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Analysis of *Avicennia* Sp. Plants Herbivory and Associated Insects in Mangrove Ecosystem Restoration

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ABSTRACT

Herbivory is a natural mechanisms for adjustment of tree growth, form, survivorship, and reproductive output of forest ecology including in mangrove ecosystem. The purpose of this study was to compare herbivory and insect diversity in various growth stages of *Avicennia* Sp. related with restoration of mangrove ecosystem. The research was carried out four months (July-October 2020) in Pagatan Besar mangrove ecosystem in Tanah Laut District, South Kalimantan Province. The results showed that marginal pattern is the most leaf attack case, both in every plant growth stages (39-68%) and canopy (53-58%) of *Avicennia* Sp. The highest average of leaf damage was found in lower canopy (3.06%), and the growth stage of seedling (3.62%). Herbivory most often found at lower canopy (3.17%) and seedling life stages (3.76%) of *Avicennia* Sp. It was found about 13 species of insects in all growth stages of Avicennia Sp. with the highest Biodiversity Index found in seedling (0.753). Insects function on all life stages of *Avicennia* Sp. was dominated by predator.

Keywords: *Avicennia*, herbivory, insect, mangroves

INTRODUCTION

Most mangrove forests in the tropical areas consist of monocultural stands or mixtures of a few tree species (Burrows, 2003). *Avicennia* sp. is one kind of true mangrove (Alongi, 2008), with the structural and floristic diversity arranges by the leaf (Burrows, 2003). The performance of *Avicennia* Sp. depends on *Avicennia's* growth stages, the interactions between the tree and animals, and with the insects (Rinker & Lowman, 2004).

Herbivoral insects play an important regulatory function in the ecology of forest ecosystems., The presence of the herbivoral insect affect the shape of *Avicennia* due to the insects predation on *Avicennia* leaf (Amalia et al., 2019). The presence of insects also affects significantly the longevity of leaves, time of leaf fall, and the quality of leaf litter, especially in young plant seeds (Burrows, 2003). Moreover, predation of insect on *Avicennia* lead to increase of nutrient cycle in forest ecosystem. In the other hand, the presence of insects and other herbivores in roots, stems and leaves of

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Avicinnia cause of nutrient loss from plants (Cannicci et al., 2008). Herbivorous insect is affected by the tidal inundation modes in mangroves. The tidal movement affects insects living in the lower canopy, movement of non-flying insects (mostly larvae) from tree to tree, and emergency og pupate living in the soil (Burrows, 2003).

Herbivory is a natural mechanisms where the animals feed plant. The animals that eat plants is called herbivore. Herbivory affects plant growth, canopy form, seed survivorship, and reproductive growth stages of plant (Kairo et al., 2001: Burrows, 2003). Herbivory may damage apical leaf and shoot. However, herbivores also involve several useful mechanisms in the appearance of vegetation. The changes of stand performance is very useful indicators for natural ecosystem (Ansari et al., 2014) and the success of mangrove restoration effort (Devi & Pathak, 2016).

For the recent research herbivory has shown a significant role of insects in mangrove ecosystems more important than previously (Rinker & Lowman, 2004). .

Pagatan Besar mangrove ecosystem is one location of mangrove restoration in South Kalimantan Province where *Avicennia* Sp. is the dominant indigenous plant. However, there is still no comprehensive data about herbivory and number or type of in Pagatan Besar as affected by restoration project. Information on herbivory and insect are needed for understanding of plant-host interaction and for managing the resistance and sustainability of restoration efforts. The purpose of this study was to compare herbivory and insect diversity in various life stage of *Avicennia* Sp. related with restoration of mangrove ecosystem.

MATERIALS AND METHODS

Study sites

The study was conducted in Pagatan Besar, Tanah Laut Regency, South Kalimantan, Indonesia (Figure 1). The area has been under restoration project by Provincial Government of South Kalimantan since 2003 (Soendjoto, 2003). The study was carried out from July until October 2020.

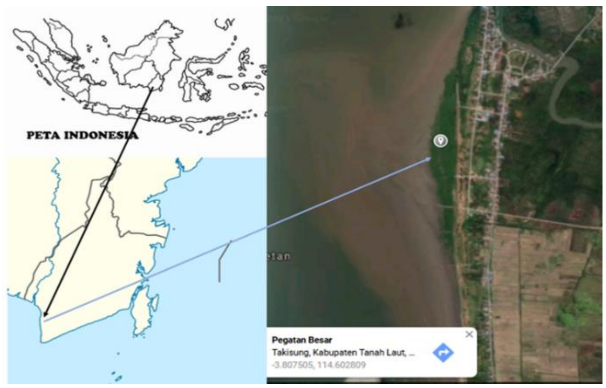

Figure 1. Sampling sites in Pagatan Besar mangrove ecosystems, Tanah Laut, South Kalimantan, Indonesia (latitude: -3.8085378502031086, longitude: 114.60293845489215)

Sampling and assay

This research used discrete methode. Herbivory was carried out by collecting leaves in the field and analysing them in the laboratory., Capture technique was used to observe herbivores habits through visual observation (Burrows, 2003). A direct one-time method was employed to compare areas of leaf damage between samples (Burrows, 2003). Leaf samples were taken from three different *Avicennia* Sp growth stages (seedling, sapling, and tree) and canopy parts

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(lower canopy and upper canopy). Herbivory measurements was carried out using the method as described by Rinker & Lowman (2004). In this method, three research stations were established based on the *Avicienna* growth stages. Three plots (10 m x 10 m) were established in each station. From each plot three plants were chosen as sample and the total of six hundred leaves were taken from all stations (Figure 2).

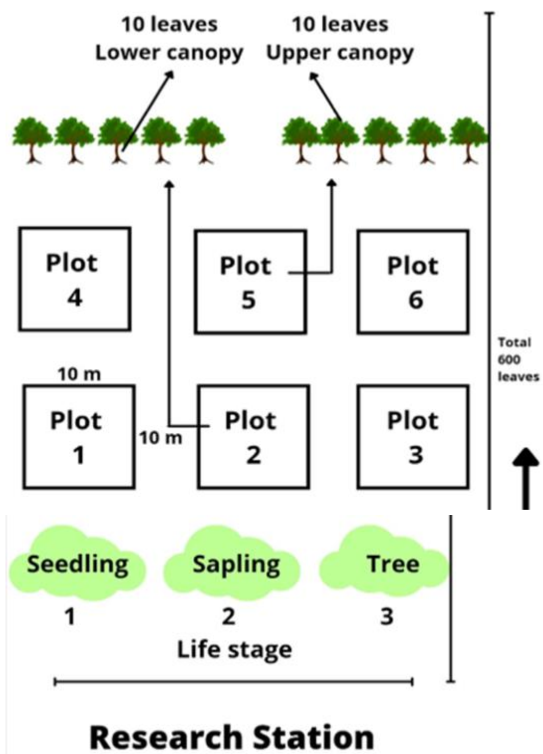

Figure 2. Sampling methods of herbivory.

The area of leaf damaged was then quantified using a millimeter block paper. The leaves are then sorted based on the attack pattern category (i.e., marginal, internal, and combination) and the condition of the leaves (i.e., intact or damaged). There are three parameters used to calculate herbivory i.e., 1) attack patterns, 2) leaf damage, and 3) comparison of herbivory. Attack patterns were classified based on visual observation into (1) marginal, (2) internal, and 3) combined between marginal and internal. This observed data then divided by the total attack pattern and multiplied by 100 in the form of a percent (%) (Kathiresan, 2003). Damaged leaf area was divided by intack leaf and multiply by 100 to quantify the % leaf damaged. Generally, there are four types of leaf damage, i.e., type I (1 - 20%), type II (21 - 40%), type III (41 - 60%) and type IV (61 - 80%) (Burrows, 2003). Similarly, the comparison of herbivory was calculated with formula : $\%\, Herbivori\ in\ a\ given\ leaf = \frac{\Sigma fx}{\Sigma f}$, that f is frequency of leaf area no exposed to herbivores, and x is percentage of leaf area consumed by herbivores (Saifullah & Ali, 2004).

Diversity of insects

Insect samples were taken using the Yellow Pan Trap method and direct collection 3 times along with leaf sampling for herbivory observation. Insect identification uses reference sources such as (Borror et al., 2005) and insect data search tools on https://www.insectidentification.org/ page. The Shannon-Wiener Diversity Index (H) is calculated using the following equation : $H = -\sum P_i(\ln P_i)$ where P_i is the proportion of each species in the sample (Mendes et al., 2008). Three parameters used were the type, diversity and density of insects at each level of plant life *Avicennia* Sp. The relationship between hebivory events and the presence of insects is in accordance with the succession of the mangrove ecosystem. Survival rate of *Avicennia* Sp. with the type and density of insects were analyzed

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using Chi-Square at a confidence level of 95%.

RESULTS

Attack patterns

In general, there are three known patterns of herbivory attack, the first is attack direction start from the edge of leaf (marginal), second is starting from the middle (internal) and third the attacks starting with the edge and also int the middle (combination). From the Figure 3 below, we found an example attack pattern on the leaves of *Avicennia* Sp. plant, i.e., marginal patterns (A), internal patterns (B), and combination patterns (C) from *Avicennia* Sp. in Pagatan Besar mangrove ecosystem, of South Kalimantan.

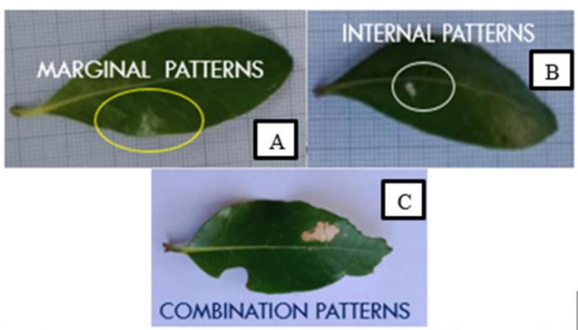

Figure 3. Attack patterns models of herbivory at the various life stages of *Avicennia* Sp. (A. Marginal patterns, B. Internal patterns, C. Combination patterns).

Based on the development on all life stages (seedling, sapling and tree) of *Avicennia* Sp., found the most accident is marginal attack patterns (39 – 68%), and then the internal attack pattern (23 – 45 %), and the lowest is combination patterns (9 - 16%). See Figure 4 below.

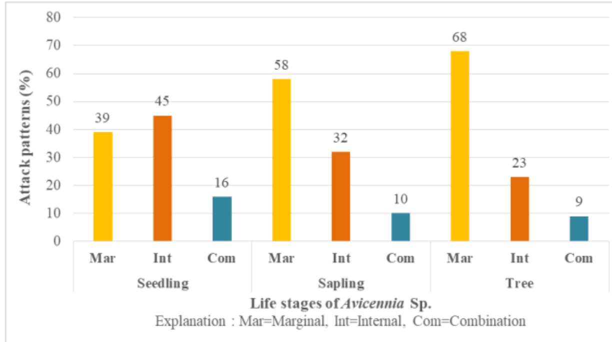

Figure 4. Comparison attack patterns of herbivory (%) at the various life stages of *Avicennia* Sp.

Compared with canopy position, its also dominated by marginal attack patterns both in lower and top of the *Avicennia* Sp.canopy (53-58%). And the lowest is combination attack patterns with value from 10.33 – 13%. All of this can be seen in Figure 5 below.

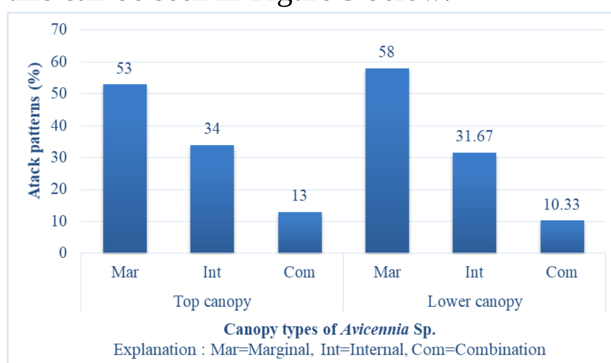

Figure 5. Comparison of herbivory attack patterns (%) in the canopy of *Avicennia* Sp.

Attack patterns

Results average analysis of leaf damage in *Avicennia* Sp. on the upper canopy recorded at 2.54%, which is lower than the lower canopy (3.06%) (Figure 6.left). Meanwhile, based on the life stages of *Avicennia* Sp., it is known that the highest mean values were carried out from seedling (3.62%) and the lowest from sapling

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(2.45%) (Figure 6, right). All of this explanation can be seen in the Figure 6 below.

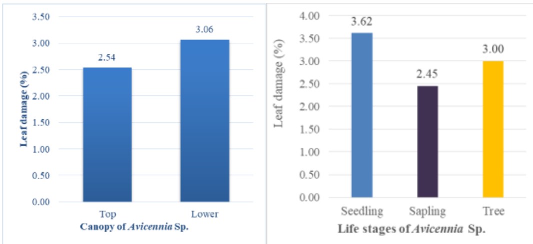

Figure 6. Leaf damage (%) at the canopy (left), and at the life stages of *Avicennia* Sp. (right).

Herbivory

The results showed (Figure 7, left) that the highest herbivory value was obtained from the lower canopy (3.17%). Meanwhile, based on the life stages of *Avicennia* Sp. (Figure 7, right side) obtained the highest herbivory value from the seedling period (3.76%).

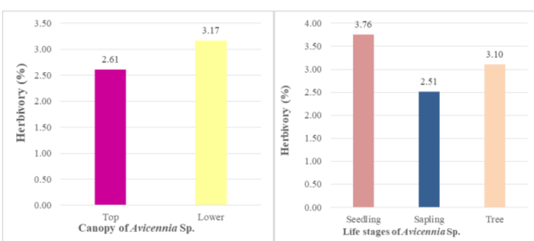

Figure 7. Comparison of herbivory at the canopy (left) and at the life stages of *Avicennia* Sp. (right).

Insects Diversity

There are approximately 13 types of insects found in *Avicennia* Sp. They are *Archichauliodes diversus*, *Blattella germanica*, *Camponotus maculatus*, *Chrysomya megacephala*, *Dolomedes triton*, *Drosophila melanogaster*, *Echthromorpha intricatori*, *Limonethe maurator*, *Microchrysa polita*, *Philanthus gibbosus*, *Pseudomyrmex gracilis*, *Tanystoma maculicolle*, and *Xanthocryptus novozealandicus*. The percentage value of the presence of *Chrysomya megacephala* (Decomposer : Family Calliphoridae) was the highest (20.2%) in all the life levels of *Avicennia* Sp.. Then followed by *Tanystoma maculicolle* (Predator: Family Carabidae) by 17.2% and *Pseudomyrmex gracilis* (Predator: Family Formicidae) by 16.6%. The complete results are seen in Table 1 below.

Attendance of insect based on its function on all life stages of *Avicennia* Sp. show the highest value get from the insect predator type (Carabidae, Corydalidae, Crabronidae, Ichneumonidae, Pisauridae, Stratiomyidae and Formicidae) about 60%, then decomposer (Calliphoridae) about 20%, herbivore (Drosophilidae) 11% and the lowest is detritivore (Ectobiidae and Stratiomyidae) 9%). All of this information can be seen in Figure 8 below.

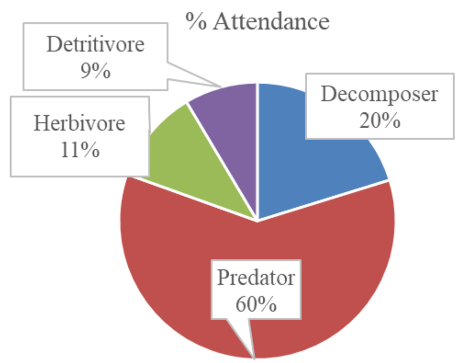

Figure 8. Attendance of insects family (A) and its function (B) on all the life stages of *Avicennia* Sp.

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Table 1. Insects attendance on various life stages of *Avicennia* Sp. from Pagatan Besar mangrove ecosystem

No.	***Name of Insect***	***Family***	***Food web Function***	***% Attendance[1)]***
1	*Chrysomya megacephala*	Calliphoridae	Decomposer	20.2
2	*Tanystoma maculicolle*	Carabidae	Predator	17.2
3	*Pseudomyrmex gracilis*	Formicidae	Predator	16.6
4	*Drosophila melanogaster*	Drosophilidae	Detritivor	11.0
5	*Echthromorpha intricatoria*	Ichneumonidae	Predator	10.0
6	*Microchrysa polita*	Stratiomyidae	Detritivor	7.4
7	*Limonethe maurator*	Ichneumonidae	Predator	4.3
8	*Camponotus maculatus*	Formicidae	Predator	3.3
9	*Dolomedes triton*	Pisauridae	Predator	3.3
10	*Philanthus gibbosus*	Crabronidae	Predator	2.2
11	*Xanthocryptus novozealandicus*	Ichneumonidae	Predator	2.2
12	*Archichauliodes diversus*	Corydalidae	Predator	1.1
13	*Blattella germanica*	Ectobiidae	Detritivor	1.1

Note: [1)] averaged values from 3 replicate.

The counting of insect biodiversity using Shannon-Wiener Index (Mason, 2002) from the various life stages of *Avicennia* Sp. in Pagatan Besar mangrove ecosystem show the highest value for seedling at 0.753, and the lowest for sapling (0.044). All values derived from these calculations are indicates a low species diversity. The result can be seen in the Figure 9 below.

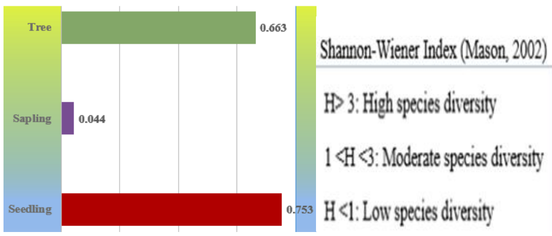

Figure 9. Shannon-Wiener Biodiversity Index of Insect from the various life stages of *Avicennia* Sp in Pagatan Besar mangrove ecosystem of South Kalimantan, Indonesia.

Correlation between type and number of insects with herbivory

Analysis of the correlation between types and numbers of insects with attack patterns and herbivores at various life stages of *Avicennia* Sp. show a higher value than the standard (α = 0.05) as shown in the Table 1 below. Generally of conclusions, there was no influence between the type and number of insects on attack patterns (both in internal, marginal and combined) and also for herbivory in *Avicennia* Sp. leaves.

Table 2. Correlation coeficients of types and number of insects with attack pattern and herbivory (α=0.05).

Parameters	Attack Pattern	Herbivory
Types of Insects	0.315	0.211
Number of Insects	0.865	0.880

DISCUSSION

Attack Patterns

Our results showed that herbivory can be found on all parts of canopy (lower and top) with variable patterns and plant growth stages (Figures 2-4). It indicates that herbivory attack has spread to all parts of *Avicennia* Sp. These can have different effects and consequences for plants both ecological and evolutionary (Mello, 2007). Variable effects of herbivory at different growth stages can be caused by plants in developing different resistance against attacks by herbivores, as also reported by Da Silva et al. (2015). It seems that these qualities possessed by plants serve as a better defense because they have a direct effect on the fertility and survival of the herbivores rather than the effects of predation (Lill & Marquis, 2001).

Leaf damage

Zvereva & Kozlov (2014) divided the levels of damage (proportion of damaged leaf area) into three groups: low (<10%), moderate (11–49%) and high (>50%). Meanwhile there were nine damage types from their research:

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holes, fungal spots, galls, undefined damage, margin damage, mining, necrosis, eggs, and rasping. The leaf herbivory percentages we found were lower as compared to other mangrove forests de Menezes & Peixoto (2009), most likely due to the high values of interstitial salinity (Da Silva et al., 2015).

Herbivory

The herbivory value obtained from this study is smaller than the herbivory value obtained from the research results of Amalia et al (2019), namely A. marina (4.66 - 11.59%) and R. *mucronata* (5.23 - 12.44 %). The herbivory attacks intensity sometimes increases and capable to destroy the target of plant, but sometimes it failurer to attack the target. This is because the plants have a physical, mechanical and chemical defense mechanisms such as secondary metabolites(Rinker & Lowman, 2004). Variability in plant responses to herbivory may be linked with the leaf economic spectrum. Premature abscission of damaged leaves can be seen as a tolerance strategy that reduces the negative consequences of local damage on the whole plant (Zvereva & Kozlov, 2014; Burrows, 2003).

Insect diversity

The insect families found in this study differed with those found by Dwihandayani's (2017) who found the most frequent insect families were Acrididae, Formicidae, Chrysomelidae, Tettiginidae, and Gryllidae in the Batutegi Tanggamus Protected Forest Area in Lampung. There are many factors which influence insect herbivore diversity and it can be viewed at several scales. At the whole ecosystem level, insect herbivore diversity is affected by the variety of the vegetation types present whilst the diversity of insects attacking individual tree species depends on factors such as the trees' geographic range, their architecture, their chemical and physical defense mechanisms and the number of their nearby conspecifics (Burrows, 2003).

CONCLUSIONS

Attack patterns on all life stages of *Avicennia* Sp. showed that marginal pattern is the most frequent, both in every plant growth stages (39-68%) and canopy (53-58%). Herbivory on all plant growth stages of (2,51 – 3,71%) indicated that *Avicennia* Sp. was in a normal or healthy conditions. We found that the insects function on all growth stages of *Avicennia* Sp. was dominated by predator.

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