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Original research article

Diversity and Abundance of Carabidae and Staphylinidae (Insecta: Coleoptera) in Four Montane Habitat Types on Mt. Bawakaraeng, South Sulawesi

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ABSTRACT

Carabidae and Staphylinidae are the two beetle families frequently found to be most abundant and diverse in forest ecosystem. Their roles especially as generalist predators are important in forest ecosystem. No studies reported their diversity and abundance in forest ecosystem on Mt. Bawakaraeng, specifically in montane habitat yet. This study was aimed to analyze diversity and abundance of Carabidae and Staphylinidae in four montane habitat types, i.e. agricultural area, pine forest, eucalypts and natural forest (1,835 m asl), and natural forest (2,165 m asl). They were collected using pitfall traps. A total of 42 carabid beetles belonging to nine species and 260 staphylinid beetles belonging to 37 species were collected. Diversity and abundance of Staphylinidae were higher than Carabidae, this is predicted because of higher mobility in Staphylinidae compared to Carabidae. In Carabidae, the highest species richness was recorded in agricultural area, whereas the highest species richness of Staphylinidae occurred in natural forest (2165 m asl). In Staphylinidae, the two largest subfamilies are Aleocharinae and Staphylininae. *Aephinidius adelioides* occupied the highest abundance of Carabidae and found in agricultural area. The differences in each montane habitat type are presumed to cause variation in species richness of soil beetles, especially for Carabidae.

1. Introduction

The geological history of Sulawesi Island in forming four different arm (north, south, east, southeast) was caused by tectonic processes of active plate boundaries (Hamilton 1979). Mt. Bawakaraeng (2830 m asl) is located in the south arm in Gowa district, South Sulawesi, and the mountain was formed through the volcanic activity in the Pleistocene (Hasnawir and Kubota 2008). Sulawesi has several types of forest, i.e. lowland (0–400 m asl), hill (400–850 m asl), upland (850–1500 m asl), montane (1500–2500 m asl), and tropalpine forest (>2500 m asl) (Cannon *et al.* 2007). Montane forest is often considered as less diverse area than lowland forest, but high endemism occurs in this area (Anderson and Ashe 2000).

In forest ecosystems, soil beetles show important roles in soil food chain being predators, decomposers, and phytophagous. Carabidae is one of the beetle families, which are predominantly predators (Nitzu *et al.* 2008), especially as generalist predators (feed on a variety of arthropod preys, such as Collembola, soil mites, and larvae of Diptera) (Ribera *et al.* 1999). Besides Carabidae, Staphylinidae is also a generalist predator (Pohl *et al.* 2008). As a generalist predator, they serve as seed eaters and pollen feeders, respectively (Steel 1970; Hanski and Hammond 1986).

The species richness of soil beetle decreased with the increasing altitude in montane forest (Hanski and Hammond 1986; Maveety *et al.* 2011). Thus, different types of montane forest or altitudes may inhabit different diversity of Carabidae and Staphylinidae. *Anotylus* sp. (Oxytelinae) and *Philonthus* sp. (Staphylininae) are the common staphylinids that occur in montane forests in Gunung Mulu National Park, Sarawak, Malaysia (Hanski and Hammond 1986). Another example, the three genus of three tribes, i.e. *Pelmatellus* (Harpalini), *Dyscolus* (Platynini), and *Bembidion* (Bembidiini) are commonly found in tropical montane forest, Andes mountains, southeastern Peru (Maveety *et al.* 2011).

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Research on diversity and abundance of Carabidae and Staphylinidae in the area of Mt. Bawakaraeng particularly related to montane habitats has not been reported yet. Therefore, it is necessary to conduct a research on the diversity and abundance of Carabidae and Staphylinidae in various montane habitat types on Mt. Bawakaraeng. The objective of this study was to analyze diversity and abundance of Carabidae and Staphylinidae in four montane habitat types on Mt. Bawakaraeng, South Sulawesi. This result is expected to provide scientific information on the area richness related to diversity and abundance of Carabidae and Staphylinidae.

2. Materials and Methods

2.1. Study sites

Collecting sample of Carabidae and Staphylinidae was conducted once in dry season from September until October 2013 in four montane habitat types on Mt. Bawakaraeng. Those habitats are (1) agricultural area (1465 m asl), consisted of tomatoes (Solanaceae), gourds (Cucurbitaceae), leeks (Alliaceae), and mustards (Brassicaceae). There was no canopy cover in this habitat. (2) Pine forest (1545 m asl), dominated by pine trees and ferns. There were also weeds of *Ageratum* sp. in this habitat. (3) Mixed forest, i.e. partly eucalypts forest, partly natural forest (1835 m asl). The natural forest in this altitude was dominated by trees of *Magnolia vrieseana* (Magnoliaceae), and the trees of other families were coated by mosses and epiphytic plants. This habitat was overgrown by shrubs *Leucosyke capitellata* (Urticaceae). (4) Natural forest (2165 m asl), dominated by trees of *Melicope accedens* (Rutaceae) and the trees of other families were coated by bryophytes and epiphytic plants, as well as had the most dense canopy cover (Table 1).

2.2. Specimen collection

Carabid and staphylinid beetles were collected using pitfall traps. Fifteen pitfall traps were positioned systematically in agricultural area and set up randomly in pine forest, mixed forest, and natural forest. The space between pitfall traps were 10–20 m in a plot area of 2400 m^2 in all habitats, and we kept the traps for 2 days. The differential arrangement model of pitfall traps between the three montane habitat types (pine forest, mixed forest, and natural forest) and agricultural area was due to the obstacles in those three montane types, such as the disarrangement of trees disposition and oblique soil surface contour. The pitfall traps were made of a plastic cup (height 10 cm, base diameter 5.7 cm, and diameter of upper base 9.2 cm) and were placed in the ground with the mouth flat against the soil surface. Each trap was filled with 70% alcohol which serves as a preservative agent of the specimens. Transparent roofs (20 × 20 cm) were used as the protective of pitfall trap from rain and litter. The distance between the roof and soil surface is 10 cm. Collected Carabidae and Staphylinidae were identified in the Laboratory of Entomology, Zoology Division, and Research Center for Biology LIPI.

2.3. Identification

Family level identification was identified using Triplehorn and Johnson (2005). Carabidae was identified according to Darlington (1970), Sawada and Wiesner (2000), Ito (2009), and specimen references in Museum Zoologicum Bogoriense (MZB) LIPI Cibinong. The further identification for Staphylinidae was performed using Cameron (1930) and specimen references in MZB. For morphospecies level was identified based on external morphology. Almost all species of Carabidae and Staphylinidae were verified by Coleopterists listed at Table 2. All specimens were deposited in MZB.

2.4. Environmental variables

We measured the environmental variables, i.e. temperature, humidity, soil temperature, soil moisture, and soil pH. Temperature and humidity were measured using digital thermohygrometer. Soil temperature was measured using soil thermometer. Soil moisture and pH were measured using soil tester Takemura. The range of soil moisture value at soil tester is 1%–8% and soil pH value ranges from 3 to 8.

2.5. Data analysis

Data of Carabidae and Staphylinidae were analyzed for species richness (*S*), Shannon's diversity index (*H*'), Pielou's evenness index (*E*), and Simpson's index/dominance of species (*D*) (Magurran 1988). The relationship among species, habitats, and environmental variables was analyzed using canonical correspondence analysis (CCA) implemented in the Paleontological Statistics (PAST) program version 1.93 (Hammer and Harper 2006).

3. Results

3.1. The diversity and abundance of Carabidae

Compared to Staphylinidae, number of collected Carabidae was less, i.e. a total of 42 individuals, those from three subfamilies and nine species of carabids. The subfamily Harpalinae was the most common carabids collected in the areas of Mt. Bawakaraeng, belonging to seven species. From each subfamily Cicindelinae and Scaritinae one species was collected, i.e. *Hipparidium shinjii* and *Clivina* sp., respectively. The highest Carabidae diversity was in natural forest (2165 m asl). However, agricultural area revealed home for the highest abundance and species richness of carabids and *Aephnidius adelioides* (Harpalinae) was the most dominant in this area. Nevertheless, the dominance of *A. adelioides* (Figure 1A) in agricultural area led to the lower diversity in that area compared to mixed forest and natural forest (2165 m asl). The other carabid species, i.e. *H. shinjii* (Cicindelinae) (Figure 1B), Trigonotomi (*Lesticus* sp.?) (Harpalinae) (Figure 1C), and Platynini sp.1 (Harpalinae), respectively were found in pine forest, in mixed forest: natural

Table 1. Description of montane habitat types at study sites on Mt. Bawakaraeng

Code	Coordinate	Montane habitat types	Altitude (m asl)
AA	S 05° 15′ 03.1″ E 119° 53′ 56.7″	Agricultural area	1465
PF	S 05° 15′ 29.3″ E 119° 54′ 31.8″	Pine forest	1545
MF	S 05° 16′ 42.5″ E 119° 54′ 58.5″	Mixed forest: eucalypts forest and natural forest	1835
NF	S 05° 17′ 11.4″ E 119° 55′ 47.6″	Natural forest	2165

In the four montane habitat types were found cattle dungs.

Table 2. Verification of Carabidae and Staphylinidae species collected on Mt. Bawakaraeng

No.	Family	Species	Verifier	Institution/address
1	Carabidae	*Hipparidium shinjii*	David L. Pearson Jürgen Wiesner	School of Life Sciences, Arizona State University Dresdener Ring 11, 38444, Wolfsburg, Germany
2		*Aephnidius adelioides*	Noboru Ito	Konica Minolta Business Technologies, Toyokawa, Japan
3			Kipling Will	Essig Museum of Entomology, University of California, Berkeley
4		*Harpaloxenus* sp.	Noboru Ito	Konica Minolta Business Technologies,
5		*Pseudotrichotichnus* sp.		Toyokawa, Japan
6		*Clivina* sp.		
7		Trigonotomi (*Lesticus* sp.?)	Kipling Will	Essig Museum of Entomology, University of California, Berkeley
8		Platynini sp.	Dmitri N. Fedorenko	A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Moscow 119071, Russia
9	Staphylinidae	*Aleochara* sp.	Munetoshi Maruyama	Kyushu University Museum, Fukuoka, Japan
10		*Anomognathus* sp.		
11		*Atheta* sp.		
12		Athetini sp.		
13		*Coenonica* sp.		
14		*Drusilla* sp.		
15		Homalotini sp.		
16		*Neosilusa* sp.		
17		*Tropimenelytron* sp.		
18		*Paederus* sp.	Adam J. Brunke	Naturhistoriches Museum Wien
19		Medonina sp.		
20		*Erichsonius* sp.		
21		*Philonthus* sp.		
22		Xantholinini sp.		
23		Mycetoporini sp.		
24		*Sepedophilus* sp.		
25		*Anotylus* sp.	Harald Schillhammer	Natural History Museum Vienna, International
26		*Astenus* sp.		Research Institute for Entomology, Burgring 7
27		*Stenus* sp.		A – 1010 WIEN, Austria
28		*Phloeonomus* sp.	Margaret K. Thayer	Field Museum of Natural History, Chicago, USA

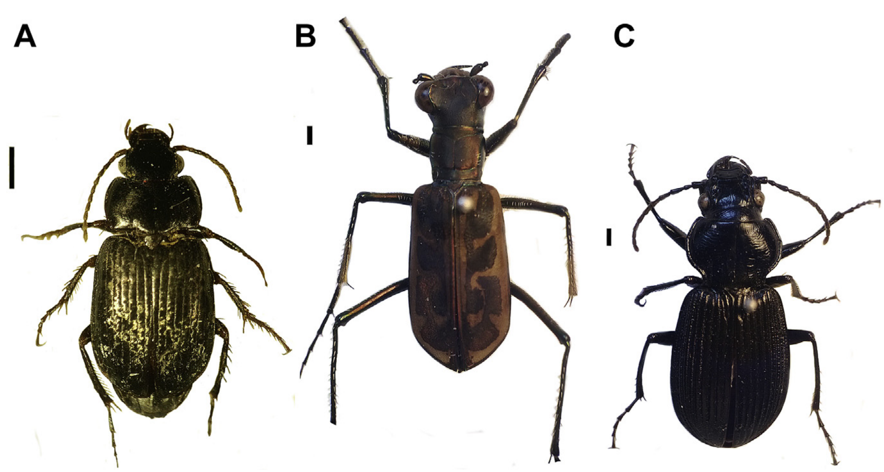

Figure 1. Species of Carabidae. (A) *Aephnidius adelioides*, (B) *Hipparidium shinjii*, (C) Trigonotomi (*Lesticus* sp.?). Scale bar: 1 mm.

forest (1835 m asl) under the forest canopy adjacent to open area, and in both natural forest (1835 and 2165 m asl) (Table 3).

3.2. The diversity and abundance of Staphylinidae

A total of 260 individuals from eight subfamilies and 37 species were collected and the two largest subfamilies were Aleocharinae and Staphylininae. The subfamily Aleocharinae comprised 13 species and subfamily Staphylininae comprised eight species. Most of them dominated in three montane types, i.e. (1) agricultural area was dominated by *Aleochara* sp. (Aleocharinae) and Xantholinini sp. (Staphylininae) (Figure 2A), (2) pine forest was dominated by *Tropimenelytron* sp.1 (Aleocharinae) and *Philonthus* sp.3 (Staphylininae), and (3) natural forest (2165 m asl) was dominated by Athetini sp.1 (Aleocharinae). No species dominated in mixed forest. Surprisingly, Staphylinidae diversity increased from agricultural area to natural forest (2165 m asl). The highest abundance was in natural forest (2165 m asl), whereas the lowest abundance was in mixed forest. The other staphylinid species, i.e. *Paederus* sp.1 (Paederinae) was found in agricultural area, and *Paederus* sp.2 (Paederinae) (Figure 2B) and Mycetoporini sp.2 (Tachyporinae) were collected in both natural forest (1835 and 2165 m asl) (Table 4).

3.3. Environmental variables

We recorded environmental data in Mt. Bawakaraeng, and showed that the agricultural area has the highest for temperature

Table 3. Diversity and abundance of Carabidae of the three subfamilies in four montane types on Mt. Bawakaraeng

No	Subfamily	Species	Montane habitat types				Total
			Agricultural area (1465 m asl)	Pine forest (1545 m asl)	Eucalypts and natural forest (1835 m asl)	Natural forest (2165 m asl)	
1	Cicindelinae	*Hipparidium shinjii*	0	1	0	0	1
2	Harpalinae	*Aephnidius adeliodes*	30	0	0	0	30
3		*Egadroma* sp.	1	0	0	0	1
4		*Harpaloxenus* sp.	3	0	0	0	3
5		*Pseudotrichotichnus* sp.	0	0	0	1	1
6		Trigonotomi (*Lesticus* sp.?)	0	0	1	0	1
7		Platynini sp.1	0	0	1	1	2
8		Platynini sp.2	0	0	0	1	1
9	Scaritinae	*Clivina* sp.	2	0	0	0	2
		N (Abundance)	36	1	2	3	42
		S (Species richness)	4	1	2	3	9
		H' (Diversity)	0.619	0	0.693	1.098	
		E (Evenness)	0.446	0	1	1	
		D (Dominance)	0.705	1	0.5	0.33	

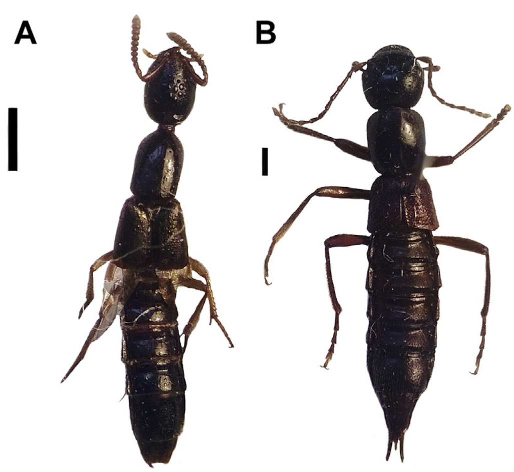

Figure 2. Species of Staphylinidae. (A) Xantholinini sp., (B) *Paederus* sp.2. Scale bar: 1 mm.

(33.77°C) and soil temperature (21.63°C), whereas this area had the lowest for humidity (31.67%) and soil moisture (1.33%) compared to others. As expected, the natural forest (2165 m asl) was recorded to have the lowest temperature (22.77°C) and soil temperature (18.23°C), and the highest humidity (66%) and soil moisture (7%) (Table 5).

3.4. Correlation among Carabidae species to environmental variables

A. adelioides was the most abundant carabid in agricultural area. The carabid species that was only collected in pine forest was *H. shinjii*. Based on CCA, *A. adelioides* that was clustered in agricultural area together with *Egadroma* sp., *Harpaloxenus* sp. (Harpalinae), and *Clivina* sp. (Scaritinae) had positive correlation with temperature and soil temperature, however, *H. shinjii* was not correlated to all environmental variables (Figure 3).

3.5. Correlation among Staphylinidae species to environmental variables

The highest abundance of Staphylinidae occurred in agricultural area was *Aleochara* sp. (Aleocharinae) and Xantholinini sp. (Staphylininae). CCA revealed that *Aleochara* sp. and Xantholinini sp. were clustered in agricultural area together with *Paederus* sp.1 (Paederinae) and had positive correlation with temperature and soil temperature (Figure 4).

The two staphylinid species that were only found in natural forest (2165 m asl) were Athetini sp.1 (Aleocharinae) and *Phloeonomus* sp. (Omaliinae). Both were clustered in natural forest (2165 m asl) together with *Anotylus* sp.1, *Anotylus* sp.2, and *Anotylus* sp.3 (Oxytelinae), and had positive correlation with humidity and soil moisture (Figure 4).

4. Discussion

The results of this study indicated that the diversity and abundance of Staphylinidae were higher than Carabidae. The presence or absence of the ability to fly is predicted to affect carabid ecology and distribution. Carabidae in Australia do not have ability to fly in both lowlands and highlands. In contrast, Carabidae in Papua New Guinea in the lowlands mostly have the ability to fly, but in the highlands they are incapable to fly (Darlington 1961).

The great diversity and abundance of Staphylinidae were suspected caused by their movement capability which are higher than Carabidae. The high movement of Staphylinidae is supported by its well-developed wings (Pohl *et al.* 2008), shown by *Dolatia coriaria* (Aleocharinae) that has rapid movement across surface of the ground and is able to escape quickly when there is a disturbance (Meihls and Hibbard 2009). Distribution of *Orsunius* (Paederinae) in oriental region was supported by ability of the rear wings to fly (Assing 2011). Although in general, species richness and abundance of Staphylinidae were higher than Carabidae (Ferro *et al.* 2012; Lee *et al.* 2014), however, several studies indicated that abundance of Carabidae is greater than Staphylinidae but species richness is contrary (Nitzu *et al.* 2008; Yu *et al.* 2013).

Aleocharinae and Staphylininae were more abundant and diverse than others (Table 4), presumably because both subfamilies have the abilities to forage, detect and locate dung and decaying mushroom from long distance (Pohl *et al.* 2008). Thus, their ability in finding food makes them able to have fast adaption to the environmental change and further to the longer temporal change (Pohl *et al.* 2008).

The great abundance, diversity, and species richness of Staphylinidae in natural forest (2165 m asl) (Table 4) were expected because of their role as saproxylic in addition as predator. Saproxylic is defined as organisms that play a role in the process of fungal decay in trees or in association with living and dead trees (Alexander 2008). Our environment data in natural forest (2165 m asl) showed the natural forest has the highest humidity (Table 5) thus in agreement with fungi habitat. The member of three subfamilies Aleocharinae, Omaliinae, and Staphylininae

Table 4. Diversity and abundance of Staphylinidae of the eight subfamilies in four montane types on Mt. Bawakaraeng

No	Subfamily	Species	Montane habitat types				Total
			Agricultural area (1465 m asl)	Pine forest (1545 m asl)	Eucalypts and natural forest (1835 m asl)	Natural forest (2165 m asl)	
1	Aleocharinae	*Aleochara* sp.	17	0	0	0	17
2		*Anomognathus* sp.	0	1	0	0	1
3		*Atheta* sp.	0	0	2	0	2
4		Athetini sp.1	0	0	0	17	17
5		Athetini sp.2	5	5	1	1	12
6		Athetini sp.3	1	8	0	2	11
7		Athetini sp.4	0	3	0	0	3
8		*Coenonica* sp.	0	0	0	1	1
9		*Drusilla* sp.	0	0	0	3	3
10		Homalotini sp.	0	0	1	0	1
11		*Neosilusa* sp.	1	0	0	0	1
12		*Tropimenelytron* sp.1	0	24	2	11	37
13		*Tropimenelytron* sp.2	0	2	3	13	18
14	Omaliinae	*Phloeonomus* sp.	0	0	0	4	4
15	Osoriinae	*Eleusis* sp.	0	0	0	2	2
16	Oxytelinae	*Anotylus* sp.1	0	0	0	13	13
17		*Anotylus* sp.2	0	0	0	3	3
18		*Anotylus* sp.3	0	0	0	1	1
19		*Anotylus* sp.4	0	0	1	0	1
20		*Anotylus* sp.5	0	1	0	0	1
21		*Anotylus* sp.6	1	0	0	0	1
22	Paederinae	*Astenus* sp.	0	0	2	0	2
23		*Paederus* sp.1	2	0	0	0	2
24		*Paederus* sp.2	0	0	4	6	10
25		Medonina sp.	1	0	1	0	2
26	Staphylininae	*Erichsonius* sp.	0	0	1	0	1
27		*Philonthus* sp.1	8	0	0	0	8
28		*Philonthus* sp.2	4	0	0	0	4
29		*Philonthus* sp.3	0	16	1	2	19
30		*Philonthus* sp.4	0	7	1	1	9
31		*Philonthus* sp.5	0	0	0	1	1
32		*Philonthus* sp.6	0	3	0	1	4
33		Xantholinini sp.	36	0	0	0	36
34	Steninae	*Stenus* sp.	0	0	0	2	2
35	Tachyporinae	Mycetoporini sp.1	0	0	0	1	1
36		Mycetoporini sp.2	0	0	3	5	8
37		*Sepedophilus* sp.	1	0	0	0	1
		N (Abundance)	77	70	23	90	260
		S (Species richness)	11	10	13	20	37
		H' (Diversity)	1.632	1.863	2.426	2.525	
		E (Evenness)	0.68	0.809	0.945	0.842	
		D (Dominance)	0.286	0.202	0.1	0.106	

(Table 4) were supposed to play role as saproxylic beetles. These data are supported by the finding of Toivanen and Kotiaho (2010) that several species of Staphylinidae which act as saproxylic are *Phloeonomus pusillus* (Omalinae), *Homalota plana* (Aleocharinae), and *Quedius xanthopus* (Staphylininae).

Although Staphylinidae has many species, however, only the agriculture area and natural forest showed the species characterized for these two habitats. Montane type at low altitude (1465 m asl), i.e. agricultural area (Table 1), was characterized by species *Aleochara* sp. (Aleocharinae), Xantholinini sp. (Staphylininae) (Figure 2A), and *Paederus* sp.1 (Paederinae). They are presumed to have strong responses with vegetation in this area that serve food sources for them as shown by *Aleochara bipustulata* (Aleocharinae) that occur in cruciferous crops (Brassicaceae) of their roles as predators on larva of cabbage root flies *Delia radicum* (Balog *et al.* 2008). The genus *Xantholinus* (Staphylininae: Xantholinini) often inhabit and dominate in open and disturbed areas (Brunke and Majka 2010). *Paederus* sp.1 is similar to *P. fuscipes* based on external morphology characters (Cameron 1930). *Paederus fuscipes* occurs only in agricultural area (in large number, collected in gourd), and not found in forest area (Nasir *et al.* 2012).

The natural forest at altitudes 1835 and 2165 m asl was characterized by species *Paederus* sp.2 (Paederinae) (Figure 2B) and Mycetoporini sp.2 (Tachyporinae), respectively. The dark body coloration of Mycetoporini sp.2 in this instance is expected in accordance with habitat that has low light intensity to support it for foraging. The most dense canopy cover in natural forest specifically is supposed to cause the low light intensity, which was also supported by existence of bryophytes and high humidity (Table 5). The genus *Ischnosoma* and *Mycetoporus* (Tachyporinae: Mycetoporini) are often collected from moist leaf litter and moss in mature forests (Webster *et al.* 2012).

Despite lower diversity of Carabidae compare to Staphylinidae in this present study, it was showed that every single montane type on Mt. Bawakaraeng has several characterized carabid species. Abundance and species richness of Carabidae were the highest in agricultural area (low montane type), presumed in this area Carabidae has a role as generalist predator, and it could be an effective regulator of crop pests (Bukejs *et al.* 2009). *A. Adelioides* (Harpalinae) (Figure 1A) has the greatest abundance in agricultural area (Table 3) which is a bioindicator for open areas (Fujita *et al.* 2008). The high abundance of *A. adelioides* was supposed to be due to its inability to fly (Baehr 2007), thus its dispersal power is low.

H. shinjii (Cicindelinae) was the only carabid collected in pine forest (Table 3). Lots of ferns and litters of pine trees in pine forest might be a suitable habitat for *H. shinjii* (Figure 1B). *H. shinjii*

Table 5. Environmental variables in the four montane habitat types on Mt. Bawakaraeng

No.	Variables	Montane habitat types							
		AA	SD	PF	SD	MF	SD	NF	SD
1	Temperature (°C)	33.77	0.76	23.83	0	24.13	1.22	22.77	0.20
2	Humidity (%)	31.67	3.21	56.67	4.72	55.16	6.33	66	3.60
3	Soil pH	6.83	0.28	6.83	0.28	6	1.09	4	0
4	Soil moisture (%)	1.33	0.57	5.83	0.28	5.75	0.82	7	0
5	Soil temperature (°C)	21.63	1.35	18.87	0.37	19.13	0.66	18.23	0.37

AA = agricultural area; MF = mixed forest: eucalypts forest and natural forest; NF = natural forest; PF = pine forest; SD = standard deviation.

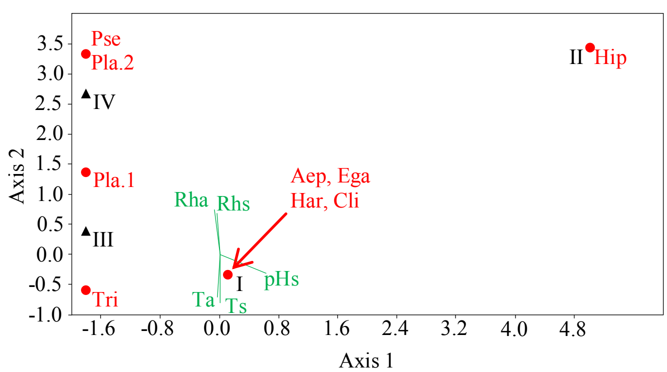

Figure 3. CCA showed the relationship among Carabidae species (●), habitat (▲), and environmental variables (———). Name of species: Hip, *Hipparidium shinjii*; Aep, *Aephnidius adelioides*; Har, *Harpaloxenus* sp.; Les, Trigonotomi (*Lesticus* sp.?); Pse, *Pseudotrichotichnus* sp.; Ega, *Egadroma* sp.; Pla.1, Platynini sp.1; Pla.2, Platynini sp.2; Cli, *Clivina* sp. Environmental variables: pHs, soil pH; Rha, humidity; Rhs, soil moisture; Ta, temperature; Ts, soil temperature. Habitat: I (agricultural area), II (pine forest), III (mixed forest: eucalypts and natural forest), IV (natural forest).

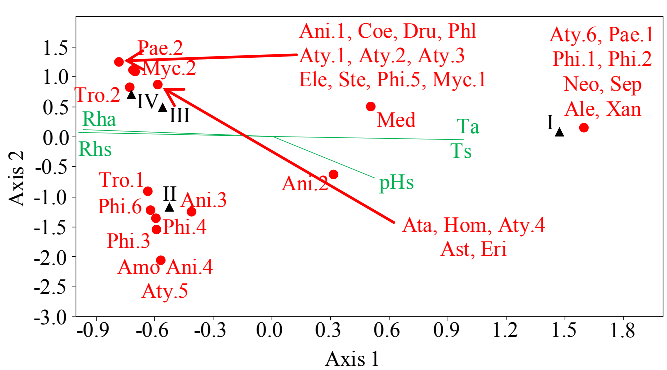

Figure 4. CCA showed the relationship among Staphylinidae species (●), habitat (▲), and environmental variables (———). Name of species: Ale, *Aleochara* sp.; Ano, *Anomognathus* sp.; Tro.1, *Tropimenelytron* sp.1; Tro.2, *Tropimenelytron* sp.2; Ath, *Atheta* sp.; Ath.1, Athetini sp.1; Ath.2, Athetini sp.2; Ath.3, Athetini sp.3; Ath.4, Athetini sp.4; Coe, *Coenonica* sp.; Dru, *Drusilla* sp.; Hom, Homalotini sp.; Neo, *Neosilusa* sp.; Phl, *Phloeonomus* sp.; Ele, *Eleusis* sp.; Ani.1, *Anotylus* sp.1; Ani.2, *Anotylus* sp.2; Ani.3, *Anotylus* sp.3; Ani.4, *Anotylus* sp.4; Ani.5, *Anotylus* sp.5; Ani.6, *Anotylus* sp.6; Ast, *Astenus* sp.; Pae.1, *Paederus* sp.1; Pae.2, *Paederus* sp.2; Med, Medonina sp.; Phi.1, *Philonthus* sp.1; Phi.2, *Philonthus* sp.2; Phi.3, *Philonthus* sp.3; Phi.4, *Philonthus* sp.4; Phi.5, *Philonthus* sp.5; Phi.6, *Philonthus* sp.6; Xan, Xantholinini sp.; Ste, *Stenus* sp.; Myc.1, Mycetoporini sp.1; Myc.2, Mycetoporini sp.2; Sep, *Sepedophilus* sp. Environmental variables: pHs, soil pH; Rha, humidity; Rhs, soil moisture; Ta, temperature; Ts, soil temperature. Habitat: I (agricultural area), II (pine forest), III (mixed forest: eucalypts and natural forest), IV (natural forest).

collected in this study is green colored on the ventral part of body and dark brown colored on the dorsal part of body. The green and dark brown body coloration of *H. shinjii* was expected to disguise its existence from both preys and predators while it is among ferns or pine litters. *Cicindela patruela consentanea* (Cicindelinae) which is closely related to *H. shinjii* has black and white body coloration that camouflages its presence while hiding in vegetation and litters (Mawdsley 2007).

Trigonotomi (*Lesticus* sp.?) (Harpalinae: Pterostichini) was collected only in natural forest (1835 m asl) (Table 3) in the closed-canopy area near open area (Figure 1C). This result is in accordance with *Lesticus finisterrae* (Harpalinae: Pterostichini) collected in closed-canopy area, but close to open area in upper montane moss forest, Finisterre Range, Papua New Guinea (Will and Kavanaugh 2012). The second carabid species characterized of closed area in natural forest is Platynini sp.1 (Harpalinae), which occurred in both natural forests (1835 and 2165 m asl) (Table 3). The humidity and soil moisture were high in both natural forests in 1835 and 2165 m asl) (Table 5). These conditions are presumably favor for Platynini sp.1 that we found in these habitats. *Dalatagonum* (Harpalinae: Platynini) also recorded at the leaf litter in montane subtropical broad-leaved forests (Fedorenko 2011).

No Carabidae was found in eucalypts forest (1835 m asl) probably due to the allelopathic effects of eucalypts, and mostly does the Staphylinidae. Only a few of staphylinid species, i.e. two individuals of *Atheta* sp. (Aleocharinae), one individual of *Astenus* sp. (Paederinae), and one individual of species *Philonthus* sp.4 (Staphylininae) were collected in eucalypts forest. *Eucalyptus* essential oil possesses a utility as unnatural pesticide or insecticide, which controls beetle pests and other insects (Batish *et al.* 2008).

Besides living in soil habitat, tropical Carabidae have arboreal morphological characters, and 30%–60% of them belong to the Harpalinae (Ober 2003). Arboreal characters allow Harpalinae to not only live on the ground but adapt to live on plants (barks and trunks) (Ober 2003). In addition to morphological characters of arboreal, Harpalinae also play a role as plant seed eaters (spermophages), such as herbaceous plants seeds (Honek *et al.* 2003). Thus, this ability might be possible to lead to the great number of Harpalinae species richness in Mt. Bawakaraeng (Table 3).

We conclude that differences of diversity, abundance, and species richness in Carabidae and Staphylinidae are responses to each montane habitat type. Mobility of Staphylinidae is higher than Carabidae and becomes one of the reasons of greater staphylinid diversity and abundance. The different species in the same genus could have different habitat and behavior, thus it is necessary to identify Carabidae and Staphylinidae up to particular species for further research.

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