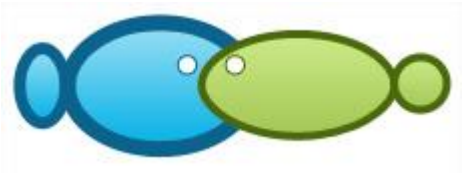

# Abundance of marine gastropods (Mollusca: Gastropoda) in replanted mangrove forests along Kerteh River, Terengganu, Malaysia

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**Abstract**. A variety of gastropod species can be found in the mangrove ecosystem. The presence of gastropod is critical to the mangrove ecosystem's long-term viability. This study is aimed to determine the abundance of gastropods in the replanted mangrove forests along the Kerteh River, Terengganu. A total of 1,676 gastropod individuals, representing 9 species and 6 families, were observed at 2 study sites. A transect line of 30 m was laid out at each area of the sampling sites. In each transect line, quadrats (1 x 1 m) were laid at 10 m intervals and the distance between each transect line was 20 m. The results from this study showed a significantly higher diversity in a 5 year replanted forest than in a 10 year replanted forest by using the t test=2.968 ($p<0.05$). The gastropods abundance was also higher in the younger replanted forest than in the older replanted forest, although not significantly: M=101.1 and SD=242.6, versus M=85.1 and SD=215.5, respectively; t(df)=0.15, p=0.882. In term of species composition, *Pirenella cingulata* and *Optediceros brevicula* were the dominant species at both sites. The gastropod evenness index at 5 and 10 years replanted forests were close: 0.25 and 0.21, respectively, indicating an almost similar distribution of the gastropods in both the replanted mangrove forests. This research provided some insights into the diversity of gastropods as bioindicator of changes and disturbances in the replanted mangrove and it is useful in planning conservation areas and in the evaluation of biodiversity in the river habitats.
**Key Words**: conservation, ecosystem, marine gastropod, biodiversity, river.

**Introduction**. Mangroves are amongst the most productive marine ecosystems on earth, providing a unique habitat opportunity for many species and services for human beings. Mangrove forests provide different microhabitats with a high level of ecological variety. These ecosystems require a special attention among coastal ecosystems in the world, not only because of their unique habitat characteristics, but also because of their abundant biodiversity (FAO 2007; Sandilyan & Kathiresan 2012). Since various fish, crustacean, and bird species are dependent on this type of ecosystem during their life cycles, enriching the biodiversity in mangrove areas (Carugati et al 2018). However, in Malaysia this unique ecosystem is converted into aquaculture ponds and residential areas. Human perception on mangrove forests as 'dirty' or 'rubbish' places has turned quickly after tsunami hit countries such as Thailand, Indonesia and also Malaysia. Its ecological roles and ecosystem services became obvious and later on appreciated especially for acting as barrier against disasters.

The phylum Mollusca includes Gastropoda, or snails (Class Gastropoda). With an estimated 80,000-100,000 described species is the second largest phylum after

Arthropoda (insects) (Strong et al 2008; Pechenik 2016; Baharuddin et al 2018). Gastropods have a substantial environmental impact and contribute to the global economy. In ecology, gastropods are a good indicator of water quality and the presence of some species can indicate the status of pound waters (Galan et al 2015). Gastropods are one of the most common and visible macrofauna in mangrove ecosystems, occupying a variety of ecological niches. A number of gastropod species appear to be live only in mangrove ecosystems (Plaziat 1984; Kabir et al 2014).

Gastropods play an essential role in the economy as a source of protein, decoration, dyes and medications (Haszprunar & Wanninger 2012; Garza et al 2012; Ahmad et al 2018; Baharuddin et al 2018). Besides, they are also vital components in the food webs of mangrove environments. Their feeding guilds include detritivores, deposit feeders, algal feeders as well as carnivorous. Certain species eat debris, leaf litter and serve as shorebird prey (food) (Rahmawati et al 2015). In addition, numbers of gastropod species have commercial value and are also edible.

The scarcity of studies on their abundance in mangrove forests along Kerteh River has driven this study. Kerteh River sides were replanted with mangrove species 10 years ago, in an effort to rehabilitate the areas affected by petroleum refinery and other industrial activities in the neighborhoods. Due to its success, another replanting program was carried out 5 years ago. Hence, this study will provide information on the diversity of gastropod species, which are bioindicators of changes and disturbances. This could further encourage stakeholders to replant more mangroves to secure sustainable natural areas.

## Material and Method

***Description of the study sites***. This study was carried out in January and March 2022 and located on the replanted area mangrove forest near the Kerteh River, Terengganu (4º52.720 N,103º44.461E) (Figure 1). Two sampling sites were selected along the river, which are 10 years and 5 years replanted areas. The main mangrove trees include *Rhizophora apiculata* and *Rhizophora mucronata.*

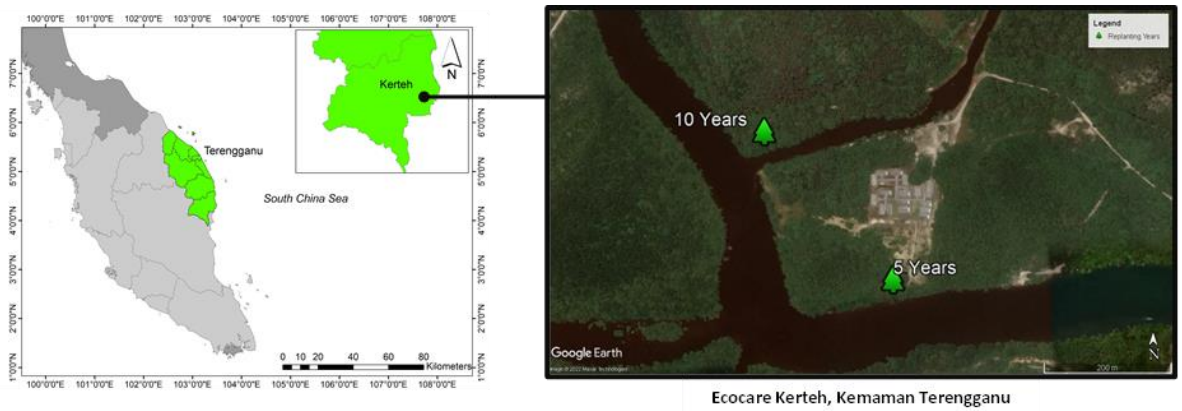


Figure 1. The sampling area in 5 and 10 years replanted mangrove forest areas along Kerteh River (Source: Google Earth).

***Sampling method***. The methodology of this study followed Faezah & Farah (2011). A 30 meter transect line was laid out in each area of the sampling sites. Then, along each transect line, quadrats (1 x 1 m) were laid at 10 m intervals. The distance between the transect lines was of 20 m. The gastropods were collected by hand. Then the gastropods from each station were gathered and placed in zip-locked plastic bags. The bags were labelled with date and station numbers. The samples were kept at -20ºC. The identification of gastropods was based on morphological characteristics such as shape, color and shell characteristics. The gastropod species were identified based on morphology characteristics, by referring to Baharuddin & Marshall (2014) and verified via the World Register of Marine Species (WoRMS, www.marinespecies.org) and Molluscabase (molluscabase.org).

***Statistical analysis***. The Shannon-Wiener diversity index (H'), the Margalef species richness index (R), and the evenness index (E) have been used to assess data on the number of species and the number of individuals of each species that have been collected.

***Shannon-Wiener Diversity Index (H')***. The number of individuals and of species were used when counting for Shannon Index to find species diversity. Shannon index of diversity was used to calculate the probability of two individual species from selected samples of different species. The higher the value of H', the greater the diversity obtained. The Shannon diversity index is classified into three levels: low (H'<2), moderate (2<H'<4), and high (H'>4) (Odum & Barret 2004).

$$H' = -\sum [(ni / N) \ln (ni / N)]$$

Where:
H'- Shannon index;
N - total individuals of populations sampled;
ni - total individuals belonging to the i species.

***Margalef's Richness Index (R)***. The Margalef's Richness Index was used to measure the species richness that derived by the combination of S (number of species recorded) and N (total number individual recorded). The index indicates the number of species in a sample or the abundance of the species per unit area (Ludwig & Reynolds 1988).

$$R = (S-1) / \ln (N)$$

Where:
R - Margalef's richness index;
S - total number species recorded;
N - total of individuals recorded.

***Evenness index***. The evenness index was used to measure the unequal representation of species in the sample area. Evenness is derived from other diversity measurements such as Shannon Index and Simpson Index because of these indices' inherent richness and evenness component. Species evenness ranges from 0-1, with 0 signifying no evenness and 1, a complete evenness (Ludwig & Reynolds 1988; Metcalfe 1989).

$$E = H' / H' \max$$

Where:
E - Evenness index;
H' - Shannon index;
H' max - diversity index observed to a maximum diversity.

***Diversity t-test***. The Shannon t test was described by e.g. Hutcheson (1970), Poole (1974), and Magurran (1988). This is an alternative to the randomization test available in the diversity permutation test module. Requires two columns of abundance data with taxa down the rows.

$$t = H'_1-H'_2 / \sqrt{(\text{Var } H'_1+\text{Var } H'_2)}$$

Where:
$H'_1$ - Shannon index 5 years replanted mangrove forests;
$H'_2$ - Shannon index 10 years replanted mangrove forests;
Var $H'_1$ - variance Shannon index 5 years replanted mangrove forests;
Var $H'_2$ - variance Shannon index 10 years replanted mangrove forests.

A diversity t-test was performed using H' value to compare the species diversity of gastropods between the 5 and 10 years replanted mangrove forests. Paleontological Statistics Software (PAST) was used to measure and to compare the diversity of gastropods between the 5 and 10 years mangrove forests on the Kerteh River.

## Results

***Abundance of gastropod***. A total of 1,676 gastropods, representing nine and six families, were recorded at both sites (Table 1). The abundance of gastropods community in the 5 years replanted mangrove forest was found higher than in the 10 years replanted forest, although not significantly: M=101.1 and SD=242.6, versus M=85.1 and SD=215.5, respectively; t(df)=0.15, p=0.882. Based on the data collected at each site, a total of 910 and 766 gastropods from eight species were found in both 5 and 10 year replanted mangrove forest, respectively. There are 3 species that were found abundantly in the 5 years replanted mangrove forest: *Optediceros breviculum*, *Pirenella cingulata* and *Clithon oualaniensis*, while only two species were collected in large numbers, in the 10 years replanted mangrove forest: *O. breviculum* and *P. cingulata*, as shown in Table 1. The morphology of the species recorded is presented in Figure 2.

Table 1

Abundance of gastropods in the replanted mangrove forest at Kerteh River at five and 10 years replanted areas

| *Family* | *Species* | *Total number of individuals $m^{-2}$ in the station* | |
|---|---|---|---|
| | | *5 years* | *10 years* |
| Assimineidae | *Optediceros breviculum* | 59 | 655 |
| Ellobiidae | *Cassidula aurisfelis* | 2 | 0 |
| Ellobiidae | *Cassidula nucleus* | 4 | 2 |
| Littorinidae | *Littoraria fasciata* | 6 | 4 |
| Neritidae | *Clithon oualaniensis* | 85 | 7 |
| Neritidae | *Nerita balteata* | 3 | 2 |
| Neritidae | *Neripteron violaceum* | 8 | 3 |
| Pachychilidae | *Faunus ater* | 0 | 5 |
| Potamididae | *Pirenella cingulata* | 743 | 88 |
| | Total | 910 | 766 |


Figure 2. Species recorded in the study: 1. *Cassidula nucleus*; 2. *Cassidula aurisfelis*; 3. *Littoraria scabra*; 4. *Neripteron violaceum*; 5. *Clithon oualaniensis*; 6. *Nerita balteata;*7. *Optediceros breviculum*; 8. *Pirenella cingulata* 9. *Faunus ater.*

***Composition of gastropods***. The study also recorded 5 families in the 5 years replanted area (Figure 3) and 6 families in the 10 years replanted area (Figure 4). Assimineidae, Ellobiidae, Littorinidae, Neritidae and Potamididae species occurred at both study sites, as showed by the Venn diagram below (Figure 5). Neritidae has the highest species composition at both study sites.

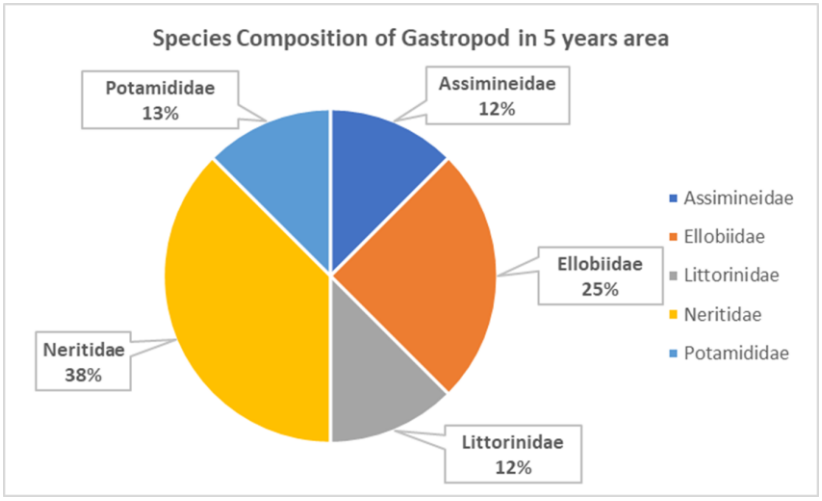


Figure 3. Species composition at 5 years replanted mangrove area.

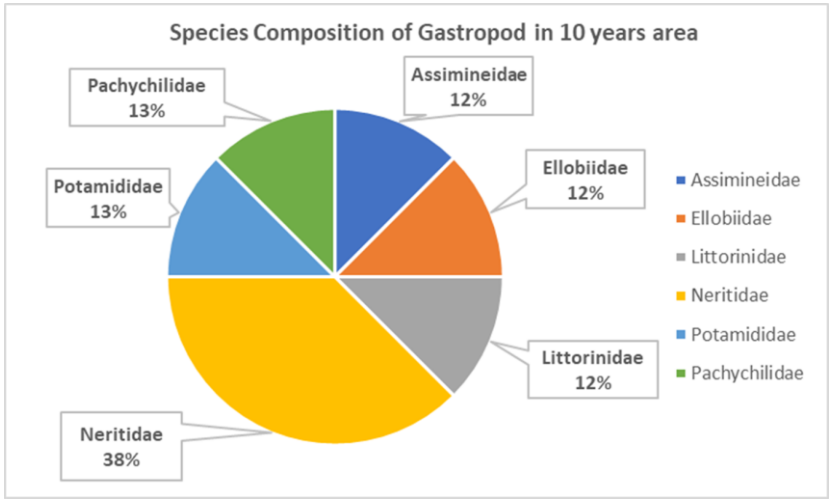


Figure 4. Species composition at 10 years replanted mangrove area.

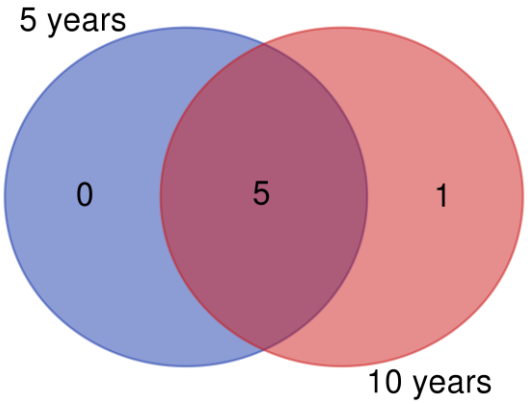


Figure 5. Venn diagram showing that almost similar species were found at both sites.

***Ecological index***. The Shannon diversity index is classified into three levels: low (H'<2), moderate (2<H'<4), and high (H'>4) (Odum & Barret 2004) whilst the evenness index is

used to assess the homogeneity and the pattern distribution of each species in a given community. In this study, the diversity index of the 5 years replanted mangrove forest was significantly higher than for the 10 years replanted forest, t (1657.8)=2.968, p<0.05 (Table 2), using diversity t-test using Shannon (H') value to compare the species diversity of gastropods, where the recorded H' values were 0.70 and 0.54 for the 5 and 10 years replanted forests, respectively (Table 3). The species richness is defined as the number of species in a given area. For each unit, the species richness index is matched with the individual abundance. The species richness index value in the 5 years and 10 years replanted areas is 1.03 and 1.05, respectively. As a result, both study sites are classified as 'low' in terms of gastropod species richness. In term of species evenness, gastropod evenness index in the 5 and 10 years replanted forests were of 0.25 and 0.21, respectively, indicating an almost similar distribution of the gastropods for both replanted mangrove forests (Table 3).

Table 2

Diversity t-test using Shannon diversities in 5 and 10 years replanted mangrove areas

| *Site* | *H'* | *Variance* | *t* | *df* | *p* |
|---|---|---|---|---|---|
| 5 years replanted area | 0.695 | 0.001 | 2.968 | 1,657.8 | 0.003* |
| 10 years replanted area | 0.538 | 0.001 | | | |

* significant difference with 95% confidence limit (α:0.05).

Table 3

Summary on species diversity, richness and evenness indices at the mangrove forests of Kerteh River

| *Study site* | *Shannon Weiner Diversity Index* | *Margalef Species Richness Index* | *Evenness Index* |
|---|---|---|---|
| 5 years replanted area | 0.70 | 1.03 | 0.25 |
| 10 years replanted area | 0.54 | 1.05 | 0.21 |

## Discussion

***Abundance of gastropod and ecological index***. The abundance of gastropods community did not vary between 5 and 10 years replanted forests, although there were differences in terms of species diversity. This finding suggesting that the younger replanted mangrove forest has a more diverse gastropods community and a higher total number of gastropods individuals compared to the older replanted forest. This finding might reflect the variety of microhabitats in the form of roots, branches and stems of mangrove plants in the replanted 5 years stand based on our observation during the fieldwork. The abundance of gastropod species may also improve the sustainability in the 5 years replanted mangrove environments, which provide an ideal habitat for the malacofauna (Kabir et al 2014). Additionally, the molluscs, including gastropods, are decreasing in the 10 years replanted forest, due to an intensive exploitation by the local communities. For the locals, gastropods are known to be valuable and sought after for consumption. The meat is high in protein, while the shell is used to make souvenirs (Poutiers 1998; Bloch 2012). The locals eat snails and elderly teach their young generation how to capture them in the mangrove. Moreover, mature mangrove trees provided minimal microhabitat given its sturdy structure such as big trunk whereby climbing snails such as Littorinidae preferred to rest behind leaves, branches, or complex roots. This is also to ensure its protection from predators such as birds, crabs or fishes. In term of species evenness, the abundance of gastropod community in both replanted mangrove forest is almost similarly distributed. According to Krebs (1972), values in the range of 0.21–0.40 indicate that the species evenness belongs to the 'poor' category, suggesting a quite unevenly distributed overall abundance.

***Gastropods species composition***. The largest contributors to the abundance were the Potamididae, Neritidae and Assimidae families, their habitats consisting of mangrove plants (Faezah & Farah 2011; Jahid & Singh 2021). Littorinidae, Neritidae, Potamididae and Ellobiidae are all common gastropod families of tropical mangroves (Faezah & Farah 2011). The same gastropod families were found in both mangrove forests along Kerteh. In particular, 2 other species, Assimineidae and Pachychilidae, were also found in these habitats. Neritidae family has the largest number of species in this study, contributing with 3 species: *Nerita balteata, Neripteron violaceum* and *Clithon oualaniensis.* According to Yadav et al (2019), the Neritidae and Ellobiidae were also observed to be the dominant families in Indian mangrove ecosystems. *Pirenella cingulata*, from the Potamididae family, is the most dominant gastropod species in the mangrove forest of the Kerteh River, with the highest abundance. These species were also found in high abundance in eastern Thailand (Sri-aroon et al 2004). Substrates of both areas were found to be more sandy, based on observation during the fieldwork. Gary and Richard (2006) reported that *P. cingulata* is most often found in areas of sandy substrate. Gastropods from the family Potamididae are also known as mud creeper.

**Conclusions**. The replanted mangrove forest of Kerteh River contains diverse ranges of gastropods, with the majority of gastropods community belonging to the Neritidae family. It is recommended to supplement this study with ecological factors, such as soil nutrient analysis, leaf litter, soil depth and tidal frequency, that may influence the gastropod species abundance and composition in the replanted forests, in order to properly quantify the influence of the replanted mangroves plants on the biodiversity and thus to build a benchmark project on the sustainability of the restored mangrove ecosystems.

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**Conflict of interest**. The authors declare no conflict of interest.

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