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Changes in insect biodiversity on rehabilitation sites in the southern coastal areas of Java Island, Indonesia

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Abstract. *Budiadi, Musyafa, Hardiwinoto S, Syahbudin A. 2020. Changes in insect biodiversity on rehabilitation sites in the southern coastal areas of Java Island, Indonesia. Biodiversitas 21: 1-7.* Rehabilitation activities on coastal areas such as mangrove wetlands and dry-sandy soils may cause a change in the environmental quality, including insect diversity and their role. The research was conducted to compare the effect of stand structure on the rehabilitation areas of the south coast of Java Island and measure insect biodiversity affected by the changes to land cover. Systematic sampling technique was employed in four different land covers, i.e., dryland site of 10-year old *Casuarina equisetifolia*, and wetland sites of 12-year old *Avicennia* sp., mixed mangrove, and open grassland. Experimental plots (100 m x 10 m) were established for day- and night-time insect observation and tree inventory. Results showed that stand structure in the rehabilitation areas was low in tree diversity and lesser occurrence of natural regeneration. The insect taxa were dominated by Coleoptera in the *Avicennia* and mangrove stands, while different types of grasshopper of Acrididae were found in the grassland and Casuarina stands. Richer and more roles of insect species were found in mixed stands than in monoculture, and more in established stands than open grasslands. The rehabilitation activities change the microenvironment and insect diversity but have yet not been considered as an indicator of the success of rehabilitation.

Keywords: Biodiversity, bioindicator, mangrove, man-made forest, stand structure

INTRODUCTION

Coastal ecosystems that comprise of wetland (including mangrove) and dryland habitats protect the land from saltwater intrusion, erosion, and abrasion. They also act as a biofilter, a food chain of coastal organisms, establish new island area (Waas and Nababan 2010; Khairuddin et al. 2016), and habitat for transitional fishes (Walters et al. 2008). Coastal ecosystems have significantly unique biodiversity with specific functions, compared to that of other natural terrestrial ecosystems (Carranza et al. 2008); hence, the sustainability of such ecosystems should be maintained, and integrated within the overall developmental plan of the country (Adhikari and Baral 2018).

Casuarina equisetifolia var *Incana* Benth. of the *Casuarinaceae* family (also called Coastal She-oak or Horsetail She-oak) is found in the dry-sandy soils of southern Java Island. These plants are well adapted to the marginal and saline soils, resistant to drought stress, and develop deep rooting systems (Kabirun et al. 2012) with dense vegetation structure (Pinyopusarerk et al. 2004). Mangrove species can grow naturally in wet mudflat soils in high salinity environments especially in the arboreal ecosystems of tropical forests (Ellison dan Stoddart 1991). However, very few natural stands of Casuarina and mangroves could develop in the coastal areas due to the direct impact of strong waves of the Indian Ocean (Hogarth 1999; Syahbudin et al. 2013). Due to the pivotal role of Casuarina and mangroves in mitigating drought stress, and other benefits such as wave energy, tidal energy, sedimentation, mineralogy and neotectonic effect (Jenning and Bird 1967; Idawaty 1999) in the coastal areas, replenishment activities of this vegetation should be accelerated, and its impact to communities, biodiversity, and other functions should be consistently evaluated.

Evaluation of the rehabilitation activities can be conducted in terms of growth, productivity, and adaptability of the selected species alongside other environment indicators (Brown et al. 2014). The number of both above- and belowground, micro- and macro-flora and fauna and changes in the biodiversity caused by the change of habitat are good indicators for evaluating ecosystem quality (Macintosh et al. 2002). Established stands of these plants provide food, shelter and congenial reproductive opportunities for macrofauna (Wardhani 2014). Changes occurring to the biological processes, species and communities serve as the bioindicators of the impact of human-made activities to environment quality (Carignan and Villard 2002; Holt and Miller 2010); and ecosystem health (Alongi 2002; Macintosh et al. 2002; Ashton et al. 2003; Ellison 2008). The aim of this current research was to evaluate the stand structure located at the rehabilitation sites of the coastal areas of south-central Java Island (i.e., Special Province of Yogyakarta, Indonesia); and to measure the biodiversity of the insects in the form of an important ecosystem component impacted by the changes to the land cover or stand type.

MATERIALS AND METHODS

Measurements were recorded from August to October 2016 at two locations consisting of four different types of land covers viz. a 10-year old *Casuarina equisetifolia* var *incana* Benth. monoculture stand and a grassland both located at Trisik beach (7°58'01.48"S; 110°10'57.39"E); a 12-year old *Avicennia* sp. monoculture stand and a 12-year old mixed mangrove (of *Rhizophora*, *Avicennia, and Bruguiera*) located in the Baros mangrove conservation area (7°59'43.18"S; 110°17'07.64"E). Both sites represent the coastal areas of south-central Java in the Special Province of Yogyakarta, Indonesia (Figure 1).

In each type of land cover, three replicates of experimental plots (100 m x 10 m) were established for insect collection, and within each plot, nine subplots (10 m x 10 m) were set for determining the tree inventory. Tree species were identified, and height (h, m) and diameter at breast height (dbh, cm) were measured. Woody plants were classified into seedling (h ≤ 150 cm), sapling (h > 150 cm, dbh ≤ 10 cm), and pole-tree (dbh > 10 cm) (Eilu and Joseph 2005).

Vegetation analysis was performed to measure the stand density (N/ha) and the importance value index (IVI) using the following formula:

$$IVI = RD + RF + Rd$$

Where,
RD = relative density
FR = relative frequency
Rd = relative dominance

Insects were collected by direct sweeping (using a sweeping net) and the light trap method (Susilawati 2007). Direct sweeping was done in the morning (07: 00-10: 00 am) and then in the evening (03: 00-06: 00 pm). The light trap method included an electrical light to attract the nocturnal insect with measurements recorded during 07: 00-10: 00 pm. Collected insects were temporarily preserved in 70% alcohol, and brought to the laboratory for identification. Air temperature and humidity were measured thrice from each subplot using a thermo-hygrometer. The collected insects were identified at the Laboratory of Basic Entomology, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia.

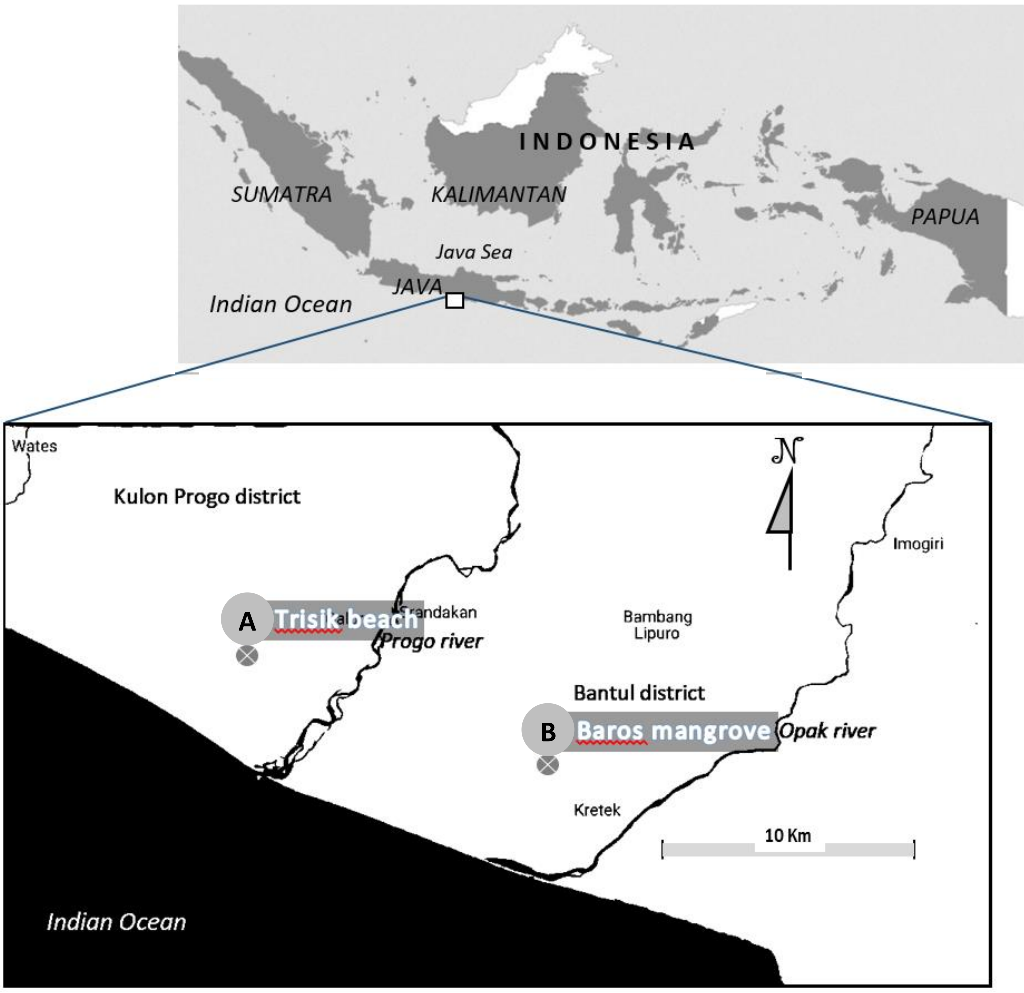

Figure 1. Location of the experimental area in the south coastal area of Java Island, Indonesia: A. Trisik beach and B. Baros mangrove conservation area

The identification of the insects was classified up to the family level in the taxonomic hierarchy. Morphospecies identification of the insect was also made to determine the diversity, evenness, species richness, and similarity indices of the insect. Analyses were done to measure

Biodiversity index (H') using Shannon and Wiener

$$H' = -\sum_{i=1}^{s}\left[\left(\frac{ni}{N}\right) Ln \left(\frac{ni}{N}\right)\right]$$

Where,
H' : Diversity index
N : Total number of species
ni : Number of species i
Biodiversity value was classified into three levels:
H' < 1: low diversity
1 < H' < 3: medium diversity
H' > 3: high diversity

Evenness index (J) using Peilou

$$J: \frac{H}{H'max}$$

Where,
J : Peilou evenness index
H'max: ln S
S : Total number of individuals in the community
In the evenness concept, if the value was close to 1, the individuals were distributed evenly.

Species richness using Margalef (R)

$$R = \frac{S-1}{Ln\ N}$$

Where,
R : Species richness
N : Number of individuals of each species

Similarity index to measure community structure using Sorensen (S)

$$S = \frac{2C}{A+B} x\ 100\%$$

Where,
S : Similarity index
C : Total number of captured insect species in habitats a and b
A : total number of species A in habitat a
B : total number of species B in habitat b

Similarity (S) of two habitats were classified as follow: (i) 80-100%: similar, (ii) 50-80%: different, (iii) S < 50%: very different

RESULTS AND DISCUSSION

Stand structure

We observed changes in the stand structures of the rehabilitation area, for both the mangrove and the Casuarina sites (Table 1). For the *Avicennia* and mixed mangrove stands, saplings were the most abundant compared to the other growth stages, while in the Casuarina stands, poles were dominant. In a normal stand, the number of seedlings must be proportionally higher than the bigger ones (Haneda et al. 2013). Less number of seedlings were probably due to the physiological characteristics of the species that lower the growing capacity under dense stands, less viable seeds, and other environmental threats, including pests and diseases (Creissen et al. 2016). In such conditions, silvicultural treatments such as canopy opening and seedling enrichment are required (Widiyatno et al. 2014); otherwise, the long-term sustainability may be compromised.

Insect abundance and composition

Coleoptera was the most dominant taxa in the *Avicennia* and mixed mangrove stands (Table 2). Coleoptera beetles are mostly active at night to get food, while at daytime, they hide under stones, leaves, barks, flowing upper groundwater, that represent mangrove and riparian ecosystems (Resh and Carde 2009). Along with Lepidoptera, Coleoptera is a potential bioindicator of moist ecosystems (Balakrishnan et al. 2014).

In the grassland and Casuarina stands, grasshoppers of the Acrididae family were the most abundant. Grassland grasshoppers were relatively smaller than the Casuarinas', and mostly green in color while Casuarina grasshoppers were bigger with various clear colors such as red, violet, and green. Acrididae grasshoppers are characterized by a short antenna and various colors from dark brown to green (Latip et al. 2015). Grasshoppers have straight wings and are very active especially in the daytime to get food. They are abundant in grasslands because grasslands consist of 41% of other grass-eating insects (Resh and Carde 2009), and therefore the grasshoppers should have adapted well to the grassland, and the Casuarina stands in this current experiment.

The role of insects in the ecosystem

In this current experiment, the dominant insects captured at daytime were different from that captured at night, which includes insects from the Pyralidae family of the Hymenoptera and Coleoptera orders that were the most dominant at night time (Table 2). Each insect has a specific role in the ecosystem's stability and energy balance (Weisser and Siemann, 2004). Insects belonging to the Pyralidae family were small nocturnal moths found in both dry and wetlands; they are leaf-eating herbivores, and generally a pest of rice (Baehaki 2013). Insects found in the Hymenoptera were nocturnal insects and important parasitoids contributing to biological control (Wackers 2004). The results also showed that Carabidae (ground beetle) were only found in the *Avicennia* stands. Carabidae are predators of various larvae and other mature insects (Borror et al. 1982; Amin et al. 2016). Ground beetles are nocturnal, larvae hunters with strong mandible that can cut the prey, which is mostly found on the ground, and rarely climb up on plant stem to find the prey (Purnomo 2010). The predator likes moist ecosystems such as the paddy field, lives on rice stems, and footpaths of the paddy fields (Herlinda et al. 2004).

Table 1. Stand density (Nha^{-1}) and Importance value index (IVI, %) of the tree species at each growing stage in various stand types of the rehabilitation sites of the south coastal area of Java Island, Indonesia

Stand type	Species	Seedling		Sapling		Pole		Tree	
		N	IVI	N	IVI	N	IVI	N	IVI
Avicennia stand	*Avicennia* sp.	44	200.0	3,322	200.0	0.0	0.0	444	300.0
Mixed mangrove stand	*Rhizophora* sp.	871	146.5	3,588	121.8	0.0	0.0	140	180.2
	Avicennia sp.	216	36.3	1,632	55.4	0.0	0.0	20	25.7
	Bruguiera gymnorrhiza	77	12.9	501	17.0	0.0	0.0	0.0	0.0
	Acanthus ilicifolius	103	17.3	169	5.7	0.0	0.0	0.0	0.0
	Hibiscus tiliaceus	0	0.0	0.0	0.0	0.0	0.0	73	94.1
	(SUM)	1,267	200.0	5,890	199.9	0.0	0.0	233	300.0
Casuarina stand	*Casuarina equisetifolia*	0	0.0	22	200.0	6,333	300.0	22	300.0

Table 2. Insect abundance under different land covers in the rehabilitation sites of the south coastal area of Java Island, Indonesia

Ordo	Family	Insect abundance (ind/ha)							
		Avicennia stand		Mixed mangrove stand		Casuarina stand		Grassland	
		Day	Night	Day	Night	Day	Night	Day	Night
Coleoptera	Carabidae	1	1						
	Coccinellidae			3	6	1		39	4
	Curculionidae						3	7	12
	Scarabaeidae		1		2				2
	Unidentified		18		38		2		
Diptera	Calliphoridae	1				1			
	Culicidae	9	7				1		
	Micropezidae					1			
	Sarcophagidae			7					
	Stratiomyiidae			5		1			
Hemiptera	Alydidae			7		3			
	Chrysomelidae	5			1			66	
	Coreidae							119	
	Flattidae	1		1		2			
	Pyrrhocoridae			1				13	
Hymenoptera	Eumenidae			8					
	Ichneumonidae	1		2					
	Mutillidae			5				1	
	Pompilidae	1		1					
	Vespidae	4	1	4					
	Unidentified	1	15				4		33
Lepidoptera	Noctuidae					4		3	9
	Nymphalidae					1		18	
	Pieridae	2	1	2				3	
	Pyralidae		1	4	3		17		4
	Satyridae	2		1				5	
Mantodea	Mantidae			3		18		2	
Neuroptera	Chrysopidae		12				7		
Odonata	Libellulidae					2			
Orthoptera	Acrididae	13	1	7		87		261	1
	Gryllacrididae							3	
	Gryllidae			2	1				
	Pyrgomorphidae	5		2		3		84	1
	Tettigoniidae	2					6	193	
Trichoptera	Unidentified		1				6		

Insect group that was mostly captured in the mixed mangrove stands were from the Eumenidae or wasp family. These potter wasps are parasites (Erniwati and Kahono 2009), but its presence in the estate plantation exerts pressure on the pest populations (Borror et al. 1982). Some of the trees and grasses at the experimental sites bear flowers that attract these wasps. The wasps have an important role in the pollination of flowers. In addition to wasps, flesh flies (Sarcophagidae) were also abundantly found at the sites because these flies put their larvae on the moist viviparous plant leaves (Spradbery 2002). Dragonflies (Libellulidae and Micropezidae) were only captured in the Casuarina stands. Lubellulidae is a member of the Odonata order which lives in the surrounding wet ecosystem consisting of clean flowing rivers with medium-light intensity under the forest canopy (Rahadi et al. 2013). In these ecosystems, dragonflies have a significant role in maintaining the food web because insects of the Libellulidae and Coenagrionidae families are aggressive predators that eat almost all kinds of insects (Kandibane et al. 2005; Sharma and Joshi 2007). Flies (a member of Micropezidae) were also found in the Casuarina stands, probably due to the presence of fishponds in the surrounding areas.

The role of various insects, such as wasps and butterflies as pollinators, dragonflies as pest predators, grasshoppers as herbivores, and flies and beetles as decomposers, can be considered as a bioindicator of the forests' succession or rehabilitation (Carignan and Villard 2002; Ellison 2008; Holt and Miller 2010; Chaiwong et al. 2014). Grasshoppers of the Orthoptera order (a member of Acrididae, Tettigoniidae, Gryllidae) as herbivores are dominant in most of the forested habitats, and therefore, have an important role in decomposing the litter produced from a proliferating stand (Erawati and Kahono 2010).

Insect diversity

The highest insect diversity was found in the mixed mangrove stands, slightly higher than in the *Avicennia* stands, which were both categorized as medium diversity, while the lowest diversity was found in the Casuarina stands (Table 3). Environmental conditions and the number and species distribution are the main factors affecting insect diversity (Alikodra 2002). The results of the richness index corroborated with the above having the highest values in the mangrove stands, and the lowest in the grasslands. The Margalef richness index shows a measure of diversity in terms of the number of species in a specific site (Gamito 2010), while the richest habitat represents a higher number and lower domination of species (Iglesias-Rios and Mazzoni 2014). Mixed stands tend to be richer in insect species compared to monocultures, while established stands (of rehabilitation activity) are richer in insect diversity than in open grasslands. In short, rehabilitation activities are able to increase insect richness (Holt and Miller 2010; Haneda et al. 2013) but has yet not been considered as an indicator of the success of rehabilitation.

The effect of rehabilitation activities on insects was also measured using the evenness index (J) at the sites. In the mixed mangrove and *Avicennia* stands, the J value was relatively higher than the other land cover types. The evenness index shows the distribution pattern of a species in a community, in which a higher value indicates a better balance of species distribution, and vice versa (Haneda et al. 2013).

The dominance of certain insects in the Casuarina stands, and grasslands were probably due to a specific environmental condition that was more suitable for their survival (Buchori et al. 2018). In addition, the domination of a particular tree or vegetation in habitat such as in a monoculture will stimulate the dominant insect species (Weisser and Seiman 2004) and may affect environmental stability.

There were no similarities in the insect species due to the type of stand or land cover (Table 4). The Sorensen's index ranged from 0 to 100%, while the value close to 100% represents similarities and vice versa at 0% (Haneda et al. 2013). The mixed mangrove stands were very different from the Casuarina stands, and *Avicennia* stands to grasslands because the value was less than 50%. These differences represent that the rehabilitation activities in the coastal areas may cause an increase or decrease in the number of insect species through the changing habitat conditions.

Table 4. Sorensen's index of the insect species among different land covers in the rehabilitation sites of the south coastal area of Java Island, Indonesia

Land cover	Mangrove mixture	Casuarina	Grassland
Avicennia stand	60.0%	51.3%	48.6%
Mixed mangrove stand		43.9%	56.4%
Casuarina stand			52.6%

Note: 80%-100%: similar, 50%-80%: different, <50%: significantly different

Table 3. Number of insect families, biodiversity (H'), richness (R), and evenness (J) index of each land cover in the rehabilitation sites of the south coastal area of Java Island, Indonesia

Land cover	Number of families	Number of individuals	H'	R	J
Avicennia stand	19	107	2.438	3.852	0.522
Mixed mangrove stand	21	116	2.487	4.207	0.523
Casuarina stand	20	170	1.906	3.700	0.371
Grassland	18	883	2.062	2.506	0.304

Note: H' = Shannon-Wiener diversity index; R = Margalef richness index; J = Evenness index

Table 5. Correlation between air temperature and humidity vs. the number of insect families in the rehabilitation sites of the south coastal area of Java Island, Indonesia

Land cover	Air temperature	Air humidity
Avicennia stand	−0.277	0.319
Mixed mangrove stand	0.536	−0.624
Casuarina stand	0.367	−0.045
Grassland	0.731	−0.700

Insect environment

Air temperature in the grasslands had a positive correlation to the number of insects, while the other land cover had none (Table 5). In the open area of grasslands, there were drastic changes in temperature during the whole day due to reduced canopy cover. The range of tolerated temperature for insects is 15° to 45°C and optimum at 25°C (Borror et al. 1982). In this current experiment, the air temperature was 23°C to 34°C that was favorable to the insects. Furthermore, we found that the fluctuation in the air temperature affected the diversity and group of the captured insects.

Air humidity had a strong negative correlation to the insect biodiversity in the grassland, while there was no correlation to the other land covers. The absence of canopy shade affected the change of species diversity. Air humidity has a vital role in the internal moisture content and the live cycle, activity, and distribution of the insects (Resh and Carde 2009).

In conclusion, coastal areas located especially in the south of Java Island directly face the disaster risks of the Indian Ocean. Rehabilitation to improve land cover and stand structure is important to protect the mainland from abrasion, saltwater intrusion, erosion, as a biofilter, etc. Successful rehabilitation can establish a healthy environment, and also change the biodiversity of the coastal vegetation, animals, and insects. Changes to the insects' diversity may be a good indicator of the changing ecosystem affected by the rehabilitation activities of the coastal area. The study found that some of the insects have an interrelationship with the existence of different vegetation, for food source as well as shelter and growth, while others need an open space to hunt prey. Richer and more roles of the insect species were found in mixed stands than that in monocultures, and more so in established stands than open grassland. Although the study cannot determine insect diversity as a bioindicator of land-use change, changes to land cover, as a result of rehabilitation activities in the coastal area caused a change in the insect structure and composition, with or without changes in the microenvironmental condition.

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