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Migratory speed and pattern of *Littorina scabra* on mangrove trees *Sonneratia alba* during incoming and outgoing tides in Tanjung Tiram, Ambon Bay

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Abstract. Migratory behaviour in *Littorina scabra* (Linne 1758) was studied in a mangrove ecosystem and observations were made in their natural habitat or *in situ* observation in Tanjung Tiram, Ambon. Migratory speed and pattern of *L. scabra* of different sizes (small and large) particularly in mangrove *Sonneratia alba* were observed throughout of the February 19th to March 11th 2019 during the day and night on incoming or outgoing tides and these are usually a 3 hours (270 minutes) observation. Marked snails were used to track the position to investigate their migratory direction and speed during advancing and receding tides. Those organisms migrate up and down the trees following the tidal cycles. This study indicates that small size organisms which live on leaves, branches or trunks move faster than the big organisms and they move faster during the incoming tide than outgoing tide. For a big size *L. scabra*, they move slower during the incoming tide than the outgoing tide. This behaviour indicates that they move faster to avoid immersion during incoming tide than during the outgoing tide when they move slower because they are searching for food. The migration trials showed different patterns for all sizes of *L. scabra* and this pattern seems to be influenced by the area of surface they occupy such as leaves, branches or trunks. They tend to move forward in one direction (almost straight line) when they are on a small surface such as trunks and on the larger surface such as leaves and braches most *L. scabra* of all sizes make different trial patterns such zig-zag.

1. Introduction

Mollusc are mobile invertebrates known to be able to navigate up or down the shore if displaced from their preferred habitat or if physiological or environmental factors induce a change in habitat preference [1]. One of them is Littorinids, these organisms are mainly found on boulders, rocks, and mangrove trees in the upper part of the intertidal zone. They attach to the branches, trunks and leaves of mangrove tree by mucus. These organisms are active grazers on micro-organisms, filamentous algae and other organic tissues found along mangrove tree surfaces [2] and they are moving up and down following tidal movement and make different patern [3]. Aggregation by *Nodilittorina unifasciata* may respond to aspects of habitat, e.g. features of the substratum [4] or local patterns of water-movement during the receding tide. Alternatively, individuals may follow conspecific trails while or after foraging during high tide, thereby accumulating in aggregations when movement ceases [5]. Some littorinids follow trails [6,7], although this behaviour has not been demonstrated to cause aggregations.

Many studies have been done around the distribution of grazing snails on mangrove trees [8,9,10], but there is still limited information that focused on migratory patterns [1,11,12,13]. It is important to understand the movement of the organism because this behaviour involves a combination of different aspects such as morphology, biology, ecology, physiology of the animals [14] such as *L. scabra* that can be found in a high abundance in the mangrove ecosystem around Tanjung Tiram, Ambon Bay. They can be found in different parts of the tree such as in the leaves, branches, trunks and roots of mangrove trees and they play an important role in the food chain in mangrove ecosystems but the knowledge about migration behaviour remains limited. Snails that live in the mangrove ecosystem were found to move upward during the incoming tides and migrate downwards during the outgoing tide [3, 13]. [11] reported that *L. scabra* moved up and down mangrove trunks to avoid immersion during the rising tide. In tropical and subtropical regions, several species of snails live at high levels in mangrove swamps [15] and these organisms are protected from the spray [12]. Genus *Littoraria* are among the most successful gastropods in mangrove forests in the Indo-Pacific region [16], where they play an important role in food web [13, 17]. Furthermore, basic ecological studies of this species are lacking in the Moluccas Islands that consists of a thousand small islands, where these snails can be found easily and are an integral part of the mangrove food web in the mangrove ecosystem around the islands.

Most of animal living in the intertidal zone tend to active and freed only at night [18, 19] but some species may feed both day and night, although their activity is often greater at night [20]. Light is a cue for movement in *Littorina obtusata* . *L. saxtilis* and *Melaraphe neritoides* [18]. Some species are restricted to daytime foraging as their activity may be limited by their orientation to light during homing and / or by the nocturnal activity of predators [21]. In mangrove ecosystem, snails may exhibit different activity pattern compared to rocky shore species as the physical condition such as substratum , wave action, tidal change, physical stress , and also biotic interaction, differ greatly between these two habitats. Snails in mangrove tree have a resting stage when trees are dry and feed only during wet periods when the high tide occured [2, 22]. Most mangrove species are inactive when submerged because feeding may be more efficient out of water [23]. Most *Littorina* species migrate with the tide to remain above the water surface and only feed above the high water mark [24].

Tropical mangrove ecosystems provide various habitats for different marine fauna. *L. scabra* are common species in the mangrove ecosystem in Tanjung Tiram, Ambon. The destruction of the mangrove ecosystem along the Ambon bay will have a big impact on the sustainability of all organisms particularly *L. scabra* that use mangrove ecosystems as their habitat. The migratory pattern and speed of *L. scabra* were observed in the mangrove ecosystem in Tanjung Tiram, Ambon. This study focuses on *S. alba* that occupy the front part of mangrove ecosystem. The activity of *L. scabra* is likely to be affected by tidal cycle, especially wetting by water in triggering the migratory of this littorinids. The present study set out to investigate and study the behaviour regarding the migratory pattern and speed of *L. scabra* on mangrove tree *Sonneratia alba* during the incoming and outgoing tide in Tanjung Tiram, Ambon. These organisms are found in the high abundance, live and attach on different parts of mangrove tree that grow in the intertidal zone which make them are ideal environments for investigating the patterns of movement of *L. scabra* .

2. Materials and Methods

The study was conducted for three weeks (February 19th – March 11th 2019) on mangrove ecosystem in Tanjung Tiram Poka, Ambon Bay to investigate the migration speed and trial of *L. scabra* on mangrove tree, *Sonneratia alba* . Geographically, Tanjung Tiram locates on 3°39’13”S and 128°11’54”E (Figure 1).

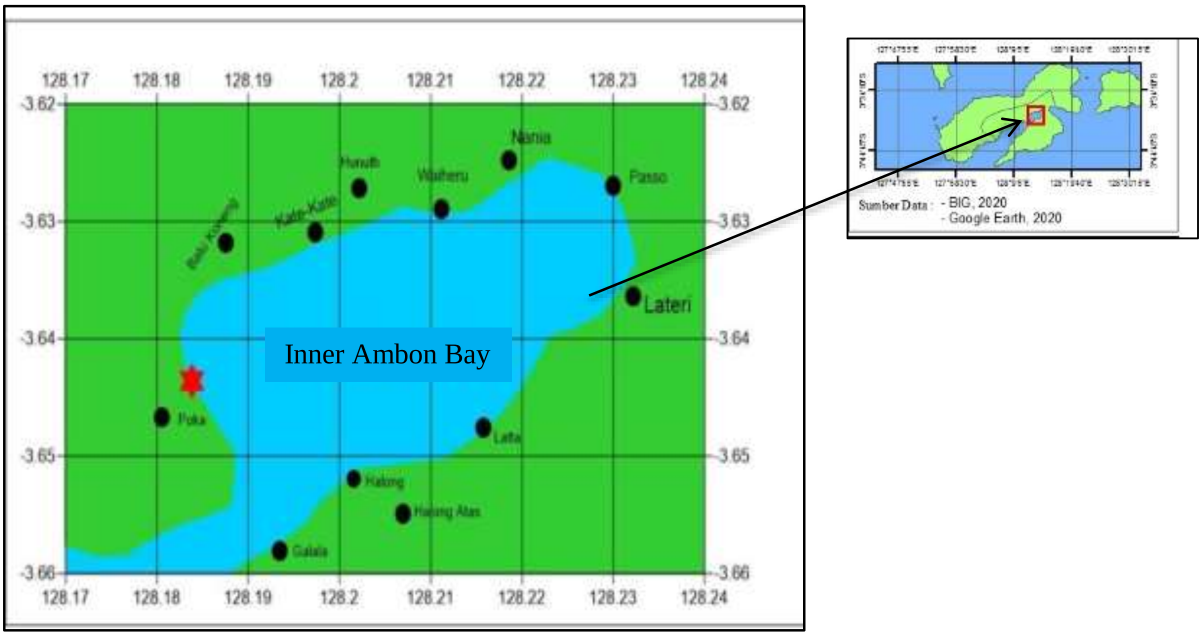

Figure 1. Map of the study area is indicated by the red star.

A total of 60 individuals were examined in *situ* on the leaves, trunks and branches during the incoming and outgoing tide-day or night. Prior to the *in situ* investigation, a number of *L. scabra* of different sizes (small size *n*=30 and big size *n*=30) were taken to the laboratory for identification to get familiar acquainted with *L. scabra* species. *L. scabra* were randomly selected just a day before the field investigation, given a mark on their shell by using tip-ex or permanent marker (Figure 2). Those organisms were freed without any disturbances before the investigation took place.

During the investigation, the marked *L. scabra* were observed for almost 24 days consecutive days, day and night. Each observed individual was measured by using callipers and grouped into two groups; small size (< 1.5 cm; n=30) and big size (>1,6 cm; *n*=30). For small individuals were marked as s1, s2, …,s30; and the large as l1, l2,…,l30. Snail sizes ranged from 0.6 to 2.7cm in shell length.. Each snail was observed for almost 3 hours to calculate the migratory speed (*v*). A nail and a small plastic rope were used to indicate the start (s_0) and end (s_n) point makes by each snail. The time was recorded as starting point (t_0) and last point (t_1) using a stopwatch.

Formula to calculate speed (*v)* = s/t., where *t* = time (sec); *s* = distance (cm). Migratory pattern was drawn following their mucus or feces or the track recorded by using the small rope on the surface of branch, trunk, or leaf. Water temperature and salinity around the mangrove ecosystem was measured using a thermometer and a refractometer, respectively.

Figure 2. Photograph of marked snails on mangrove leaf (a) and trunk (b).

Descriptive statistical analysis was performed using Excel 2010 and data analyses was performed with SPSS software. All data was tested for parametric assumptions and no transformations were necessary.

3. Results and Discussion

The mangrove ecosystem in Tanjung Tiram, Ambon bay has characteristic of mixed sandy and muddy anaerobic soil, get influence by mix diurnal tidal current, and its salinity lower than the surrounding waters. In this mangrove ecosystem can only be found three species of mangrove *Sonneratia alba, Rhizophora apiculata* and *Bruguiera gimnorrhiza* and *Sonneratia alba* a wide spread mangrove species in Maluku. Recently, there has been increased pressure on mangrove resources in the coastal zone around the study area from increased population that their activities have a negative impact on the mangrove ecosystem, especially a huge amount of anthropogenic debris, cutting three for houses and pig husbandry, which can destroy the habitat and marine organism such as mollusc community. Adding to that, the phenomena of sea level rise around the small island such as Ambon Island, will have impact on *L. scabra,* organisms that are found as the dominant grazers in mangrove habitat in this study area and they may play an important role in the food web dynamics of these ecosystem.

Based on the observation of 60 organisms of *L. scabra* on the leaves, branches and trunks of *S. alba* (Figure 2), their migratory speed during the incoming tide were found to be different between the big and small size of organisms (Mann Whitney test; n=30, p < 0.05), where the mean speed migratory for big size *L. scabra* is 0.80 ± 0.1 cm/min and small one is 0.92± 0.3 cm/min. During the outgoing tide, there was not found the different in speed migratory for small and big *L. scabra* (Mann Whitney test; p > 0.05) (Tabel 1).

Tabel 1. Migratory speed between big (B) and small (S) size of *L. scabra* during incoming and outgoing tide (Mann Whitney test; p < 0.05*).

Incoming tide (n = 30)	Outgoing tide (n=30)	Incoming & outgoing tide
B & S*	B & S	B & B *
B & B	B & B	B & S*
S & S	S & S	S & S*

During this study, it is observed that *L. scabra* had daily vertical migration move up and down follow the tide and to avoid tidal submersion. The comparison of speed migratory between the big and small sizes of *L. scabra* during incoming and outgoing tide are all show significant different (Table 1, Mann Whitney test; p< 0.05). The small *L. scabra* move faster than the bigger one during the incoming tide more to avoid tidal submersion then searching for the food. The average speed for big one during high tide is slower (0.80 ± 0.1 cm/min) than during the low tide (1.0 ± 0.1 cm/min) (Figure 3). The same trend was also found the the small *L.scabra*, where their average speed of migratory is slower during the incoming tide (0.91 ± 0.3 cm/min) than the outgoing tide (1.04 ± 0.25 cm/min) (Figure 4). The movement pattern of *L. scabra* may also related to the environmental stresses. Desiccation one of the factors that is thought to be important factor in the evolution of the timing of foraging patterns [24].While they migrated, they may encounter different sources of food [17] and most *Littoraria* spesies, migrate with tide to remain above the water surface and only feed above the high water mark [24, 25].

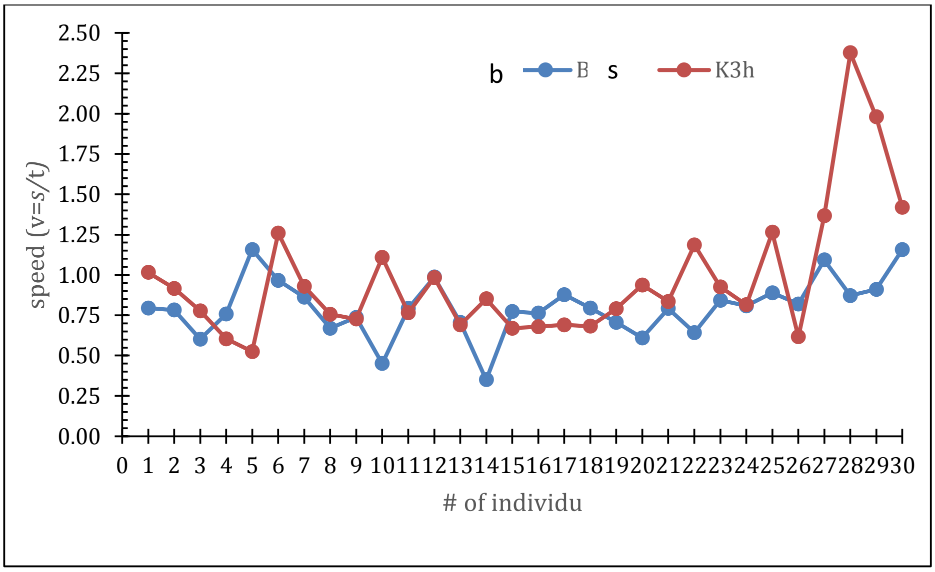

Figure 3. Migratory speed of *L.scabra* (b=big; s=small) during the incoming tide

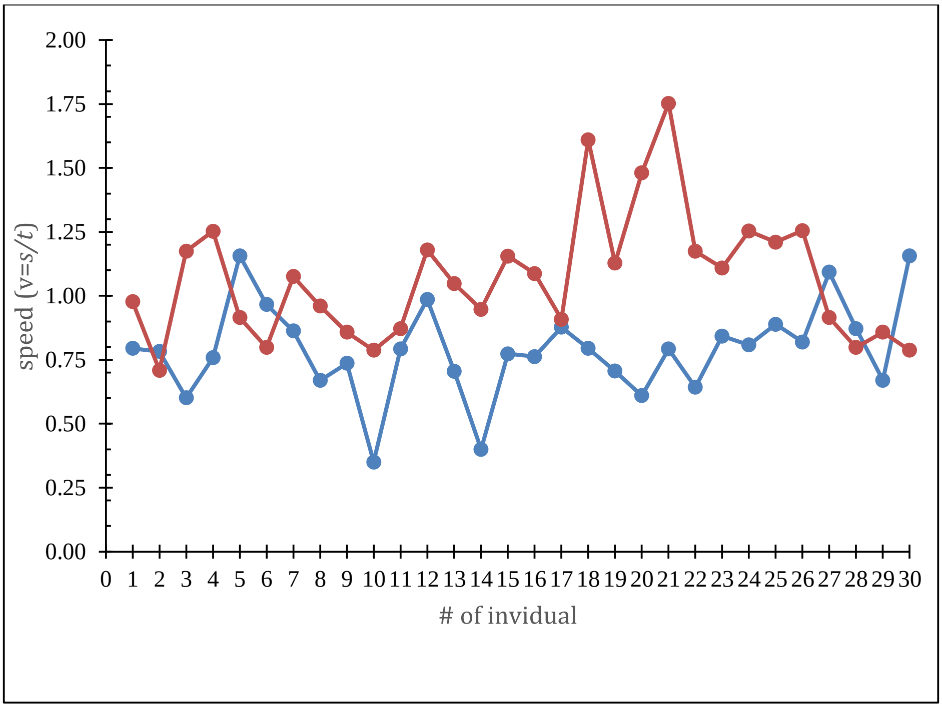

Figure 4. Migratory speed of big size *L.scabra* (big) during the incoming (blue line) and outgoing tide (red line).

Our studies also revealed that during their migration, the organisms show different pattern of movement when they were on the branch (Figure 5a), trunk (Figure 5b) and leaves (Figure 5c). It can be seen that *L. scabra* have more complex pattern of movement on wider surface such as on the leaves and branch than in narrower surface such as trunk. Their pattern of movement on the leaves and is look like a zig zag and on the trunk look like a straight line. The movement pattern of *L.scabra* may be affected by the spatial distribution of food in the surface different part of the tree. This was also observed on *L. littorea* movement behavior is likely control by the spatial distribution of food [14]. This organisms living in the intertidal environment that they have to survive from wave action, exposure to the air and heat during low tide and predation and also completion for space and food [27]. Another factor that have to take into account is a structure of the surface that may have impact on pattern of movement on surface of leave which are smoother that trunk and branch. Daily movement of snail is often random, probably because the animals do not respond to cues at a distance [28]. However, the specific patterns and reasons for this vertical migration on mangrove trees especially in different part of the tree are still poorly understood.

The seawater temperature during the day ranged from 27.1–30.2°C and 26.0–29.6°C at night. These range of temperature below the optimum leaf temperature for photosynthesis because according to [29] the high sea surface temperature are not favourable for leaves of mangrove cause their photosynthetic capacity get reduced as the optimum leaf temperature for photosynthesis is 28-32^{o}C.

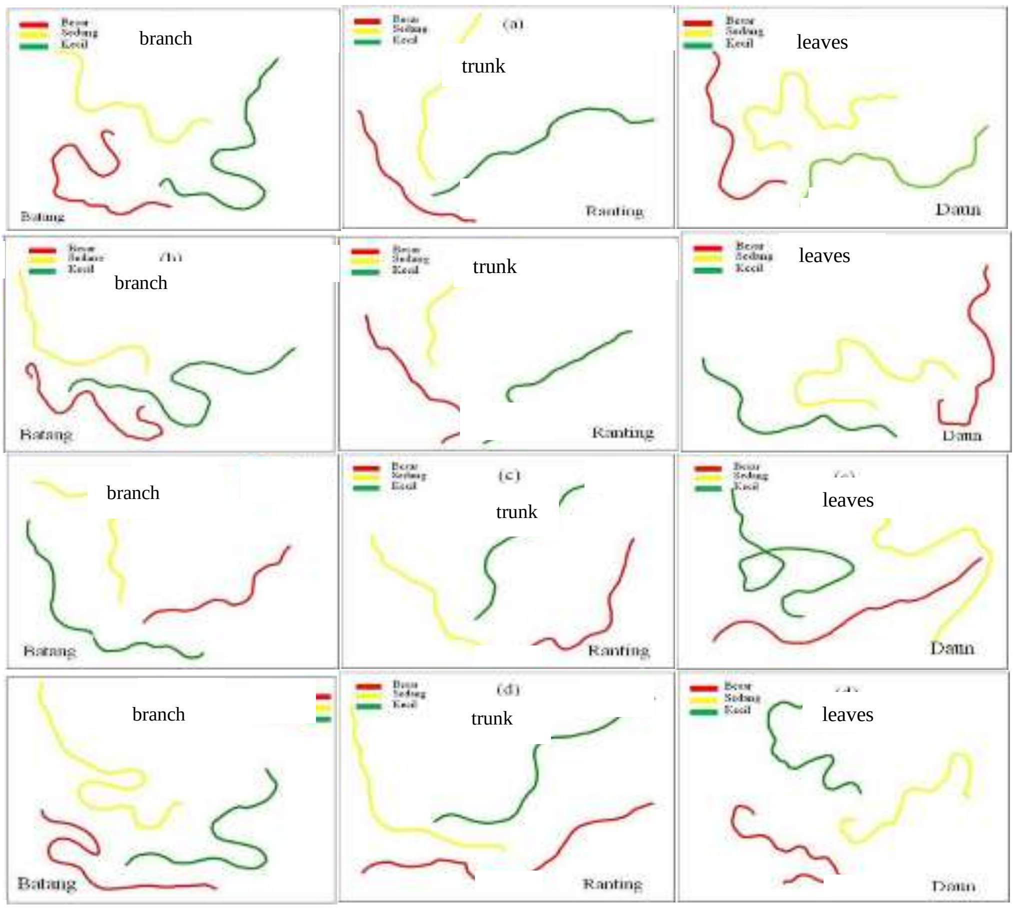

Figure 5. Migratory pattern of *L. scabra* in branch, trunk and leave during incoming (a, b) and outgoing (c,b) tide. *red= big zise; yellow & green = small size*

4. Conclusion

The pattern of movement by *L.scabra* in mangrove tree Tanjung Tiram, Ambon bay differently in leaves, branches and trunk and the speed of movement may be different to based on their sizes and the tidal cycle. Those activities were assumed to be a combination with their predator behaviour and pray items and distribution and food availability.

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