Population Parameters of Asiatic Hard Clam, *Meretrix meretrix* (Bivalvia: Veneridae), in Panguil Bay, Philippines

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Date received: February 25, 2020
Revision accepted: December 6, 2022

Abstract

Asiatic hard clam (Meretrix meretrix) is abundant and artisanally harvested in Panguil Bay, Philippines. Information about its current status through stock assessment is vital to support management measures. In this study, estimation of the population parameters of the clam was done using FiSAT II software from May 2018 to April 2019. A total of 2,760 clams were collected and analyzed. The length-weight relationship showed negative allometric growth. The asymptotic length (L_∞) and growth coefficient (K) of the von Bertalanffy growth formula for M. meretrix were estimated at 40.95 mm and 0.71 year^{-1}, respectively. The estimated growth performance index (φ') was 3.07. The predicted maximum life span (t_{max}) of the clam was 6.47 years. Recruitment occurred throughout the year except for April and was bimodal. Estimated total mortality (Z) was 3.18 year^{-1}, fishing mortality (F) at 1.96 year^{-1}, natural mortality (M) at 1.22 year^{-1}, and exploitation level (E) was 0.62. High recorded fishing and exploitation rate can indicate that the M. meretrix stock in Panguil Bay experiences overexploitation that demands immediate sustainable management.

***Keywords**:* Asiatic hard clam, mortality, Panguil Bay, population dynamics, recruitment

1. Introduction

The Asiatic hard clam (*Meretrix meretrix*) is widely distributed in the Indo-Pacific region (Poutiers, 1998). This clam species is an active burrower and a suspension-feeding species that grows well in intertidal areas with muddy or silty substrate types such as mangroves and estuaries (Roy, 2006; Zhang *et al.*, 2022) making it easily accessible to glean. The clam is a commercially important species in coastal areas of South and Southeast Asia collected by artisanal fishermen either for consumption or direct selling in markets (Liu *et al*., 2006; Tan *et al*., 2017; Desrita *et al*., 2019). Studies have shown that the decline of *M. meretrix* population across Asia is mainly due to habitat alteration and destruction such as reclamation of tidal flats and industrial development, overexploitation and pollution (Roy, 2006; Soon and Ransangan, 2019).

Panguil Bay is a small but rich fishing ground that supports the livelihood of small-scale fishers in Northwestern Mindanao, Philippines where *M. meretrix* is present and collected by artisanal fisherfolks (Jimenez *et al*., 2009; Jumawan *et al*., 2015). In an assessment conducted by Jimenez *et al*. (2009), four bivalve species dominated the landed catch of molluscs; one of which is the Asiatic hard clam (*M. meretrix*) with a total landed catch of 12.4 tons annually and revealed that the clam is under the pressure of overharvesting. Both studies done by Jumawan *et al*. (2015) and Jimenez *et al*. (2009) claimed that the major threats to *M. meretrix* are overharvesting, anthropogenic intrusion through sedimentation and lower salinity levels. Additionally, the current hydrological parameters in Panguil Bay are being altered by the increasing density of fixed fishing structures (Roxas and Gorospe, 2007).

The harvesting and deteriorating hydrological parameters in Panguil Bay are exerting pressure on the *M. meretrix* population. Hence, a sustainable fisheries management plan for this species is needed. However, such a management plan can only be developed and implemented effectively when sufficient scientific information about the species is available. Therefore, this study was carried out to understand the population dynamics and estimate key population parameters of *M. meretrix* so that a management plan for the species in Panguil Bay can be established.

2. Methodology

2.1 Sampling Site and Collection

The collection of samples was done in Panguil Bay (Figure 1). Situated in Northern Mindanao, the bay is bordered by three administrative regions, 10 municipalities and two cities belonging to three provinces (Lanao del Norte, Zamboanga del Sur and Misamis Occidental). The mouth of the bay is sandy and gradually becomes muddy towards its shallower inner and southern portions. Prior to data collection, proper communication and permission with the concerned Local Government Units through the different Barangay Council, Municipal Agriculture Office (MAO) and Municipal Environment and Natural Resources Office (MENRO) were established.

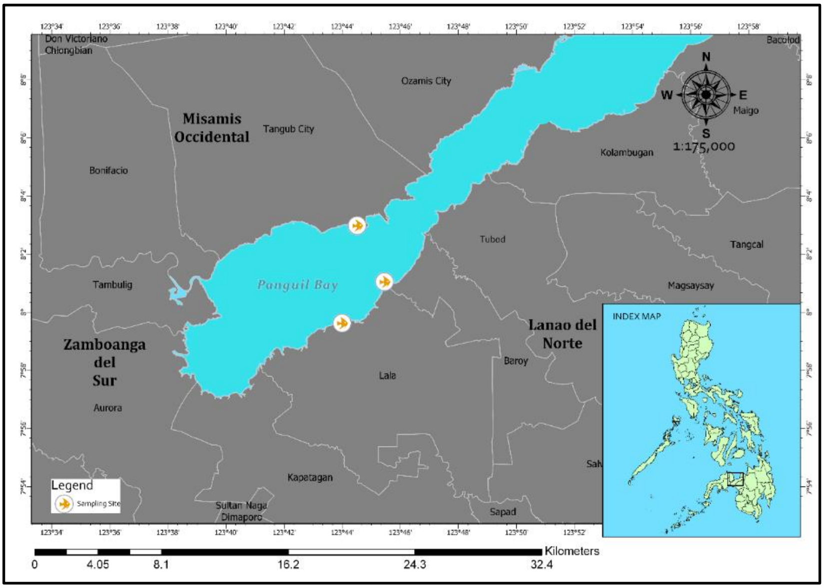

Figure 1. Sampling area in Panguil Bay where *M. meretrix* were collected; inserted is the Philippine map showing the location of Panguil Bay (in rectangle).

Monthly sampling was carried out during low tide from May 2018 to April 2019 in the intertidal and subtidal zones of inner Panguil Bay by collecting 80 bivalve individuals per station every month except for April 2019 wherein only 40 individuals were collected per station. Sampling was conducted at three stations, namely in the Municipalities of Lala and Baroy, Province of Lanao del Norte and Tangub City, Province of Misamis Occidental. These three inshore sampling sites are known fishing grounds of *M. meretrix*. Ecological studies have been conducted at these sites and biophysical characteristics have been described by Canini *et al*. (2013) and Metillo *et al*. (2015). A total of 2,760 specimens were collected throughout the study period. All bivalve individuals collected monthly from the three sampling sites were pooled since the three sites have the same sandy-muddy substrate. It was assumed that *M. meretrix* from the inner Panguil Bay belongs to the same fish stock as the species is a broadcast spawner, and the hydrodynamics in the area would keep the population genetically homogeneous. Pooling increased the monthly number of individuals per month improving the quality of the length-frequency analysis using FiSAT II. Shell length (antero-posterior body length) of all individuals was measured with an accuracy of 0.1 mm using a Vernier caliper (INGCO HDCD01150, China). The total weight was recorded using an electronic balance (ORIA Digital Milligram Scale High Precision, China) to the nearest 0.01 g.

2.2 Length-Weight Relationship

The length-weight relationship of *M. meretrix* was estimated using $W = aL^b$, where W is the total weight and L is the shell length; and a is the intercept (condition factor) and b is the slope (growth coefficient). The relationship established was used to interpret if growth was isometric or allometric. When $b = 3$, growth is isometric while when $b > 3$, growth is positive allometric and negative allometric if $b < 3$.

2.3 Population Growth Parameters

To estimate the asymptotic length (L_∞) and growth coefficient (K) of the von Bertalanffy Growth Function (VBGF), monthly length-frequency distributions (LFD) were grouped into 1.0-mm size classes and analyzed using the ELEFAN-I routine of the FiSAT II software (Gayanilo *et al*., 2005). The estimates of L_∞ and K were used to estimate the growth performances index (φ') to assess these growth parameters (Equation 1) in relation to other bivalve species (Pauly and Munro, 1984).

$$\varphi' = 2 \log L_\infty + \log K \tag{1}$$

The inverse von Bertalanffy growth equation (Equation 2) (Sparre and Venema, 1998) was used to estimate the average length of *M. meretrix* at a certain age.

$$L_t = L_\infty \left[1 - e^{-k(t - t_0)}\right] \tag{2}$$

where L_t is the mean length at age t and $t0$ is the hypothetical age at which the length is zero (Newman, 2002). The t_0 value was predicted following Equation 3 used by Pauly (1983).

$$Log(-t_0) = -0.3922 - 0.2752 log(L_\infty) - 1.038 log(K) \tag{3}$$

Annual growth rates (Equation 4) were also estimated based on the VBGF model (Sparre and Venema, 1998).

$$\frac{\Delta L}{\Delta t} = K \times (L_\infty - L_t) \tag{4}$$

where $\frac{\Delta L}{\Delta t}$ is the growth rate at age *t*.

The theoretical lifespan (t_{max}) was estimated using an inverse of the von Bertalanffy growth equation (Equation 5) assuming a maximum shell length of 99% of the asymptotic length (Sparre and Venema, 1998).

$$t_{max} = \left[\frac{\ln L_{99\%} - \ln(L_\infty - L_{99\%})}{K}\right] \quad (5)$$

2.4 Recruitment

The recruitment of *M. meretrix* was done by backward projection on the length axis of a set of available length-frequency data as described in the electronic length frequency analysis module of the FiSAT II routine.

2.5 Mortality and Exploitation Rate

The total mortality (*Z*) of *M. meretrix* was estimated using the length-converted catch curve method using pooled monthly length-frequency data. Estimation of natural mortality (*M*) was done using the average of *M*/*K* values from the genera of *Meretrix* in literature (Table 1) and multiplied by the estimated *K* value from this study (Argente and Estacion, 2014; Del Norte-Campos *et al*., 2021).

Table 1. Natural mortality (*M*) and growth coefficient (*K*) literature estimates of different *Meretrix* species used to compute the *M* value of *M. meretrix* population in Panguil Bay

Species	*M* (yr^{-1})	*K* (yr^{-1})	*M/K*	Location	Literature
M. meretrix	1.60	0.80	2.00	Panguil Bay, Philippines	Jimenez *et al*. (2009)
M. meretrix	0.78	0.47	1.66	Marudu Bay, Malaysia	Admodisastro *et al*. (2021)
M. casta	2.78	1.80	1.54	Chaliyar Estuary, India	Laxmilatha (2013)
M. casta	2.96	2.00	1.48	Kavvai Estuary, India	Laxmilatha (2013)
M. meretrix	2.61	0.97	2.69	Moheshkali Island, Bangladesh	Amin *et al*. (2009)
M. casta	1.12	1.12	1.00	Dutch Canal, Sri Lanka	Jayawickrema and Wijeyaratne (2009)
Mean	1.96	1.19	1.73		

Once *Z* and *M* are obtained, fishing mortality (*F*) can be estimated using the relationship $F = Z - M$, where *F* is the fishing mortality, *Z* is the total mortality, and *M* is the natural mortality. The exploitation rate (*E*) was calculated by dividing the *F* by *Z*.

3. Results and Discussion

3.1 Length-Weight Relationship

The shell length and total weight of *M. meretrix* ranged from 17.2-39.1 mm and 1.92-18.51 g, respectively. The calculated length-weight relationship equation was $W = 0.0018L^{2.4814}$ ($R^2 = 0.6219$) from the line of best fit of the scatterplot of data comprising 2,760 clam individuals (Figure 2).

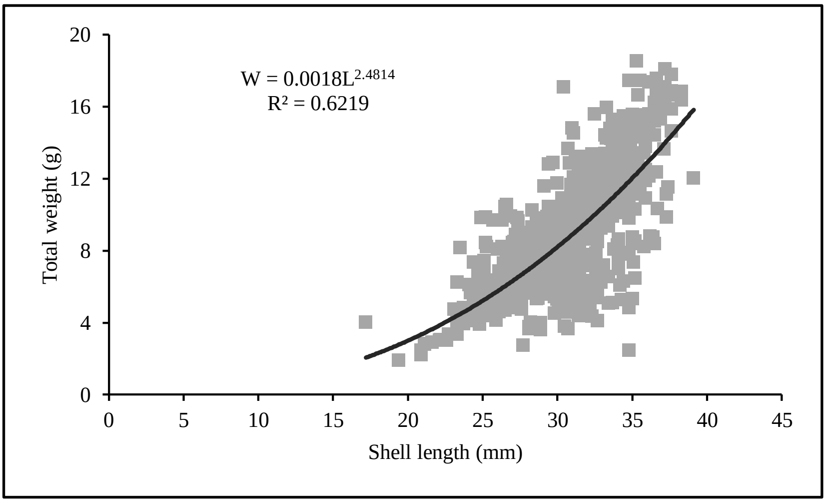

Figure 2. Shell length-total weight relationship of *M. meretrix* in Panguil Bay

The computed coefficient *b* for the length-weight relationship of *M. meretrix* in Panguil Bay was 2.48 indicating negative allometric growth. This implies that the weight of *M. meretrix* does not remain isometric as the length changes (Sharma *et al*., 2005). A similar result was observed by Sharma *et al*. (2005) where *M. meretrix* had an estimated *b* value of less than 3. Relative *b* values for *M. meretrix* were also obtained by Desrita *et al*. (2019) in Indonesia (*b* = 2.78, 2.58, 2.16) and Admodisastro *et al*. (2021) in Malaysia (*b* = 2.77). This demonstrates that the relative growth of *M. meretrix* in length was higher compared with body weight. Moreover, the proportions of the clam's body parts grow at different rates with the length growing faster than the weight (Doinsing *et al*., 2021).

3.2 Growth Parameters

The derived VBGF parameters of *M. meretrix* population in Panguil Bay from the monthly length-frequency data (Figure 3) were L_∞ = 40.95 mm, K = 0.71 yr^{-1}. The estimated growth performance index (φ') was 3.07 and the theoretical age at length zero (t_0) was estimated to be -0.208.

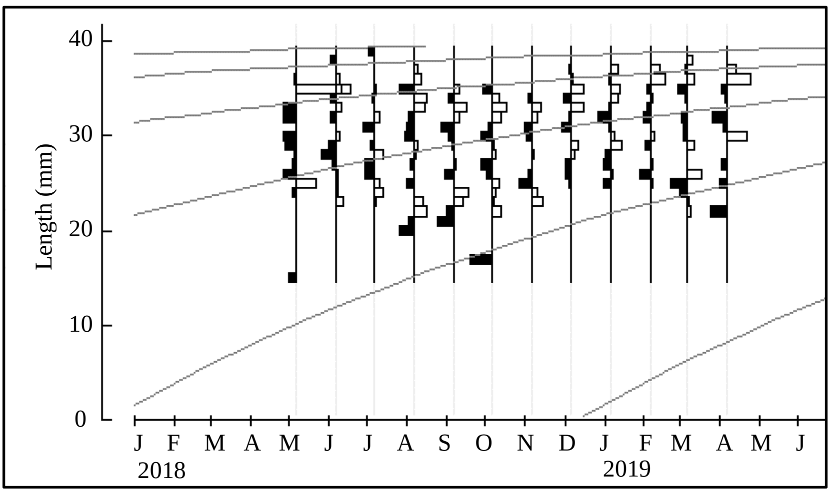

Figure 3. Growth curve derived using the VBGF of *M. meretrix* in Panguil Bay from May 2018 to April 2019

A study by Jimenez *et al*. (2009) on the same bay in 2005 showed a relatively higher L_∞ = 44.5, K = 0.8 year^{-1}, φ' = 3.2 compared with the recent study (Table 2). The L_∞ of *M. meretrix* in this study was also lower compared with populations of the same species in Malaysia (107.63 mm) (Admodisastro *et al*., 2021) and Bangladesh (81.4 mm) (Amin *et al*., 2009) but relatively comparable to populations in Indonesia (40.6 mm) (Desrita *et al*., 2019) (Table 3). Favorable environmental condition displays higher asymptotic length (Jayawickrema and Wijeyaratne, 2009). Meanwhile, K value of *M. meretrix* in Panguil Bay was higher than populations in Malaysia and Indonesia with 0.47 and 0.010, respectively (Desrita *et al*., 2019; Admodisastro *et al*., 2021).

Table 2. Growth parameters, mortality and exploitation rate of *M. meretrix* in Panguil Bay of the present study and study conducted in 2005

Literature	$L\infty$ (mm)	K (yr^{-1})	φ'	Z (yr^{-1})	M (yr^{-1})	F (yr^{-1})	E	Recruitment
Present Study	40.95	0.71	3.07	3.18	1.22	1.96	0.62	Bimodal
Jimenez *et al.* (2009)	44.50	0.80	3.20	4.13	1.60	2.53	0.61	Unimodal

Table 3. Growth parameters of *M. meretrix* as reported in different countries

Location	Species	$L\infty$ (mm)	K ($year^{-1}$)	φ'	Literature
Philippines	*M. meretrix*	40.95	0.71	3.07	Present Study
Bangladesh	*M. meretrix*	81.40	0.97	2.07	Amin *et al.* (2009)
Malaysia	*M. meretrix*	107.63	0.47	3.736	Admodisastro *et al.* (2021)
Indonesia	*M. meretrix*	40.60	0.010	1.22	Desrita *et al.* (2019)
India	*M. casta*	54.10	0.77	3.24	Takar *et al.* (2022)

The growth performance index of *M. meretrix* in this study was slightly lower as exhibited by Jimenez *et al.* (2009) and Admodisastro *et al.* (2021). These variations in growth can be influenced by geographical location (Beukema and Meehan, 1985; Valdovinos and Pedreros, 2007; Moss *et al.*, 2016), differences in ecological conditions (Balasubramanian and Natarajan, 1987; Joubert *et al.*, 2014; Saulsbury *et al.*, 2019), as well as population density (Peterson and Beal, 1989) and fishing pressure (Rouyer *et al.*, 2008; Vânia *et al.*, 2014; Clarke *et al.*, 2019).

The estimated longevity (t_{max}) of *M. meretrix* was 6.4 years. A similar result was obtained from the Asiatic hard clam population in Malaysia (t_{max} = 6.38 years) (Admodisastro *et al.*, 2021). Narasimham *et al.* (1988) had a relatively higher t_{max} (7.8 years) in India using hatchery-reared clams suggesting ideal conditions in a cultured setting. The results of this study concurred with previous reports that *M. meretrix* is a short-lived clam species.

The calculated lengths are 24.45, 32.84, 38.99 and 40.47 mm at the end of one, two, four and six years of age, respectively (Figure 4). A fast growth rate was observed in the population up to two years of age with 11.71 and 5.76 mm yr^{-1} during year one and two, respectively.

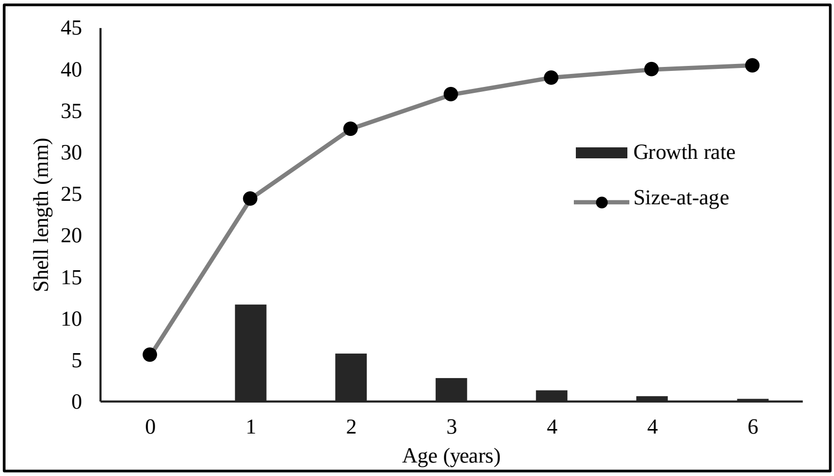

Figure 4. Size-at-age and growth rates of *M. meretrix* population in Panguil bay

3.3 Recruitment

The recruitment of *M. meretrix* in Panguil Bay occurred throughout the year except from month 12 (April). Recruitment showed two apparent peaks: one was in March (21.25%), and another was in December (19.90%) (Figure 5).

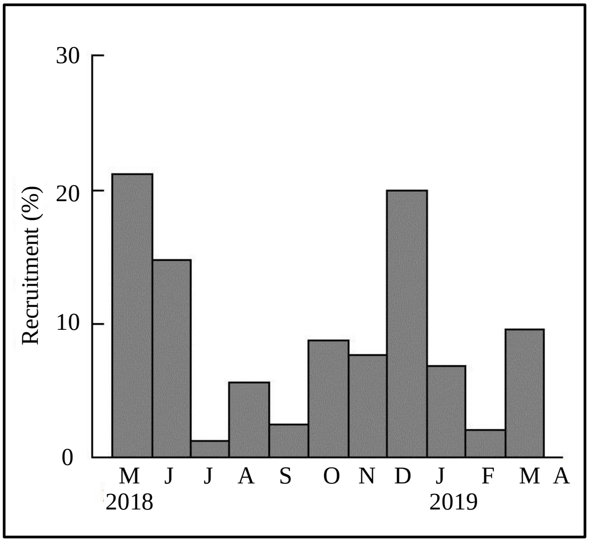

Figure 5. Recruitment pattern of *M. meretrix* in Panguil Bay derived using FiSAT II

Like other tropical bivalves, *M. meretrix* can spawn throughout the year under favorable conditions due to minimal fluctuations in environmental parameters (Pouvreau *et al*., 2000; Morillo-Manalo *et al*., 2016; Admodisastro *et al*., 2021). The two recruitment peaks (March and December) observed in this study contrasted the unimodal result obtained during the 2005 assessment of *M. meretrix* in Panguil Bay (Jimenez *et al*., 2009). This variation can be possibly attributed to both environmental changes and fishing pressure (Vânia *et al*., 2014; Vázquez *et al*., 2021). Roxas and Gorospe (2007) revealed that the hydrological parameters in Panguil Bay are being altered by the high density and proliferation of fixed fishing structures.

3.4 Mortality and Exploitation Rate

Based on the length converted catch curve, total mortality (Z) was 3.18 yr^{-1}. The M/K values derived from other *Meretrix* species (Table 1) indicated that the natural mortality (M) for the *M. meretrix* population in Panguil Bay was 1.22 yr^{-1}. Fishing mortality (F) derived from subtracting Z by M was 1.96 yr^{-1} and an exploitation rate (E) value of 0.62.

Gulland (1983) suggested the exploitation rate of 0.5 as sustainable exploitation where the fishing mortality is equal to natural mortality. In the current study, a higher fishing mortality rate (F = 1.96 yr^{-1}) compared with the natural mortality rate (M = 1.22 yr^{-1}) was obtained. This shows the unbalanced position of the stock suggesting that harvesting contributes to the major cause of death for the stock. Similar results were obtained by Jimenez *et al*. (2009) wherein F (= 2.53 yr^{-1}) was higher than M (= 1.6 yr^{-1}) in Panguil Bay. The exploitation rate obtained from this study (E = 0.62) was also in agreement with the result of Jimenez *et al*. (2009) (E = 0.61) suggesting that clam population is under the pressure of overharvesting since 2005. This is also the case for some bivalve populations in the Philippines such as *Atrina pectinata* in San Dionisio, Iloilo (E = 0.58) (Del Norte-Campos *et al*., 2021), *Geloina expansa* in Bohol (E = 0.69) (Argente and Ilano, 2021) and *Polymesoda erosa* in Iwahig Bay, Palawan (E = 0.62) (Dolorosa and Dangan-Galon, 2014). Overexploitation of bivalve species may eventually lead to poor recruitment, slow growth and possible collapse of the natural population (Dang *et al*., 2010; Baeta *et al*., 2014; Marquardt *et al*., 2022).

High exploitation rates were also documented to other commercially important species present within the bay (Jimenez *et al*., 2009; Jumawan *et al*., 2021). To effectively manage fishery resources in Panguil Bay, including *M. meretrix*, measures such as reactivation of the Panguil Bay Development

Council and strict implementation of regulated harvesting of mud crabs and bivalves, particularly of juvenile or pre-adult populations, should be undertaken (Jimenez *et al*., 2009).

4. Conclusion and Recommendation

The current study showed that *M. meretrix* population in Panguil Bay is fast growing and recruitment happens all throughout the year with two recruitment peaks. The study also demonstrated high fishing mortality and exploitation rate of *M. meretrix* population in Panguil Bay indicating that it is overfished. Thus, an ecosystem-based management plan for sustainable use of fishery resources including *M. meretrix* in Panguil Bay is highly recommended to ensure conservation and management of the clam population.

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