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Research Article

The Diversity of Scarabaeid Beetles (Scarabaeidae: Coleoptera) in The Lowland Rainforest Ecosystem of Sorong Nature Tourism Park, West Papua, Indonesia

La Ode Fitradiansyah[1], Tri Atmowidi[2]*, Windra Priawandiputra[2], Sih Kahono[3]
1)Student of Animal Biosciences Study Program, Graduate School, IPB University
2)Department of Biology, Faculty of Mathematics and Natural Sciences, IPB University, Campus Dramaga, Bogor 16680
3)Research Centre for Applied Zoology, National Research and Innovation Agency (BRIN), Cibinong 16912, Indonesia
* Corresponding author, email: atmowidi@apps.ipb.ac.id

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ABSTRACT
Scarabaeid beetles have an essential role in forest ecosystems, such as nutrient recycling, seed dispersal, forest regeneration, controlling parasite populations, and reducing carbon emissions. This study aims to analyse the diversity of scarabaeid beetles in the lowland rainforest ecosystem of Sorong Nature Tourism Park (SNTP), West Papua, Indonesia. The purposive sampling method was used to determine the study sites in three habitat types, i.e., rehabilitation zone, conservation zone, and protection zone. Collection of beetles were conducted by baited dung traps (type A, B, and C), light trap, and active sampling. The baits, i.e., cow and human excrements were used and was replaced every 24 hours (68 repetitions for 68 days) in each habitat. Results showed a total of 30 individuals belonging to 13 species of scarabaeid beetles were collected. *Onthophagus* has a highest species richness (5 species) compared to *Aphodius* sp., *Anomala* sp., and *Adoretus* sp. (1 species). The protection zone has a highest diversity index (H'=2.09), followed by conservation zone (H'=2) and rehabilitation zone (H'=0.5). Based on trap type, dung trap collected the most beetle species (9 species), followed by light trap (6 species) and active sampling (2 species). Pearson correlation analysis showed soil pH significantly correlated with beetle abundance. This study was the first report of scarabaeid beetles in West Papua, Indonesia.

INTRODUCTION
Scarabaeid beetles (Scarabaieidae: Coleoptera) have various colours, from brown and black to bright-metallic colour, body size from 1.5 to 160 mm, antennae to sense odours, forelegs to dig, males and sometimes females have prominent horns to fight for mates or food (Arnett et al. 2002; Bouchard et al. 2011). Arnett et al. (2002) reported the scarabaeid beetle consisting of 27.800 species worldwide. Subfamilies, such as Aphodiinae and Scarabaeinae consisting of 6.850 species, while Orphninae, Melolonthinae, Dystinae, Ruthelinae, and Cetoniinae consisting of 20.950 species.

The description and biodiversity of scarabaeid beetle is widely studied in tropical and temperate areas (Allegro & Sciaky 2003; Nichols et al. 2007). Adult Scarabaeid have diverse feed preferences, such as animal manure, carrion, fungi, herbs, pollen, fruit, compost, and plant root. Some scarabaeid live in ant nest (myrmecophiles), termite nests (termitophiles), and rodent and bird nests (Arnett et al. 2002). Whereas some families of Scarabaeidae, Geotrupidae, and Hybosoridae feed on microbial-rich fluids of mammalian excrement and use them to incubate larvae (Halffter & Edmonds 1982).

Some publications of scarabaeid beetles in Indonesia have been reported previously. Kahono and Setiadi (2007) reported 28 species of dung beetle in mountain forest ecosystem of Pangrango National Park, West Java and the dominant species was *Onthophagus variolaris* Lansb (382 individuals). Priawandiputra et al. (2020) also reported in the lowland forest ecosystem in the Pangandaran Nature Reserve, West Java and the dominant species was *Onthophagus babirussa* Eschscholtz (434 individuals). Dung beetles have also been reported in montane forest of the Harau Valley Nature Reserve, West Sumatra (Putri et al. 2014); Kayan Mentaran National Park, East Kalimantan (Kahono & Ubaidillah 2003); Gunung Palung National Park, West Kalimantan (Malina et al. 2018); and Lambusango Forest, Buton, Sulawesi (Moy et al. 2016). Latifa et al. (2019) reported the diversity and abundance of coprophagous beetles in organic and non-organic farms in West Java consist of 15 species belonging to 2 families i.e Scarabaeidae and Aphodiidae. The dominant species were *Copris reflexus* and *Onthopagus pauper*.

Sorong Nature Tourism Park (SNTP) is a nature conservation area located in West Papua, Indonesia which was established based on the Decree of the Minister of Agriculture No. 397/Kpts/Um/5/1981 with an area of 945.90 ha (MoA 1981; BKSDA 2008). SNTP is a lowland rainforest ecosystem with varied topography, such as flat, wavy, and steep with a slope of 0-15%. Annual rainfall is 3,066 mm, with 193.3 rainy days per year (BKSDA 2008). The tourism park has type A climate and as home of various fauna such as mammals, aves, reptiles, amphibians, and butterflies (BKSDA 2008; Beljai 2017). Compared to other faunas, there is no information regarding scarabaeid beetle diversity in this area. This study aims to analyse the diversity of scarabaeid beetles in the lowland rainforest ecosystem of Sorong Nature Tourism Park, Papua, Indonesia.

MATERIALS AND METHODS

Study Area

The collection of scarabaeid beetles was carried out in three habitats of lowland rainforest ecosystem of SNTP, i.e., rehabilitation zone (RZ) (0°54'35"S 131°20'35"E), conservation zone (CZ) (0°55'02"S 131°20'21"E), and protection zone (PZ) (0°55'56"S 131°20'36"E) (Figure 1). The rehabilitation zone is bordered by community gardens dominated by shrubs and herbaceous plants such as Poaceae and Bromeliaceae. In this zone, some species of mammals were found, such as wild boars (*Sus* sp.) and moles (Geomyidae). The conservation zone has a relatively large canopy and is dominated by shrubs and trees. The protection zone is the most expansive area in the SNTP compared to other zones. This zone has more complex plants, such as merbau (*Insia* spp.), papuan palm (*Sammieria leucophylla*: Palmae), matoa (*Pometia pinnata*: Sapindaceae), rambutan (*Nephelium lappaceum*: Sapindaceae), medang (*Beilshmiedia* sp.: Lauraceae), angsana (Fabaceae), amugia, langsat (*Lansium domesticum*: Meliaceae), cempedak (*Artocarpus integer*: Moraceae), *Araucaria* spp. Some mammals found in this zone, such as wild boar (*Sus* sp.), mole (Geomyidae), ground kangaroo (Macropodidae), and kuskus (Phalangeridae).

Collection of Beetles

Beetles were collected during six months on sunny days for sixty-eight days from August to December 2021 in three zone habitats (rehabilitation, conservation, protection zones) of the SNTP lowland

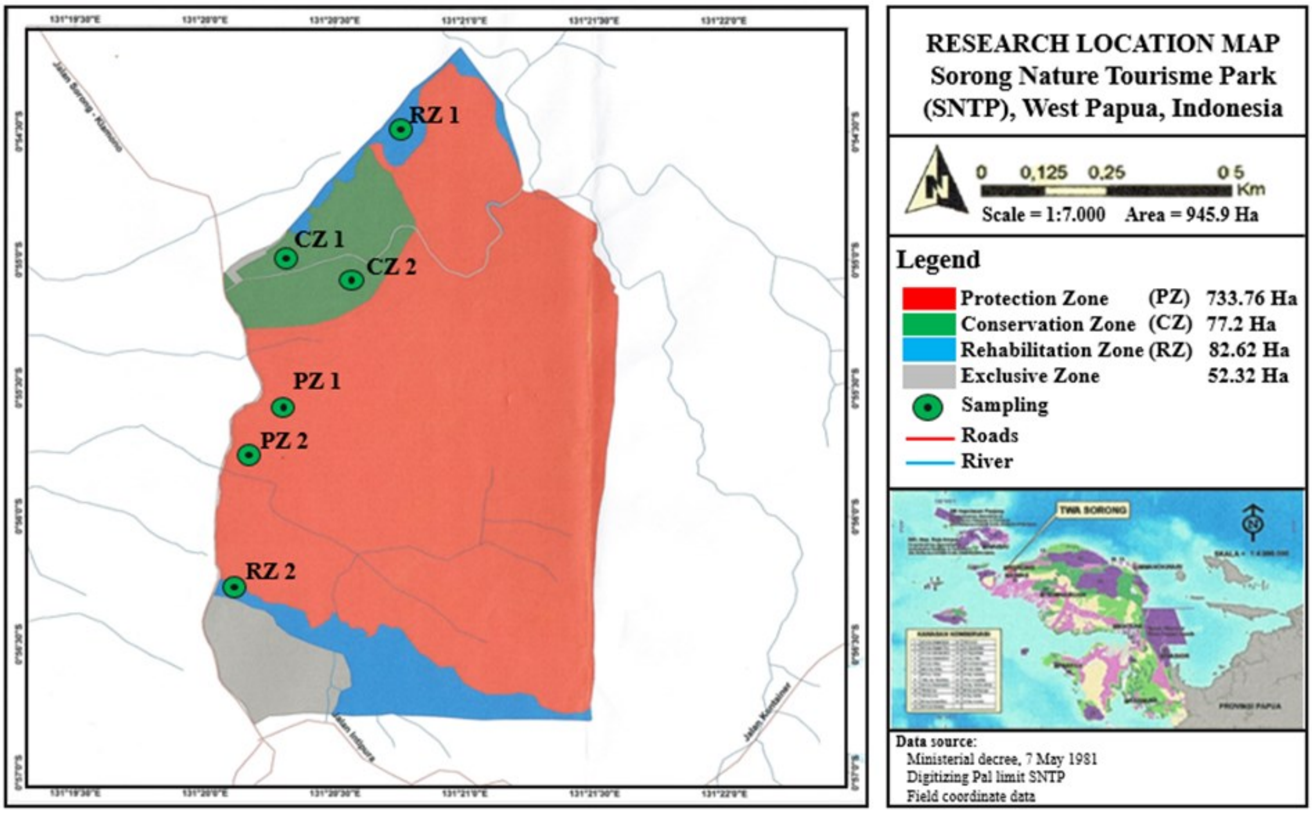

Figure 1. Sampling location of scarabaeid beetles in Sorong Nature Park, West Papua.

rainforest ecosystem. Beetles were collected using dung traps, light trap, and active sampling (Figure 2) (Abot et al. 2012; Milotić et al. 2018; Priawandiputra et al. 2020). Three types of dung traps (type A, B, and C) were used (Milotić et al. 2018). Type A dung trap was made from plastic cups (13 cm in height, 6 cm in bottom diameter, 9 cm in top diameter, and 480 ml in volume). At the top of the trap was hanged with 10 g of excrement and wrapped with gauze. Type B dung trap was made of plastic containers (12 cm in height, 10 cm in bottom diameter, 12 cm in top diameter, and 1000 ml in volume). At the top of the trap was hanged with about 1000 g of mammal dung. Type C dung trap was made of a plastic plate with 1000 g of excrement. In a total, we used 75 dung traps with 25 traps in each zone. The traps were baited with cow excrement (*Bos* sp.) and sometimes were replaced by human excrement because cow excrement was not available continuously. The beetle samples were collected every 24 hours. The excrement was replaced every 24 hours (68 repetitions for 68 days) in each habitat. Two light traps were installed in each zone for 12 hours, from 06.00 pm to 06.00 am. The light trap consists of one set (two 15-watt lamps, a car battery, and a net). Sample of beetles was also collected by using the active sampling method, i.e., collecting by hands along the road (Priawandiputra et al. 2020). Environmental parameters, such as air humidity and temperature, soil moisture and pH, and light intensity were also measured. Vegetation type, altitude and topography of three habitats were also recorded.

Preservation and Identification of Beetle Specimens

Beetle samples were soaked in 70% ethanol and pinned for dry preservation. The beetle body length was also measured. Specimen identification based on Balthasar (1963), Creedy and Mann (2012), and the website (www.boldsystem.org). The beetle specimens were verified with the specimen collection of Bogor Zoological Museum, National Research and Innovation Agency (BRIN), Cibinong, Indonesia.

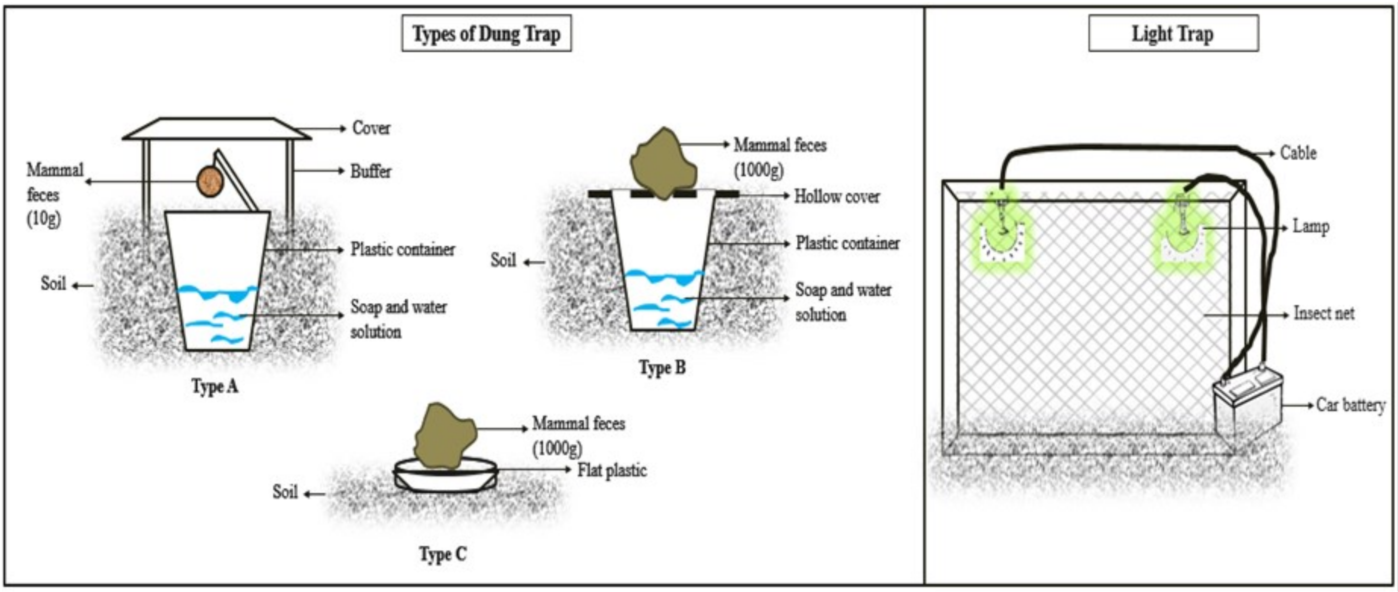

Figure 2. Model of dung trap and light trap used in this research.

Data Analysis

The diversity of beetle species was analysed using the Shannon-Wiener diversity index, evenness index, and Simpson dominance index (Sweke et al. 2013). The t-test was used to analyse the beetle diversity among sites (Hutcheson 1970; Magurran 1988). The analysis of similarity (ANOSIM-SIMPER) was used to show the species composition at each site (Clarke & Ainsworth 1993; Clarke 1993). Statistical analysis was performed using PAST (Paleontological Statistics) software version 3.14 (Hammer et al. 2001).

RESULTS AND DISCUSSION

Abundance, Species Richness and Composition

In this study, 30 individuals belonging to 13 species of scarabaeid beetles were found. Based on body size, *Xylotrupes*, *Holotrichia*, and *Anomala* have a large body sizes (38-50 mm) compared to other specis (less than 10 mm) (Figure 3). The scarabaeid beetles found in this study were dominated by small body size. The large beetles are more difficult to survive because they require more food and a longer reproductive time (Slade et al. 2014; Sa'roni et al. 2020).

The accumulated number of beetles fluctuated from August to December 2021. The highest diversity of beetles occurred in October (12 individuals, 8 species), followed by December (9 individuals, 7 species), November (5 individuals, 4 species), and August (4 individuals, 4 species) (Table 1). The beetles were not found in September, may be due to a high rainfall (400-500 mm) and only 5 sunny days (Table 1). Heavy rainfall inhibits the activity of scarabaeid beetles. These results supported Wardhaugh et al. (2018) that stated a high rainfall affected beetle abundance in wet tropics of Queensland (low abundance in September and high in December). In contrast in Java, Indonesia the highest abundance of dung beetles occurred in the rainy season compared to the dry season (Priawandiputra et al. 2020).

Based on sampling coverage ratio, this sampling covered 55.6% of beetle species in SNTP (Table 2). The highest beetle abundance was found in conservation zone (13 individuals), followed by protection zone (12 individuals), and rehabilitation zone (5 individuals). The species richness was also high in conservation and protection zones (9 species), followed by conservation zone (8 species), and rehabilitation zone (2 spe-

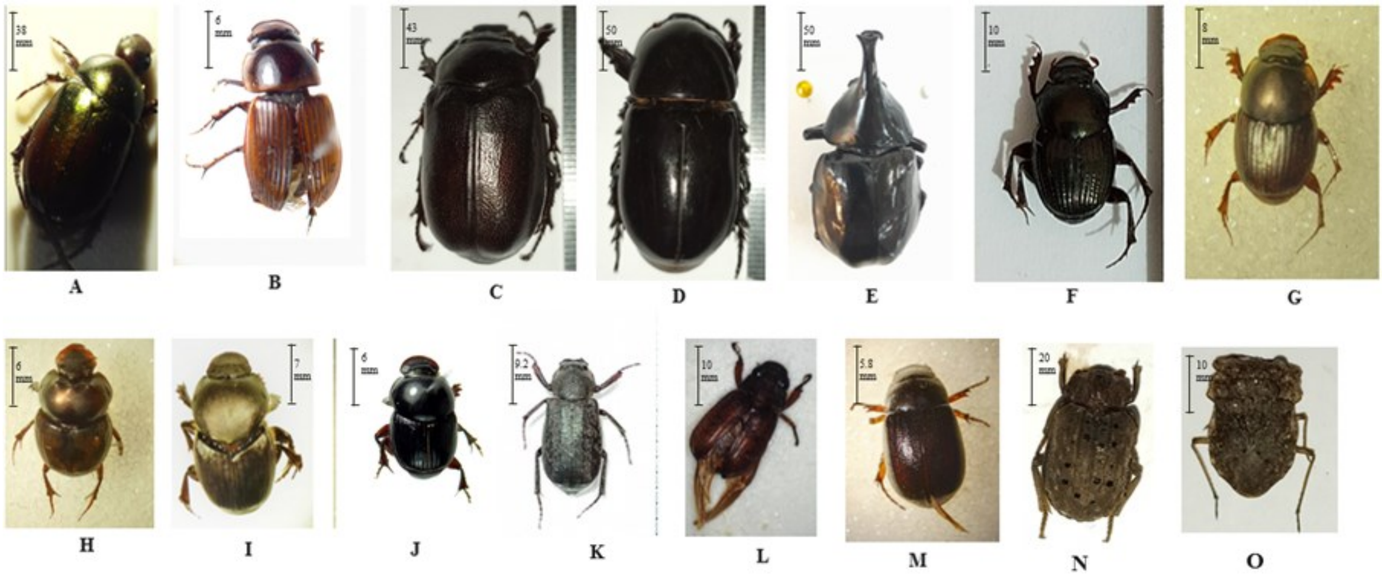

Figure 3. Scarabaeid beetle found at SNTP. A: *Anomala* sp.; B: *Aphodius* sp.; C: *Holotrichia* sp.; D: *Xylotrupes* sp.; E: *Xylotrupes gideon;* F: *Onthophagus* sp1; G: *Onthophagus* sp2; H: *Onthophagus* sp3; I: *Onthophagus* sp4; J: *Onthophagus* sp5; K: *Apgonia* sp1; L: *Adoretus* sp; M: *Apogonia* sp2; N: *Omorgus* sp.; O: *Gelastocoris* sp.

Table 1. The rainfall in August-December 2021 at study site (data from the Meteorology, Climatology and Ge physics Agency at SNTP).

Collection time	Rainfall (mm)	Category	Number of rainy days	Number of days without rain (sampling time)
August	300-400	High	21	10
September	400-500	High	25	5
October	200-300	Medium	9	22
November	300-400	High	19	11
December	200-300	Medium	11	20

cies). Protection zone has a highest diversity index (H'=2.09), followed by conservation zone (H'=2), and rehabilitation zone (H'=0.5). The highest species richness was found in conservation zone (a=0.91), followed by protection zone (a=0.90) and rehabilitation zone (a=0.82) (Table 2).

The high abundance of beetles in the protection and rehabilitation zones may related to the presence of mammals and the complexity of plant species. Similarly, Simba et al. (2022) reported the abundance and species richness of beetles was higher in protected area compared to agricultural area. The abundance of beetles also increases along the number of mammals in the area. The distribution and presence of large mammals that provide manure as a food for beetles and affect their abundance, composition, and diversity (Priawandiputra et al. 2020).

The highest dominance index was found in conservation zone (D=0.15), followed by protection zone (D=0.14) and rehabilitation zone (D=0.68). The results of the ANOSIM-SIMPER multivariance analysis showed differences in species composition of scarabaeid beetle in three habitat types (p=0.0001). The species that the most contributed was *Holotrichia* sp. (22.69%), followed by *Apogonia* sp1 (16.33%), *Adoretus* sp. (11.56%), *Apogonia* sp2 (9.97%), *Onthophagus* sp1 (6.57%), *Xylotrupes* sp. (6.35%), *Xylotrupes gideon*, *Onthophagus* sp3, and *Onthophagus* sp5 (3.94%), *Onthophagus* sp2, *Onthophagus* sp4, *Aphodius* sp., and *Anomala* sp. (2.46%).

Four species of beetles (*Anomala* sp., *Aphodius* sp., *Onthophagus* sp2, and *Onthophagus* sp4) were only found in the protection zone. Tsunoda et al. (2017) revealed that *Anomala* is omnivorous, which feeds on roots of various plant species and soil organic matter. Three species of beetles

(*Xylotrupes gideon*, *Onthophagus* sp3, *Onthophagus* sp5) were only found in the conservation zone. While in the rehabilitation zone was only found 1 species (*Xylotrupes* sp.) which was not found in other zones. *Xylotrupes* is a polyphagous, both fruits and leaves (Firake et al. 2013). The species found in three different habitats was *Holotrichia* sp. *Holotrichia* is a herbivore, their larvae and adult eat leaves (Rizwangul et al. 2018). While, *Aphodius* and *Onthophagus* are decomposers that consume the excrement of large mammals (Priawandiputra et al. 2020). The genus with the highest species richness was *Onthophagus*. *Onthophagus* successfully wide dispersed due to its smaller body size, aggressive and competitive behaviour, and high survival in disturbed habitats (Hanski & Cambefort 1991; Muhaimin et al. 2015).

This study showed the diversity of beetles was lower than in previous studies in Kalimantan, Sulawesi, Java, and Sumatera. Moy et al. (2016) reported 1710 individuals belonging to 29 species of scarabaeid beetles were found in the Lambusango forest in Southeast Sulawesi. Meanwhile, 8073 individuals belonging to 65 species were collected in East Kalimantan (Ueda et al. 2017). Priawandiputra et al. (2020) reported in lowland forests of Pangandaran Nature Reserve was collected 853 individuals belonging to 17 species of beetles. While Putri et al. (2014) in the montane forest of the Harau Valley Nature Reserve, West Sumatra collected 539 individuals belonging to 18 species of scarabaeid beetles.

Compared to the beetle of lowland forest in West Java (Priawandiputra et al. 2020), Southeast Sulawesi (Moy et al. 2016), and East Kalimantan (Ueda et al. 2017), the species of beetles collected in this study were different. Results of this study showed some species of beetles attracted to mammal excrement of *Omorgus* sp. and *Gelastocoris* sp. that has not been reported previously. Differences in species composition of beetles between study sites were caused by differences in sampling time,

Table 2. The species and abundance of scarabaeid beetles collected in three zone habitats in SNTP. PZ: protection zone, CZ: conservation zone, RZ: rehabilisation zone.

Species	Collection method	Number of Individuals			Total	Role in the ecosystems
		PZ	CZ	RZ		
Anomala sp.	light trap	1	0	0	1	herbivore
Aphodius sp.	dung trap	1	0	0	1	decomposer
Holotrichia sp.	light trap, dung trap	3	2	4	9	herbivore
Xylotrupes sp.	active sampling	0	0	1	1	herbivore
Xylotrupes gideon	light trap	0	1	0	1	herbivore
Onthophagus sp1	dung trap	1	1	0	2	decomposer
Onthophagus sp2	dung trap	1	0	0	1	decomposer
Onthophagus sp3	dung trap	0	1	0	1	decomposer
Onthophagus sp4	dung trap	1	0	0	1	decomposer
Onthophagus sp5	dung trap	0	1	0	1	decomposer
Apogonia sp1	*light trap, dung trap*	1	3	0	4	decomposer
Apogonia sp2	*light trap, dung trap, active sampling*	1	2	0	3	herbivore
Adoretus sp.	light trap	2	2	0	4	herbivore
Number of individuals		12	13	5	30	
Species richness (a)		9	8	2	13	
Chaol (b)		19.5	9.5	2	27	
Sampling coverage ratio (a/b x 100%)		46.15	84.21	100	55.6	
Shannon-Wiener (*H'*)		2.09	2	0.50	2.2	
Evenness (*E*)		0.90	0.91	0.82	0.7056	
Dominance (*D*)		0.138	0.147	0.68	0.148	

bait type, number of traps, sampling area, and biogeographical history (Priawandiputra et al. 2020). Kalimantan and Java islands were fragments of the Sunda continental until they separated in the Eocene, while East Sulawesi including southeast Sulawesi was originally part of Australasia to the early Miocene (Cox et al. 2016). Therefore, Sulawesi has many endemic fauna species including the beetle which is not found on other western islands, including Java and Kalimantan (Balthasar 1963; Shahabuddin 2010).

Papua has a wilderness type with the largest and oldest tropical rainforest in the Asia-Pacific region (Marshall et al. 2011). The Papua Island originates from the Australian tectonic plate which has shifted to the north, forming the central cordillera, and shifting the tip of the island to the north and northwest. The middle cordillera has been formed by the compression of the Australian plate with the Pacific plate, with massive uplift over several million years. Apart from the geological linkages, there are considerable environmental differences between the continents of Australia and New Guinea. Australia is drier and temperate, while Papua is tropical and humid. These two basic differences explain difference biota in the two areas. Climatologically, Papua is one of the cloudiest places on earth stretching the equator to 12 degrees south latitude. Papua's equatorial climate is seasonally dominated by the northwest monsoon and southeast trade winds. In most parts of Papua, the influence of the northwest monsoon brings rain and unpredictable weather, while the southeast trade wind tends to bring cool and dry weather. The large size of the island, its constant climate that supports vegetative growth, rugged topography, and proximity to the source areas of the Asian and Australian continents have made Papua a hyper generator of biodiversity including insects.

Based on the collection method, the highest number of individuals collected was light trap (14 individuals), followed by dung trap (14 individuals), and active sampling (2 individuals) (Figure 4). Light trap is effective for trapping many groups of insects including beetles that are active at night (Garcia-Lopez et al. 2011). Dung trap collected the highest beetle richness (9 species consist of *Aphodius* sp., *Holotrichia* sp., *Onthophagus* sp1, *Onthophagus* sp2, *Onthophagus* sp3, *Onthophagus* sp4, *Onthophagus* sp5, *Apogonia* sp1, *Apogonia* sp2), followed by light trap (6 species consist of *Anomala* sp., *Holotrichia* sp., *Xylotrupes gideon*, *Adoretus* sp., *Apogonia* sp1, *Apogonia* sp2) and active sampling (2 species consist of *Xylotrupes* sp. and *Apogonia* sp2). Dung trap type C collected the highest number of individuals (9 individuals), followed by type B (3 individuals) and type A (2 individuals) (Figure 4). Types B and C dung traps have a high abundance due to the larger bait than type A. This result supported Errouissi et al. (2004) that large baits attract significantly more dung beetles than small baits. Few beetles were attracted to the small dung size of sheep and goats compared to large and bulky cow dung.

Environmental Factors

The environmental parameters measured in each collection zone were different, except for soil pH (Table 3). Based on Pearson correlation, soil pH significantly correlated ($p=0.00$), while air temperature and humidity, light intensity, and soil humidity were not correlated ($p=0.95$, $p=0.84$, $p=0.80$, and $p=0.93$) with beetle abundance (Table 4). Juniarti and Rusniarsyah (2022) reported in the neutral pH of soil, the diversity of insects was high. Wet soil interferes beetle excavation and affects of its larvae (Sowig 1995, 1996; Nichols et al. 2008). Temperature affects beetle reproduction, feeding, and breeding behaviour (Lobo et al. 1998; Chown 2001).

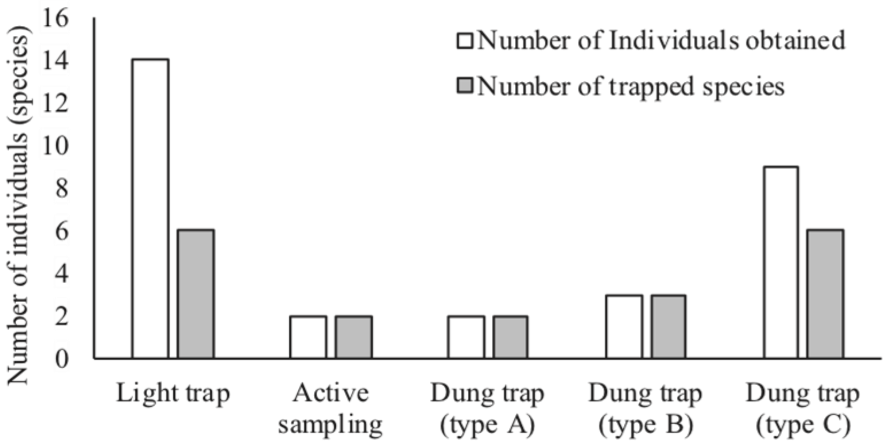

Figure 4. The number of species and individuals of beetles based on the collection method.

Table 3. Environmental factors at three zones of study sites (rehabilitation, conservation, protection) in SNTP (means ± Standard deviation).

Habitat type (zone)	Air temperature (°C)	Air humidity (%)	Soil moisture (%)	Soil pH	Light intensity (lux)
Rehabilitation zone	28 ± 1.41	82.2 ± 1.92	84.2 ± 1.92	7 ± 0	900 ± 7.91
Conservation zone	27 ± 0	88.2 ± 0.96	88.5 ± 1.29	7 ± 0	752 ± 5.70
Protection zone	27 ± 0	90.5 ± 0.71	90.7 ± 0.58	7 ± 0	738 ± 5.70

Table 4. Pearson correlation between environmental parameters and beetle abundance (*=significant).

Environmental parameters	Correlation coefficient (r)	p-value
Air temperature (°C)	-0.5	0.95
Air humidity (%)	0.6	0.84
Soil humidity (%)	0.6	0.80
Soil pH	1.0	0.00*
Light intensity	-0.5	0.93

CONCLUSIONS

A total of 30 individuals belonging to 13 species of beetles were collected in SNTP, West Papua, Indonesia. The highest species richness was *Onthophagus*, followed by *Aphodius* sp., *Anomala* sp., *Adoretus* sp., *Apogonia* sp., and *Omorgus* sp. The highest diversity of sacrabaeid beetles was found in the protection zone, followed by the conservation zone and rehabilitation zones. Light trap and type C dung trap were effective for collecting scarabaeid beetles compared to others traps.

AUTHOR CONTRIBUTION

L.O.F.: designed of the research, collected and analysed the data, funding acquisition, writing-original draft. T.A., W.P., and S.K.: wrote , reviewed and edited the manuscript. L.O.F. and S.K.: specimen identification of beetles.

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CONFLICT OF INTEREST

The authors declare no conflict of interests regarding the research or the research funding.

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