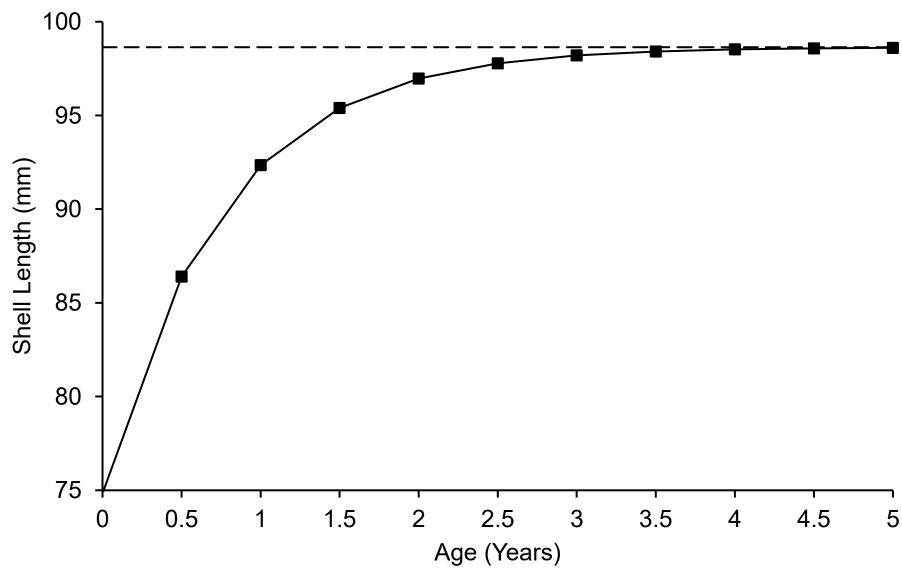

Figure 5. The Von Bertalanffy growth curve of Mangrove clam *Pegophysema philippiana* in the Davao region based on growth parameters

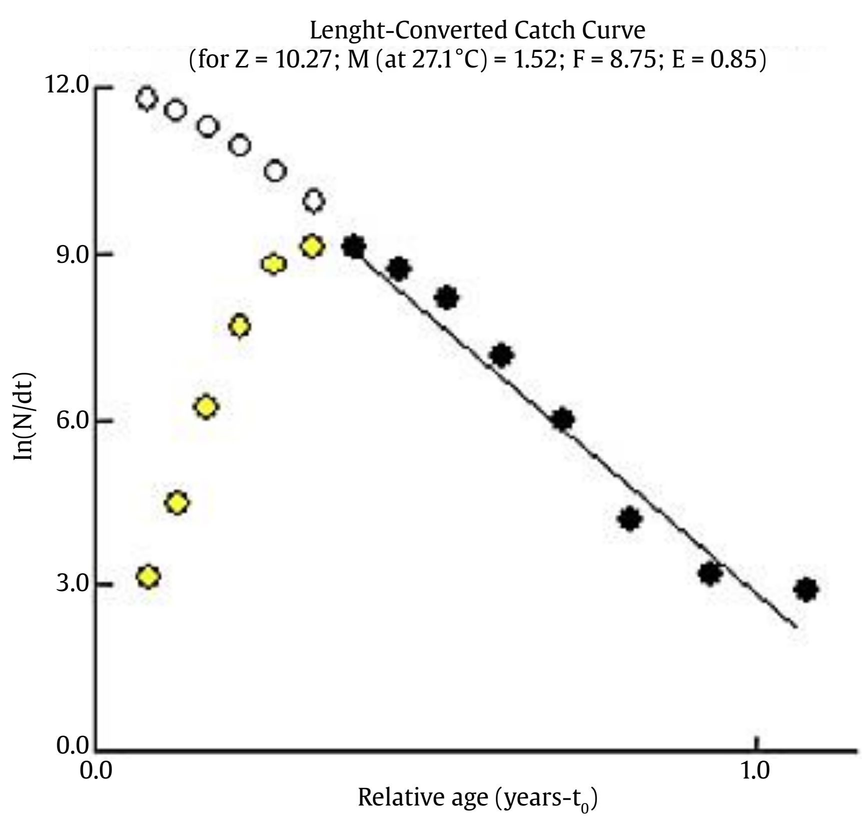

Figure 6. Length converted catch curve of mangrove clam *Pegophysema philippiana* in the Davao region

The length at first capture (L_{c50}) estimated in the probability of capture was 34.83 mm SL, with L_{c25} and L_{c75} estimates at 31.66 mm SL and 38 mm SL, respectively (Figure 7). The computed length at first maturity (L_{m50}) was 65.76 mm SL. The computed length at first maturity was larger compared to the length at first capture, implying that the majority of the harvested mangrove clam *P. philippiana* was sexually immature.

3.4. Recruitment and Virtual Population Analysis

The recruitment pattern of *P. philippiana* in the Davao region was bimodal, with two recorded peaks in July (20.7%) and August (18.78%), although small recruitments occur year-round (Figure 8).

The length-structured virtual population analysis estimated that *P. philippiana* with lengths 10-25 mm SL were prone to predation and other natural causes of clam death. Furthermore, results revealed that *P. philippiana* in the Davao region with shell lengths 30-85mm were more susceptible to gleaning, with a peak of fishing mortality (F = 11.66 $year^{-1}$) observed at shell length 60 mm (Figure 9).

3.5. Yield Per Recruit and Biomass Per Cecruit

The yield-per-recruit and biomass-per-recruit of *P. philippiana* in the Davao region were estimated using Beverton and Holt yield-per-recruit analysis routine using $L_{c50}/L\infty$ and M/K ratio as input parameters, equivalent to 0.35 and 1.14, respectively. The estimates of relative yield-per-recruit (Y'/R) and relative biomass-per-recruit (B'/R) are presented in Figure 10. In the Davao region, the maximum yield-per-recruit of *P. philippiana* was obtained at the optimum exploitation rate of E_{max} = 0.551. $E_{0.1}$ = 0.47 represented the exploitation rate when the marginal increase of Y'/R was 10% of the virgin stock, and $E_{0.5}$ = 0.328 represented the exploitation rate when the stock was reduced to half of its virgin biomass. Lower values for $E_{0.5}$ and E_{max} were observed compared to the current exploitation rate (E) of 0.85, implying that the mangrove clam *P. philippiana* in the Davao region was overexploited.

The yield isopleths were generated in the Beverton and Holts yield-per-recruit analysis selection Ogive routine using the values of M/K = 1.14 and L∞ = 98.64mm. Furthermore, based on the interception

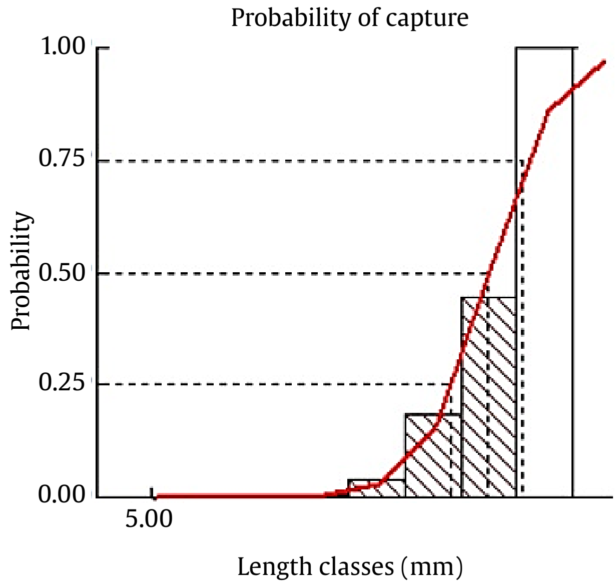

Figure 7. Capture probability of mangrove clam *Pegophysema philippiana* in the Davao region

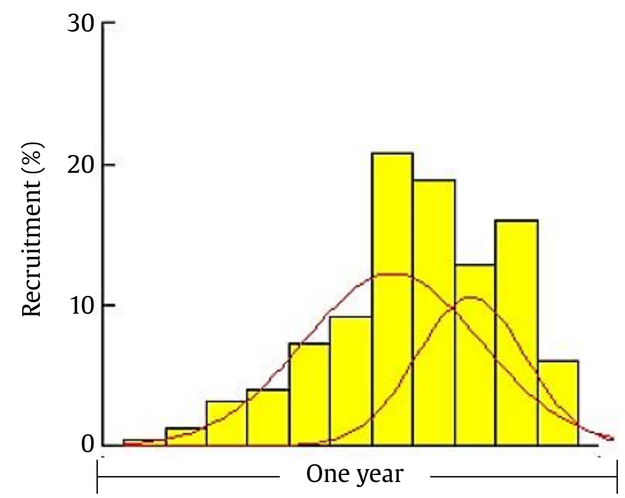

Figure 8. Recruitment pattern of Mangrove clam *Pegophysema philippiana* in the Davao region

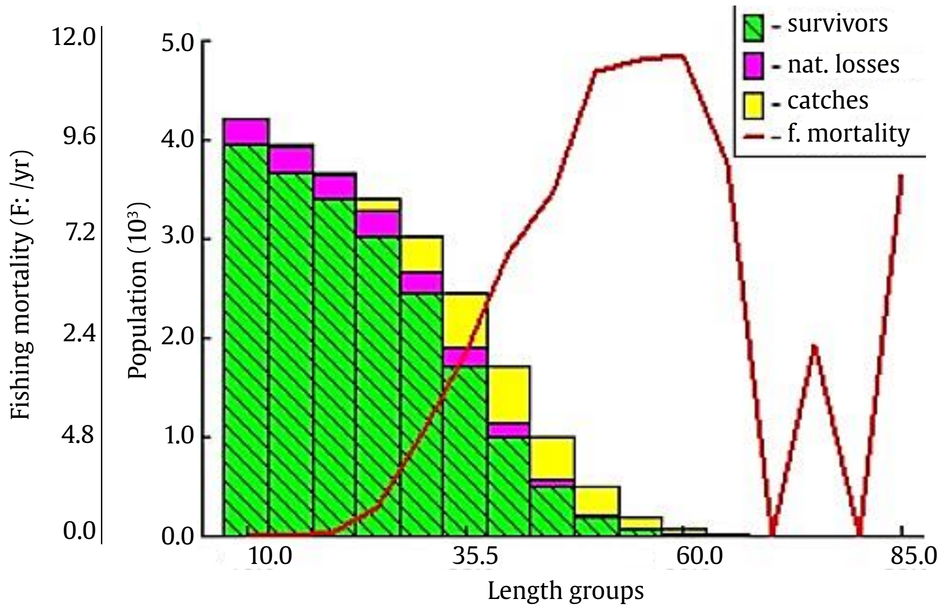

Figure 9. Virtual population analysis of mangrove clam *Pegophysema philippiana* in the Davao region

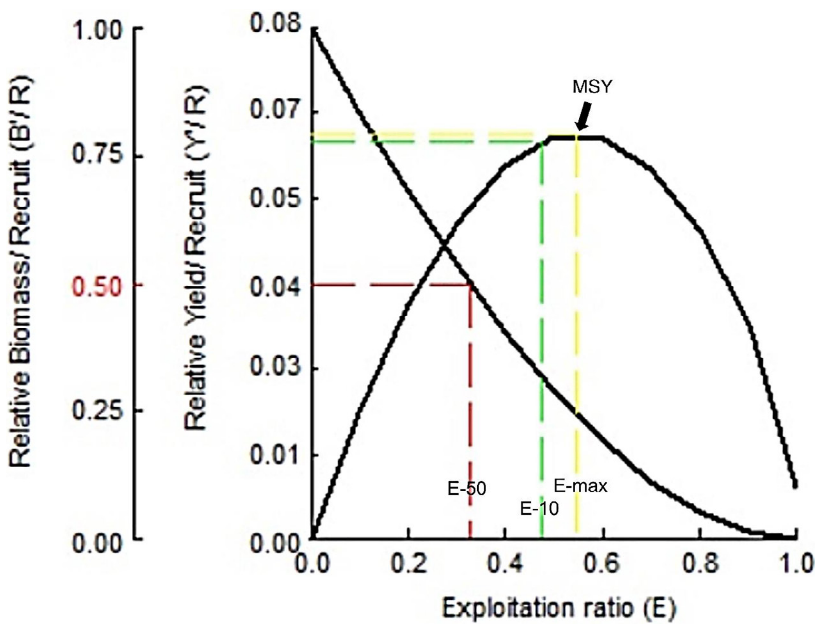

Figure 10. Relative yield per recruit (Y'/R) and biomass per recruit (B'/R) of mangrove clam *Pegophysema philippiana* in the Davao region

of $L_{c50}/L\infty$ = 0.353 and E = 0.85, the mangrove clam *P. philippiana* fishery in the Davao region falls into quadrant D, which is considered an overfished or overexploited area (Figure 11).

4. Discussion

The exploited mangrove clam *Pegophysema philippiana* in the Davao region provides food and livelihood to coastal communities where these resources exist. A population dynamics study was required to provide information on the region's current stock of mangrove clams, which would assist fishery managers in developing management strategies for the sustainable harvest of this commodity. The current study provides baseline information on growth estimates, mortality, exploitation, and yield of *P. philippiana* based on length frequency data utilized in FISAT II (FAO-ICLARM Stock Assessment Tool) routines.

4.1. Population Structure and Morphometric Relationship

Length frequency data of *P. philippiana* collected in the Davao region from December 20018 to December 2020 showed that 87.77% of gleaned clams in the area were within 30-50 mm SL (Figure 2). According to a previous study of mangrove clams in Panay Island, 30 mm SL was the minimum size of clams with mature gonads (Primavera *et al.* 2002) and at least 30-50 mm SL were considered sexually mature, as observed in the study of Araneta (2016). However, the computation of length at first maturity (65.76 mm) showed that the majority of the clams were small and young, as supported by the findings of Adan (2000), who observed adult mangrove clams ranging from 57 to 73 mm SL. As a limitation of this study, histological analysis of mangrove clam gonads should be incorporated to determine their actual maturity, which could support SL measurements. Clam shell length is greatly affected by multiple factors, such as the availability of food, changes in environmental parameters, and development of gonads (Sarà *et al.* 2009; Thomas 2013; Singh, 2017).

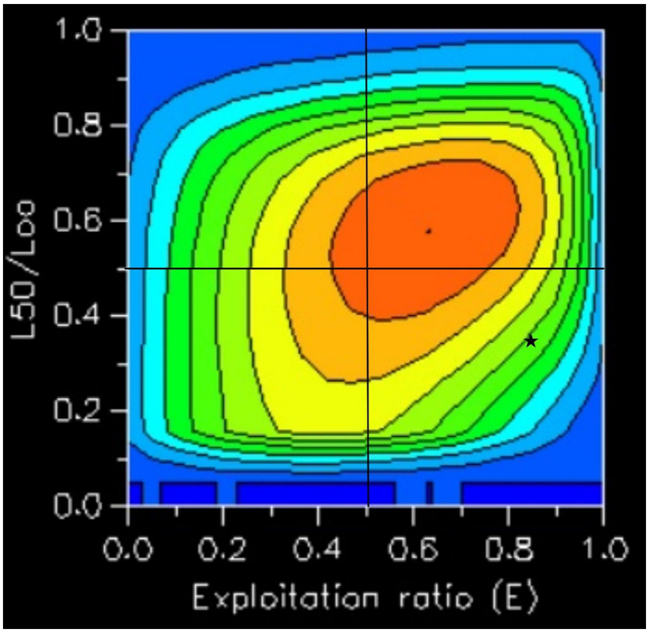

Figure 11. The mangrove clam *Pegophysema philippiana* in the Davao region yields an isopleths diagram showing stock position (A = under-fishing, B = developing fishery, C = fully developed fishery, and D = over-fishing, according to Pauly and Soriano (1986))

Morphometric measurement of the length-weight relationship (LWR) of *P. philippiana* in the Davao region revealed a negative allometric growth pattern (b = 2.62; P<0.001) and a very low mean condition factor (kn) of 1.03±0.31 (Figure 3). The value of slope b, which indicates growth patterns, was comparable to several studies showing negative allometric growth with values of 2.905, 2.77, and 2.98, respectively (Gimin *et al.* 2004; Ramesha *et al.* 2009; Thomas 2013). However, Singh (2017) and Idris *et al.*(2012) recorded higher b values of 3.52 and 3.11, respectively. In tropical marine organisms, b values between 2.5 and 3.5 is very common and acceptable, whereas isometric growth patterns (b = 3) are extremely rare in the wild (Froese 2006; Albogast *et al.* 2020). The different growth patterns observed in bivalves is mainly due to dense stock in the wild, sea level and food (Franz 1993); burrowing behavior and depth, (Gaspar *et al.* 2001); changes in shell structure as a result of phenotypical variances and presence of predators (McKinney *et al.* 2004); and the varying sizes observed in the sampled data (Froese 2006). The observed relatively low condition factor of mangrove clam in the study is comparable to the findings of Widianingsih *et al.* (2020) and is mainly driven by reproduction, secretion, and varied environmental conditions such as temperature and salinity (Bhatkar *et al.* 2021).

4.2. Growth Parameter

The given estimates for asymptotic length ($L\infty$) and annual growth coefficient (K) of the ELEFAN I routine are 98.64 mm and 1.33year^{-1}, respectively is presented in figure 5, which shows three cohorts of sampled data and spawning periods between July and August. The computed L∞ in the current study is smaller than 107.1 mm observed in Iwahig, Palawan (Dolorosa and Dangan-Galon 2014) while higher compared to Loay, Bohol (91.35 mm), Seitu District, Malaysia (76.1 mm), and Bangladesh (81.4 mm) (Amin *et al.* 2009; Dolorosa and Dangan-Galon 2014; Yahya *et al.* 2018). Further, the calculated K value in this study is bigger than the four mentioned studies with K values of 1 in Palawan, 0.7 in Malaysia, 0.75 in Bohol and 0.97 in Bangladesh. Moreover, different findings for growth performance index (Ø') is noted between this study and the studies of Dolorosa and Dangan-Galon (2014) (4.06), Yahya *et al.* (2018) (3.6), Argente and Ilano (2021) (3.79) and Amin *et al.* (2009) (2.07). The variations observed in L∞ and K between studies are mainly driven by fishing pressure and size of collected clams in each area, while the disparity in Ø' observed is probably due to the unique value of L∞ and K used during computations (Zan-bi *et al.* 2022). Accordingly, Pauly (1991) and Sparre and Venema (1998) stated that Ø' should not significantly differ when comparing related species because this will be the basis for determining the growth of clams if it follows the Von Bertalanffy growth function (VGBF) model.

Aside from otoliths for fish and growth ring analysis for clams, the length frequency data can also be used to identify the age of a certain sampled organism (Baali *et al.* 2021). The VGBF equation Lt = 98.64 (1 - E -1.33 (t+1.07)) is computed to plot the age of mangrove clam in Davao region that approached L∞ (Figure 5). Younger mangrove clam *P. philippiana* grows rapidly from birth to 2 years, reaching more than 95 mm SL, then the growth rate declines as it approaches L∞ at the age 2.5-3 years. This result coincides with the calculated longevity (t_{max}) or life expectancy of 2.25 years. Several studies on bivalves show short life spans, as these invertebrate animals are considered short-lived organism (Wolff 2010; So *et al.* 2021). Accordingly, Pauly (1978) emphasized that higher estimated K value equate to shorter life expectancy with rapid growth, while lower K value organisms likely live longer and grow slower (Table 2, Figure 5).

4.3. Mortality and Exploitation

Mangrove clam mortality is driven by multiple factors such as environmental parameters (temperature and salinity), natural causes (predation and disease) and gleaning (Gosling 2003). Total Mortality (Z) is 10.27 year^{-1}, natural mortality (M) is 1.52 year^{-1}, fishing mortality (F) is 8.75 year^{-1} and current exploitation rate (E) is 0.85 of mangrove clam *P. philippiana* in Davao region, which are higher compared to the study conducted in Palawan by Dolorosa and Dangan-Galon (2014) with values Z = 3.74 year^{-1}, M = 1.41 year^{-1}, F = 2.33 year^{-1} and E = 0.62; Malaysia (Yahya *et al.* 2018) Z = 2.1 year^{-1}, M = 1.1 year^{-1}, F = 1 year^{-1}, and E = 0.47; Bangladesh Z = 2.63 year^{-1}, M = 2.61 year^{-1}, F = 0.02 year^{-1} (Amin *et al.* 2009); and in Bohol (Argente and Ilano 2021) Z = 2.89 year^{-1}, M = 0.9 year^{-1}, F = 1.99 year^{-1} and E = 0.69 (Table 3). The different findings observed in each area mainly influenced by its

Table 2. Growth parameters of varied bivalve's species estimated in different locations

Species	Location	L∞	K	Ø'	t_{max}	Author
Polymesoda erosa	Iwahig, Palawan	107.1	1	4.06	3	Dolorosa and Dangan-Galon 2014
Geloina expansa	Setiu District, Malaysia	76.1	0.7	3.6	4.3	Yahya *et al.* 2018
Meretrix meretrix	Cox's Bazaar Coast, Bangladesh	81.4	0.97	2.07	3.1*	Amin *et al.* 2009
Geloina expansa	Loay, Bohol	91.35	0.75	3.79*	4*	Argente and Ilano 2021
Pegophysema philippiana	Davao region	98.64*	1.33*	4.1*	2.25*	This study

*computed in this study

Table 3. Mortality and exploitation estimate of varied bivalve species in different locations

Species	Location	Z	M	F	E	Author
Polymesoda erosa	Iwahig, Palawan	3.74	1.41	2.33	0.62	Dolorosa and Dangan-Galon 2014
Gelonia expansa	Setiu district, Malaysia	2.1	1.1	1	0.47	Yahya *et al.* 2018
Meretrix meretrix	Cox's Bazar Coast, Bangladesh	2.63	2.61	0.02	0.01	Amin *et al.* 2009
Gelonia expansa	Loay, Bohol	2.89	0.9	1.99	0.69	Argente and Ilano 2021
Pegophysema philippiana	Davao region	10.27	1.52	8.75	0.85	This study

unique ecological parameters, over-all well-being of clams, food availability, magnitude of gleaning, existing predators, and varied sample data collected (Zan-bi *et al.* 2022). To highlight findings in the current study, F (8.75 $year^{-1}$) is very high compared to M and computed optimum fishing mortality (F_{opt}) value of 0.76 $year^{-1}$. This data is further supported by the calculated value E 0.85 which is also above the optimum exploitation level 0.5 (Figure 6). These results reveal that the mangrove clam in Davao region is declining due to overexploitation or overfishing. According to Niamaimandi *et al.* (2015), an F value above F_{opt} means fishery resources are fished unsustainably leading to a decrease in its stock, and an E higher than 0.5 indicates that the area is overexploited or heavily fished and management strategies should be implemented to sustain its stock (Dalzell and Peñaflor 1989; Tesfaye and Wolff 2015). Moreover, if the current fishing pressure on mangrove clam in the region continues, a possible collapse of this fishery and diminished wild population stock will be possible (Argente and Estacio 2014).

The length at first capture (L_{c50}) of 34.83 mm SL, length at first maturity (L_{m50}) of 65.76 mm SL and optimum length (L_{opt}) of 71.48 mm SL shows that most gleaned mangrove clam *P. philippiana* in Davao region were juveniles (Figure 7). The computed L_{m50} which is greater than L_{c50} of this study, is in congruence with other bivalve studies conducted in Mexico (López-Rocha *et al.* 2018) and India (Sajan *et al.* 2015). Hence, it indicates that mangrove clam in the Davao region is prone to be harvested at smaller size prior to maturation. Accordingly, harvesting of small or juvenile organisms, which are sexually immature and do not have the capacity to spawn even once, may greatly impact its sustainable biological stock in the wild (Prasad *et al.* 2012).

4.4. Recruitment and Virtual Population Analysis (VPA)

The recruitment pattern of mangrove clam *P. philippiana* occurs year-round in the Davao region, with the highest recruitment observed from June to October and two peaks noted in July and August, aligning with Pauly's (1982) observation that tropical organisms commonly exhibit two recruitment peaks annually (Figure 8). This finding is consistent with the study conducted by Yahya *et al.* (2018), which reported recruitment peaks during southwest monsoon (June to August 2020) when nutrient enhancement happens. Spawning and recruitment are dependent on the gonadal development. To developed mature gonads for reproduction, clams must meet biological requirement such as food, temperature and limited environmental disturbance (Akombo *et al.* 2014). Understanding reproduction is crucial for predicting the spawning time of species and aiding in conservation efforts (Faizah *et al.* 2018). According to Rehatta *et al.* (2021), aspects such as the availability of adult stocks, reproductive success, and pre-recruitment mortality at both the larval and juvenile stages influence recruitment. Furthermore, the stability of wild bivalve populations relies on the continuous addition of younger clams through recruitment and the elimination due to various factors, including natural and fishing mortality (El-Hosainy *et al.* 2017). The stock of mangrove clam in the Davao region is dominated by small immature clams (<Lm) and fishing mortality is very high (>F_{opt}), implying reduced availability of brood stock prepared to spawn, as supported by VPA estimates.

Virtual population analysis revealed that immature clams sized 30-60 mm SL (<Lm) are affected by gleaning, with heavily gleaned (F = 11.66 $year^{-1}$) observed at 60 mm SL, while clams sized 10-20 mm SL are removed from the environment due to predation and disease (Figure 9). Fishing mortality varies with size, with smaller clams being less frequently gleaned compared to larger ones bigger, a common phenomenon observed in marine organisms throughout their lifespan (Mirza *et al.* 2012). The fishing scenario in the Davao region, where younger mangrove clams dominate the harvest, hampers the natural renewal of the stock through recruitment due to the limited number of brood stock, posing a risk to this resource (Dahel *et al.* 2019). Mangrove clams are essential in providing food and livelihood for the poorest sectors of the community, highlighting the importance of implementing fishery management measures to conserved and protect these resources for sustainability.

4.5. Yield Per Recruit and Biomass Per Recruit

Maximum exploitation (E_{max} = 0.551) and optimum exploitation ($E_{0.5}$ = 0.328) rates estimated in the current study are below the current exploitation rate (E = 0.85), negatively impacting the relative yield per recruit of mangrove clam in the Davao region and implying an overexploited area (Figure 10). Sajan *et al.* (2015) noted that exploitation rate and relative yield per recruit of wild stock are inversely proportional. In this study, higher value of E is observed compared to E_{max}, indicating overfishing, as supported by multiple studies (Azim *et al.* 2017; Dahel *et al.* 2019). Overfishing or over harvesting of mangrove clam populations can lead to a decreased in their size in the wild (Jamabo *et al.* 2009). Additionally, the exploitation of mangrove clam can be determined using the Z/K ratio, as described by Sajan *et al.* (2015) as a rule of thumb. Species with growth domination have Z/K value of 1 and beyond 2 for species with high mortality (Balli *et al.* 2011); for this study Z/K is 7.72. Furthermore, ratio of F and E_{max} can also be used to identify the exploitation level; F/E_{max} >1 indicates overfished species (Hashemi *et al.* 2020), and for this study, the computed F/E_{max} ratio is 15.88. In general, using the value of E_{max} and $E_{0.5}$ compared to E, along with the ratio of Z/K and F/Emax, mangrove clam *P. philippiana* is heavily exploited in the Davao region and requires conservation and management. This result is further supported by the yield isopleths generated using the Beverton and Holt Y/R analysis selection Ogive.

According to Pauly and Soriano (1986) yield isopleth model, the stock position of a certain species can be plotted according to four quadrants. A stock plot the lies within quadrant A (upper left) is considered underfished, quadrant B (lower left) represents a developing fishery, quadrant C (upper right) indicates a fully developed fishery and quadrant D (lower right) signifies an overfished fishery. Based on the intercept between the proportions of $L_{c50}/L\infty$ (0.353) and E (0.85), the mangrove clam *P. philippiana* fishery in the Davao region is overfished, with gleaned clams commonly being smaller and younger. Hence, the computed length at maturity (65.76 mm SL) is higher than length at first capture (34.83 mm SL), indicating that the mangrove clam fishery in the region is experiencing growth overfishing. Therefore, management strategies such as regulating the harvested clam size is necessary and essential, along with controlling the frequency of gleaning in the area.

In conclusion, the current study provides critical insights into the existing fishery of *P. philippiana* in the Davao region. Mangrove clams in Davao are overexploited resources, with most of those gleaned being small and immature. Therefore, a fishery management strategy is needed to preserve and protect this species. Furthermore, it is crucial to continue monitoring the harvest of mangrove clam in the region to provide annual catch data for future stock assessment and population dynamic studies. Lastly, the result of this study will serve as a basis for the development of policies that will aid conservation efforts for the sustainable harvest of mangrove clams in the Davao Region and the Philippines as a whole.

References

Aban, S.M., Albert, F., Argente, T., Raguindin, R.S., Garcia, A. C., Ibarra, C.E., De Vera, R.B., 2017. Length-weight relationships of the Asian Green Mussel, *Perna viridis* (Linnaeus 1758) (Bivalvia: Mytilidae) population in Bolinao Bay, Pangasinan, Northern Philippines. *PSU Journal of Natural and Allied Sciences*. 1, 1–6.

Abreo, N.A.S., Siblos, S.K.V., Macusi, E.D., 2021. Anthropogenic marine debris (AMD) in Mangrove Forests of Pujada Bay, Davao Oriental, Philippines. *Journal of Marine and Island Cultures*. 9, 38–53. https://doi.org/10.21463/jmic.2020.09.1.03

Adan, R.I.Y., 2000. Imbao , the mangrove clam. *SEAFDEC Asian Aquaculture*. 22, 30.

Akombo, P.M., Akange, E.T., Adikwu, I.A., Araoye, P.A., 2014. Length-weight relationship , condition factor and feeding habits of *Synodontis schall* (Bloch and Schneider , 1801) In river Benue at Makurdi , Nigeria. *International Journal of Fisheries and Aquatic Studies*. 1, 42–48.

Albogast, T., Kamukuru, S., Mahongo, B., Baraka, C., Sekadende, J.S.S., 2020. Age, growth and mortality of the anchovy *Stolephorus commersonnii* (Lacepède, 1803) (Clupeiformes) caught off the coast of Tanga, Tanzania. *Western Indian Ocean Journal of Marine Science*. 1, 95–104. https://doi.org/http://dx.doi.org/10.4314/wiojms.si2020.1.9

Amin, S.M.N., Zafar, M., Barua, M., 2009. Population dynamics of venus clam meretrix meretrix from the Moheshkali Island in the Cox's Bazar Coast of Bangladesh. *Asian Fisheries Science*. 22, 1031-1043. https://doi.org/10.33997/j.afs.2009.22.3.013

Araneta, B.Y.G., 2016. Characterization of the embryonic and larval development of the mangrove clam anodontia edentula (Family: Lucinidae). *International Journal of Life Sciences Research*. 4, 39–45.

Argente, F.A.T, Ilano, A., 2021.Population dynamics and aquaculture potential of the mud clam, geloina expansa (Mousson, 1849) (Bivalvia: Cyrenidae) in loay-loboc river, bohol, central Philippines. *Journal of Sustainability Science and Management.* 16, 43–55. DOI:10.46754/JSSM.2021.04.004

Argente, F.A.T., Estacion, J.S., 2014. Effect of different harvesting practices on the dynamics of Paphia textile (Gmelin 1792) (Bivalvia: Veneridae) populations at two sites in Zamboanga del Norte, southern Philippines. *Environmental and Experimental Biology*, 12, 113-120.

Azim, M.K.M., Amin, S.M.N., Romano, N., Arshad, A., Yusoff, F.M., Arshad, A., Yusoff, F.M., 2017. Population dynamics of yellowtail scad, atule mate (cuvier 1833) in marudu bay, sabah, malaysia. *Sains Malaysiana*. 46, 2263–2271. https://doi.org/10.17576/jsm-2017-4612-02

Baali, A., Belhsen, O.K., Ouazzani, K.C., Amenzoui, K., Yahyaoui, A., 2021. Age, growth and ovarian histology of *Sardinella aurita* (valenciennes, 1847) in the south of atlantic moroccan coast. *Turkish Journal of Fisheries and Aquatic Sciences*. 21, 191–204. https://doi.org/10.4194/1303-2712-v21_4_04

Balli, J.J., Chakraborty, S.K., Jaiswar, A.K., 2011. Population dynamics of Bombay duck Harpadontidae nehereus (Ham. 1822) (Teleostomi/Harpontidae) from Mumbai waters, India. *Indian Journal of Geo-Marine Sciences* 40, 67-70.

Bersaldo, M.J., Lacuna, M.L.D., Macusi, E., 2022. Status of mangrove clam (*Anodontia philippiana* Reeve , 1850) in Baganga , Davao Oriental , Philippines. *Animal Biology and Husbandry (ABAH) Bioflux*. 14, 55–66.

Bersaldo, M.J.I., Dalagan, G.E.P., Felix, C.J., Orbita, M.L., 2023. Growth dynamics and survival of mangroves (*Rhizophoraceae*) seedlings in Guang-guang, Mati City, Davao Oriental, Philippines. *AACL Bioflux.* 16, 534- 545.

Bhatkar, V.R., Pawase, A.S., Pair, R., Shirdhankar, M.S., Pathan, D., 2021. Effect of salinity and temperature on broodstock conditioning of mangrove clam *Polymesoda erosa* (Solander, 1786). *International Journal of Fisheries and Aquatic Studies*. 9, 340–344. https://doi.org/10.22271/fish.2021.v9.i3e.2507

Camacho, L.D., Gevaña, D.T., Sabino, L.L., Ruzol, C.D., Garcia, J.E., Camacho, A.C.D., Oo, T.N., Maung, A.C., Saxena, K.G., Liang, L., Yiu, E., Takeuchi, K., 2020. Sustainable mangrove rehabilitation: lessons and insights from community-based management in the Philippines and Myanmar. *APN Science Bulletin*. 10, 18–25. https://doi.org/10.30852/sb.2020.983

Dahel, A., Rachedi, M., Tahri, M., Benchikh, N., Diaf, A., 2019. Fisheries status of the bogue *Boops boops* (Linnaeus, 1758) in Algerian East Coast (Western Mediterranean Sea). *Egyptian Journal of Aquatic Biology and Fisheries*. 23, 577–589.

Dai, W., Xiong, J., Zheng, H., Ni, S., Ye, Y., Wang, C., 2020. Effect of *Rhizophora apiculata* plantation for improving water quality, growth, and health of mud crab. *Applied Microbiology and Biotechnology*. 104, 6813–6824. https://doi.org/10.1007/s00253-020-10716-7

Dalzell, P., Peñaflor, G., 1989. The fisheries biology of the big-eye scad, *Selar crumenophthalmus* (Bloch) in the Philippines. *Asian Fisheries Science*. 3, 115–131.

Dolorosa, R.G., Dangan-Galon, F., 2014. Population dynamics of the mangrove clam *Polymesoda erosa* (Bivalvia: Corbiculidae) in Iwahig, Palawan, Philippines. *International Journal of Fauna and Biological Studies*. 1, 11–15.

El-Hosainy, A., Zahran, M., Sabry, S., 2017. Provided for non-commercial research and education use. Not for reproduction, distribution or commercial use. Hepatoprotective Agents in Rats. *Egyptian Academic Journal of Biological Sciences.* 9, 31–54.

Faizah, R., Sadiyah, L., Fauzi, M., 2018. Population parameter and reproductive biology of Indian mackerel rastrelliger kanagurta (Cuvier, 1817) caught by lift net in kwandang waters, North Gorontalo. *Indonesian Fisheries Research Journal*. 23, 107. https://doi.org/10.15578/ifrj.23.2.2017.107-115

[FAO] Food and Agriculture Organization of the United Nations. 2020. Fisheries and aquaculture software. FISAT II - FAO-ICLARM Stock Assessment Tool. Updated 24 February 2020. Available at: http://www.fao.org/fishery [Date accessed: 4 November 2022]

Franz, D.R., 1993. Allometry of shell and body weight in relation to shore level in the intertidal bivalve *Geukensia demissa* (Bivalvia: Mytilidae). *Journal of Experimental Marine Biology and Ecology*. 174, 193–207. https://doi.org/10.1016/0022-0981(93)90017-I

Friess, D.A., Krauss, K.W., Taillardat, P., Adame, M.F., Yando, E.S., Cameron, C., Sasmito, S.D., Sillanpää, M., 2020. Mangrove blue carbon in the face of deforestation, climate change, and restoration. *In Annual Plant Reviews Online.* 3, 427-456. https://doi.org/10.1002/9781119312994.apr0752

Froese, R., 2006. Cube law, condition factor and length weight relationships: history, meta-analysis and rec- ommendations. *Journal of Applied Ichthyology*. 22, 241-253.

Froese, R., Binohlan, C., 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit of fishes, with a simple method to evaluate length-frequency data. *Journal of Fish Biology.* 56, 758-773.

Gaspar, M.B., Santos, M.N., Vasconcelos, P.m 2001. Weight-length relationships of 25 bivalve species (Mollusca: Bivalvia) from the Algarve coast (southern Portugal). *Journal of the Marine Biological Association of the United Kingdom*. 81, 805–807. https://doi.org/10.1017/s0025315401004623

Gayanilo, F.C., Jr Sparre, P., Pauly, D., 1996. *FAO- ICLARM Stock Assessment Tools (FiSAT). User's Guide. FAO Computerized Information Series (Fisheries)*. FAO, Rome.

Gayanilo, F.C., Sparre, F., Pauly, D., 2005. FAO-ICLARM Stock Assessment Tools II (FiSAT II). Revised version. User's guide. FAO, United Nations.

Gimin, R., Mohan, R., Thinh, L.V., Griffiths, A.D., 2004. The relationship of shell dimensions and shell volume to live weight and soft tissue weight in the mangrove clam , *Polymesoda erosa* (Solander, 1786) from northern Australia. *NAGA, WorldFish Center Quarterly*. 27, 32–35.

Gosling, E., 2003. *Bivalve Molluscs: Biology, Ecology and Culture.* Fishing News Books, Blackwell Publishing, Oxford.

Guilland, J.A., 1971. The Fish Resources of the Ocean. In West Byfleet Survey, Fishing News Ltd, FAO, United Nations. https://doi.org/10.1016/0044-8486(72)90050-6

Hashemi, S.A.R., Doustdar, M., Gholampour, A., Khanehzaei, M., 2020. Length-based fishery status of yellowfin tuna (*Thunnus albacares* Bonnaterre, 1788) in the northern waters of the Oman Sea. *Iranian Journal of Fisheries Sciences*. 19, 2790–2803. https://doi.org/10.22092/ijfs.2020.122747

Hoggarth, D.D., Abeyasekera, S., Arthur, R.I., Beddington, J.R., Burn, R.W., Halls, A.S., 2006. *Stock Assessment for Fish-Ery Management: a Framework Guide to the Stock Assessment Tools of the Fisheries Management Science Program*. Fisheries Technical Paper No 487. FAO, United Nation.

Honda, K., Nakamura, Y., Nakaoka, M., Uy, W.H., Fortes, M.D., 2013. Habitat use by fishes in coral reefs, seagrass beds and mangrove habitats in the Philippines. *PLoS One.* 8, 1–10. https://doi.org/10.1371/journal.pone.0065735

Idris, M.H., Arshad, A., Amin, S.M.N., Japar, S.B., Daud, S.K., Mazlan, A.G., Zakaria, M.S., Yusoff, F.M., 2012. Age, growth and length-weight relationships of *Pinna bicolor* Gmelin (Bivalvia: Pinnidae) in the seagrass beds of Sungai Pulai Estuary, Johor, Peninsular Malaysia. *Journal of Applied Ichthyology*. 28, 597–600. https://doi.org/10.1111/j.1439-0426.2011.01807.x

IUCN 2022. Available at: https://www.iucnredlist.org. [Date accessed: 5 November 2022]

Jamabo, N.A., Chindah, A.C., Alfred-Ockiya, J.F., 2009. Length-weight relationship of a mangrove prosobranch *Tympanotonus fuscatus* var fuscatus (Linnaeus, 1758) from the Bonny Estuary, Niger Delta, Nigeria. *World Journal of Agricultural Sciences*. 5, 384–388.

Kabir, M., Abolfathi, M., Hajimoradloo, A., Zahedi, S., Kathiresan, K., Goli, S., 2014. Effect of mangroves on distribution, diversity and abundance of molluscs in mangrove ecosystem: a review. *AACL Bioflux.* 7, 286–300.

Konan, K.J., Gnahoré, T., Joanny, T., Sylla, S., Lianthuam, L., Kumar, K.L., 2015. Stock assessment of the bigeye grunt *Brachydeuterus auritus* (Valenciennes, 1832) in the coastal water of Ivory Coast. *International Journal of Agricultural Policy and Research*. 3, 222–230. https://doi.org/10.15739/IJAPR.043

Lebata, M.J.H.L.L., 2001. Oxygen, sulphide and nutrient uptake of the mangrove mud clam *Anodontia edentula* (Family: Lucinidae). *Marine Pollution Bulletin*. 42, 1133–1138. https://doi.org/10.1016/S0025-326X(01)00113-8

Le Cren, E.D., 1951. The length–weight relationship and seasonal cycle in gonad weight and condition in the perch *Perca fluviatilis. Journal of Animal Ecology*. 20, 201-219.

López-Rocha, J.A., Melo, F.J.F.R., Gastélum-Nava, E., Larios-Castro, E., Romo-Piñera, A., 2018. Morphometric relationship, growth parameters, and natural mortality as estimated primary inputs for fishery management in newfishing areas for bivalve molluscs (Bivalvia: Veneridae). *Journal of Shellfish Research*. 37, 591–600. https://doi.org/10.2983/035.037.0312

Lumogdang, L.P., Llameg, M.B., Antonio, E.S., Bersaldo, M.J.I., 2022. DNA barcoding based on 16S mitochondrial DNA (mtDNA) molecular marker of mangrove clams from the selected sites of Davao Region, Philippines. *Asian Journal of Fisheries and Aquatic Research.* 16, 40-47.

McKinney, R.A., Glatt, S.M., Williams, S.R. 2004. Allometric length-weight relationships for benthic prey of aquatic wildlife in coastal marine habitats. *Wildlife Biology*. 10, 241–249. https://doi.org/10.2981/wlb.2004.029

Mirzaei, M.R., Yasin, Z., Shau Hwai, A.T., 2015. Length-weight relationship, growth and mortality of *Anadara granosa* in Penang Island, Malaysia: an approach using length-frequency data sets. *Journal of the Marine Biological Association of the United Kingdom*. 95, 381–390. https://doi.org/10.1017/S0025315414001337

Mirza, Z.S., Nadeem, M.S., Beg, M.A., Qayyum, M., 2012. Population status and biological characteristics of common carp, cyprinus carpio, in Mangla reservoir (Pakistan). *Journal of Animal and Plant Sciences*. 22, 933–938.

Moreau, J., Cuende, F., 1991. On improving the resolution of the recruitment patterns of fishes. *Fishbyte.* 1, 45–46.

Myers, R.A., Fuller, S.D., Kehler, D.G., 2000. A fisheries management strategy robust to ignorance: rotational harvest in the presence of indirect fishing mortality. *Canadian Journal of Fisheries and Aquatic Sciences*. 57, 2357–2362. https://doi.org/10.1139/f00-250

Myers, Ransom, A., Fuller, S.D., Kehler, D.G., 2011. A fisheries management strategy robust to ignorance: rotational harvest in the presence of indirect fishing mortality. *Canadian Journal of Fisheries and Aquatic Sciences*, 57, 2357–2362. https://doi.org/10.1139/f00-250

Nagelkerken, I., Blaber, S.J.M., Bouillon, S., Green, P., Haywood, M., Kirton, L.G., Meynecke, J.O., Pawlik, J., Penrose, H.M., Sasekumar, A., Somerfield, P.J., 2008. The habitat function of mangroves for terrestrial and marine fauna: a review. *Aquatic Botany*. 89, 155–185. https://doi.org/10.1016/j.aquabot.2007.12.007

Niamaimandi, N., Kaymaram, F., Hoolihan, J.P., Mohammadi, G.H., Fatemi, S.M.R., 2015. Population dynamics parameters of narrow-barred Spanish mackerel, *Scomberomorus commerson* (Lacèpéde, 1800), from commercial catch in the northern Persian Gulf. *Global Ecology and Conservation*. 4, 666–672. https://doi.org/10.1016/j.gecco.2015.10.012

Pacyao, J.P.R., Barail, S., 2020. Anthropogenic activities inside the mangrove conservation and rehabilitation area: a case of Davao Occidental, Philippines. *Int. J. Fish. Aquat. Sci*. 8, 294–298.

Palma Gil, A., Nemenzo-Calica, P., Villegas, J., 2023. Local conservation status and economic value of mangrove clam (*Pegophysema philippiana*) in Sitio Maitom, Barangay Dahican, Mati City, Davao Oriental. *Davao Research Journal*. 14, 66-79.

Palomares, M.L.D., Pauly, D., 2022. SeaLifeBase. World Wide Web electronic publication. Available at: www.sealifebase.org. [Date accessed: 12 December 2023]

Patterson, K., 1992. Fisheries for small pelagic species: an empirical approach to management targets. *Reviews in Fish Biology and Fisheries*. 2, 321–338. https://doi.org/10.1007/BF00043521

Pauly, D., 1978. *A Preliminary Compilation of Fish Length Growth Parameters,* Vol. 55. Kiel, Germany.

Pauly, D., 1979. Theory and management of tropical multispecies stocks: a review with emphasis on the Southern Asian demersal fisheries. ICLARM Studies and Review. *Manila.* 1, 35.

Pauly, D., 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *Journal du Conseil International pour l'Exploration de la Mer.* 39, 175-192.

Pauly, D., 1982. Studying single-species dynamics in tropical multi-species context, in: Pauly, D., Murphy, G.I. (Eds.), *ICLARM Conference Proceedings on Theory and Management of Tropical Fisheries*. 9, 33-40.

Pauly, D., 1984. Fish population dynamics in tropical waters: a manual for use with programmable calculators. *ICLARM Stud. Rev.* 8, 325.

Pauly, D., 1991. Growth performance in fishes: rigorous description of patterns as a basis for understanding causal mechanisms. *Aquabyte.* 4, 3-6.

Pauly, D., Munro, J.L., 1984. Once more on the comparison of growth in fish and invertebrates. *Fishbyte.* 2, 21-22.

Pauly, D., Soriano, M.L., 1986. Some practical extensions to beverton and holt's relative yield-per- recruit model, in: Maclean, J., Dizon, L.B., Hosillo, L.V., (Eds.), *The first Asian fisheries forum.* Asian Fisheries Society, Manila, pp. 491-496.

Prasad, G., Ali, A., Harikrishnan, M., Raghavan, R., 2012. Population dynamics of an endemic and threatened Yellow Catfish *Horabagrus brachysoma* from Periyar River, southern Western Ghats, India. *Journal of Threatened Taxa.* 4, 2333-2342.

Primavera, J.H., 2000. Development and conservation of Philippine mangroves: institutional issues. *Ecological Economics*. 35, 91–106. https://doi.org/10.1016/S0921-8009(00)00170-1

Primavera, J.H., Lebata, M.J.H.L., Gustilo, L.F., Altamirano, J.P., 2002. Collection of the clam *Anodontia edentula* in mangrove habitats in Panay and Guimaras, central Philippines. *Wetlands Ecology and Management*. 10, 363–370. https://doi.org/10.1023/A:1020983218203

Primavera, J.H., dela Cruz, M., Montilijao, C., Consunji, H., dela Paz, M., Rollon, R.N., Maranan, K., Samson, M.S., Blanco, A., 2016. Preliminary assessment of post-Haiyan mangrove damage and short-term recovery in Eastern Samar, central Philippines. *Mar. Pollut. Bull.* 109, 744–750. https://doi.org/10.1016/j.marpolbul.2016.05.050

Quevedo, J.M.D., Uchiyama, Y., Kohsaka, R., 2020. Perceptions of local communities on mangrove forests, their services and management: implications for Eco-DRR and blue carbon management for Eastern Samar, Philippines. *Journal of Forest Research*. 25, 1–11. https://doi.org/10.1080/13416979.2019.1696441

Raheman, N.Y., Nordin, R.M., Abdullah, M., Hassim, M.F.N., 2020. Association between root complexity of rhizophora apiculata and sedimentation at pantai kelanang, Selangor. *Malaysian Applied Biology*. 49, 141–148. https://doi.org/10.55230/mabjournal.v49i4.1605

Ramesha, M.M., Seetharamaiah, Thippeswamy, 2009. Allometry and condition index in the freshwater bivalve *Parreysia corrugata* (Muller) from river Kempuhole, India. *Asian Fisheries Science*. 22, 203–214. https://doi.org/10.33997/j.afs.2009.22.1.019

Rehatta, B.M., Kamal, M.M., Boer, M., Fahrudin, A., Zairion, Ninef, J.S.R., 2021. Growth, mortality, recruitment pattern, and exploitation rate of shared stock flying fish (Exocoetidae) at border area of Indonesia and Timor Leste in Ombai Strait. *IOP Conference Series: Earth and Environmental Science*. 744, 012062. https://doi.org/10.1088/1755-1315/744/1/012062

Sajan, S., Anna Mercy, T.V., Malika, V., 2015. Age, Growth and population dynamics of an endangered fish *Sahyadria denisonii* (Day 1865) from the Western Ghats Hotspot of India. *Asian Fisheries Science*. 28, 130–142. https://doi.org/10.33997/j.afs.2015.28.3.004

Sajol-degamon, L., Fernandez-gamalinda, E.V., 2021. Length–weight relationships of *Anodontia edentula* from Mangrove Habitats of Surigao City, Philippines. *International Journal of Biosciences*. 6655, 110–118. https://doi.org/http://dx.doi.org/10.12692/ijb/19.3.110-118

Sarà, G., Zenone, A., Tomasello, A., 2009. Growth of mytilus galloprovincialis (Mollusca, bivalvia) close to fish farms: a case of integrated multi-trophic aquaculture within the Tyrrhenian sea. *Hydrobiologia*. 636, 129–136. https://doi.org/10.1007/s10750-009-9942-2

Singh, Y.T., 2017. Relationships between environmental factors and biological parameters of Asian wedge clam, Donax scortum, morphometric analysis, length-weight relationship and condition index: a first report in Asia. *Journal of the Marine Biological Association of the United Kingdom*. 97, 1617–1633. https://doi.org/10.1017/S002531541600103X

So, K.J.Y., Cheang, C.C., Hui, T.Y., Chan, J.K.Y., 2021. Understanding the behavioural gap between perceived and actual environmental behaviour: Investigating the clam-harvesting pattern in Hong Kong SAR, China. *Journal of Cleaner Production*. 316, 128259. https://doi.org/10.1016/j.jclepro.2021.128259

Sparre, P., Venema, S.C., 1998. *Introduction to Tropical Fish Stock Assessment*, Part 1: Manual. 2nd Rev. Food and Agriculture Organization, United Nations

Tesfaye, G., Wolff, M., 2015. Stock assessment of fishery target species in Lake Koka, Ethiopia. *Revista de Biologia Tropical*. 63, 755–770. https://doi.org/10.15517/rbt.v63i3.16715

Thomas, S., 2013. Allometric relationships of short neck clam *Paphia malabarica* from Dharmadom estuary, Kerala. *Journal of the Marine Biological Association of India*. 55, 50–54. https://doi.org/10.6024/jmbai.2013.55.1.01755-08

Widianingsih, W., Azizah, R., Nuraini, T., Riniatsih, I., Hartati, R., 2020. The population of mangrove clam (Polymesoda expansa) in The Panikel Village, Segara Anakan, Cilacap. *In: Proceedings of the 3rd International Symposium on Marine and Fisheries Research, Indonesia Vol 147*. ES3 Web of Conferences. pp. 1-6. https://doi.org/https://doi.org/10.1051/e3sconf/202014702018

Wolff, N.Z.A.I.H.W.J., 2010. Population structure , biomass and production of the West African lucinid *Keletistes rhizoecus* (Bivalvia , Mollusca) in Sivibilagbara swamp at Bodo Creek, Niger Delta, Nigeria. *Hydrobiologia*, 193–203. https://doi.org/10.1007/s10750-010-0381-x

Yahya, N., Idris, I., Rosli, N.S., 2018. Population dynamics of mangrove clam , *Geloina expansa* (Mousson , 1849) (Mollusca , Bivalvia) in a Malaysian mangrove system of South China Sea. *Jounal of Sustainability Science and Management*, January 2019.

Zan-bi, T.T., Sylla, S., David, N.G., Kouakou, V., Kweku, S., Amponsah, K., 2022. Population dynamics parameters of Bigeye grunt *Brachydeuterus auratus* (Pisces, Haemulidae) from the continental shelf of Côte d ' Ivoire (West Africa). *Journal of Wildlife and Biodiversity*. 6, 1–15. https://doi.org/https://doi.org/10.5281/zenodo.6795832