Population dynamics of marsh clam, *Polymesoda* spp. (Bivalvia: Corbiculidae) in Marudu Bay, Malaysia

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Abstract. Population parameters of *Polymesoda erosa* and *P. expansa* in Marudu Bay were estimated based on 1 year (June 2017 to May 2018) monthly length-weight frequency data. A total of 1087 and 2057 specimens of *P. erosa* and *P. expansa,* respectively were successfully collected and analysed. Results of the study demonstrated that the estimated asymptotic length (L_∞), growth coefficient (K), total mortality (Z), natural mortality (M), fishing mortality (F) and growth performance (ϕ) of *P. erosa* were 92.4 mm, 0.76 yr^{-1}, 2.22 yr^{-1}, 0.76 yr^{-1}, 1.44 yr^{-1} and 3.81 yr^{-1}, respectively. The exponent b of the length-weight relationship was 2.27 and exploitation level (E) was 0.65. On the other hand, the asymptotic length (L_∞), growth coefficient (K), total mortality (Z), natural mortality (M), fishing mortality (F) and growth performance (ϕ) of *P. expansa* were 92.4 mm, 0.82 yr^{-1}, 2.77 yr^{-1}, 0.82 yr^{-1}, 1.95 yr^{-1} and 3.85 yr^{-1}, respectively. The exponent b of the length-weight relationship was 2.24 and exploitation level (E) was 0.7. The condition index of *P. erosa* and *P. expansa* were 2.28±0.49 and 2.31±0.67, respectively. It was also noted that both *P. erosa* and *P. expansa* exhibited continuous recruitment with the peak in June and November, respectively. However, they seemed to experience over-fishing as evidenced by the level of exploitation which was beyond the maximum sustainable yield (MSY). Hence, immediate implementation of a sustainable management plan is critically needed to ensure this resource remains viable in Marudu bay.

Key Words: mangrove clam, Sabah, Borneo, Tun Mustapha Park, Coral Triangle Initiative.

Introduction. The marsh clam, *Polymesoda* spp. from the family Corbiculidae, are distributed widely across the Indo-Pacific region most notably in the tidal flats of Southeast Asia (Morton 1984). Three species of the marsh clam are reported to exist in the Indo-Pacific region; *Polymesoda erosa*, *P. bengalensis* and *P. expansa* (Ingole et al 2002). However, the distribution of *P. bengalensis* is restricted to the Bay of Bengal, whereas *P. erosa* and *P. expansa* are known to have a wider and somewhat overlapping distribution from India to Vanuatu; to Vietnam in the north and Eastern Java in the south. It has been speculated that *P. expansa* is less tolerant to colder waters of the northern and southern extremities of its distribution.

Marsh clam lives semi-infaunally in the soft sediment accumulated around the roots of the mangrove trees and spend a considerable portion of its life exposed to air in mangrove swamps where salinity fluctuates greatly (Ingole et al 2002). In Marudu Bay, two species of marsh clam were reported to occur which are *P. expansa* and *P. erosa* (Ransangan & Soon 2018). This clam is often collected from the mangrove swamps of Marudu Bay by fisherman and sold at local wet markets. The attractive market price for the clam has motivated fishermen to exploit the resource extensively.

Excessive exploitation i.e. intense fishing of the marsh clam is known to threaten the sustainability of its natural stock (Ransangan & Soon 2018). One way to overcome this problem is by introducing a sustainable fishery management plan such as zoning of fishing areas, size restriction and close fishing season. However, introducing such a management plan is quite challenging in view of information scarcity of the marsh clam in Marudu Bay. This therefore inspires us to conduct the present study with the aims to understand population parameters and to determine the degree of exploitation of the species.

Material and Method

Sampling. Marudu Bay (6°35' to 6°37' N and 116°45' to 116°50' E) is part of the Tun Mustapha Park, the second largest marine protected area in South East Asia, and included in the Malaysian region of the Coral Triangle Initiative (Figure 1). The bay is characterized by a mesotrophic water body (Soon & Ransangan 2017) that is free from threats of harmful algal bloom (Soon & Ransangan 2016) and heavy metal pollution (Soon et al 2016). Monthly sampling of marsh clams was conducted from June 2017 to May 2018 in areas of 500 m^2 (50 m x 10 m). A total of 1087 *P. erosa* and 2057 *P. expansa* specimens with shell length ranging from 3.39 to 9.18 cm and 2.23 to 9.24 cm, respectively were collected during the 1 year sampling period. Shell length of each specimen was measured with accuracy of 0.1 mm using digital Vernier calipers. The total weight was measured using an electronic balance to the nearest 0.01 g. The monthly length frequency distribution data of *P. erosa* and *P. expansa* were grouped into 5 mm intervals and used to estimate growth and population parameters using the FiSAT software (Gayanilo et al 1997).

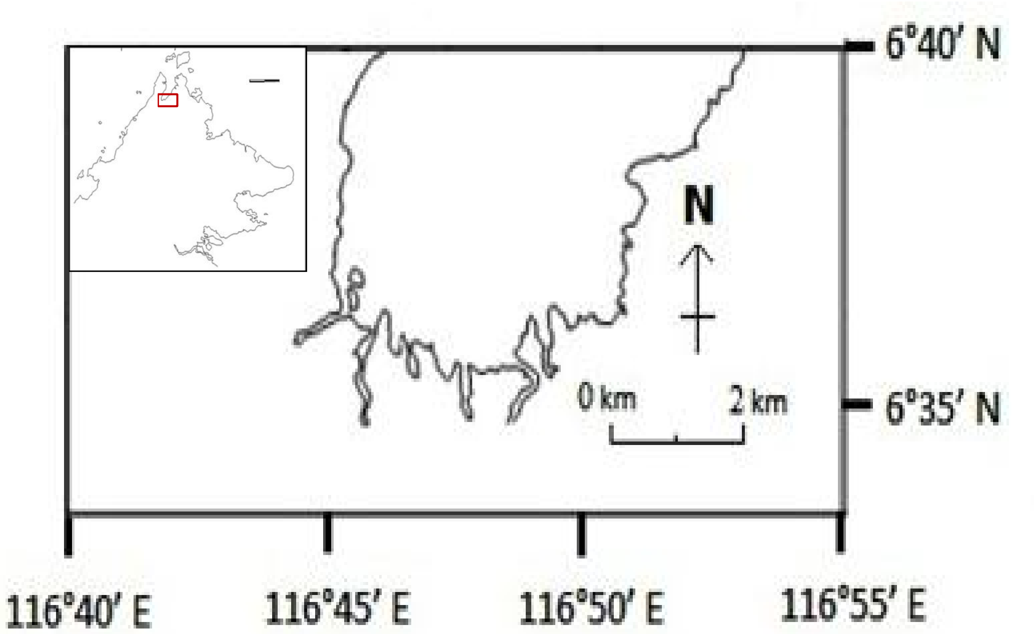

Figure 1. Sampling site in Marudu Bay, Malaysia.

Condition index. Five specimens were collected randomly each month for the condition index analysis (n = 60). Condition indices (CI) were then calculated from the ratio of dry tissue/organic weight (DW) and the dry weight of the shells (VW), following Freeman (1974):

$$CI = (DW/VW) \times 100$$

Statistical analysis. Condition indices were analysed using the SPSS Windows Statistical Package (version 21, Chicago, USA). Tests were judged to be significant at $p < 0.05$ level. Prior to analysis, all variables were tested for normality and homogeneity of variances.

The length-frequency data of the clams were grouped into shell length classes by 5 mm interval prior to analysis using FAO-ICLARM Stock Assessment Tools (FiSAT). Asymptotic length (L_∞) and growth coefficient (K) of the von Bertalanffy growth function

(VBGF) were estimated by means of ELEFAN-1 (Pauly & David 1981). Longevity (t_{max}) of the clam was estimated using the formula $t_{max} = 3/K$. The growth performance index (ϕ) was calculated using the estimated L_∞ and K values (Pauly & Munro 1984) based on the following equation:

$$\phi = 2\log_{10} L_\infty + \log_{10}K$$

The relationship of $W = aL^b$ (W= weight (g); L = length (mm); a = condition factor; b = growth coefficient) was used to establish the length-weight relationship (Quinn & Deriso 1999). The inverse von Bertalanffy growth equation (Sparre & Venema 1992) was used to estimate the average length of the clams at a certain age by the equation:

$$L_t = L_\infty (1-e^{-k(t-t0)})$$

where: L_t is the mean length at age t and t_0 is the hypothetical age at which the length is zero (Newman 2002). The t0 value was predicted as follow:

$$Log(-t0)\approx-0.3922-0.2752 \log_{10}L_\infty-1.038 \log_{10}K$$

The natural mortality rate (*M*) was considered approximately equal to the growth coefficient K (Gayanilo et al 1997). The total mortality (*Z*) was estimated by the length converted catch curve method (Pauly & Munro 1984) and fishing mortality (F) was estimated by subtracting M from Z. The exploitation level (E) was estimated based on the equation described by Gulland (1965) as follows:

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

The recruitment rate was obtained by backward projection of the length axis of length-frequency data as described in FiSAT routine (Pauly & David 1981).

Results

Growth parameters. The restructured length distribution based on length-frequency data is illustrated in Figure 2. The estimated asymptotic length (L_∞) of the *P. erosa* and *P. expansa* was 9.24 cm, whereas the growth coefficient (K) was 0.76 yr^{-1} and 0.82 yr^{-1} for *P. erosa* and *P. expansa*, respectively. The estimated maximum life span (t_{max}) for *P. erosa* and *P. expansa* were 1.32 and 1.22 years, respectively.

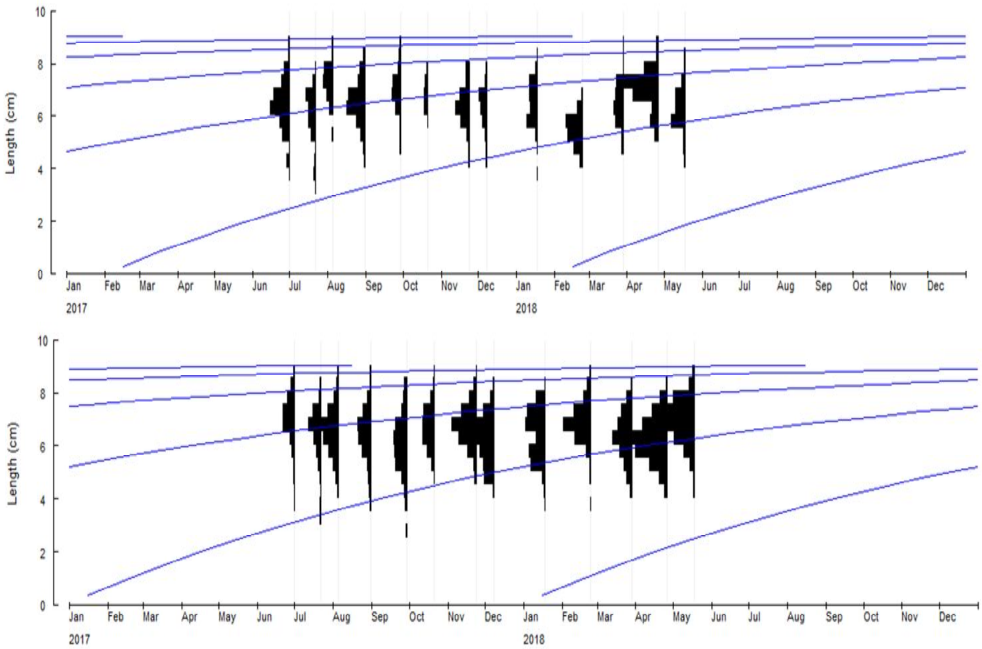

Figure 2. Length-frequency distribution with growth curves superimposed using ELEFAN-1 for *P. erosa* (top) and *P. expansa* (bottom).

The observed maximum length of *P. erosa* was 88.0 mm and the predicted maximum length was 94.6 mm (Figure 3). The confidence interval was 89.3 to 99.9 mm (95% probability of occurrence). The mean lengths of the natural stock of *P. erosa* were 34.36, 41.26, 47.35, 52.71, 57.43, 61.59 mm at the end of 2, 4, 6, 8, 10 and 12 months of age, respectively. On the other hand, the observed maximum length of *P. expansa* was 88.0 mm and the predicted maximum length was 91.0 mm (Figure 3). The confidence interval was 88.7 to 93.2 mm (95% probability of occurrence). The mean lengths of natural stock of *P. expansa* were 34.34, 41.76, 48.23, 53.87, 58.79 and 63.08 mm at the end of 2, 4, 6, 8, 10 and 12 months of age, respectively. In addition, the growth performance index (ф) was 3.81 and 3.85 for *P. erosa* and *P. expansa*, respectively (Figure 4).

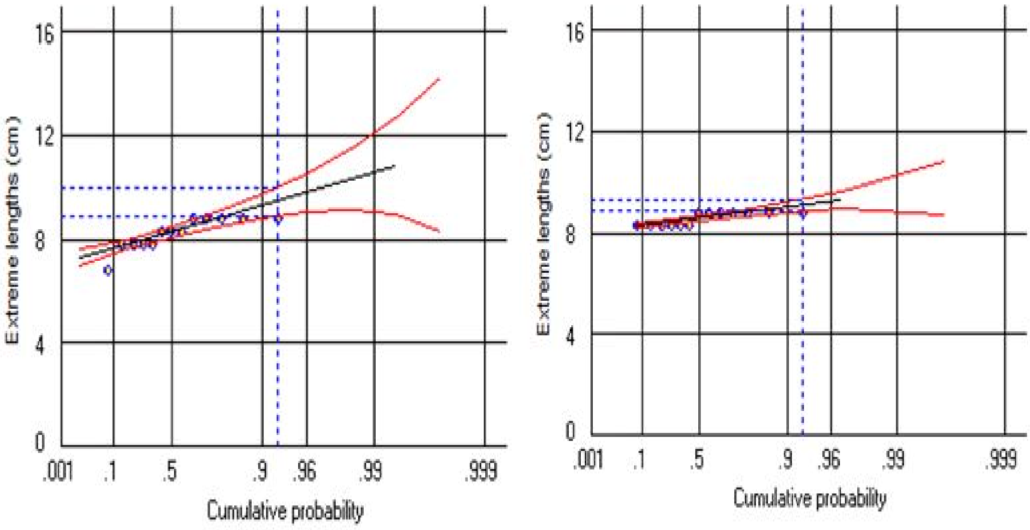

Figure 3. Estimation of maximum length of *P. erosa* (left) and *P. expansa* (right).

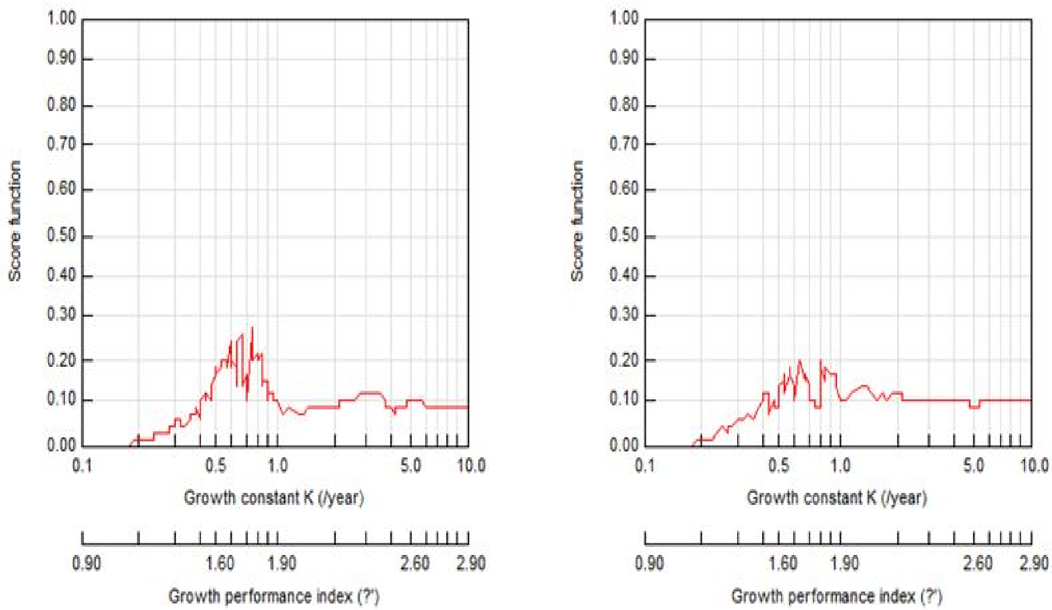

Figure 4. Estimation of growth constant (K) and growth performance index (ф) of *P. erosa* (left) and *P. expansa* (right).

Mortality and exploitation. Estimated total mortality, natural mortality and fishing mortality for *P. erosa* were 2.20 yr^{-1}, 0.76 yr^{-1} and 1.44 yr^{-1}, respectively (Figure 5). For *P. expansa*, the estimated total mortality, natural mortality and fishing mortality were 2.77 yr^{-1}, 0.82 yr^{-1} and 1.95 yr^{-1}, respectively. The estimated exploitation level (E) of *P. erosa* and *P. expansa* were 0.65 and 0.70, respectively.

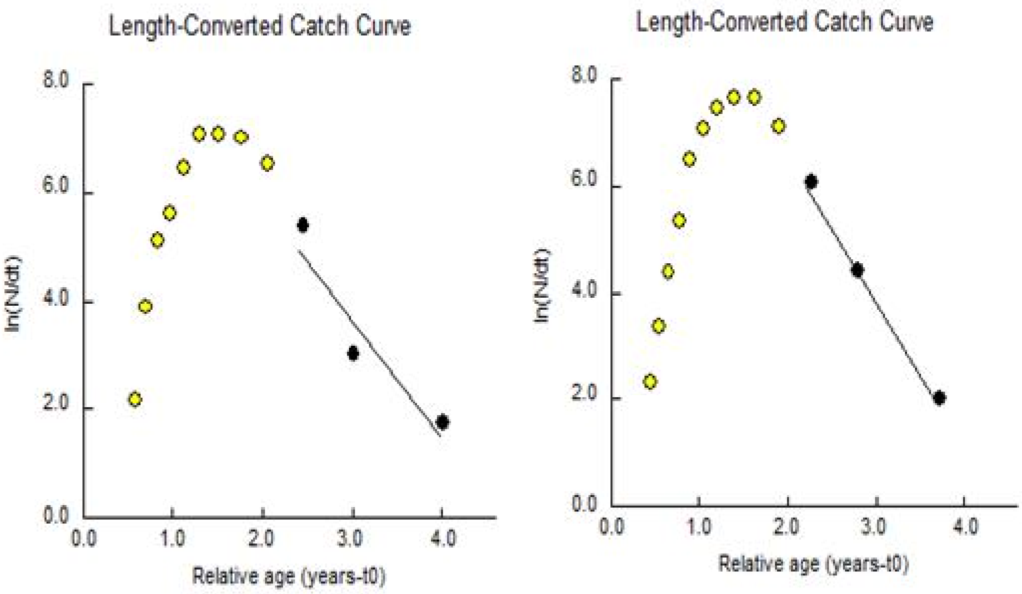

Figure 5. Length converted catch curve of *P. erosa* (left) and *P. expansa* (right).

Length-weight relationship*.* The calculated length-weight relationship equation of *P. erosa* and *P. expansa* were log W = 2.27logL – 0.786 and log W = 2.24logL – 0.657, respectively. The exponential form of the equation for *P. erosa* and *P. expansa* were W = $0.1636L^{2.274}$ and W = $0.2203L^{2.241}$, respectively (Figure 6). The computed growth coefficient *(b) was* 2.27 and 2.24 for *P. erosa* and *P. expansa*, respectively at 95% confidence limit.

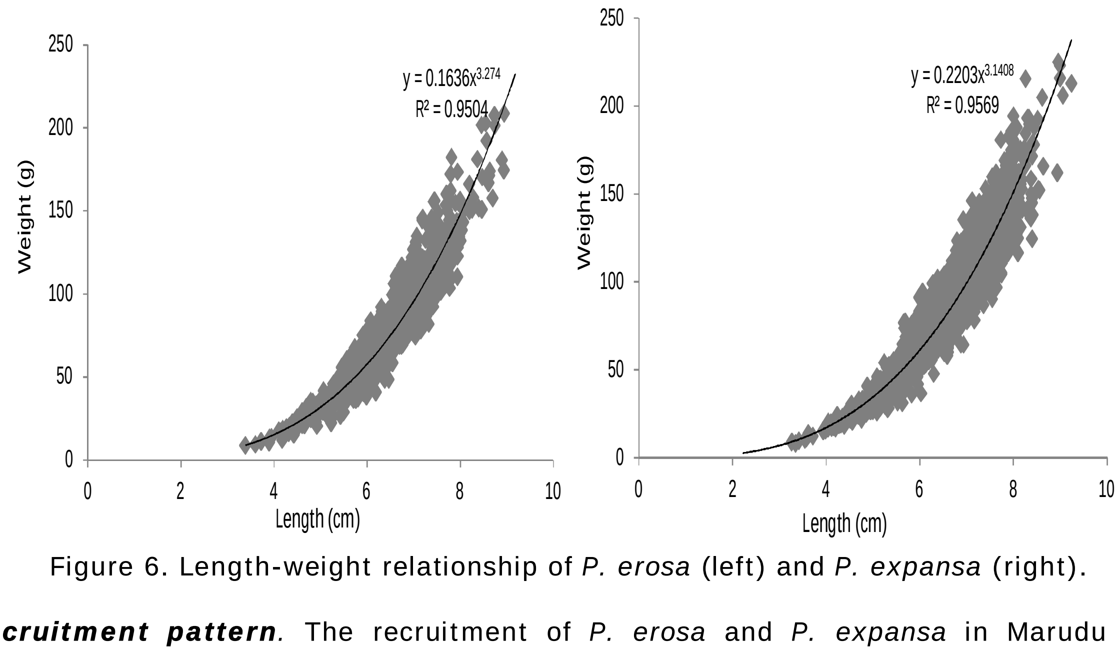

Figure 6. Length-weight relationship of *P. erosa* (left) and *P. expansa* (right).

Recruitment pattern*.* The recruitment of *P. erosa* and *P. expansa* in Marudu Bay seemed to occur throughout the year. However, the recruitment peak (Figure 7) for *P. erosa* was in June (19.39%) while *P. expansa* was in November (18.49%).

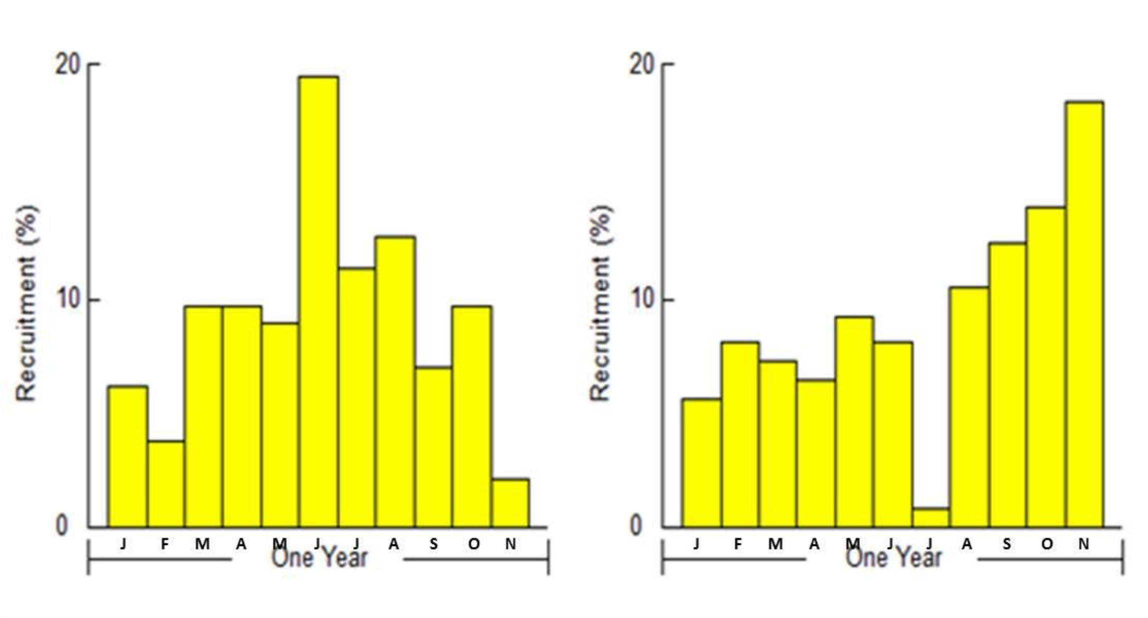

Figure 7. Recruitment pattern of *P. erosa* (left) and *P. expansa* (right) in Marudu bay.

Condition index. The condition indices of *P. erosa* and *P. expansa* in Marudu Bay ranged from 1.18 to 3.58 and 1.12 to 5.96 with a mean (±SD) of 2.28±0.49 and 2.31±0.67, respectively (Figure 8). The condition index of *P. erosa* and *P. expansa* was slightly higher in December and September, respectively compared to other months.

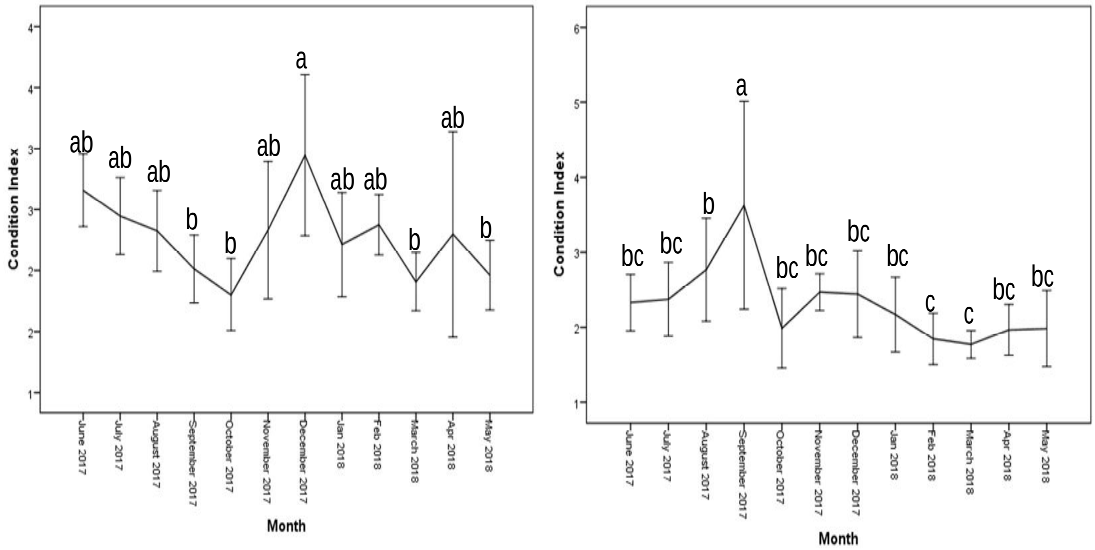

Figure 8. Condition index of *P. erosa* (left) and *P. expansa* (right) in Marudu Bay recorded from July 2017 to June 2018.

Discussion. The L_∞ (92.4 mm) of *P. erosa* and *P. expansa* in Marudu Bay was comparable to the L_∞ of *P. expansa* (91.5 mm) in Bohol, Philippines (Argente & Ilano 2013) (Table 1). However, the L_∞ of *Polymesoda* spp. in the current study was slightly lower compared to the L_∞ of *P. erosa* (107.1 mm) in Palawan, Philippines (Dolorosa & Dangan-Galon 2014). The K values recorded for *P. erosa* (0.76) and *P. expansa* (0.82) in Marudu Bay was higher than those of *P. expansa* (0.51) in Bohol, Philippines and *P. solida* (0.2) in Columbia (Rueda & Urban 1998) but lower compared to *P. erosa* (1.00) in Palawan, Philippines (Dolorosa & Dangan-Galon 2014).

Table 1
Comparison of growth and mortality parameters between current study and published values

Location	*Species*	*L∞ (mm)*	*K*	*F*	*E*	*Reference*
Marudu Bay, Malaysia	*P. erosa*	92.4	0.76	1.44	0.65	This study
Marudu Bay, Malaysia	*P. expansa*	92.4	0.82	1.95	0.70	This study
Palawan, Philippines	*P. erosa*	107.1	1.00	2.33	0.62	Dolorosa & Dangan-Galon (2014)
Bohol, Philippines	*P. expansa*	91.5	0.51	0.19	0.20	Argente & Ilano (2013)
Columbia	*P. solida*	47.3	0.2	0.54	0.72	Rueda & Urban (1998)

Mortality rate parameters can provide information on the stock status of an organism in an environment, where the exploitation is sustainable when fishing mortality is lower or equal to natural mortality (Al-Barwani et al 2007). In the current study, fishing mortality of both *P. erosa* (1.44) and *P. expansa* (1.95) is higher compared to their respective natural mortality (M = 0.76 and 0.82 for *P. erosa* and *P. expansa*, respectively), which suggests that the marsh clam in Marudu Bay is experiencing overfishing. On the other hand, the exploitation rates (E) of *P. erosa* (0.65) and *P. expansa* (0.70) are much higher than the maximum exploitation rate (E_{max} = 0.50). This clearly indicates that both clams are over-fished. Similar exploitation rates of *P. erosa* (0.62) and *P. solida* (0.72) were reported in Palawan, Philippines (Dolorosa & Dangan-Galon 2014) and Columbia (Rueda & Urban 1998), respectively, where marsh clams are usually collected by fisherman and sold to restaurants and local wet markets.

Estimated growth coefficient (b) value from length-weight relationship can range from 2 to 4 and is said to be isometric when it is equal to 3 (Koutrakis & Tsikliras 2003). The computed growth coefficient of *P. erosa* (2.27) and *P. expansa* (2.24) stocks in Marudu Bay demonstrates a clear negative allometric growth (Table 2). Although isometric growth rarely observed in marsh clams, the “b” values of the current study seemed smaller compared to the findings of Elvira & Jumawan (2017), Glimin et al (2004) and Akbar et al (2014) in Butuan Bay, Philippines, Northern Australia and Kendar bay, Indonesia, respectively. It has been suggested that food availability can influence the weight of soft tissue relative to shell length (Nakaoka 1992). Low abundance of phytoplankton in the mesotrophic water of Marudu Bay (Soon & Ransangan 2017) could partly explain this growth condition of marsh clams in the bay.

Table 2
Comparison of estimated length-weight relationships parameters between current study and published values

Location	*Species*	*a*	*b*	*Reference*
Marudu Bay, Malaysia	*P. erosa*	0.79	2.27	This study
Marudu Bay, Malaysia	*P. expansa*	0.66	2.24	This study
Butuan Bay, Philippines	*P. erosa*	1.24	3.12	Elvira & Jumawan (2017)
Northern Australia	*P. erosa*	0.37	2.91	Glimin et al (2004)
Kendar Bay, Indonesia	*P. erosa*	0.21	2.62	Akbar et al (2014)

Condition index (CI) is a method to measure overall health of an animal and it has been extensively used to estimate the effect of different environmental factors on meat quality (Li et al 2009). In this regard, three fatness categories (CI ≤ 2 (thin); CI = 2 to 4 (moderate); CI ≥ 4 (fat)) have been suggested (Devenport & Chen 1987). *P. erosa* and *P. expansa* in Marudu Bay have a condition index of 2.28±0.49 and 2.31±0.67, respectively which both fall in the category of moderate fatness (Table 3). Although the condition indices of marsh clams in Marudu Bay were higher than *P. erosa* in Kendar Bay, Indonesia (Akbar et al 2014), they are much lower compared to *P. expansa* in Kelulit, Sarawak (Rahim et al 2012). This indicates that growth and meat quality of the marsh clams are very much influenced by the environmental conditions in Marudu Bay.

Table 3
Comparison of condition index (mean±standard error) between current study and published values

Location	*Species*	*CI*	*Reference*
Marudu Bay, Malaysia	*P. erosa*	2.28±0.49	This study
Marudu Bay, Malaysia	*P. expansa*	2.31±0.67	This study
Kendar Bay, Indonesia	*P. erosa*	1.92±0.63	Akbar et al (2014)
Kelulit, Sarawak	*P. expansa*	2.7	Rahim et al (2012)

Conclusions. The current study demonstrated that marsh clams (*P. erosa* and *P. expansa*) populations in Marudu Bay are characterized by moderate condition index and continuous recruitment but grew in negative allometric fashion. The exploitation level was far beyond the maximum sustainable yield which makes them vulnerable. Hence, it is suggested that a sustainable management plan is critically needed to make sure this important fishery resource remains viable in the bay.

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