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Original Article

Species diversity and vertical distribution of arboreal organisms on the Paradiso Mangrove environment of Kupang Bay, East Nusa Tenggara, Indonesia

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Abstract

This research was directed to analyze the level of species diversity and distribution patterns of arboreal organisms on the mangrove forest environment of Paradiso coastal of Kupang Bay. The observation unit is a circle of mangrove stems that is divided into three levels of height, i.e., 0.0 - 1.0 m, 1.1 - 2.0 m and 2.1 - 3.0 m. The assessment of mangrove trees as the observation unit is zigzagged by following the Z pattern starting from the lowest tide to the highest tide. Mangrove trees encountered in Z pattern were defined as observation units. The data collected in this study consisted of species and the number of individuals from each species attached to mangrove stem. Data of arboreal organisms were analyzed for relative abundance, diversity Index and species evenness, and distribution pattern. The results showed that in the mangrove forest area found 8 species of arboreal organisms consists of 7 species of molluscs and 1 species of crustacean. Mangrove mollusc group consisted of *Littorina scabra*, *Littorina undulata*, *Terebralia sulcata*, *Nerita plasnospira*, *Nassarius distortus*, *Morula margariticula* and *Saccostrea cucullata*. Species included in the Crustaceae group is *Semibalanus* sp. The index of species diversity is 1.119 (in low category), and species evenness of 0.704 (in high category). A total of 7 species from 8 arboreal organisms distributed in clustered patterns and 1 species in a uniform pattern. All environmental parameters support the life of arboreal organisms.

Keywords: Vertical distribution, Mangrove molluscs, Species diversity, Species evenness, Abundance

Introduction

Ecologically, the mangrove ecosystem has a strategic function for an organism's life. Strategic function of mangrove ecosystem as a spawning ground, nursery grounds and feeding ground (Bengen, 2001; Nybakken, 1992). UV-B radiation, 'greenhouse' effects, and fury of cyclones, floods, sea level rise, wave action and coastal erosion (Kathiresan, 2012). Lee et al. (2014) suggest that morphology, once established, directly influence vertical land development by enhancing sedimentation and/or by direct organic contribution to soil volume (peat formation) in some settings. Mangroves provide protection against floods and hurricanes, reduction of shoreline and riverbank erosion, and maintenance of biodiversity. Doydee et al. (2010) state that mangrove forests provide shelter, food, and breeding sites for a large number of marine and terrestrial organisms. Mangrove forests are important ecosystems of the world because they provide an important and unique ecosystem that impacts positively human society by stabilizing shorelines and reducing the devastating impact of natural disasters, as well as providing food, medicines, fuels and building materials (Giri et al., 2011).

In the mangrove ecosystem found various organisms. Kustanti (2011) suggests that the mangrove ecosystem inhabited by mangroves crabs, and other invertebrates, such as molluscs and crustaceans. Bivalvia and gastropods are dominant molluscs in the mangrove forest. Nazim et al. (2015) explained that gastropods and bivalves are important members of molluscs associated with mangrove forests. Whitmore et al. (2016) suggest that crustaceans and bivalves are not only diverse in these communities, but they also dominate the biomass in the mangrove forest. Molluscs are the commonly found invertebrates in the mangrove ecosystem. They account for a good portion of biomass and key components of trophic level and create a link between phytoplankton communities (Nazim et al., 2015).

Imakulata (2007) suggested that some species were found on the forests floor, roots and mangrove stem, even certain species of gastropods found in mangrove leaves. Mujiono (2008) explains that differences in the way of life and distribution of gastropods are caused by variations in environmental factors. Gastropods on the mangrove ecosystem can life as non-arboreal (at the substrate surface), infauna (in the substrate), and *arboreal* (sticking on roots, stems, and mangrove leaves).

In the mangrove ecosystems, organisms can spread horizontally on the forest floor as well as vertically on mangrove stems. Distribution and diversity of organisms on the mangrove ecosystem affected by changes in environmental quality. Kumar and Khan (2013) emphasized that distribution, abundance, and diversity of these mangrove benthic invertebrates and their relationships to environmental conditions are important parts of understanding the structure and function of mangrove ecosystems. Molluscs and crustaceans tend to survive in mangrove forests even though these organisms are often affected by any changes in the environment, both from outside and from within the mangrove forest. Molluscs and crustaceans respond to environmental changes by distributing, either vertically or horizontally.

Ability to adapt greatly determines the distribution of organisms. Adaptation to get food and mating pairs, adaptation to prevent water loss and high salinity determines the distribution of organisms on the mangrove forest. Horizontal distribution pattern has been studied by some researchers, however, the vertical distribution pattern has not been done. Similar studies have been conducted by Tuheteru et al. (2014) but only limited to the vertical distribution of gastropods without examining distribution patterns in certain altitude classes. Diversity and density of the macrobenthos dependent on chance settlement of pelagic larval forms of different species, affinity to the suitable substratum and also the degree of stress effect caused by strong waves and tide currents (Kumar and Khan, 2013). Amir et al. (2013) explain that *Chthamalus malayensis* was found to be more densely populated on upper zonation; *Euraphia withers* on middle zonation; and *Balanus amphitrite* on lower zonation.

In relation to the above explanation, this research is very important to be done to study the distribution pattern and diversity of organisms on each unit of the height level. This information is expected to contribute to explaining the adaptability of arboreal organisms to survive in dry environmental conditions (stems and leaves) beyond the reach of seawater.

Material and Methods

Sites and time of research

This research was conducted on the mangrove environmental of Paradiso beach, Kupang bay. Selection of this location is based on the consideration that this location is a tourism beach that is easily accessible by the community. It is thus expected that the results of this study can provide an overview of the condition of the mangrove ecosystem based on the level of diversity and distribution pattern of the arboreal organisms. This research was conducted for 6 months, starting from May to October 2017.

Data collection technique

Data were collected conducted by the transect method with the zig-zag pattern in the form of letters Z to cover the entire area of mangrove forest. The mangrove tree passed by the transect line as a unit or plot of data collection.

Data collection procedure

Setting the starting point for the mangrove forest area (near the lowest tide) to create a transect line. The first transect was pulled up parallel to the coastline splitting the mangrove forests to the north along the 100 meters. Furthermore, the second transect was pulled to the shoreline with a 45^o angle of angle along 111.8 meters. The third transect was pulled parallel to the first transect northward so as to form a Z pattern. The mangrove trees found on the transect line and its vicinity used as the sampling unit. On each tree divided to 3 classes of altitude, i.e, 0 - 1.0 m, 1.1 - 2.0 m and 2.1 - 3.0 m. In each level of the altitude measured the diameter of the mangrove stem to calculate the mangrove stem surface area. This surface area is used as the basis for calculating species abundance. In this study transect in Z pattern as much as 4 (12 transect lines)

Arboreal organisms found in each level of altitude were recorded and counted a number of each species. The unknown arboreal species was preserved with 70% alcohol for identification. Identification refers to Dharma (1998). In this study also taken environmental data consist of pH, temperature, dissolved oxygen and salinity. Environmental parameters, such as pH, dissolved oxygen, salinity is measured at high tide, while the temperature other than measured at high tide is also measured at low tide to determine the air temperature in the mangrove environment. Measurement of environmental parameters is not carried out for each altitude class with the consideration that sea water is always subjected to stirring due to wave blast on mangrove trunks so that environmental parameters are considered the same between one altitude class and another altitude class.

Data analysis

Data of the species and number of individuals of each species are tabulated and organized and displayed in tables or graph forms as well as described. Data on the number of individuals from arboreal organisms in each class of height and surface area of the stem are used as a basis for calculating species abundance, diversity index and evenness of species and distribution patterns. Analysis of species abundance and evenness of species based on Odum (1993), diversity index (Shannon-Wiener Index) and distribution patterns (Morisita Index) were analyzed based on Krebs (1989). The formula used is as follows:

$$SA = \frac{ni}{N} \text{ and } RA = \frac{ni}{N} x\ 100\%$$

where *SA* = species abundance, *ni* = the number of individuals per species, *N* = the number of individuals of all species and *RA* = relative abundance

$$SE = \frac{H\prime}{logS}$$

where *SE* = species evenness, *H'* = species diversity and *S* = the number of species

$$H' = -\sum\left(\frac{ni}{N}\right) + ln\left(\frac{ni}{N}\right)$$

where *H'* = species diversity, n_i = the number of individuals per species, *N* = the number of individuals of all species

$$DI = n\frac{\sum x^2}{(\sum x)^2} - \frac{\sum x}{\sum x}$$

where *DI* = Dispersal index, *n* = number of height units, Σx = the total number of individuals of a species in height units, Σx^2 = the total of the square number of individuals of a species in the height unit. With criteria: *DI* < 1: species distribution in uniform pattern, *DI* = 1: species distribution in random pattern and *DI* > 1: species distribution in clustered/clumped pattern.

Results and Discussion

Relative abundance of mangrove arboreal organisms

In this study found 8 species of mangrove arboreal organisms belonging to 3 classes, namely gastropods bivalves and Crustacea. The abundance of each species is summarized in table 1.

Based on table 1 it is concluded that the mangrove species with the highest abundance is barnacles *Semibalanus* sp with a relative abundance value of 85.58%. The lowest relative abundance is *Morula margariticula* with an abundance value of 0.011008%.

Judging from the height units of the substrate surface, an abundance of *Semibalanus* sp is higher in altitude 0.0 – 1.0 m with relative abundance value of 52.556%. In this altitude, the species with the lowest abundance is *Morula margariticula* with a relative abundance value of 0.238%. In an altitude of 1.1 – 2.0 m, the species with the highest relative abundance is *Semibalanus* sp with relative abundance value 92.412%. In an altitude of 1.1 - 2.0 m, the species with the highest relative abundance is *Semibalanus* sp with a relative abundance of 92.412%. In this altitude, the species with the lowest relative abundance are *Terebralia sulcata* and *Morula margariticula* which both have the same relative abundance value of 0.195%. In the altitude of 2.1 – 3.0 m, the species with the highest abundance is *Semibalanus sp* with a relative abundance of 25%. In this altitude, the species with the lowest abundance is *Nassarius distorsus* and *Saccostrea cucculata* which have the same relative abundance value of 6.25%.

The species abundance is affected by local environmental conditions, food availability, predators and competition. Pressure and environmental changes can affect the number of species (Ruswaningsih, 2012). While Kariono (2013), that the abundance of a species in the ecosystem is determined by the level of resource availability as well as environmental chemical-physical factors.

Based on all opinions, it can be argued that the existence of *Semibalanus* sp supported by resources in this case food (plankton and microalgae) and chemical-physical factors in the mangrove environment.

Species diversity

Based on species richness, it can be argued that *Semibalanus* sp is the species that has the most number of individuals compared to other species. Table 1 shows the individual number of *Semibalanus* sp of 925 found in 35 sample units. The species with the smallest number of individuals is the *Morula margariticula* with 7 individuals in 7 sample units or 1 individual per sample unit.

Table 1 shows that the diversity of mangrove arboreal organisms in the Paradiso mangrove forest is 1.1188. Based on the diversity index, it is concluded that the diversity of mangrove arboreal organisms classified in the low category (1.1188 < 1.5000). The value of species diversity in the altitude of 0.0 - 1.0 m is 1.31478 and in the altitude of 1.0 - 2.0 m and 2.0 - 3.0 m respectively of 0.37987 and 0.97071. The species diversity in the altitudes 1 and 2 is low (H' < 1.5) whereas in the altitude 3 is moderate (1.5 ≤ H' < 3.0). The altitude 0 - 1.0 and 1.1 - 2.0 have a lower diversity index than the altitude 2.1 – 3.0 m. This is because the proportion of the number of individuals of each species is almost the same so that the ratio of the number of individuals of a species to the number of individuals of all species (value ρi) is relatively similar between one species and another. Conversely in the altitude of 0.0 - 1.0 m and 1.1 - 2.0 m, the number of individuals between species is not balanced. In the altitude of 0 - 1.0 m and 1.1 - 2.0 m, the number of individuals *Semibalanus* sp of 442 and 475, respectively, while other species, such as *Morula margariticula*, has only 2 and 1 individuals respectively. Thus ρi obtained from the ratio of the number of individuals to the total individuals of all species becomes smaller. The comparison between the number of individuals of a species and the number of individuals in the whole species determines the value of the species diversity.

Species evenness

The results showed that the species evenness value was 0.703871. Based on the value of evenness of this species, it is concluded that the mangrove arboreal organism has a high level of evenness.

The results of this study indicate that individuals from mangrove arboreal organisms come from different species. The number of individuals as many as 1387 comes from 8 species of mangrove arboreal organisms. Odum (1993), states that the value of diversity and evenness can show a balance in the division of the number of individuals of each species.

Evenness is of great value if the individual is found to belong to a different species or genera, whereas diversity has a value that is small or equal to zero if all individuals belong to a species. An evenness index is a number that does not have units, the value of evenness ranges from zero to one. The smaller the value of evenness, the less evenness in the community.

The distribution pattern of mangrove arboreal organisms

Distribution index of mangrove arboreal organisms can be seen in table 2. Based on table 2 it is concluded that the distribution of arboreal organisms in Paradiso mangroves generally follows a clustering pattern, except for the distribution of *Morula margariticula* with a uniform pattern.

Table 1: **Abundance, diversity, evenness and dominance of arboreal organisms**

No.	Species name	Relative Abundance (%)	Species diversity	Species evenness
1	*Littorina scabra*	11.5205	0.308839	
2	*Littorina undulata*	0.748534	0.134307	
3	*Terebralia sulcata*	0.292494	0.102264	
4	*Nerita plasnospira*	1.096067	0.116408	
5	*Semibalanus* sp	85.57658	0.270167	
6	*Nassarius distorsus*	0.24689	0.063445	
7	*Morula margariticula*	0.011008	0.026693	
8	*Saccostrea cucculata*	0.507934	0.096674	
			1.1188	**0.703871**

Table 2: **Distribution index of mangrove arboreal organisms**

No	Species	ΣX^2	$(\Sigma X)^2$	Σindividu	Σplot	ID	Distribution Patterns
1	*Littorina scabra*	7326	62500	250	21	2.387084	Clumped
2	*Littorina undulata*	697	3481	59	26	4.847458	Clumped
3	*Terebralia sulcata*	476	1600	40	13	3.633333	Clumped
4	*Nerita plasnospira*	186	2304	48	20	1.223404	Clumped
5	*Semibalanus* sp	54419	855625	925	35	2.190581	Clumped
6	*Nassarius distor tus*	157	441	21	8	2.590476	Clumped
7	*Morula margariticula*	7	49	7	7	0	Uniform
8	*Saccostrea cucculata*	323	1369	37	10	2.147147	Clumped

The distribution of arboreal organisms, such as gastropods, bivalves and crustaceans, is influenced by biotic and abiotic factors, such as environmental conditions, food availability, predation and competition. Susiana (2011) suggests that pressure and environmental changes affect the number of species and structural differences of gastropods and bivalves. Gastropods that have the ability to climb, such as Littorina using mangrove stems as a medium to find food. Even Littorina is often found in mangrove leaves. The presence of Littorina in mangrove leaves indicates that this biota is herbivorous. Plankton or microalgae attached to mangrove stems are utilized by arboreal biota as a food source. The climbing activity takes place during the tide. Muhsin et al. (2016) suggest that the spread of gastropods vertically depends on the range of high tide and low tide. Field observations show that at low tide the arboreal biota does not climb. Gastropoda attaches tightly to the mangrove stem and closes its operculum to prevent water loss.

The results showed that 7 species of mangrove arboreal showed a clustered distribution pattern while 1 species (*Morula margariticula*) exhibited a uniform distribution pattern. Colin *et al*. (1992) explain that the clustered distribution patterns are related to the distribution of habitats and other animals. While the uniform distribution pattern is related to the nature of the area. While McNaughton (1990) explains that clustered distribution patterns indicate that the existence of individuals at a point increases the chances for the same individual at another point nearby. The uniform distribution pattern, the existence of the individual at a point decreases the chances of the same individual at a point nearby.

The results clearly show that the presence of an individual from each species increases the chances of individuals forming a population at a point around the individual of that species. While *Morula margariticula*, it is clear that at the location of the study only found 7 individuals in 7 sample units or 1 individual in each sample unit. The results of this study clearly illustrate that the individual existence of this species decreases the chances of other individuals of the same species to be present around the individual. The species' ability to choose suitable habitat types allows the species to survive their lives. Mangrove stems as a habitat that provides food sources and a suitable place for arboreal organisms to carry out activities. Individual gastropods that have the ability to climb mangrove stems will be distributed to obtain food sources provided by mangrove stems as their habitat. Similarly, bivalves (Sacsostrea) and crustaceans (Semibalanus) that attach themselves relatively permanently to mangrove stems. Mangrove stems provide a place as a habitat to obtain food at high tide. The predation factor also greatly determines the distribution of arboreal organisms. Vertical distribution may be related to predation. Species that have the ability to climb avoid predators on the floor of mangrove forest. Whitmore et al. (2016) explain that crustaceans are predators of gastropods in mangrove forests.

Environmental factors, such as temperature, humidity, pH, salinity and others greatly affect the presence of mangrove arboreal organisms. The measurement results show that temperature water ranging between 25-26ºC with a mean of 25.3ºC while the air temperature ranges between 30-32ºC temperature range is still within the normal range for growth of molluscs. Rahmasari et al. (2015) suggested that the optimal temperature range between 25-35ºC. Hutagalung (1988) suggested that the optimum temperature for benthic molluscs ranged from 15-28ºC. At this temperature range, metabolic activity was normal. Hitalessy et al. (2015) suggests that temperatures beyond the tolerance limit can cause decreased metabolic activity, even causing death in gastropods.

Results showed that the pH at the study site ranged from 6.5 to 6.7 with the average of 6.6. This pH value is still within the normal range for growth of gastropods. Rusnaningsih (2012), explains that the pH targets Gastropods range from 5-9. While Handayani (2006) suggests that the optimum pH for the life of marine organisms is between 6-8. Asikin (1982) suggests that the condition waters are very acidic or very alkaline will endanger the survival of aquatic organisms because it can cause metabolic and respiratory disorders.

Salinity measurements showed that salinity in the Paradiso mangrove forest ranged from 31 to 32 ‰ with a mean of 31.6 ‰. This salinity value is still within the normal range for the life of molluscs. According to Hitalessy (2015), in general, the species of gastropods can live in waters with salinity ranging from 31 ‰ - 37 ‰.

The results showed that dissolved oxygen in the Paradiso coastal mangrove forest area ranged from 3.2 to 3.5 mg/L with a 3.3 mg/L average. The value of DO (Dissolved oxygen) is still within the normal range for the life of aquatic organisms. The optimum DO content for the life of benthic molluscs ranges from 4.5 to 6.6 mg/L. Effendi (2003) suggests that if the DO value below 2.0 mg/L can cause organisms death.

The arboreal molluscs in mangrove stems maintain oxygen loss by closing the operculum during low tide. Allegedly to maintain sufficient oxygen demand during low tide, the operculum is opened to allow free oxygen to enter through the respiratory system. Dissolved oxygen is a basic requirement for the life of aquatic organisms. Gastropods have a wide range of tolerance to oxygen so that the spread of this gastropods is very wide.

Conclusion

Based on the results of present study it is concluded that eight species of arboreal organisms were found in this research project i.e., *Littorina scabra*, *Littorina undulata*, *Terebralia sulcata*, *Nerita plasnospira*, *Semibalanus sp*, *Nassarius distortus*, *and Morula margariticula* and species belonging to bivalves, namely *Saccostrea cucculata*. *Semibalanus sp* is a species of crustacean mangrove which has the highest relative abundance (85.58%). The index value of mangrove molluscs diversity is 1.119 or belong to low diversity level. Index to species evenness of 0.704 and belong to the high-level similarity species. The pattern of arboreal organism distribution is generally in a clustering pattern. All environmental parameters support the life of arboreal organisms. The average value of the temperature, pH, dissolved oxygen and salinity are 25.3°C, 6.6, 3.3 mg/L and 31.6% respectively within the normal range for growth of the organism arboreal.

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