Density and characteristic of bioturbation of *Uca* spp at Tanjung Tiram mangrove ecosystem in Poka village, District of Ambon Bay

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Abstract. Mangrove ecosystem provides high ecological contribution to various biological resources including fiddler crab, *Uca* spp in its ecological and economic role in the ecosystem. The study held in September to October 2020 to analyze species composition, density and characteristic of bioturbation (color, substrate structure and the shape). The study was conducted at 3 station using purposive sampling method. The stations are determined based on the characteristic of the fiddler crabs habitats (living status, the vegetation of mangrove, substrate types and utilization level). Three species of fiddler crabs are found in the study namely *Uca perpelexa*, *U. lactea*, and *U. mjoebergi*. The highest density is represented by *U. perpelexa*. The highest density of fiddler crab is found in station 2 with various habitats characteristics. The color of the bioturbation are different in every station considering the substrate structure. Substrate fraction is dominated by sand in various catagories in every station especially on its roughness (rough, medium and soft). Five shapes of bioturbation are found by the study considering the various percentage of total and the various of inhabitant species in every station. The bioturbations are influenced morfologically by substrate structure and the existing rooting of the mangrove vegetation.

1. Introduction

Mangrove ecosystem is one of the typical tropical marine ecosystems in the intertidal zone, which provides an ecological contribution to the surrounding ecosystem, directly or indirectly. It has many roles such as trapping water and sediment, producing detritus and recycling nutrients. Thus mangrove ecosystem is a productive ecosystem which is used by many organisms for shelter, nursery ground and spawning ground.

One of the benthic organisms in mangrove ecosystem is fiddler crab (*Uca* spp.) that generally live in its own digging bioturbation [1]. *Uca* spp have economic value as an ornamental marine aquarium as well as ecological value [2]. Bioturbation burrows by *Uca* spp enable oxygen to flow to the inside of the substrate layer to increase aeration which allows nutrient changes to occur so that mineral accumulation is reduced [3]. In addition, it drains inorganic nutrients from the surface of the substrate. Thus there is nutrient stability and environmental fertility [4]. This condition is very favorable also for the various benthic microorganisms that live around the bioturbation hole.

Fiddler crabs have important roles in the persistence of food chain and nitrogen cycle. As the detritus feeder from the decomposition of mangrove leaves and twigs [5], fiddler crabs also play a role in destroying litter so that they can accelerate decomposition process of the litter. In addition, *Uca* spp also have an important role in helping the spread of mangrove saplings by pulling propagules into bioturbation holes or on aqueous substrates so as to help their growth. [6].

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The mangrove ecosystem of Tanjung Tiram in Poka Village is located around a residential area with high utilization of the area. Various forms of utilization such as residential land, household waste disposal, boat anchorage, jetty construction, rock and sand mining, construction of the sea for lodging and culinary tourism have put high ecological pressure on the growth and development of the mangrove community and its various organisms, including fiddler crabs. Decrease in mangrove community and changes in substrate structure due to various anthropogenic activities will have an impact on the presence and dispersion of fiddler crabs. For its economic and ecological roles, it is important to maintain the population and habitat of fiddler crabs by bioecological data based management.

This research was conducted to analyse species composition, density and bioturbation characteristic of fiddler crabs in mangrove ecosystem of Tanjung Tiram. It is hope that the study could provide scientific data and information of the potential and characteristics of *Uca* spp. habitat as the basic data and information in *Uca* spp. resources management policy especially in mangrove ecosystem of Tanjung Tiram, Poka Village.

2. Materials and Method

2.1. Location and date

The study is done in September to October 2020 at mangrove ecosystem of Tanjung Tiram in Poka Village, District of Ambon Bay (Figure 1).

![Figure 1. Location of the study](image)

The station in the study are determined based on the condition and character of the habitats using purposive sampling method. Astromonic position of each site are: Station 1 (3°39'9.0" LS/128°11'50.0"BT), Station 2 (3°39'14.0"LS/128°11'54.0"BT), Station 3 (3°39'21.0" LS/128°11'58.0"BT).
2.2. Data collection
Data collection starts on the observation of the difference of characters and condition of the habitat of fiddler crabs such as basic substrate, the existing of mangrove vegetation, space utilization and antrophogenic activities. Samples are taken in the lowest tide in three of 1 x 1 m² framed for each location as repetition. Observation was done at 1 m distance from bioturbation pit in order to avoid misidentification of the marked individual crab.

Every marked fiddler crabs which comes out of the bioturbation is caught using a small spade then stored in a labeled sampling bottle with alcohol solution. In the laboratory, the crabs are washed and identified based on Murniati and Pratiwi (2015) [7] and Crane (1975) [8]. Shape and size of the bioturbation data is collected by pouring wax into the marked pit slowly then let it to harden. The wax is is taken out by unloading the substrate surround the bioturbation carefully to prevent damage and then documented. Substrate structure data of the bioturbation is taken by pricking off the PVC pipe into the substrate then taken it off slowly. The both sides of the pipe is torn to enable the observation and documentation of the color of the substrate. The substrate is then dried and sifted using an automatic sieve shaker.

2.3. Data analysis
Species composition data of fiddler crabs found is classified into their taxa based on the stations they are found. The density of fiddler crab and the color of substrate data are calculated according to Brower et al. (1990) [9], while the shape of bioturbation data in every station is plotted according the inhabitant species of crabs. Substrate fraction percentage is analyzed using Wentworth scale.

3. Results and Discussion

3.1. Species composition
A total of 352 specimen of fiddler crabs collected during the study at mangrove ecosystem of Tanjung Tiram in Poka Village which consist of three species namely Uca perpelexa, U. lactea, and U. mjoeberti. They are all from Crustacea Class, Decapoda Order, Ocypodidae Family and Uca Genus. Generally all of the species are the inhabitant of soft substrate with mangrove vegetation. U. aperpelexa can disperse well in mangrove ecosystem on the open area, sandy substrate, muddy substrate, muddy substrate ang mixed sandy mud substrate. U. lactea prefers the habitat with more closed mangrove ecosystem with sandy substrate and keen on digging bioturbation on the substrate around the roots or mangrove bushes near the fresh water flow or at the lower course of a river. U. lactea often associates with U. perpelexa. U.mjoeberti prefers habitat with muddy or mixed sandy mud substrate.

Mangrove ecosystem at Tanjung Tiram is dominated by Uca perpelexa. It is also the dominate species found in all study stations. Sandy substrate dominates the substrate in Tanjung Tiram mangrove ecosystem and this condition is favorable for U. perpelexa. Hasan (2015) [10] stated that U. perpelexa prefers habitat surround emangrove root with sandy substrate.

There are 16 species of fiddler crabs in Indonesia [7]. The species of fiddler crabs found in this study at mangrove ecosystem of Tanjung Tiram in Poka Village is lower than both mangrove ecosystem at Passo in Ambon Island [7] and other ecosystem mangrove in Indonesia [4, 11, 12, 13, 14, 15]. The small amount of fiddler crabs at Tanjung Tiram mangrove ecosystem could be due to the effect of the high of ecological pressure caused by the high antrophogenic activity.

3.2. Species density of fiddler crabs (Uca spp.)
Total density of fiddler crabs analysis shows various numbers among the species in the stations. Total density level diagram of fiddler crabs among the species shows that all the three species are found in all study sites in variative macrohabitat characters. Weis and Weis (2003) [16] stated that some of Uca species were found...
in the same macrohabitat, but were expected to have different ecology hollow indicated the microhabitat of each species. Moreover, Hasan (2015) [10] stated that every species of fiddler crab had its own specific microhabitat, except to U. perpelexa which was found in more than one microhabitats.

This study finds that U. perpelexa has the highest density level in Tanjung Tiram mangrove ecosystem, and it is also the species with the highest density level in every study station. Its density level is about 0.409-0.681 ind/m². On the second place is U lactea with 0.134-0.404 ind/m² in density level, then U. mjoebergi at 0.015-0.354 ind/m² in density level (Figure 2). It means that U. perpelexa is the species is adaptable in various characters of habitat in mangrove ecosystem.

![Figure 2. Density of fiddler crab species in mangrove ecosystem of Tanjung Tiram](image)

The highest average density is found in station 2 (1.169 ind/m²) then followed by station 1 (0.829 ind/m²) and station 3 (0.765 ind/m²). Station 2 is in mangrove area with high density and a large canopy. This area is relative closed with most muddy basic substrate structure caused by deployment and morphology structure of mangrove roots but it is also caused by household waste flow from the residential area. Most of the substrate structure in this station is sand and sandy mud. Station 2 is located further from the residential area than the other stations, so the space utilization is lower than the other stations. The high density level in this area is supported by the soft substrate to dig, it also contain of rich organic material and high detritus from mangrove vegetation. The availability of organic materials is one of the important factors influenced fiddler crabs precense, for it is deposit and detritus feeder. Besides the deposits and detritus, fiddler crab also eats bacteria, protozoa, microalgae and diatom [16, 17]. Station 2 is dominated by U. perpelexa (0.681 ind/m²) and U. mjoebergi (0.354 ind/m²). On the contrary, station 1 and station 3 are in the high utilization areas with various antropogenic activities such as littering, residential expanding activities, sand mining, and mangrove vegetation cutting. This ecological pressure has driven degradation of mangrove ecosystem. Mangrove ecosystem degradation affects the alleviation of detritus and soil nutrient, increase in sun shine intensity and substrate structure alteration indicated by the changing of substrate color and the increase of rough fraction in the substrate. All of these circumstances influence the spreading and density of fiddler crabs in the area.

3.3. Characteristic of bioturbation of Uca spp.

3.3.1. Substrate color. Mangrove ecosystem is an area with high dynamic environment caused by the tide. Substrate in this area is formed by vegetation growth with a complex rooting system which traps the sediment brought in regurarly. Beside it, watery and soft substrate in mangrove ecosystem is also formed by process of dead organism decomposition to deposit slowly which then becomes teristerial area. This area turns to be rich natural habitat for organisms in mangrove ecosystem. Buckman and Brady (1982) [18] stated that mangrove ecosystem is rich because of the composition of organic material contained in it. According to
Siahainenia et al. (2014) [19], substrate color is one of physics condition indicating the environment change. Observation on the color of substrate surround the bioturbation of fiddler crabs showed that generally the substrate is blackish gray. Even so, color degradation of the substrates is visible (Table 1)

### Table 1. Description of substrate color in fiddler crabs’ habitat

| Station | Substrate Figure | Description |
|---------|------------------|-------------|
| 1       | ![Image](image1.png) | Surface layer of the substrate is gray, while the next layer is blackish. |
| 2       | ![Image](image2.png) | Surface layer of the substrate is gray, while the next layer is coal black. |
| 3       | ![Image](image3.png) | Surface layer of the substrate is brownish, while the next layer is blackish gray. |

Substrate color differences among the stations is due to the high utilization activities. It is expected that color change in substrate layers in station 1 and 3 is caused by effect of sedimentation of upper land clearing for residential area. Similarly, sand mining activities in station 3 has changed the substrate of land to the substrate from upper land brought by the rain or household litter flows. While the blackish gray color of the inner layer of the substrate in station 1 and 3 is mostly caused by waste particle deposit and household disposal.

### 3.3.2. Structure of substrate.
Structure of substrate in station 1 is dominated by medium sand (MS) fraction (57%), then follows by very fine sand (VFS) fraction (15%). The lowest fraction percentage are silt (1%) and coarse sand (CS) and very coarse sand (VCS) fraction (3% each) (Figure 3). On the other hand, structure of the substrate in station 2 is dominated by VFS fraction substrate (39%), follows by fine sand (FS) fraction (19%), and silt fraction (17%). The lowest measurement fractions percentage is gravel (G, 1%) and pebbles (P, 2%). Moreover in station 3, structure of the substrate is dominated by CS fraction (70%), then follows by MS fraction (10%) and CS fraction (8%). The lowest measurement fractions percentage are silt and FS (1% each) and P fraction (2%).
In general, structure of substrate in station 2 is still in the natural character of mangrove ecosystem with less changing. On the contrary, structure of the substrate in stations 1 and 3 shows more changes due to the anthropogenic activities surround the both stations. Anthropogenic activity is one among contributing factors that forms degradation of mangrove ecosystem in Indonesia [20]. Some anthropogenic activities such as settlements, illegal logging and mining have led to the conversion of mangrove ecosystems, thus impacting on the degradation and extinction of mangrove ecosystems.

3.3.3. Shapes of bioturbation of Uca spp. Bioturbation is movement activities such as digging, crawling or consuming cediment by bentos organism that causes lay out changing of basic substrate layers [21, 22]. Bioturbation activity which is done by digging the substrate affected the ecosystem. In this process, substrate in the inner layer is brought to the surface so both organic and anorganic material depositioned in the substrate is able to be consumed by other organism. In this phase soil nutrient has been well recycled. Besides, Mulsow and Boudreau (1998) cited in Sunaryo (2012) [23] explained that digging activity was able to increase the porocity of the substrate that was soft and solid and enable increasing the oxygen level in the substrate. Bioturbation activity by digging while eating deposit particles and then brings out by wasting process is positively affected the decomposition and soil nutrient cycle that enable oxygen changing to fix the anaerobic condition of the substrate.

In the case of Uca spp. bioturbation activity, digging a pit is done in order to make its shelter, hiding pit, foraging and copulation. Reise (1985) cited in Volkenborn et al (2007) [24] stated that size and shape of the bioturbation is different from one species to the other especially on the digging activity. Bioturbation of the fiddler crab in Tanjung Tiram mangrove ecosystem are “I”, “J”, “L”, “U”, and “H” shaped (Table 2). Most of the bioturbation are “H” and “U” shaped.

The domination of “L” and “J” shaped bioturbation that hard substrate is the tipe of basic substrate in Tanjung Tiram mangrove ecosystem. Murniati and Pratiwi explained that the shape of bioturbation of fiddler crabs are not totally vertically straight but curled considering the slope of the inner pit as the shelter area. On other hand, Obenlander (2007) cited in Sunaryo (2012) [23] stated that commonly the shape of bioturbation of fiddler crab was linier vertical, but they could be different considering the structure of the substrate. Plastic waste is found in the inner layer of the substrate in Tanjung Tiram mangrove ecosystem. The facts indicates the disability of the fiddler crab to dig the bioturbation linear vertically, but turn the digging direction to the left or to the right when hard substrate is found. Muniarti and Pratiwi (2015) [7] stated that variety of the

![Figure 3. Substrate fraction percentage in habitat of Uca spp.](image-url)
Bioturbation shape is influenced by density of the substrate, vegetation presence, water level, temperature and humidity of the substrate.

**Table 2.** Shape of bioturbation percentage according to the species in every station

| Station | Percentage of the Bioturbation (%) | Inhabitant Species |
|---------|-----------------------------------|--------------------|
|         |                                   |                    |
| 1       | I: 20, J: 49, L: 27, H: 3, U: 1   | Uca perplexa       |
|         |                                   |                    |
| 2       | I: 72, J: 16, L: 11, H: 1, U: 0   | Uca perplexa       |
|         |                                   |                    |
| 3       | I: 21, J: 37, L: 33, H: 2, U: 7   | Uca perplexa       |

“J” and “L” shapes also dominate station 1 and 3 which are sandy substrate structured. Shape “I” dominates station 2 which has VFS substrate structured. Sandy substrate helps fiddler crab does its digging activity [25]. The sandy substrate contains rich organic material from high decomposition process and the condition drives the high level of fiddler crab density in station 2.

Bioturbation with “H” and “U” shapes are also found in Tanjung Tiram mangrove ecosystem. The “H” shape indicates complexity morphologic starts with only 1 entrance and bend, then create new path on the left or on the right. The “H” shaped pit is commonly found at the soft sand and muddy substrate near the mangrove vegetation. A curve pit is easily dug in a soft base substrate according to Muniarti and Pratiwi (2015) [7], rooting structure of mangrove vegetation is one among the determining factors of bioturbation digging activities that affected the morphologic of the bioturbation. Complexity of the bioturbation shape is easily to be dug in the soft and mild substrate because of its stability (Rudnick et al 2005 cited in Qureshi and Saher 2012) [26]. It is said that curved pit can enlarge space volume of the limited depth pit. Morphologically the “H” shaped pit is better for shelter.

Morphologically, the “U” shaped bioturbation starts with 2 entrances connected by a horizontal path in the inner substrate. According to Sunaryo (2011) [23], the “U” shaped pit is dug by a male-female pair of crabs for copulation purpose. It is rarely found in Tanjung Tiram mangrove ecosystem, so it is concluded that the time of sampling is not at the reproduction season. Analysis result of the bioturbation shape of the species found in the study shows that bioturbation of *U. perplexa* are mostly “I” and “J” shaped, the “L” and “I” shaped expected to be dug by *U. lactea*, while the “J” and “I” shaped pits are dug by *U. mjoebergi*. 
4. Conclusion

1. Three species of fiddler crab are found in Tanjung Tiram mangrove ecosystem, Poka Village, District of Ambon Bay namely Uca perpelexa, Uca latea, and Uca mjoebergi.

2. The highest species density is represented by Uca perpelexa. The highest species density level is found in station 2 that has dense of mangrove vegetation with soft and mild basic substrate type variation, isolated from the residential area and affected by low anthropogenic activities.

3. Substrate of fiddler crab bioturbation are reddish, blackish gray and coal black. Structure of the substrates are dominated by soft, medium and rough sand fractions. Five shapes of bioturbation are identified in the study, dominated by the “L” and “J” shapes.

Based on the result of the study, it is suggested to do a longer term study to explore bioecology aspects of fiddler crab in a different season.

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