Influence of understorey diversity on wildlife at the coal mining reclamation area in South Kalimantan, Indonesia

**YUSANTO NUGROHO[1], SUPANDI[2], SUYANTO[1], JERIELS MATATULA[3],
PANDU YUDHA ADI PUTRA WIRABUANA[4,♥]**

[1]Faculty of Forestry, Universitas Lambung Mangkurat. Jl. Ahmad Yani Km 36, Banjarbaru 70722, South Kalimantan, Indonesia
[2]PT Borneo Indobara. Jl. Propinsi Km 180, Angsana, Tanah Bumbu 72275, South Kalimantan, Indonesia
[3]Forestry Field Program, Politeknik Pertanian Negeri Kupang. Jl. Prof. Johanes, Lasiana, Kupang 85228, East Nusa Tenggara, Indonesia
[4]Faculty of Forestry, Universitas Gadjah Mada. Jl. Agro No. 1. Bulaksumur, Sleman 55281, Yogyakarta, Indonesia
Telp./Fax. +62-274-548815, ♥email: pandu.yudha.a.p@ugm.ac.id

Abstract. *Nugroho Y, Supandi, Suyanto, Matatula J, Wirabuana PYAP. 2021. Influence of understorey diversity on wildlife at the coal mining reclamation area in South Kalimantan, Indonesia. Biodiversitas 22: 3736-3742.* The existence of understorey at the coal mining reclamation area provides an important contribution to improve the environmental quality, especially the wildlife presence. Therefore, this study aims to determine the influence of understorey diversity on the wildlife at the coal mining reclamation area managed by the PT Borneo Indobara, South Kalimantan. This study used an ecological survey conducted in three reclamation areas classified based on the dominant species supporting the process, namely *Paraserianthes falcataria (L-1), Anthocephalus cadamba (L-2)*, and a mixture of both species (L-3). The data were collected in two observation periods, namely August 2019 and August 2020. The results showed that at the first observation, ten families of understorey were observed from the survey and the highest diversity was recorded in L-2 (H'=1.71), followed by L-1 (H'=1.54), and L-3 (H'=1.27). Meanwhile, the wildlife in the first periods was only 6 species consisting of 3 birds, 2 reptiles, and 1 mammal. The number of species from every site was relatively equal at the first observation. In the second observation, the diversity of understorey considerably increased with approximately 22 families from the inventory. The highest understorey diversity in this observation was recorded in L-1 (H'=3.30), L-2 (H'=3.05), and L-3 (H'=3.04). Also, the higher understorey diversity was followed by the higher wildlife with 29 species, which consists of 26 birds, 2 reptiles, and 1 mammal. The highest appearance of bird species was in the L-1 with approximately 19 species, while the number of birds in L-2 and L-3 was relatively similar with approximately 15 species. Based on these results, the understorey diversity significantly contributes to improving the wildlife diversity at the coal mining reclamation area, primarily from the bird species.

Keywords: Birds, ecological survey, environmental quality, mammals, post-mining, reptiles

INTRODUCTION

Coal mining is activities changing the landscape due to the use of an open pit in mining operations commonly referred to as open-cut mining. This method is carried out to excavate mineral deposits in a rock, which is suitable for horizontal ore bodies for high production at low costs (Marinin et al. 2021). Meanwhile, the open-pit mining system is carried out by clearing land, removing topsoil and rocks that cover the coal, and taking the coal using excavators and trucks (Setiawan et al. 2021). Therefore, coal mining activities influence changes in vegetation, soil structure, and geology, decrease the quality, and change the soil hydrology (Dejun et al. 2016). To anticipate these problems, successful land reclamation is required after excavation of coal deposits, which involves closing the mining hole and returning topsoil to cover the rock for revegetation activities. These reclamation and revegetation activities restore plant communities and ecosystems around mining to reduce the effects of mining operations on the environment (Buta et al. 2019).

Post-mining land reclamation activities were implemented at PT Borneo Indobara using fast-growing species such as *Paraserianthes falcataria* and *Antocephalus cadamba* with the addition of *Pterocarpus indicus*, *Mangifera indica*, *Swietenia macrophylla*, and *Acacia mangium* plants that grow naturally. Furthermore, understorey such as grass, ferns, and herbs are often overgrown, especially *Acacia mangium*, which grows naturally. Meanwhile, this understorey is considered a weed that disturbs the main crop, and the cleaning is sometimes carried out. The ecological clearing of land under the stands has an impact on decrease in the diversity of understorey which is important for the soil health in the reclamation area. Moreover, cleaning of understorey under tree stands in the reclamation area reduces the presence of fauna. Sasaki et al. (2015) stated that the changes in plant habitat in mining areas affect wildlife populations. A previous study by Partasasmita et al. (2017) stated that birds' use of vegetation space is divided into the lower stratum in the form of understorey plants and the upper in the form of tree crowns. Furthermore, Bradfer-Lawrence et al. (2018) stated that various species of birds like habitats in stratum D and E are dominated by understorey species. Therefore, the presence of fauna in the reclamation area is an indicator of land recovery after coal mining activities.

The understorey plants in ecosystems play a very important role, namely a source of nutrients, germplasm, food for animals, and preventing erosion (Mestre et al. 2017). Hence, a study is required to determine the important role of understorey for the wildlife in the reclamation area, evaluate the level of animals, and analyze the presence of understorey after cleaning for one month and a year. This study aims to analyze the effect of understorey presence and diversity on the wildlife level of the birds, reptiles, and mammals in the reclamation area after coal mining.

MATERIALS AND METHODS

Study area

The site was located in the reclamation area of PT Borneo Indobara where the coal mining operation is carried out. This study was implemented in 14 months at different stages: field preparation, understorey cleaning, data collection, and analysis. Meanwhile, the observation was carried out in 2 stages, with the first in August 2019 and the second in 2020. The geographical coordinates of location are E115°54'38" 115°39'00" and S3°35'30" 3°36'30". The reclamation area is with 2 main species of plants, namely *Paraserianthes falcataria* and *Antocephalus cadamba* which were established in 2013. The site is administratively situated in Sungai Loban District, Tanah Bumbu Regency, South Kalimantan Province (Figure 1). The field survey was carried out in three sites of reclamations classified based on the dominant vegetation species (Table 1).

Procedures

This study was conducted in a reclamation area with plant species *Paraserianthes falcataria* and *Antocephalus cadamba*, and the two types of data collected include the presence and diversity of understorey and wildlife. The treatment was carried out by cleaning the understorey in the reclamation area in a manual and chemical combination, while land clearing was conducted once and observations were made subsequently. Moreover, field observations were conducted in two stages, where the first was after one month and the second after one year of understorey cleaning activities. During this one year, the understorey was allowed to grow and develop without any disturbance. At each stage of observation, identification of the presence of understorey species and wildlife species, such as birds, reptiles, and mammals was carried out. This treatment was carried out to identify the presence and diversity of understorey together with wildlife species after land clearing activities.

Table 1. Location of ecological survey for monitoring understorey diversity and wildlife presence at the coal mining reclamation area

Site	Species	Symbol	Planting year
1	*Paraserianthe falcataria*	L-1	2013
2	*Antocephalus cadamba*	L-2	2013
3	Mixed species (*P. falcataria × A. cadamba*)	L-3	2013
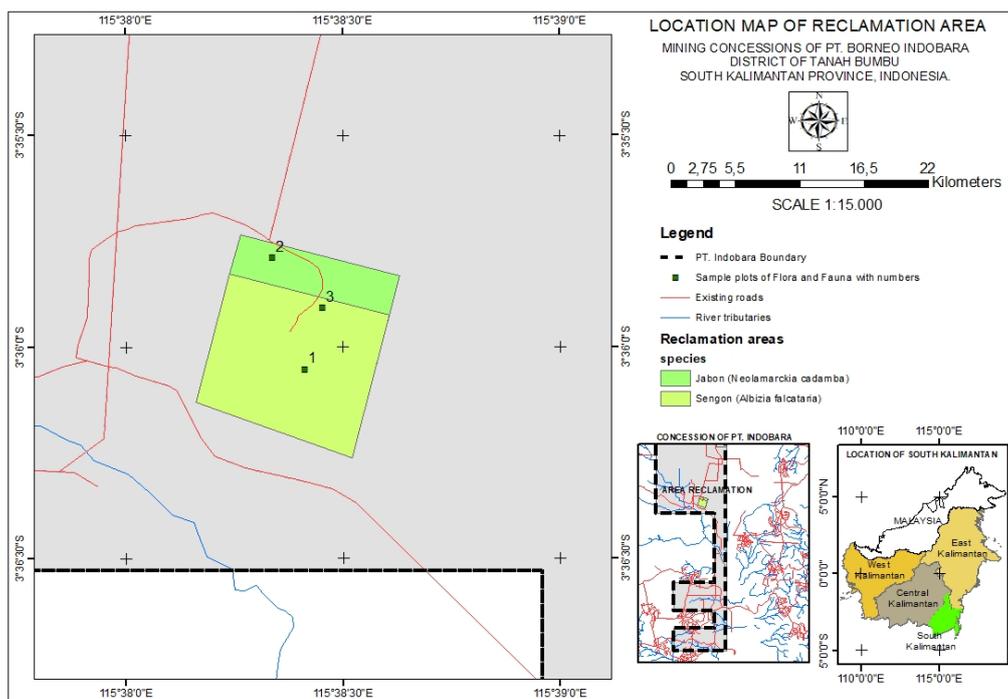
Figure 1. The study site of coal mining reclamation area in the PT Borneo Indobara. The number indicated the position of sampling location

Understorey data were obtained using the transect-line method up to six measuring plots at each observation point. The measuring plot size was 2×2 m and each was spaced at an interval of one plot to achieve a path length of 24 m. Meanwhile, the observation data for understorey flora include species presence, relative frequency and density, important value index, and diversity of understorey species. The understorey recorded were grasses, herbs, ferns, and woody plant seedlings and were included in the observation plot.

Wildlife observation data were obtained at the understorey point using the sampling method with a circle radius of 25 m, while each point data were recorded in the morning from 07.00 to 11.00 and the afternoon at 14.00-18.00. The data recorded include the types and the number of individual wildlife species encountered, consisting of bird species (bird fauna), mammals, and reptiles. The observed wildlife in form of birds was identified using MacKinnon et al. (2010). Furthermore, wildlife in form of mammals was identified by Francis (2013) or Payne et al. (2000), and those in form of reptiles were identified using Das (2010).

Data analysis

Analysis of understorey data using the formula to calculate the Important Value Index according to Lü et al. (2011), that is:

Relative density = (Density of a species)/(Density of all species)x 100 (1)

Relative frequency = (Freq. of a species)/(Freq. of all species)x 100 (2)

Important value index = Relative density + Relative frequency (3)

Importance Value Index (IVI) for understorey plants ranges from 0-200. If the value is close to 200, then a species has a higher ecological level in a community and if it is close to 0, its ecological control is lower in the community. The diversity index is calculated using the formula by (Naidu and Kumar 2016), the formulation is as follows:

H' =-(pi) ln (pi) where pi = ni/N (4)

where H' was the Diversity index, ni indicates an abundance of every species, and N was the total sample observed. The greater H' of a community indicates that the community is getting better. The value of H' equal to 0 can occur if there is only one species in one sample and maximum H if all species have the same number of individuals and this indicates a perfectly distributed abundance. The criteria for the diversity index based on Shannon-Wiener was expressed below (Djufri et al. 2016):

The analysis of IVI was only applied for understorey vegetation while the determination of the Shannon-Wiener Index was done for understorey and wildlife.

RESULTS AND DISCUSSION

Understorey diversity

The results of the first stage of understorey identification showed that the presence of understorey species is 11 from 10 families (Table 3). These species naturally appear after land clearing treatment and are categorized as pioneer plants. Based on the calculation of the understorey at site L-1, there were six species with a diversity of 1.54 according to the Shannon-Wiener index having low criteria, while *Melastoma candidum* and *Imperata cylindrica* have the highest important value index. In the site observation of L-2, there were seven understorey species from six families with a diversity of 1.71 having a low classification, while *I. cylindrica* and *Blechnum orientale* have an index value of the highest importance. Furthermore, in the site observation L-3, there were four species of understorey from four families with a diversity of 1.27 having a low classification, while *I. cylindrica* and *Pueraria javanica* have the highest importance value index.

Table 2. Criteria of diversity index based on Shannon-Wiener

H' value	Descriptions
< 1	Low diversity
1-3	Moderate diversity
>3	High diversity

Table 3. Presence and diversity of understorey species on the reclamation area after one month of slashing

Species	Family	L1 AP	L1 IVI	L2 AP	L2 IVI	L3 AP	L3 IVI
Ageratum conyzoides	Asteraceae	✓	7.3	✓	6.5		
Blechnum orientale	Blechnaceaea			✓	43.5		
Brachiaria mutica	Gramineae			✓	13.0		
Imperata cylindrica	Poaceae	✓	48.5	✓	71.2	✓	93.5
Macroptilium lathyroides	Palpilionaceae			✓	17.8		
Melastoma candidum	Melastomataceae	✓	79.5				
Passiflora foetida	Passifloraceae					✓	26.8
Pueraria javanica	Fabaceae	✓	14.6			✓	41.0
Pueraria phaseoloides	Palpilionaceae	✓	20.1	✓	26.8		
Scleria sp.	Cyperaceae	✓	30.1			✓	38.7
Scoparia dulcis	Plantaginaceae			✓	21.2		
H' of each observation site			**1.54**		**1.71**		**1.27**
H' of entire reclamation site				**2.09**			

Note: AP (appearance); IVI (important value index); the checklist (✓) indicated the species has been found at the observation

Table 4. Presence and diversity of understorey species observed in the reclamation area one year after understorey clearing

Species	Family	L1 AP	L1 IVI	L2 AP	L2 IVI	L3 AP	L3 IVI
Abelmoschus moschatus	Malvaceae	✓	3.1				
Acacia mangium	Fabaceae	✓	6.7			✓	13.0
Ageratum conyzoides	Asteraceae	✓	15.1	✓	16	✓	13.5
Anacardium ocidentale	Anacardiaceae			✓	1		
Arachis pintoi	Fabaceae	✓	4.1	✓	7	✓	7.7
Asystasia gangetica	Acanthaceae	✓	7.0	✓	7	✓	8.6
Bauhinia kockiana	Fabaceae	✓	6.1	✓	7	✓	6.4
Blechnum orientale	Blechnaceae	✓	5.5			✓	8.4
Boehmeria nivea	Urticaceae	✓	2.6	✓	5	✓	9.3
Brachiria mutica	Graminaeae	✓	6.5	✓	10		
Byttneria maingayi	Malvaceae			✓	7		
Calopogium mucunoides	Leguminaceae	✓	10.2	✓	11	✓	14.1
Cayratia trifolia	Vitaceae	✓	4.9			✓	6.2
Centrosema molle	Fabaceae	✓	4.9			✓	7.5
Chromolaena odorata,	Asteraceae	✓	6.5	✓	8	✓	11.9
Cyperus eragrostis	Cyperaceae			✓	6		
Cyrtococcum patens	Poaceae	✓	7.7				
Dicranopteris linearis	Gleicheniaceae	✓	6.7	✓	7		
Fimbristylis littoralis	Cyperaceae	✓	7.1	✓	8		
Hyptis capitata	Lamiaceae	✓	7.0	✓	7	✓	7.7
Imperata cylindrica	Poaceae	✓	9.0	✓	15	✓	13.5
Ipomea cordatriloba	Convolvulaceae			✓	6		
Macaranga tanarius	Euphorbiaceae	✓	6.0			✓	5.5
Mangifera indica	Anacardiaceae	✓	5.6	✓	6		
Melastoma candidum	Melastomataceae	✓	16.5	✓	18	✓	15.2
Mimosa pudica	Fabaceae	✓	6.0	✓	7	✓	8.6
Passiflora foetida	Passifloraceae	✓	7.2	✓	8	✓	6.4
Phyllanthus reticulatus	Phyllanthaceae	✓	5.5	✓	7	✓	8.4
Phyllanthus debilis	Phyllanthaceae	✓	4.2			✓	8.6
Pterocarpus indicus	Fabaceae					✓	4.6
Rhynchospora corymbosa	Cyperaceae	✓	3.9				
Scleria sp.	Cyperaceae	✓	13.6	✓	13	✓	8.8
Swietenia macrophylla	Meliaceae			✓	8		
Syzygium aqueum	Myrtaceae	✓	3.4				
Uncaria cordata	Rubiaceae	✓	4.5	✓	6	✓	6.0
Vitex pinnata	Lamiaceae	✓	3.3				
H' of each observation site		**3.30**		**3.09**		**3.04**	
H' of entire reclamation site				**3.35**			

Note: AP (appearance); IVI (important value index); the checklist (✓) indicated the species has been found at the observation

Imperata cylindrica has fast adaptability to grow as a pioneer plant in reclamation areas where land clearing is carried out. This is because the roots of the reeds in form of rhizomes under the ground remain alive even though the top of the plant is damaged and fired (Soendjoto et al. 2014). This plant grows quickly in marginal soil conditions which makes it to be considered as weeds when shaded by other species with denser canopy densities (Kone et al. 2013). In addition, the *M. candidum* also has high adaptability because of its resistance to acid soils and ability to absorb aluminum toxins and the height is approximately 0.5-4 meters (Watanabe et al. 2005). Therefore, an increase in *M. candidum* suppresses the growth rate of *I. cylindrica* because the canopy is higher and denser.

The species diversity index in all plots in the reclamation area after one month of understorey cleaning showed a diversity index of 2.09 with a moderate level. Meanwhile, the species of understorey present after the land clearing are used to develop a land precondition to improve soil properties in the post-coal mining reclamation area. However, not all plants were able to grow and adapt to marginal soils after coal mining because the soil in the reclamation area has many limiting factors such as low porosity and high density (Noviyanto et al. 2017). Therefore, the presence of understorey species is considered an adaptive species to post-coal mining land.

The results of understorey identification after one year of understorey cleaning (Table 4) showed an increase in the number of individual presences and the index of species diversity in the reclamation area after it was allowed to grow and develop. Furthermore, the results showed that there were 36 species of understorey from 22 families. During this period, understorey was left undisturbed and there was an increase in the presence of understorey of approximately 327%. Based on the calculation of the important value and the diversity index at location 1, there were 30 understorey species from 22 families with a

diversity of 3.15 having a high classification. At location 2, there were 24 species from 18 families with a diversity index of 2.91 and a moderate classification. Furthermore, at location 3, there were 22 understorey species from 15 families with a diversity index of 2.93 and a medium classification. Therefore, the species diversity index in all plots in the reclamation area during observations of one year after slashing showed a value of 3.35 with a high classification.

Furthermore, *M. candidum* at all observation locations has the highest IVI, which showed that these species are capable of becoming a pioneer with high adaptation in post-coal mining areas. Meanwhile, *I. cylindrica* which initially had an IVI similar to the *M. candidum* was observed one year after cleaning and shifted by other species, such as *Ageratum conyzoides*. A previous study by Komara et al. (2016) showed that *A. conyzoides* observed 16 years after reclamation had an important value index of the third order of 29 species in the post-coal mining reclamation area in East Kalimantan. Meanwhile, several species of the understorey in form of woody plant seedlings in the reclamation area that grow and develop naturally include *Macaranga tanarius*, *Syzygium aqueum,* and *Vitex pinnata*. Also, several woody plants in the seedling phase are included in the observation plot and are present due to planting, including *Mangifera indica*, *Pterocarpus indicus,* and *Swietenia macrophylla*.

Out of the 36 species of understorey presented in the reclamation area after 1 year of cleaning activities, 15 were always present at the three observation locations. Meanwhile, one of these species is *Chromolaena odorata*, which grows on marginal and fertile land (Hamdani et al. 2017). The growth of this plant on land produces litter that contains a lot of nutrients due to its suitability as raw material for making compost. It also suppresses the growth of *I. cylindrica* (Juniarti 2017). Therefore, soil improvement with the presence of understorey and higher vegetation improves the function of complex ecosystems, from microorganisms to macroorganisms (Pan et al. 2018).

The species of *M. candidum* which dominates the important values in all observation locations produces several flowers as a source of food for various species of insects and flower-eating birds. Moreover, the variety of understorey that produces flowers attracts wild animals such as birds, mammals, reptiles, amphibians, and insects to migrate to the reclamation area in search of food sources.

Wildlife presence

The identified wildlife includes birds, reptiles, and mammals. The identification of the bird fauna (Table 5) showed that there is a change in its presence and diversity which is significantly high within an increase in the understorey. The classification of species presence and diversity index in the observation of one month after cleaning activities were 3 species with an index of 0.90 (H'=low), while 26 were observed one year after cleaning activities with an index of 3.35 (H'=high). According to

Casas et al. (2016), the presence and diversity of birds are strongly influenced by the composition and structure of vegetation. Similarly, changes in the structure of vegetation including understorey, saplings, poles, and trees affect the presence of animals. The existence of food sources and habitat suitability attract animals' migration to the reclamation area until the reclaimed plants become a climax. A previous study (Boer 2009) showed that in the area of land reclamation and rehabilitation, the presence of bird fauna changes continuously towards the common composition in natural forests.

Birds are the most common indicator of animals and are often used to detect and respond quickly to environmental changes (Wong and Candolin 2015). During observation after the understorey cleaning activities, the habitat of birds and other animals changes, which leads to migration to an undisturbed area. According to (Liang et al. 2021), the community of bird species declines and migrates due to a decrease in suitable habitat. Meanwhile, habitat is improved through the process of succession of the understorey in the reclamation area by allowing it to grow and develop for one year without disturbance. Also, the presence of understorey increases to show high diversity, which makes the bird community reappear until it reaches a high classification index. A previous study (Swab et al. 2017) showed that the initial success of reclamation areas in form of grass contributed to the increase in songbird populations. The development of birds and other animals evolves gradually with the succession of plants. Therefore, the use of mining land reclamation methods to create biodiversity determines the rate of presence and composition of bird species (Al-Reza et al. 2016)

The bird fauna in the reclamation area after one year of understorey cleaning activities were approximately 7.70% and categorized as water birds, such as *Todiramphus Chloris*, *Actitis hypoleucos.* Out of the 92.30% of the water birds, as described by Ducks Unlimited New Zealand (2017), there are 8 families on the west coast and 34 in the world, and 33 as described by Wetlands International (2020). The presence of waterbirds in the reclamation area is due to the availability of former mining pit water sources close to the area.

The wildlife is not only dependent on plants, but animals also influence the presence and condition of plants because vegetation requires birds, mammals, or other animals for pollination (Ratto et al. 2018). Meanwhile, many species of birds often forage and make nests in the stratum of understorey such as *Orthotomus ruficeps, Prinia flaviventris, Centropus bengalensis, Rhipidura javanica, Lanius schach, Lonchura punctulata,* etc. The diversity of understorey and high-density isi a good habitat for various animals to grow and develop (Valladares et al. 2016). Birds or small animals, such as *Orthotomus ruficeps* and *Prinia flaviventris*, hide in thickets of leaves/shrubs from predators. Similarly, *Centropus bengalensis* likes short trees with thick understorey for foraging, playing, sheltering, and nesting (Rajpar and Zakaria 2011).

Table 5. Presence and diversity of bird fauna in the reclamation area during observations one month and one year after understorey cleaning

Species	Family	First observation			Second observation		
		L-1	L-2	L-3	L-1	L-2	L-3
Gerygone sulphurea	Acanthizidae				✓		✓
Aegithina tiphia	Aegithinidae				✓		✓
Todiramphus chloris	Alcedinidae				✓		
Artamus leucoryn	Artamidae	✓					✓
Caprimulgus affinis	Caprimulgidae				✓		
Orthotomus ruficeps	Cisticolidae				✓	✓	✓
Prinia flaviventris	Cisticolidae				✓	✓	✓
Geopelia striata	Columbidae				✓		✓
Spilopelia chinensis	Columbidae	✓	✓	✓	✓		
Centropus bengalensis	Cuculidae						✓
Dicaeum trochileum	Dicaeidae				✓	✓	
Dicaeum trigonostigma	Dicaeidae				✓		
Lonchura punctulata	Estrildidae				✓	✓	✓
Hirundinidae	Estrildidae						
Hirundo rustica	Estrildidae					✓	✓
Hirundo tahitica	Estrildidae				✓		✓
Lanius schach	Laniidae						✓
Meropidae	Laniidae						
Merops viridis	Laniidae					✓	✓
Nectariniidae	Laniidae						
Anthreptes malacensis	Laniidae				✓	✓	
Cinnyris jugularis	Laniidae					✓	
Dendrocopos moluccensis	Picidae				✓	✓	✓
Pycnonotidae	Picidae						
Pycnonotus aurigaster	Picidae				✓	✓	✓
Pycnonotus goiavier	Picidae	✓	✓	✓	✓	✓	
Rhipiduridae	Picidae						
Rhipidura javanica	Picidae				✓	✓	
Actitis hypoleucos	Scolopacidae						✓
Sturnidae	Scolopacidae						
Acridotheres javanicus	Scolopacidae				✓	✓	✓
Vangidae	Scolopacidae						
Hemipus hirundinaceus	Scolopacidae				✓	✓	✓
H' of each observation site		**0.69**	**0.64**	**0.64**	**2.90**	**2.69**	**2.77**
H' of entire reclamation site			**0.90**			**3.17**	

Note: the checklist (✓) indicated the species has been found at the observation

Table 6. Presence and diversity of reptiles and mammal fauna in the reclamation area during observations one month and one year after cleaning the understory

Species	Family	First observation	Second observation
Bronchocela jubata	Agamidae	✓	✓
Eutropis multifasciata	Scincidae	✓	✓
Varanus salvator	Varanidae		✓
Callosciurus notatus	Sciuridae	✓	
H' of entire reclamation site		1.10	1.10

Note: the checklist (✓) indicated the species has been found at the observation

Clean puddles are a habitat for animals to breed and also a source of food. Hence, the pool at the reclamation area is a place for animals to drink and find food, especially the waterbird *Todiramphus chloris*. In a puddle, dragonfly larvae develop, and after adulthood are food for *Merops viridis* and other insectivore species consuming flying insects (Arbeiter et al. 2014).

There are three species of non-bird fauna in the reclamation area as shown by the observation of one month after the understorey cleaning activities, namely *Eutropis multifasciata*, *Bronchocela jubata*, and *Callosciurus notatus*. Meanwhile, one year after the understorey cleaning, *E. multifasciata*, *B. jubata,* and *Varanus salvator* were discovered (Table 6).

The non-bird fauna species were identified as 1 species of mammal, namely *C. notatus*, and 3 species of reptiles, namely *B. jubata, E. multifasciata,* and *V. salvator*. They were obtained by the direct encounter. Meanwhile, the recovery of reptiles and mammals species in the reclamation land was slower than the avian fauna species. The factor of stand density and the availability of food sources significantly influenced the encounter of this mammal species. In the rehabilitated ex-coal mining area with a plant age of up to 10 years in a dense understorey condition, 15 species of mammals were discovered (Soendjoto et al. 2015). Hence, establishing a micro-climate under the stands and suitable atmosphere with a variety of plants as a source of food is required for animals

to find food, rest, play, hide from predators, sing, and breed.

Based on these results, the increase in the diversity of understorey in the reclamation area attracts the presence of birds fauna. The development of understorey and woody plants to resemble natural forest habitats makes birds, reptiles, and mammal fauna migrate to the reclamation area. Therefore, understorey provides a place for animals to rest, hide, shelter, nest, find food, make sounds, and breed.

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