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Short Communication: The diversity of butterflies (Superfamily Papilionoidea) as a success indicator of tin-mined land revegetation

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Abstract. *Wiranti D, Nurtjahya E, Dahelmi. 2019. Short Communication: The diversity of butterflies (Superfamily Papilionoidea) as a success indicator of tin-mined land revegetation. Biodiversitas 20: 1923-1928.* Some former tin-mining areas in Belitung District have been revegetated. With the increase of vegetation age, the environmental quality changes, and so does the diversity of insects living in the vegetated areas. The objective of this study was to propose the use of butterfly diversity as a success indicator of tin-mined land revegetation. The research was conducted at six locations in Belitung District, consisting of one tin-mined land that had not been revegetated, four revegetated tin-mined lands with different ages of vegetation, namely 1-5 years, 5-10 years, 10-20 years, more than 20 years, and primary forest in Gunung Tajam. The research used the Pollard walk method and specimens were obtained using insect nets. The results showed that the highest diversity of butterflies was recorded in primary forest (31 species), followed by vegetated mined lands with the following ages of vegetation: > 20 years (21 species), 10-20 years (15 species), 5-10 years (14 species), and 1-5 years (7 species), and the lowest diversity was found in tin-mined land that had not been revegetated (2 species). The Shannon-Wiener diversity index in tin- mined land that had not been revegetated was low, namely 0.56 while in the revegetated tin mined land was medium, i.e., 1.47 – 2.96 and in primary forest was high, i.e., 3.2. The diversity of butterflies in revegetated land increased with the increasing age of vegetation, and the community similarity index between revegetated land and forest also increased with the increasing age of vegetation. Therefore, the diversity of butterflies may be used as a success indicator of revegetation in former tin mining areas.

Keywords: Belitung, butterfly, diversity, tin mined revegetation

INTRODUCTION

Butterfly is one of insects that can be used as environmental indicator because the diversity of butterfly is related to the quality of the environment. High diversity of butterflies is an indicator that the environment is still natural and preserved. The changing of habitat function can affect butterflies in an area, so butterflies can be used as an indicator of environmental quality (Peggie 2014).

Tin mining activities in Bangka Belitung cause environmental damages, such as the destruction of the landscape, the changing of natural habitat, the decline of biological riches, and pollution. One of the impacts of environmental changes in Bangka Belitung caused by tin mining is the decline of animal diversity. It is, therefore, necessary to revegetate the former mining land. According to the Indonesian Forestry Minister's regulation No. P.4/Menhut-II/2011 about forest reclamation guidelines, revegetation is an attempt to restore damaged land and vegetation through cultivation and maintenance activities (MoF 2011). To restore biodiversity and ecosystem services, land reclamation has been proposed as an activity that should be conducted in all mining areas. The success of reclamation can be seen from species recovery and from the recovery processes in the ecosystem itself (Rahayu 2016).

Research on the effect of environmental changes on the diversity of butterflies in Indonesia has been done, such as the diversity of butterflies in Merapi mountain after the eruption (Widyaningrum et al. 2014) and in Ulolanang nature reserve after the decrease of some species of plants and in post-fire forest in Kalimantan (Sulistyani 2013). Based on the ecological role of butterfly as an environmental indicator, it is necessary to research the diversity of butterflies in a former mining land that has been revegetated. The objective of this study was to propose the use of butterfly diversity as a success indicator of tin-mined land revegetation.

MATERIALS AND METHODS

Study area

This research was conducted from January to September 2017 in Belitung District, Bangka-Belitung Province, Indonesia, in five former tin-mining areas, one of which had not been revegetated and the rest of which had been revegetated, and in Gunung Tajam forest area (02°46'19.30" S, 107°51'31.60" E). The five former mining sites had different ages of vegetation, namely 0 year (02°47'41.37" S, 107°37'56.43" E), 1-5 years

(02°37'11.87" S, 107°45'19.73" E), 5-10 years (02°40'24.48" S, 107°42'0.57" E), 10-20 years (02°53'26.21" S, 107°40'19.35" E), and more than 20 years (02°36'51.01" S, 107°45'19.30" E) (Figure 1). The areas were coded as areas I, II, III, IV, V and VI. Identification of butterflies was conducted in Entomology Laboratory, Research Center for Biology, Indonesian Institute of Sciences, Cibinong, Bogor, West Java, Indonesia.

Procedures

Data collection of butterfly diversity

Sampling of butterflies was conducted using the Pollard transect method, the direction of the transect line being adjusted to the field conditions (Pollard 1977). The length of transect line was 500 m at each research location. The butterflies were caught using insect nets in the morning (08.30 - 10.30 AM) and afternoon (15.00 - 17.00 PM) (Wood & Gillman 1998). Butterfly collection was carried out for 3 days in each study area. Each butterfly encountered at a radius of 5 m to the left and right of the transect line and 5 m forward was captured with insect nets, then killed by punching the thorax, and finally inserted into papilot (triangle shaped paper). The time and date of the collection, the location of the study, and the code of numbers to distinguish one species from another were recorded in each folded paper (Wood & Gillman 1998).

Preservation and identification

Each butterfly was moved from papilot (folded) paper, and stabbed with an insect pin on the thorax. The butterfly wings were stretched across the stretch board and dried in the dryer for 2 weeks. After that, identification was performed based on morphological features using the identification guide of Flemming (1975), Seki et al. (1991), Tsukada (1991), and Peggie and Amir (2006). The butterflies were also compared with the collection of butterflies in the Entomology Laboratory, Zoology, LIPI.

Environmental data measurement

The environmental data consisted of abiotic and biotic data. Abiotic data consisted of air temperature, humidity, light intensity, and wind speed. Environmental factors were measured in the morning and afternoon at the starting point, midpoint and endpoint transect. The biotic data consisted of vegetation data, taken in plots along the transect line, by skipping one or more plots in the line, so along the transect line, there were plots with the same distance from one another (Kusmana 1997). There were 5 plots (50 m x 50 m) along the transect line. Within each plot, other subplots were made for measurement of different growth stages of plants, namely 1 m x1 m plot for seedlings, 5 m x 5 m plot for saplings, 10 m x 10 m plot for poles, and 20 m x 20 m for trees. The plants within the plots were then identified using local names with the help of a key informant who knew about the local names of the forest plants, while the identification of the scientific names was done using the website www.plantamor.com.

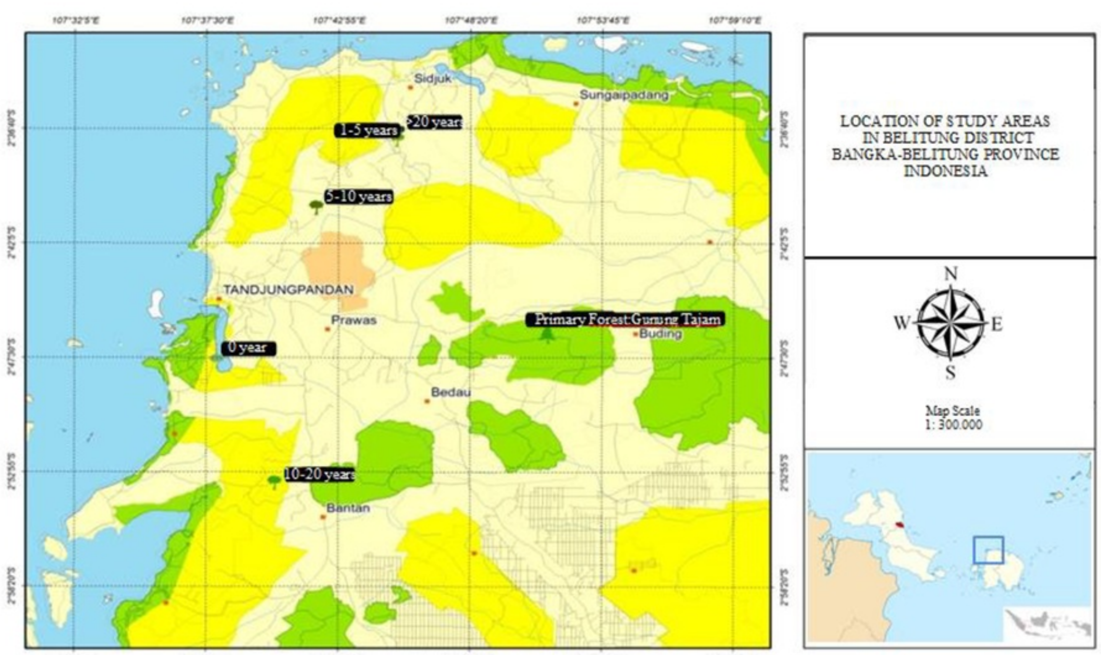

Figure 1. Location of study areas in Belitung District, Bangka-Belitung Province, Indonesia

Data analyses

Species composition of vegetation was analyzed by determining Importance Value Index for each species. Similarity Index was determined to analyze the similarity of vegetation composition among six areas. Shannon-Winner Index of general diversity (H'), Species Richness Index of Margalef (DMG), and Evenness Index (E) were determined to analyze the diversity of butterflies (Odum 1971).

RESULTS AND DISCUSSION

Results

In the study areas, there were 54 species of butterflies belonging to 38 genera and 4 families. The number of species and individuals were 2 and 4 in area I (0 year), 7 and 13 in area II (1-5 years) 14 and 26 in area III (5-10 years), 15 and 26 in area IV (10-20 years), 20 and 26 in area V (over 20 years) and 32 and 57 in area VI (primary forests) (Table 1).

Discussion

The diversity of butterflies in mined area which had not been revegetated

The diversity of butterfly species in the area which had not been revegetated was the lowest; only two species were found, namely *Ypthima horsfieldi* Moore and *Zizina otis* Fabricius (Table 1). The diversity of butterflies was low because the location did not support butterfly life, such as lack of vegetation as a source of food, lack of nectar-producing flowering plants and less suitable microclimate conditions for the life of butterflies. The land was left barren and filled with the spoil of tin mining. The grasses on the land grew naturally and were presumably eaten by *Y. horsfieldi* and *Z. otis* because, according to Peggie (2014), these butterflies feed on grasses.

The air temperature of this land was 34°C, relative humidity 67%, light intensity 883 lux, and wind speed 0.13 m/s. According to Susetya (2014), butterflies can be found at temperatures of 24-30^{0}C, air humidity not less than 71-80%, and according to Hermawanto et al. (2015) butterflies can be found on the light intensity of 664-889 lux. Therefore, the air temperature and relative humidity at the location did not support butterfly life, and the light intensity was quite high. Butterflies avoid habitat with high light intensity because they are easily dehydrated while flying (Sulistyani 2013). In addition, butterfly is a poikilotherm whose body temperature does not vary greatly with the environment; if the environment is too hot then its metabolism is disrupted.

The diversity of butterflies in post-mining lands that had been revegetated

The butterfly diversity in revegetated land was higher than that of unvegetated land (Table 1). The diversity of butterfly species in the revegetation field was 31 species belonging to 21 genera and 3 families. The highest species diversity was found in revegetation area over 20 years old, followed by that of 10-20 years old, 5-10 years old, 1-5 years old, and the lowest one was found in unrevegetated land.

Table 1. List of species and number of individuals of butterflies in each revegetation area

Species	Number of individuals in each study area					
	I	II	III	IV	V	VI
Papilionidae						
Chilasa paradoxa Linnaeus						1
Graphium agamemnon Linnaeus						2
Graphium evemon Fruhstorfer						1
Pieridae						
Catopsilia pyranthe Linnaeus					1	
Delias baracasa Semper						1
Eurema blanda Moore				1		
Eurema hecabe Moore		6	3	2		
Eurema sari Moore			1	2	1	1
Leptosia nina Fabricius				2		
Saletara liberia Butler						7
Nymphalidae						
Athyma nefte Moore						1
Charaxes borneensis Fruhstorfer						5
Charaxes durnfordi Distant						5
Cuphaery manthis Sulzer		1		1		1
Elymnias hypermnestra Fruhstorfer					2	
Elymnias panthera Fruhstorfer						1
Euploea core Moore				1		
Euploea mulciber Cramer				1	1	2
Faunis stomphax Westwood					1	
Hypolimnas bolina Linnaeus					1	1
Ideopsis juventa Fruhstorfer				1		
Lexias immaculata Snellen						1
Lexias pardalis Fruhstorfer						1
Melanitis leda Linnaeus					1	
Moduza procris Fruhstorfer						1
Mycalesis fusca C & R Felder					2	
Mycalesishors fieldi Moore		2	2	1	1	1
Mycalesis janardana Fruhstorfer			2			
Mycalesis mineus Fruhstorfer			1	1		1
Mycalesis perseus Butler				1	1	
Mycalesis visala Talbot & Corbet			1			
Neptis hylas Moore		1	1		3	2
Orsotriaena medus Butler		1	2	4	1	2
Parantica aspasia Fabricius						1
Prothoe franck Tsukada						1
Tanaecia cocytina Tsukada				1	2	
Tanaecia palguna Distant			1	2	1	3
Tanaecia pelea Snellen					2	
Ypthima horsfieldi Moore	3	1	2	5	1	
Lycaenidae						
Arhopala aedias C & R Felder						1
Cheritra freja Fruhstorfer					1	
Drupadia ravindra Staudinger						1
Drupadia theda Fruhstorfer						1
Eooxylides tharis Distant						1
Euchrysop scnejus Fabricius			1			
Flos anniella Hewitson			2			2
Lycaenopsis halandus H. Druce						1
Miletus biggsii Distant					1	
Nacaduba calauria Corbet						1
Nacaduba sanaya Corbet						1
Neocheritra amrita H.H. Druce					1	
Neomyrina nivea Godman & Salvin						5
Rapala suffusa Fabricius			1			
Zizina otis Fabricius	1	1	6		1	
Number of species	2	7	14	15	20	32
Number of individuals	4	13	26	26	26	57

Note: Area I: revegetation age 0 year, area II: revegetation age 1-5 years, area III: revegetation 5-10 years, area IV: revegetation age 10-20 years, area V: revegetation age more than 20 years, and area VI: primary forest

Table 2. Shannon-Wiener Index (H '), Species Richness Index of Margalef (DMG), and Evenness Index (E) of butterflies at each revegetation area

Parameter	Study area					
	I	II	III	IV	V	VI
Shannon-Winner Index (H')	0.56	1.47	2.45	2.52	2.96	3.20
Species Richness Index of Margalef (DMG)	1.27	6.61	13.69	14.69	20.69	30.74
Evenness Index (E)	0.40	0.57	0.75	0.77	0.90	0.80

Note: Area I: revegetation age 0 year, area II: revegetation age 1-5 years, area III: revegetation age 5-10 years, area IV: revegetation age 10-20 years, area V: revegetation age more than 20 years, and area VI: primary forest

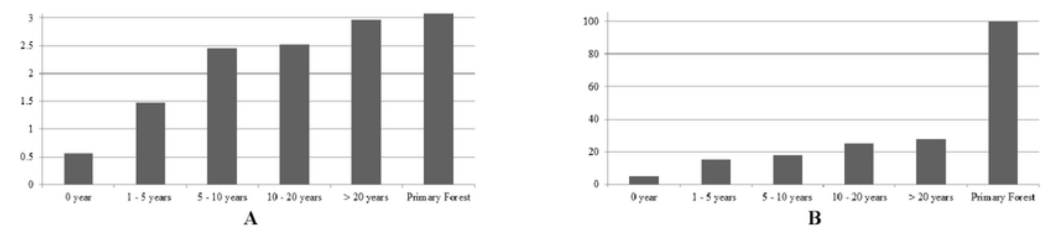

Figure 2. Shannon-Wiener Index (A) and similarity of vegetation (B) on revegetation land and primary forest

Table 3. Importance value index of each species in each study area

Study area	Plot	Family	Scientific name	Local name	IVI (%)
I	Herb	Poaceae	Unidentified A		62.83
	Shrub	Melastomataceae	*Melastoma malabatricum* Linnaeus	Kedebik	200.00
	Herb	Poaceae	Unidentified A		60.63
II	Shrub	Dilleniaceae	*Dillenia indica* Linnaeus	Simpur	71.42
	Pole	Fabaceae	*Accacia mangium* Willd	Akasia	300.00
	Tree	Fabaceae	*Acacia mangium* Willd	Akasia	300.00
	Herb	Poaceae	*Imperatacylindrica*Raeusch	Alang-alang	62.74
III	Sapling	Fabaceae	*Accacia mangium* Willd	Akasia	75.48
	Pole	Fabaceae	*Accacia mangium* Willd	Akasia	300.00
	Tree	Fabaceae	*Accacia mangium* Willd	Akasia	300.00
	Herb	Poaceae	Unidentified A		100.13
IV	Sapling	Fabaceae	*Accacia mangium* Willd	Akasia	109.71
	Pole	Fabaceae	*Accacia mangium* Willd	Akasia	228.01
	Tree	Fabaceae	*Accacia mangium* Willd	Akasia	232.93
	Herb	Poaceae	Unidentified A		300.00
V	Sapling	Dilleniaceae	*Dillenia indica* Linnaeus	Simpur	142.50
	Pole	Dilleniaceae	*Dillenia indica* Linnaeus	Simpur	300.00
	Tree	Fabaceae	*Accacia mangium* Willd	Akasia	92.15
	Herb	Poaceae	Unidentified A		
VI	Sapling	Theaceae	*Schima wallichii* DC. Korth	Seruk	8.47
	Pole	Myrtaceae	*Tristaniopsis* sp.	Pelawan	70.47
	Tree	Myrtaceae	*Tristaniopsis* sp.	Pelawan	47.56

Note: IVI : importance value index

Table 4. The air temperature, air relative humidity, light intensity, and wind velocity at each study area

Abiotic factors	Unit	Study area					
		I	II	III	IV	V	VI
Air temperature	^{0}C	34±1.20	36±0.40	34±3.40	28±0.60	27±0.50	26±0.40
Air humidity	%	67±1.00	69±0.70	74±1.10	85±2.10	86±1.50	89±0.30
Light intensity	Lux	883±25.00	685±43.00	371±35.00	94±39.00	62±32.00	26±4.00
Wind velocity	m/s	0.13±0.03	0.03±0.014	0.03±0.006	0.03±0.008	0.07±0.007	0.07±0.001

Note: *) the average value of measurement results at three points in each transect line in the morning (08.30 WIB) and afternoon (15.00 WIB) for three days of observation

The land had been revegetated using the *Acacia mangium* Willd (Table 3) which is thought to be the butterfly's food. According to Busnia (2006), the presence of a species of butterfly in a given place is determined by the availability of plants that become hosts of the caterpillar. The butterfly diversity in revegetated land more than 20 years old was 21 species, the highest among the revegetated lands (Table 1), presumably due to the high plant diversity in this land.

The older vegetation contained more diverse plants. In this land, not only *A. mangium,* the planted species, was found, but also *Tristaniopsis* sp. (*pelawan*), *Gordonia* sp. (*pelempang*), *Rhodamnia* sp. (*jemang*), *Arthrophyllum* sp. (*julokantu*), and *Calophyllum* sp. (*betor*). These trees formed a tight canopy. Some of the butterflies found in this land are butterflies with wide wings and fly slowly, such as *Elymnias hypermnestra* Fruhstorfer, *Euploea mulciber* Cramer, *Faunis stomphax* Westwood, *Hypolimnas bolina* Linnaeus, *Melanes leda* Linnaeus, *Tanaecia cocytina* Tsukada, *Tanaecia palguna* Distant, and *Tanaecia pelea* Snellen. Some of these butterflies were found only in over 20-year-old vegetation, presumably because the butterflies fly among the trees to protect themselves from direct sunlight. According to Hammer et al. (2003), butterflies have different preferences for light intensity. Some species of butterflies prefer a shaded area to reduce the evaporation of body fluids.

The values of Shannon-Wiener diversity index, species richness, and evenness in the over 20-year-old vegetation were 2.96, 20.69 and 0.9 (Table 2), higher than those of the other revegetation sites. The high evenness index means that there was no dominance by one or more species. The revegetation land area over 20 years had air temperature of 27ºC, relative humidity 86%, light intensity 39 lux, and wind speed 0.07 m/s (Table 4).

The diversity of butterflies in the forest of Gunung Tajam

The diversity of butterflies in the forests of Gunung Tajam, 31 species, was the highest among all the study areas (Table 1). The values of Shannon-Wiener diversity index, species richness and evenness were 3.2, 30.74 and 0.8 (Table 2), which means that the level of variety and richness of the species was higher than those of the revegetated areas, whereas the uneven distribution of butterflies means that there was dominance by one or more species. The high diversity of butterflies is thought to be due to the higher diversity of plants in Gunung Tajam forests that can serve as host plants and food source for the butterflies. According to Saputra et al. (2013), the high diversity of butterflies in a habitat can be caused the high plant diversity in the habitat, so the food for butterflies is also more available. Food is the most important factor in determining the spread and life cycle of butterflies. In addition, in the area of Gunung Tajam forest many nectar-producing flowering plants were found, such as *Dillenia indica* Linnaeus (*simpur*), *Pterocarpus indicus* Willd (*angsana*), and *Ficus* sp. (*beringin*). According to Schultz and Dlugosch (1998), the presence of butterfly species depends on the availability of the larva's host plant and also the source of the nectar for the adult butterflies.

The butterflies of the family *Papilionidae* were found only in the area of Gunung Tajam, because the plants which the family *Papilionidae* feed on were found only in the forest of Gunung Tajam. According to Maulidia (2010), the butterflies belonging to the *Papilionidae* are largely monophage or have only one host to support their lives, so their presence is highly dependent on the presence of the host plants. According to Peggie (2014), butterflies of the family *Papilionidae* feed on the plants belonging to the families *Annonaceae*, *Lauraceae*, and *Piperaceae* which were found only in the forests of Gunung Tajam.

The correlation between the diversity of butterflies and the success of revegetation

According to Rohyani (2012) forest are considered stable as a reference in evaluating the success of revegetation because forest has characteristics or structures that are relatively stable to carry out their functions (production, protection, and conservation). The community similarity index between the vegetation in the former tin mining areas and Gunung Tajam forest increased with the increasing age of vegetation. At 0 year or unrevegetated area, the similarity of vegetation with forest area was only 5%, but at 1-5 years it increased to 15%, at 5-10 years 18%, at 10-20 years 25%, and at more than 20 years 28%. This indicated that there was development of the vegetation in the former tin mining land from year to year, although the composition of vegetation had not matched that of the Gunung Tajam forest.

The increasing similarity of vegetation composition in revegetated land with that of forest along with the increasing age of vegetation was correlated with the increasing diversity of butterflies (Figure 2). According to Rahayu (2016), the community of insect increased with the increasing age reclamation and closer to the community of insect in forest. The index of Shannon-Wiener (H ') diversity of butterflies was 0.56 in unvegetated land, then it increased to 1.47, 2.45, 2.52 and finally 2.96 when the age of the vegetation increased from 1-5 years, to 5-10 years, to 10-20 years, and to more than 20 years respectively. The index of butterfly diversity in the forest was the highest, i.e., 3.2. The diversity of butterflies increases with the age vegetation, because the structure and composition of vegetation become more complex and closer to those of natural forest. We can conclude that the butterfly diversity can be proposed as a success indicator of former tin mining land revegetation.

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Although any errors are our own and should not tarnish the reputations of these esteemed persons.

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