*Eco. Env. & Cons. 26 (1) : 2020; pp. (356-364)*
*Copyright@ EM International*
*ISSN 0971–765X*

# Gastropods of mangrove forests in the coastal waters of Ambon island, Indonesia

**Dance N. Kho[1], Hasan Tuaputty[2], Dominggus Rumahlatu[2] and Fredy Leiwakabessy[2,*]**

***[1]Postgraduate Biology Education, Pattimura University. Jl. Dr. Tamaela, Ambon 97116, Maluku, Indonesia***
***[2]Study Program of Biology Education, Faculty of Teacher Training and Education Science, Pattimura University. Jl. Ir. M. Putuhena, Ambon 97233, Maluku, Indonesia.***

(Received 5 March, 2019; accepted 17 November, 2019)

**ABSTRACT**

This research aims at examining the physical-chemical conditions of the environment, substrate conditions, and taxa composition of gastropods in the mangrove forest area on the island of Ambon. The research was conducted for 3 months, starting from May until July 2016. This research was carried out in the mangrove area on several beaches of Ambon Island including Tawiri village, Passo village and Suli village. The results of this research showed that the temperature on the Tawiri beach ranged from 29-30 $^{o}$C, the temperature on the Passo beach ranged from 27-28$^{o}$C, while the temperature on Suli beach ranged from 26-28$^{o}$ C. The salinity of water on the Tawiri beach ranged from 24-30 $_{0/00,}$ The salinity in the Passo beach ranged between 26-29 $_{0/00}$, while the salinity on the Suli beach ranged between 18-29 $_{0/00}$. The pH of the seawater on the Tawiri beach ranged from 6-6.8, the pH of the seawater in the Passo beach ranged from 6.4-67, while the pH of the seawater on the Suli beach ranged from 6-6.5. Dissolved oxygen (DO) on the Tawiri beach ranged from 0.9-8 ppm, the dissolved Oxygen on the Passo beach ranged from 5-16.1 ppm, while Dissolved Oxygen on the Suli beach ranged from 4-10 ppm. Generally, the substrate composition in the three research locations was clay, dusty clay and sandy clay. Mangrove forest in Suli village has a higher number of species, which is as many as 23 species, and then followed by 20 species in the Tawiri village, and 12 species in the Passo village. There is a significant correlation between temperature factor and gastropod diversity in several mangrove forests on Ambon island.

***Key words:*** *Environmental factors, Substrate, Taxa composition of gastropods*

## Introduction

The total area of mangrove forests reaches 200,000 Km$^2$ spreading over tropical and sub-tropical coastlines (Cunha-Lignon *et al*., 2011; Iftekhar, 2008). Spalding *et al*. (1997) state that the total of mangrove forest area is 8% of the coastline length, where ¼ of the total mangrove forest in the world is along the coastline of the tropics. Duke *et al*. (2007) also explain that as much as 2% of mangrove forests extinct every year. This extinction has ecological, social and economic impacts on humans. Mangrove forests are recognized as important resources in economic and ecological contexts because they have high productivity (Berger *et al*., 2008; Dolorosa and Dangan-Galon, 2014). The area of the mangrove forest plays a role as a spawning area or shelter for aquatic organisms that have important ecological functions as well as high economic value. Mangrove forests also act as a source of timber production, as a place for accumulation of sediments, nutrients and pollutants. Mangroves can also play a role in preventing

***Corresponding author's email:** fredyleiwakabessy2017@gmail.com

erosion, they can even reduce the risk of natural disasters such as tsunamis. Therefore, it is called as coastal water stabilizers (Ayukai *et al*., 1998; Alongi, 2002; Alongi and Carvalho, 2008; Bouillon *et al*., 2008).

Mangrove ecosystems are a comfortable habitat for various types of marine and terrestrial fauna. Mangrove detritus is known to be a food source for decomposers in the food chain like macroinvertebrates such as crabs and gastropods (Bouillon *et al*., 2002; Kristensen *et al*., 2008). In addition, Khade and Mane (2012) explained that the roots and lower parts of the mangrove tree are substrate for several organisms such as shrimp and shellfish. Various invertebrate species are known to be associated with mangroves, but molluscs are the most in the context of species richness, biomass and density (Nagelkerken *et al*., 2008; Li *et al*., 2012). The research conducted by Maia and Coutinho (2013) concluded that mangrove deforestation had a significant effect on the distribution of gastropods *M. coffeus*, both the size and density of population. The existence of various types of fauna in mangrove ecosystem is highly dependent on several factors, such as, species composition, the production of leaves, twigs, and sediments. The results of the research conducted by Tavares *et al*. (2015) conclude that mangrove branches in the bottom of the water are a good shelter for gastropods small-sized *M. coffeus*. However, the distribution of gastropods in mangrove forests is influenced by various environmental quality factors.

The research conducted by Suratissa and Rathnayake (2017) found that gastropod diversity was lower in mangrove areas which kept a lot of household waste. Other research results also show that environmental factors, such as temperature, pH salinity and dissolved oxygen, tide elevation, salinity, sediment texture and forest types, have a significant effect on the distribution of gastropods in mangrove forests (Nagelkerken *et al*., 2008; Beasley *et al*., 2005). For example, the soil around the mangroves


**Fig. 1**. Research location (Note: Tawiri village waters, Passo village waters, Suli village waters)

in the Rhizophora zone has a higher nitrogen content than that in the Avicennia zone. Sediments that have high levels of salinity also reduce the availability of nutrients for organisms (Kathiresan *et al*., 1996). Most gastropods are a type of organism that can climb (tree climber) so that it can avoid the ups and downs of the tide. Nevertheless, Irma and Sofyatuddin (2012) suspect that the high density and distribution of gastropods in mangrove forests is more due to their mobility.

Ambon Island is one area that has the potential of mangrove forests. However, The existence of mangrove forests on the island of Ambon faces a serious threat due to the high level of development and population growth. Both of these cause the disposal of household waste in the form of plastic waste which generally will be concentrated in the mangrove area. In addition, the construction of residential areas in the highlands also causes sediment accumulation in the mangrove area. This certainly affects the existence of organisms living in mangrove forests. Therefore, this resarch aims at examining the physical-chemical conditions of the environment, substrate conditions, and gastropod diversity in the mangrove forest area on the island of Ambon.

## Materials and Methods

This research is a descriptive correlational research which aims at revealing the structure of the molluscs community in Ambon Island. This research was conducted for 3 months, starting from May until July 2016. This research was carried out in the mangrove area on several beaches of Ambon Island (Figure 1), i.e. the coastal waters of Tawiri, the coastal waters of the Passo village and the coastal waters of Suli village. These aread were selected because based on the results of the preliminary observations, the three mangrove forest areas have differences in substrate composition. Tawiri Beach has a sandy and a little rocky substrate, Passo beach has a muddy and sandy substrate, while Suli beach has a muddy, rocky and sandy substrate.

The research activities included direct data collection in the mangrove areas at designated points using Global Positioning Systems (GPS), to determine the position of transects and sample plot at the research location. Gastropod sampling was carried out when sea water receded using the linear quadratic transect method. After that, a transect with a length of 50 meters was made at each observation station. The position of the transect line was placed vertically from the coastline to the lowest tide, where the distance between transects was 20 meters. The total number of the transects were 28 transects, where 8 transects were made on the Tawiri coast, 10 transects were made at Passo coast, and 10 transects were made on the Suli coast. The size of the sample plot used at each location was $1 \times 1$ $m^2$ and placed parallel to the transect line. There were 5 quadrats at each transect with the distance between the sample plots 10 meters. Thus the total number of sample plots as a whole was 140 quadrats.

The data obtained in this study were physical-chemical conditions of water, substrate / sediment composition, and gastropod species. The Shannon-Wiener diversity index (H ʼ) was then used to determine the diversity of gastropod species (Ludwig and Reynolds, 1988). The correlation between the physical-chemical environmental factors and the diversity of the diversity of gastropods was analyzed by using inferential statistics, i.e. the multiple linear regression analysis.

## Results and Discussion

### The Physico-Chemical Factors of the Environment

The results of measurements of the physical-chemical factors of the aquatic environment in mangrove forests (Fig. 1) showed that the temperature variable on the coastal waters of Tawiri ranged from 29-30 $^{o}$C, the temperature at the coastal waters of Passo ranged from 27-28 $^{o}$C, while the temperature on the coastal waters of Suli ranged from 26-28 $^{o}$C. In addition, the seawater salinity measurement results show that the salinity of the water at the coastal waters of Tawiri beach ranged between 24-30 ‰, the salinity at the coastal waters of Passo beach ranged between 26-29‰ , while the salinity at the coastal waters of the Suli beach ranged between 18-29 ‰. Moreover, the measurement results of the pH of seawater show that the pH on the coastal waters of Tawiri beach ranged from 6-6.8, the pH of the coastal waters of Passo beach ranged from 6.4-6.7, while the pH at the coastal waters of Suli beach ranged from 6-6.5. Fig. 1 also shows that the dissolved oxygen (DO) on the Tawiri beach ranged from 0.9-8 ppm, the DO on the Passo beach ranged from 5-16.1 ppm, while the DO on the Suli beach ranged from 4-10 ppm.

The variation in water quality parameters is a regional climate pattern and biological activity. Generally, sea surface temperatures are strongly influenced by the intensity of sunlight, evaporation, freshwater flow and tides. Similarly, salinity is affected by dilution and evaporation. The entry of freshwater will reduce salinity, while evaporation will increase salinity. Besides, pH reflects $CO_2$ concentrations in seawater. If the concentration of hydrogen ions is higher, the pH will be higher or alkaline, and vice versa. The causes of reduced oxygen in water are, such as, the release of oxygen into the air, the flow of ground water into the waters, the presence of iron, reduction caused by the pressure of other gases in water, biota respiration and composition of organic matter (Palanisamy and Khan, 2013).

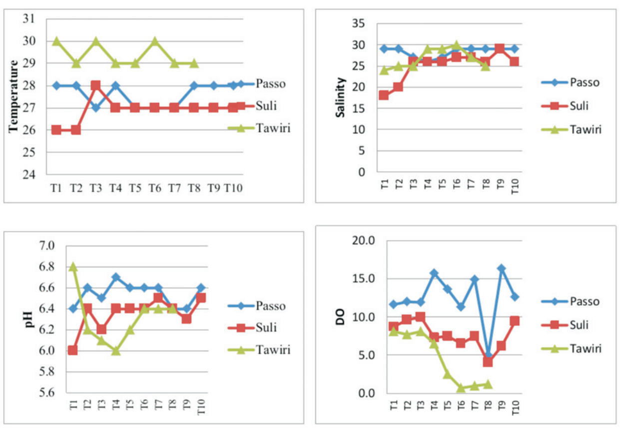


**Fig. 1.** The Physicochemical Properties of the Mangrove Ecosystems

### Composition of Substrate in Mangrove Forests

Substrates have an important role for the life of gastropods. Generally gastropods live in substrate to determine the pattern of life, death, and types of organism. Organic matter and substrate texture greatly determine the presence of gastropods. The texture of the base substrate is a place to stick and creep or walk, while organic matter is the source of food.

The results of the analysis of the water substrate in mangrove forests (Fig. 2) show that the substrate in the mangrove forest on Tawiri beach is generally formed by several elements, including stone, gravel, very rough sand, rough sand, medium texture sand, fine sand, very fine sand, clay and dust. However, the dominant elements are stone, fine sand and very fine sand. The results of the substrate analysis revealed that generally the substrate on the Tawiri

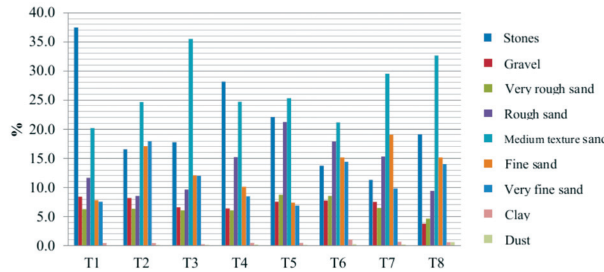


**Fig. 2.** Substrate composition of mangrove forest in Tawiri beach

beach was clay, dusty clay and sandy clay.

Different from that in Tawiri, the substrate condition of the mangrove forest in Passo village has different composition (Fig. 3), that is, the substrate is formed by elements such as stone, gravel, very rough sand, rough sand, medium texture sand, fine sand, very fine sand, clay and dust. The results of the analysis also show that medium sand and rough sand are the dominant elements. The results of the sediment analysis show that generally the sediments on the beach in Passo Village are clay, dusty clay and sandy clay.

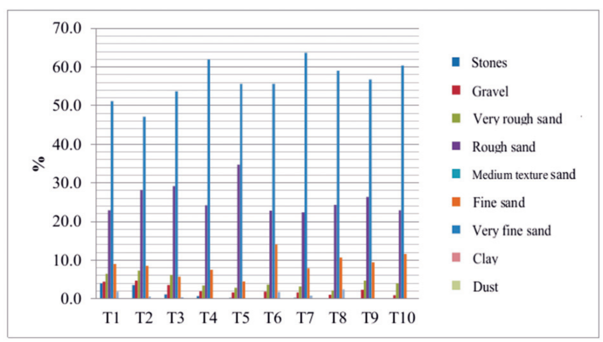


**Fig. 3.** Substrate composition of mangrove forest in Passo beach

Unlike that in Passo village, the substrate of mangrove forests in Suli village has a different composition (Fig. 4), that is, the substrate is formed by elements such as stone, gravel, very rough sand, rough sand, medium texture sand, fine sand, very fine sand, clay and dust. The results of the analysis also show that the dominant element is very fine sand and stones. The results of the sediment analysis show that generally the sediments on the Passo beach are clay, dusty clay and sandy clay.

The results of the analysis (Fig. 2, 3, 4) show that in general the sediment compositions in the three research locations are clay, dusty clay and sandy clay. This is in accordance with Palanisamy and

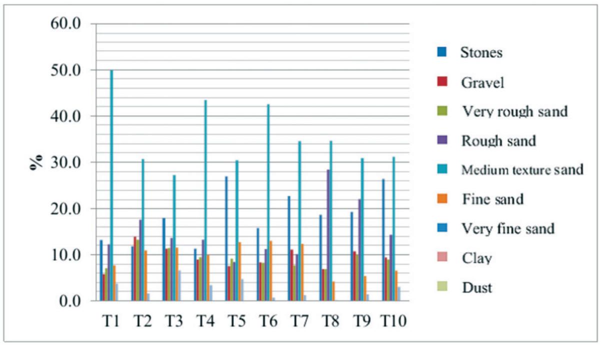


**Fig. 4.** Substrate composition of mangrove forest in Suli beach

Khan (2013) that the substrate in mangrove forests is generally composed of sand mixed with mud and clay. However, Fig. 2-4 show that there are differences in the concentration of each constituent element in the three research locations. Mokhtari *et al*. (2015) and Minchinton (2001) explain that the spatial variation of sediment characteristics of mangrove forests can cause differences in niches for the organisms that live in it. Kabir *et al*. (2014) also found that the substrate texture of the mangrove forest affected the distribution, diversity and density of molluscs.

**Taxa Composition of Gastropods**

The individuals of gastropods found in the sample plot were identified and arranged according to the taxa order. The results of the identification found that the gastropod community of mangrove forests in Tawiri village was composed of 20 species spreading over 12 genera and 9 families (Table 1). The most species found were those belonging to the Chypeomorus, Nassarius and Nerita genus. The number of species in the Chypeomorus genus was 3 species, namely *Chypeomorus coralium, Chypeomorus moniliferus, Chypeomorus pellucida.* Furthermore, the species found in the Nassarius genus were *Nassarius globosus, Nassarius olivaceus* and *Nassarius pullus.* In addition, the species in the Nerita genus were *Nerita chamaeleon, Nerita patulla, Nerita polita, Nerita signata.*

In the mangrove forest in the coastal waters of Passo village were found 12 gastropod species consisting of 8 genera and 7 families (Table 1). The most species found was in the genus Chypeomorus and Nassarius. The species in the genus Chypeomorus found were *Chypeomorus coralium, Chypeomorus moniliferus* and *Chypeomorus pellucid,* while the species in the genus Nassarius found were *Nassarius livescens, Nassarius olivaceus* and *Nassarius pullus.*

In the mangrove forest in Suli village, 24 gastropod species consisting of 14 genera and 13 families were found (Table 1). The most species found were those in the genus Chypeomorus and Nassarius. The species in the genus Chypeomorus found were *Chypeomorus coralium, Chypeomorus moniliferus* and *Chypeomorus pellucida,* while the species in the genus Nassarius found were *Nassarius globosus, Nassarius olivaceus, Nassarius pullus, Nassarius limnaeiformis* and *Nassarius crematus.*

The data on the types of gastropods in the three research locations (Table 1) showed that the mangrove forest in Suli village had the highest species which was 23 species, then followed by Tawiri village as many as 20 species, and Passo village as many as 12 species. Although the number of species differed, the taxa composition in the three research locations revealed the fact that gastropods in the mangrove forest area on Ambon Island were dominated by species from the genus Chypeomorus, Nassarius and Nerita. The research conducted by Manzo *et al*. (2014) also found that intertidal gastropods in Sarangani Filipin Province were predominantly dominated by the genus Nassarius and Nerita. Zvonareva *et al*. (2015) did a monitoring during 2005-2013 and found that there were 53 species in 21 families monitoring gastropods in mangrove forests in Nha Trang (NT) Bay and Nha Phu (NP) Bay and dominated with genus Chypeomorus and Nerita.

**Correlation Between Physico-Chemical factors and Gastropods Diversity**

An analysis was performed to determine the correlation between physico-chemical factors and gastropod diversity. The results of the regression analysis showed that temperature, salinity, pH and dissolved oxygen (DO) factors had an effect on gastropod diversity in mangrove forests on Ambon Island (Table 2).

Table 2 shows that there is a significant correlation between temperature factor and gastropod diversity in several mangrove forests on Ambon island. The regression coefficient of temperature factor is 0.728 with the t-count 9.591 and the significance of t-count is 0.000. This means that there is a significant correlaltion between water temperature and gastropod diversity. The results of this research are in line with several other research findings, such as: Selck *et al*. (2006); Miura *et al*. (2007); Schram *et al*.

**Table 1.** Composition and distribution of gastropods in the Tawiri, Passo, and Suli mangrove forests

| Family | Genus | Species | Distribution | | |
|---|---|---|---|---|---|
| | | | Tawiri | Passo | Suli |
| Cerithiidae | Chypeomorus | *Clypeomorus coralium* (Kiener, 1841) | + | + | + |
| | | *Clypeomorus moniliferus* (Kiener, 1841) | + | + | + |
| | | *Clypeomorus pellucida* (Hombron & Jacquinot, 1848) | + | + | + |
| Nassaridae | Hebra | *Hebra corticata* (A. Adams, 1852) | + | + | + |
| | Nassarius | *Nassarius globosus* (Quoy & Gaimard, 1833) | + | - | + |
| | | *Nassarius olivaceus* (Bruguière, 1789) | + | + | + |
| | | *Nassarius pullus* (Linnaeus, 1758) | + | + | + |
| | | *Nassarius livescens* (Philippi, 1849) | - | + | - |
| | | *Nassarius limnaeiformis* (Dunker, 1847) | - | - | + |
| | | *Nassarius crematus* (Hinds, 1844) | - | - | + |
| Turbinidae | Lunella | *Lunella cinerea* (Born, 1778) | + | - | - |
| Turbinellidae | Vasum | *Vasum turbinellus* (Linnaeus, 1758) | - | - | + |
| Mitridae | Pterygia | *Pterygia dactylus* (Linnaeus, 1767) | + | - | - |
| | Mitra | *Mitra decurtata* (Reeve, 1844) | + | - | - |
| | | *Mitra retusa* (Lamarck, 1811) | - | - | + |
| Muricidae | Morula | *Morula margariticola* (Broderip and Sowerby, 1833) | + | + | + |
| | | *Morula musiva* (Kiener, 1835) | + | - | + |
| | Thais | *Thais aculeata* (Deshayes, 1844) | + | - | - |
| | | *Nerita chamaeleon* (Linnaeus, 1758) | + | - | + |
| | | *Nerita patula* (Récluz, 1841) | + | - | - |
| Neritidae | Nerita | *Nerita polita* (Linnaeus, 1758) | + | - | + |
| | | *Nerita signata* (Lamarck, 1822) | + | - | + |
| Potamididae | Terebralia | *Terebralia sulcata* (Born, 1778) | + | + | + |
| Costellariidae | Vexillum | *Vexillum virgo* (Linnaeus, 1767) | + | - | + |
| | | *Vexillum rugosum* (Gmelin, 1791) | - | - | + |
| Melongenidae | Volema | *Volema myristica* (Röding, 1798) | + | - | - |
| Littorinidae | Littorina | *Littorina scabra* (Linnaeus, 1758) | - | + | - |
| Pyramidellidae | Otopleura | *Otopleura auriscati* (Holten, 1802) | - | + | + |
| Naticidae | Polinices | *Polinices mammilla* (Linnaeus, 1758)- | + | - | |
| Bucinidae | Engina | *Engina mendicaria* (Linnaeus, 1758) | - | - | + |
| Conidae | Conus | *Conus ebraeus* (Linnaeus, 1758) | - | - | + |
| Planaxidae | Planaxis | *Planaxis sulcatus* (Born, 1778) | - | - | + |
| Olividae | Oliva | *Oliva oliva* (Linnaeus, 1758) | - | - | + |

**Table 2.** Results of Linear Regression Analysis

| Independent Variables | Standardized coefficient | t-count | Prob(sig t) | alpha | Description |
|---|---|---|---|---|---|
| Temperature | 0.728 | 9.591 | 0.000 | 0.05 | Significant |
| Salinity | 0.687 | 7.140 | 0.000 | 0.05 | Significant |
| pH | 0.545 | 3.582 | 0.002 | 0.05 | Significant |
| DO | 0.724 | 6.171 | 0.000 | 0.05 | Significant |

(2016); Song *et al*. (2013); Bashevkin and Pechenik (2015). The seawater temperature factor is one of the factors that greatly affects the survival of aquatic organisms. Water temperature fluctuations are mostly caused by the penetration of sunlight and $CO_2$ levels. Several resarch results indicate that there is an increase in seawater temperature caused by human activities. This increase in temperature affects various levels of the biological system of aquatic organisms. Xiao *et al*. (2014) describe that temperature can affect respiratory rate, eating habits, respiration, metabolic activity, growth, reproduction and gametogenesis of poikiloterm organisms.

Table 2 also shows that there is a significant correlation between salinity and gastropod diversity in several mangrove forests on Ambon Island. The regression coefficient of salinity factor is 0.687 with the t-count 7.140 and the significance of t-count is 0.000. This means that the salinity of sea water has a significant effect on the the diversity of gasropods in mangrove forests. The results of this research are in line with several other research findings, such as Bashevkin and Pechenik (2015); Montory *et al*. (2014); Xiao *et al*. (2014); and Veiga *et al*. (2016). Salinity is one of the restraining factors that affects the distribution of aquatic organisms. Salinity fluctuations of waters are mostly caused by freshwater flow and evaporation factors. Too high salinity will affect the metabolism of aquatic organisms. Xiao *et al*. (2014) explains that salinity is a restraining factor for the distribution of aquatic organisms because it affects physiological processes such as endurance, osmolarity of hemolymfa and water content in tissues.

Next is the environmental pH factor, where the results of the analysis show that there is a significant correlation between environment pH and the gastropod diversity. The regression coefficient of pH factor is 0.545 with the t-count 3.582 and the significance of the t-count is 0.002. This means that water pH factor has an effect on the gastropod diversity in the mangrove forest area. The results of this research are in line with several other research findings, such as Schram *et al*. (2016); Garg *et al*. (2009); Montory *et al*. (2009); Bibby *et al*. (2007), Chen *et al*. (2015); Rumahlatu and Leiwakabessy (2017). The acidity level of seawater is one of the factors that influence the distribution of aquatic organisms. The effect is that pH is known to affect the metabolism of aquatic organisms. Parker *et al*. (2013) explained that the effect of pH on molluscs was mainly due to its impact on the early development stages such as gametogenesis and embryos.

Another factor which also has a significant correlation with gastropod diversity is dissolved oxygen (DO). The regression coefficient of the DO factor is 0.724 with the t-count 6.171 and the significance of the t-count is 0.002. This means that dissolved oxygen has a significant effect on the diversity of gastropods in the mangrove forest area. The results of this research are in line with several other resarch findings, such as Palanisamy and Khan (2013); Salman and Nassar (2014); Ekau *et al*. (2010); Kuk-Dzul and Díaz-Castañeda (2016); Rumahlatu and Leiwakabessy (2017). Oxygen is one of the key elements in the metabolism of aquatic organisms. The organisms that have a long period of dormancy generally tend to have lower oxygen requirements. This is different from the high mobility organisms that require oxygen with high concentration. Rumahlatu and Leiwakabessy (2017) explain that oxygen concentration in seawater will affect the life cycle, growth capacity, reproductive capacity and susceptibility to disease.

## Conclusion

Based on the results of the data analysis and discussion that have been presented above, it is concluded that the temperature in the coastal waters of Tawiri village ranged from 29-30°C, in the coastal waters of Passo ranged from 27-28°C, while on the coastal waters of Suli ranged from 26-28 °C. The salinity of water at the coastal waters of Tawiri ranged between 24-30 $^0/_{00}$, on the salinity on the coastal waters of Passo ranged between 26-29 $^0/_{00}$ while the salinity on the coastal waters of Suli ranged 18-29 $^0/_{00}$. The pH of seawater on the coastal waters of Tawiri ranged from 6-6.8, on the pH on the coastal waters of Passo ranged from 6.4-6.7 while the pH on the coastal waters of Suli ranged from 6-6.5. The Dissolved oxygen (DO) on the coastal waters of Tawiri ranged from 0.9-8, the DO on the coastal waters Passo ranged from 5-16.1 while the Do on the coastal waters of Suli ranged from 4-10. In addition, the composition of the substrate in the three research locations was clay, dusty clay and sandy clay. The mangrove forest in Suli village has a higher species content, which is 23 species, then followed by 20 species of Tawiri village, and 12 species of Passo village. The results of the regression analysis show that there is a significant correlation between temperature factors and the gastropod diversity in several mangrove forests on the island of Ambon.

## Acknowledgement

The authors thank the which has provided scholarship assistance for the completion of this research in Postgraduate Biology Education, Pattimura University, academic year 2014/2015.

## Reference

Ayukai, T., Miller, D., Wolanski, E. and Spagnol, S. 1998. Fluxes of nutrients and dissolved and particulate organic carbon in mangrove creeks in two northeastern Australia. *Mangroves and Salt Marshes*. 2: 223-230.

Alongi, D.M. 2002. Present state and future of the world´s mangrove forests. *Environmental Conservation*. 29: 331-349.

Alongi, D.M. and Carvalho, N.A. 2008. The effect of small-scale logging on stand characteristics and soil biogeochemistry in mangrove forests of Timor Leste. *Forest Ecology and Management*. 255 : 1359-1366.

Bibby, R., Harding, P.C., Rundle, S., Widdicombe, S. and Spice, J. 2007. Ocean acidification disrupts induced defenses in the intertidal gastropod *Littorina littorea. Biol. Lett*. 3 : 699-701. doi: 10.1098 / rsbl.2007.0457.

Bashevkin, S.M., Pechenik, J.A. 2015. The interactive influence of temperature and salinity on larval and juvenile growth in the gastropod *Crepidula fornicata* (L.). *Journal of Experimental Marine Biology and Ecology*. 470: 78-91. doi: 10.1016/j.jembe.2015.05.004.

Berger, U., Rivera-Monroy, V.H., Doyle, T.W., Dahdouh-Guebas, F., Duke, N.C., Fontalvo- Herazo, M.L., Hildenbrandt, H., Koedam, N., Mehlig, U. and Piou, C., Twilley, R.R. 2008. Advances and limitations of individual-based models and predict dynamics of mangrove forests: a review. *Aquatic Botany.* 89 : 260-274. doi: 10.1016/j.aquabot.2007.12.015.

Beasley, C.R., Fernandes, C.M., Gomes, C.P., Brito, B.A., Lima dos Santos, S.M. and Tagliaro, C.H. 2005. Molluscan Diversity and abundance among coastal habitats of Northern Brazil. *Ecotropica.* 11 : 9-20.

Bouillon, S., Koedam, N,, Raman, A.V. and Dehairs, F. 2002. Primary producers of sustaining macro-invertebrate communities in intertidal mangrove forests. *Oecologia*. 130 : 441-448. Doi: 10.1007 / s004420100814.

Bouillon, S., Borges, A.V., Castañeda-Moya, E., Diele, K., Dittmar, T., Duke, N.C., Kristensen, E., Lee, S.Y., Marchand, C., Middelburg, J.J., Rivera Monroy, V.H., Smith, III T.J. and Twilley, R.R. 2008. Production and carbon mangrove sinks: a revision of the global budget estimates. *Global Biogeochemical* Cycles.

Chen, Y.J., Wu., Y.J., Chen, C.T.A. and Liu, L.L. 2015. Effects of low-pH stress on theof the dove snail, *skinAnachis misera*, inhabiting shallow-vent environments off Kueishan Islet, Taiwan. B*iogeosciences*. 12: 2631-2639. doi: 10.5194/bg-12-2631-2015.

Cunha-Lignon, M., Coelho, Jr.C., Almeida, R., Meditating, R.P., Schaeffer-Novelli, Y., Cintrón, G. and Dahdouh-Gueba, F. 2011. Characterization of mangrove forest types in view of conservation and management: a review of mangals at the Cananéia region, São Paulo State, Brazil. *Journal of Coastal Research*. 57 : 349-353.

Dolorosa, R.G. and Dangan-Galon, F. 2014. Pecies richness of bivalves and gastropods in Iwahig River-Estuary, Palawan, the Philippines. *International Journal of Fisheries and Aquatic Studies*. 2 (1) : 207-215.

Duke, N.C., J.O. Meynecke, J,-O., Dittmann, S., Anger, K. 2007. A world without mangroves? *Science*. 317 : 41-42.

Ekau, W., Auel, H., P¨ortner, H.O. and Gilbert, D. 2010. Impacts of hypoxia on structures and processes in pelagic communities (zooplankton, macro-invertebrates and fish). *Biogeosciences*. 7 : 1669-1699. doi: 10.5194 / bg-7-1669-2010.

Garg, R.K., Rao, R.J. and Saksena, D.N. 2009. Correlation of molluscan diversity with physicochemical characteristics of the water of the Ramsagar reservoir, India. *International Journal of Biodiversity and Conservation*. 1(6) : 202-207.

Iftekhar, M.S. 2008. An Overview of Mangrove Management Strategies in Three South Asian Countries: Bangladesh, India and Sri Lanka. *International Forestry Review*. 10 (1) : 38-51.

Irma, D. and Sofyatuddin, K. 2012. Diversity of Gastropods and Bivalves in the mangrove ecosystem rehabilitation in Aceh Besar and Banda Aceh districts, Indonesia. *AACL Bioflux.* 5 (2) : 5-59.

Kabir, M., Abolfathi, M., Hajimoradloo, A., Zahedi, S., Kathiresan, K. and Goli, S. 2014. Effect of mangroves on distribution, diversity and abundance of molluscs in mangrove ecosystem: a review. *AACL Bioflux.* 7 (4) : 286-300.

Khade, S.N. and Mane, U.H. 2012. Diversity of Bivalve and Gastropod Molluscs in selected sites of Raigad district, Maharashtra, West coast of India. *Recent Research in Science and Technology*. 4(10) : 16-20.

Kristensen, E., Bouillon, S., Dittmar, T. and Marchand, C. 2008. Organic carbon dynamics in mangrove ecosystems: A review. *Aquatic Botany*. 89 : 201-219. doi: 10.1016/j.aquabot.2007.12.005.

Kuk-Dzul, J.G. and Díaz-Castañeda, V. 2016. The Relationship between Mollusks and Oxygen Concentration in Todos Santos Bay, Baja California, Mexico. *Journal of Marine Biology*. Article ID 5757198, 10 pages. doi: 10.1155/2016/5757198.

Kathiresan, K., Rajendran, N., Thangadurai, G. 1996. Growth of mangrove seedlings in the intertidal area of Vellar estuary southeast coast of India. *Indian Journal of Marine Sciences*. 25 : 240-243.

Li, Y.F., Xu, R.L. and Wang, C.F. 2012. The Structure of Molluscs in Three Different Wetland Types of Qi'ao-Dan'gan Island Mangrove Nature Reserve at Qi'ao Island, Pearl River Estuary, China. *Zoological Studies*. 51 (6) : 745-754.

Ludwig, J.A. and Reynolds, J.F. 1988. *Statistical ecology: a Primer on Methods and Computing.* John Wiley & Sons, New York, 337 pp.

Maia, R.C. and Coutinho, R. 2013. The influence of mangrove structures on the spatial distribution of *Melampus coffeus* (Gastropoda: Ellobiidae) in Brazilian stuaries. *Panamjas*. 8 (1) : 21-29.

Manzo, K., Estandarte, M.H., Dalipe, R.E., Ulangutan, J., Lecera, J.M., Acob, A., Diamalod, J., Salmo, W. and Jumawan, J. 2014. Survey of diversity and intertidal mollusks in Alabel and Maasim, Sarangani Province, Philippines. *AACL Bioflux*. 7 (6) : 449-457.

Minchinton, T.E. 2001. Canopy and substratum heterogeneity influence recruitment of the mangrove *Avicennia marina*. *Journal of Ecology*. 89 : 888-902.

Miura, O., Nishi, S. and Chiba, S. 2007. Temperature-related diversity of shell color in the Intertidal gastropod batillaria. *Journal of Molluscan Studies*. 73 : 235-240. doi: 10.1093/ mollus/eym019.

Mokhtari, M., Ghaffar, M.A., Usup, G. and Cob, Z.C. 2015. Determination of Key Environmental Factors Responsible for Distribution Patterns of Fiddler Crabs in a Tropical Mangrove Ecosystem. *PLoS ONE*. 10(1): e0117467. doi: 10.1371/journal.pone.0117467.

Montory, J.A., Pechenik, J.A., Diederich, C.M. and Chaparro, O.R. 2014. Effects of Low Salinity on Adult Behavior and Larval Performance in the Intertidal Gastropod *Crepipatella peruviana* (Calyptraeidae). *PLoS ONE*. 9(7) : e103820. doi:10.1371/ journal.pone.0103820.

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. and Somerfield, P.J. 2008. The habitat function of mangroves for terrestrial and marine fauna: a review. *Aquatic Botany*. 89: 155-185. doi: 10.1016/j.aquabot.2007.12.007.

Parker, L.M., Ross, P.M., O'Connor, W.A., Pörtner, H.O., Scanes, E. and Wright, J.M. 2013. Predicting the Response of Molluscs to the Impact of Ocean Acidification. *Biology*. 2 : 651-692. doi:10.3390/biology2020651.

Palanisamy, S.K. and Khan, A.B. 2013. The distribution and diversity of benthic macroinvertebrate fauna in Pondicherry mangroves, India. *Aquatic Biosystems*. 9: 15.

Rumahlatu, D. and Leiwakabessy, F. 2017. Biodiversity of gastropoda in the coastal waters of Ambon Island, Indonesia. *AACL Bioflux*. 10(2): 285-296.

Salman, J.M. and Nassar, A.J. 2014. Variation of Some Physico-Chemical Parameters and Biodiversity of Gastropods Species in Euphrates River, Iraq. *International Journal of Environmental Science and Development*. 5(3) : 328-331. doi: 10.7763/IJESD.2014.V5.502.

Schram, J.B., Schoenrock, K.M., McClintock, J.B., Amsler, C.D. and Angus, R.A. 2016. Testing Antarctic resilience: the effects of elevated seawater temperature and decreased pH on two gastropod species. *ICES Journal of Marine Science*. 73 (3) : 739-752. doi:10.1093/icesjms/fsv233.

Selck, H., Aufderheide, J., Pounds, N., Staples, C., Caspers, N. and Forbes, V. 2006. Effects of food type, feeding frequency, and temperature on juvenile survival and growth of *Marisa cornuarietis* (Mollusca: Gastropoda). *Invertebrate Biology*. 125 (2) : 106-116. doi: 10.1111/j.1744-7410.2006.00045.x.

Song, Z., Zhang, J., Jiang, X., Wang, C. and Xie, Z. 2013. Population structure of an endemic gastropod in Chinese plateau lakes: evidence for population decline. *Freshwater Science*. 32 (2) : 450–461. DOI: 10.1899/12-099.1.

Spalding, M., Blasco, F. and Field, C. 1997. *World Mangrove Atlas.* The International Society for Mangrove Ecosystems, Okinawa, Japan. 178 pp.

Suratissa, D.M. and Rathnayake, U. 2017. Effect of pollution on diversity of marine gastropods and its role in trophic structure at Nasese Shore, Suva, Fiji Islands. *Journal of Asia-Pacific Biodiversity*. 10 (2) : 192-198. doi: 10.1016/j.japb.2017.02.001.

Tavares, D.S., Maia, R.C., Rocha-Barreira, C. and Matthews-Cascon, H. 2015. Ecological relations between mangrove leaf litter and the spatial distribution of the gastropod *Melampus coffeus* in a fringe mangrove forest. *Iheringia, Série Zoologia, Porto Alegre*. 105 (1) : 35-40. doi: 10.1590/1678-4766201510513540.

Veiga, M.P.T., Gutierre, S.M.M., Castellano, G.C. and Freire, C.A. 2016. Tolerance of high and low salinity in the intertidal gastropod *Stramonita brasiliensis* (Muricidae): behaviour and maintenance of tissue water content. *Journal of Molluscan Studies*. 82 : 154-160. doi:10.1093/mollus/eyv044.

Xiao, B-C., Li, Er.C., Du, Z-Y., Jiang, R-I., Chen, L.Q. and Yu, N. 2014. Effects of temperature and salinity on metabolic rate of the Asiatic clam *Corbicula fluminea* (Müller, 1774). *Springer Plus*. 3 : 455 (1-9). doi:10.1186/2193-1801-3-455.

Zvonareva, S., Kantor, Y., Li, X. and Britayev, T. 2015. Long-term monitoring of Gastropoda (Mollusca) fauna in planted mangroves in central Vietnam. *Zoological Studies*. 54 : 39 (1-16). doi: 10.1186/s40555-015-0120-0.