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# Species Composition of Coleoptera (Beetles) at Silokek Geopark Ecotourism Area, West Sumatera, Indonesia

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**Abstract.** The Coleoptera, a diverse insect order, plays multifaceted roles in ecosystems, serving as herbivores, predators, scavengers, and decomposers. This study endeavors to comprehensively identify and document the rich array of Coleopteran species within the emerging ecotourism destination of Silokek Geopark in West Sumatera. Sampling was meticulously executed using both quadrant protocol and colour pan trap methods across three distinct habitats: forests, agroforestry zones, and rice fields. A total of 42 distinct Coleoptera species representing 18 families, 37 genera, and a remarkable 81 individual specimens were meticulously collected. Among these families, Staphylinidae emerged as the most abundant, boasting 14 distinct species comprising 26 individuals, followed closely by Curculionidae, which presented three species totaling 12 individuals, and Ptinidae, contributing two species encompassing 12 individuals. The standout species in terms of abundance included *Atheta transfuga* with 11 individuals, *Xyleborus glabratus* with seven individuals, as well as *Lasioderma serricorne* and *Stegobium paniceum*, each accounting for six individuals. Notably, agroforestry areas exhibited the highest diversity, hosting a diverse array of 23 species and 37 individuals, while forests presented 14 species comprising 25 individuals, and rice fields showcased 12 species with 19 individuals. The findings of this study serve as foundational data, providing valuable insights that can be leveraged for promoting environmental conservation and ecotourism development in the enchanting Silokek Geopark within the Sijunjung Regency.

**Keywords:** Coleoptera, Ecotourism, Environmental, Silokek Geopark

## 1 Introduction

Coleoptera belong to the order of insects that play an important role in the ecosystem. Coleoptera are essential in ecosystems due to their roles as plant eaters, predators, scavengers, and decomposers [1]. Therefore, Coleoptera are not detrimental; in fact, their herbivorous activities are crucial for ecosystems, as herbivorous beetles can be important pests for plants, and predatory beetles can influence other insect populations [2]. Coleoptera, such as dung beetle also play a

vital role in maintaining ecosystem balance by participating in the nutrient cycle as decomposers and aiding in the dispersal of plant seeds [3] [4].
The diversity of insects in the order Coleoptera is higher in the tropics compared to temperate regions. Abiotic factors, such as temperature, significantly influence the population density distribution of Coleoptera [5]. The order Coleoptera boasts the highest number of species, accounting for approximately 40% of all insect species and constituting a major component of animal diversity [6]. Indonesia, being a tropical country, naturally possesses a high diversity and abundance of insects in the order Coleoptera, including those found in the Silokek Geopark Ecotourism Area, Sijunjung, West Sumatra.
The Silokek Geopark Ecotourism Area is one of the geoparks in the Sijunjung area of West Sumatra, inaugurated as an ecotourism location in 2018 [7]. Covering an area of 130,000 hectares, Silokek Geopark features unique geological diversity, with rocks dating back approximately 350 million years [8]. Silokek Geopark distinguishes itself from other geoparks through its unique geological characteristics, notably the presence of mountains with pronounced fault lines and folds, as well as river flows that create a striking visual effect resembling the division of solid hills when observed from a distance. These distinctive geological features set Silokek Geopark apart and make it stand out among geoparks [8]. Another distinguishing feature is the presence of sedimentary and metamorphic rock outcrops along the river's edge, making it an excellent site for geological study. Geologically, Silokek is fascinating due to its representation of three geological eras in the arrangement of rocks throughout the area [8]. Given its unique geographical location, this region offers ample opportunities for the study of flora and fauna diversity. The rocks in this location serve as habitats for insects, particularly those in the order Coleoptera. Therefore, there is a need for research on the composition and diversity of Coleoptera in this location, which can subsequently be used as a database for the benefit of the local community and the management of the geopark.

## 2. Method

The study had been conducted in July 2023, located at Silokek Geopark Ecotourism Area in Sijunjung, West Sumatra (101°28'-101°36' E, 0°37'12-0°37'18 S) (Figure 1). The collection was carried out by pan trap and quadrant protocol method, by making line transects along the area at each research location with length 180 meter. Quadrant protocol method contains four different method such as honey bait trap, leaf-litter shifting, hand collecting, and soil core method. Each transect were divided into three sub-transect with length for each other about 60 meters, so that in every sub-transect had four different method of quadrant protocol and one pan trap with three different color. Coleopterans that have been collected are then killed by using killing bottle and then put into Eppendorf tube that has been given alcohol 70%. Further, sampling using the bait method was carried out using pan trap technique which had been filled with bait in the form of detergent and formalin 4%. Pan trap consists of three pans with different color (white, blue, and yellow) and hung with rope by using stake. The sample was collected after 48 hours. Coleopterans trapped in the pan trap are then killed in the same way as the direct capture process using quadrant protocol method. For the measurement of data on environmental factors and vegetation types, physical environmental parameters: temperature, humidity and light intensity were recorded at each entering the study site using a thermohygrometer and Luxmeter. The coordinates of the sampling location were taken using GPS. The physical parameters of the environment and the location coordinates were recorded on paper and pencil. Plant samples were taken and documented directly in the field at each location point, then identified and determined the type of vegetation.

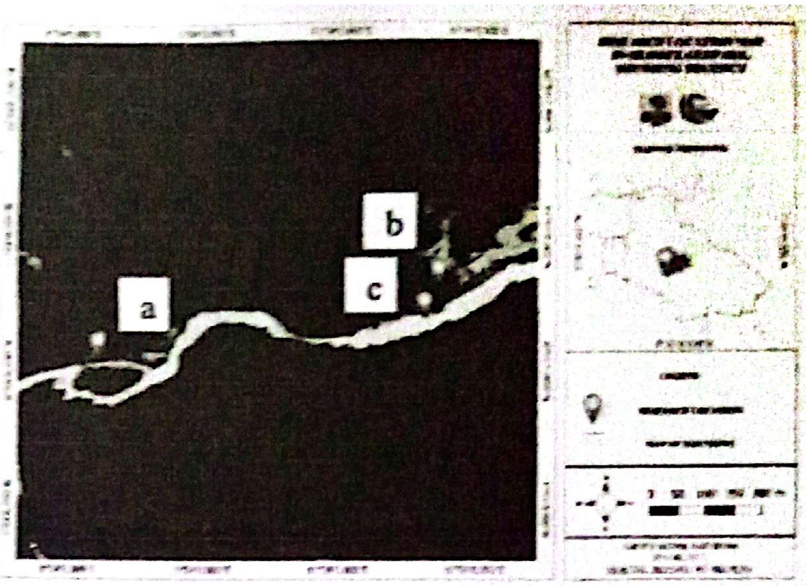


Fig 1. Map of study sites in Silokek Geopark Ecotourism Area. Collection sites was forest area (a), Rubber-plant plantation area (b), and rice field area (c). Coleopterans collection using quadrant protocol and pan trap method namely in areas a to c.

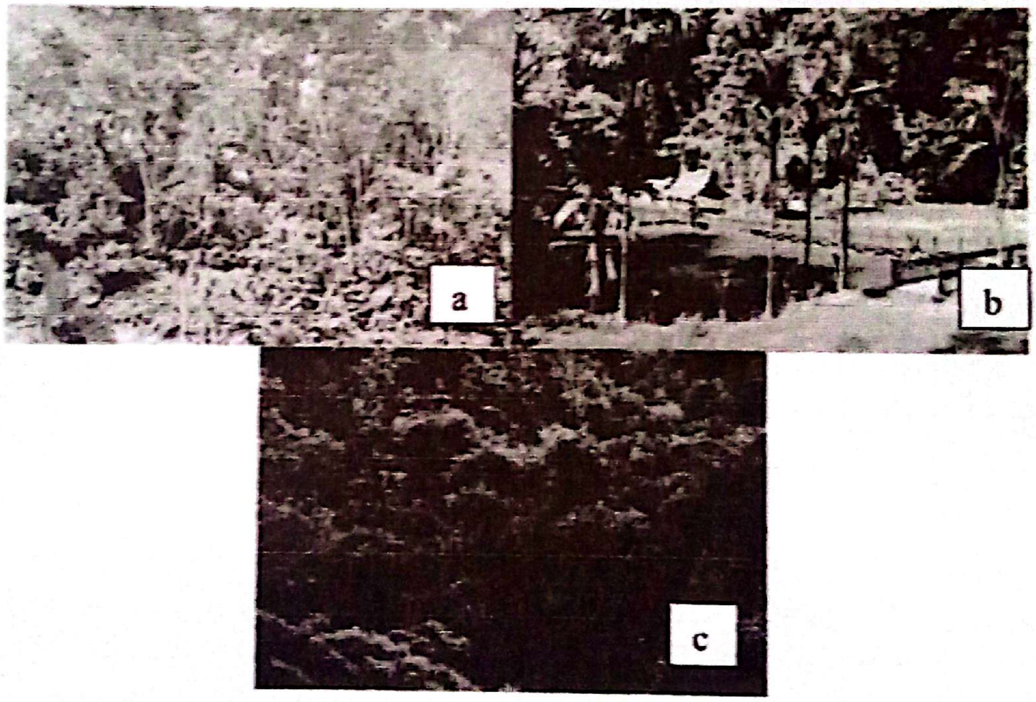


Fig 2. Sampling location at Silokek Geopark Ecotourism Area; a) Rubber-plant plantation, b) Rice field, c) Forest

**2.2 Species Identification**

Collected specimens were later identified in the Laboratory of Animal Taxonomy, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Andalas. Identification was keyed to morphological characters of Coleopterans. Collected samples are preserved accoding to standard methods of wet preservation. Preservation is done through the wet preservation method by placing it on the Eppendorf tube filled with alocohol 70%. The identification process refers to the manual by looking at the characteristics and morphometric measurements of the body shape, forewing length, wing span, and paying attention to specific markings such as spots and colors on the body and wings.

### 2.3 Data Analysis

Upon identified, Coleopterans were grouped in table according to family, genus and species level. Number of collected individuals was also presented. The result was descriptively outlined using table, picture and graph. Further, Species of Coleopterans found in ecotourism areas were analyzed descriptively using the Shannon-Wiener diversity index test then presented in the form of tables, photos, and species descriptions.

$$H' = \sum_{i=1}^{S} pi \ln pi \qquad (1)$$

Where: H'= Diversity index Pi = Proportion of each species ln = Natural logarithm (natural number) (Magurran, 2004)

## 3. Result

### 3.1 Composition of Coleopterans

A total of 42 Coleoptera species representing 18 families, 37 genera, and 81 individual specimens were collected (Table 1). Among these families, Staphylinidae was the most abundant with 14 distinct species comprising from 26 individuals, followed by Curculionidae, with 3 distinct species comprising from 12 individuals, and Ptinidae, contributing with 2 species comprising from 12 individuals. Others come from Chrysomelidae with as many as 5 individuals found, Tenebrionidae and Leiodidae as many as 4 individuals, Silvanidae as many as 3 individuals, Scarabaenidae and Phalacridae as many as 2 individuals, Anthicidae, Elateridae, Carabidae, Bostrichidae, Mycetophagidae, Laemophloeidae, Ochodaenidae, and Dermestidae are the families with the least number found, which is as many as 1 individual in each family.

**Table 1. List of Family, Species, and number individual of Coleoptera at three different habitats in Silokek Geopark Ecotourism Area.** PR = Predator, H = Herbivor, P = pest, D = decomposer, M = Myophagus, F=forest, RP=Rubber-plant Plantation, RF= Rice field

| Family | Species | Biology | F | RP | RF | Σ |
|---|---|---|---|---|---|---|
| Staphylinidae | *Achenomorphus corticinus* | PR | 1 | | | 1 |
| | *Atheta pasniki* | PR | 1 | | | 1 |
| | *Atheta klagesi* | PR | 1 | | | 1 |
| | *Atheta spinula* | PR | | | 1 | 1 |
| | *Atheta transfuga* | PR | 11 | | | 11 |
| | *Cafius vesitus* | PR | | 1 | | 1 |
| | *Ctenandropus* sp. | PR | | 1 | | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | *Diochus schaumii* | PR | | 1 | | 1 |
| | *Lobrathium* sp. | PR | | 1 | | 1 |
| | *Ochthephilum fracticorne* | PR | | 1 | | 1 |
| | *Philonthus* sp. | PR | 1 | | | 1 |
| | *Quedius novus* | PR | | 1 | | 1 |
| | *Quedius* sp. | PR | | 1 | | 1 |
| | *Staphylinus* sp. | PR | 1 | 2 | | 3 |
| Chrysomelidae | *Agelastica alni* | H/P | | | 2 | 2 |
| | *Chaetocnema hortensis* | H/P | | 1 | | 1 |
| | *Epitrix fuscula* | H/P | 1 | | | 1 |
| | *Monolepta australis* | H/P | 1 | | | 1 |
| Curculionidae | *Sitophilus oryzae* | H/P | | | 4 | 4 |
| | *Tychius* sp. | H/P | | 1 | | 1 |
| | *Xyleborus glabratus* | H/P | 2 | 4 | 1 | 7 |
| Scarabaenidae | *Heteronychus arator* | H/P | | 1 | | 1 |
| | *Onitis* sp. | H/P | 1 | | | 1 |
| Anthicidae | *Macrotomoderus* sp. | PR | 1 | | | 1 |
| Elateridae | *Pheletes aenoniger* | H/P | 1 | | | 1 |
| Tenebrionidae | *Tribolium* sp. | D | 1 | | | 1 |
| | *Corticeus* sp. | D | | 1 | | 1 |
| | *Tenebrio molitor* | D | | | 1 | 1 |
| | *Telesicles cordatus* | | | 1 | | 1 |
| Carabidae | *Brachinus crepitans* | PR | 1 | | | 1 |
| Ptinidae | *Lasioderma serricorne* | H/P | | 6 | | 6 |
| | *Stegobium paniceum* | H/P | | 4 | 2 | 6 |
| Bostrichidae | *Rhyzopertha dominica* | H/P | | 1 | | 1 |
| Silvanidae | *Ahasverus advena* | D | | 2 | 1 | 3 |
| ***cont.*** | | | | | | |
| Mycetophagidae | *Typhaea stercorea* | M | | 1 | | 1 |
| Laemophloeidae | *Cryptolestes ferrugineus* | H/P | | 1 | | 1 |
| Phalacridae | *Stilbus testaceus* | M | | | 1 | 1 |
| | *Olibrus* sp. | M | | | 1 | 1 |
| Ochodaeidae | *Parochodaeus* sp. | | | | 1 | 1 |
| Leiodidae | *Leiodes appalachiana* | D | | 2 | 2 | 4 |
| Dermestidae | *Attagenus unicolor* | D | | 1 | | 1 |
| | **TOTAL** | | **25** | **36** | **17** | **78** |

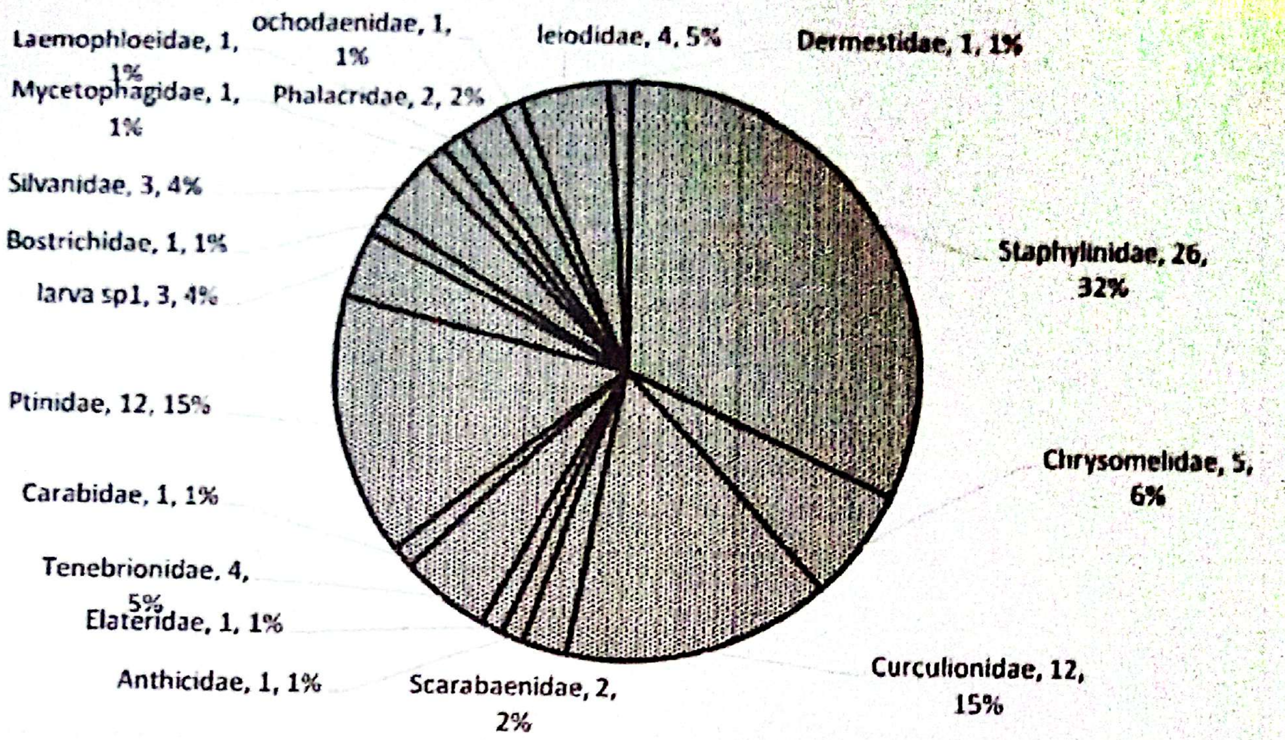


**Fig 3.** Total number of species in each family of Coleoptera found in three different habitats at Silokek Geopark Ecotourism Area

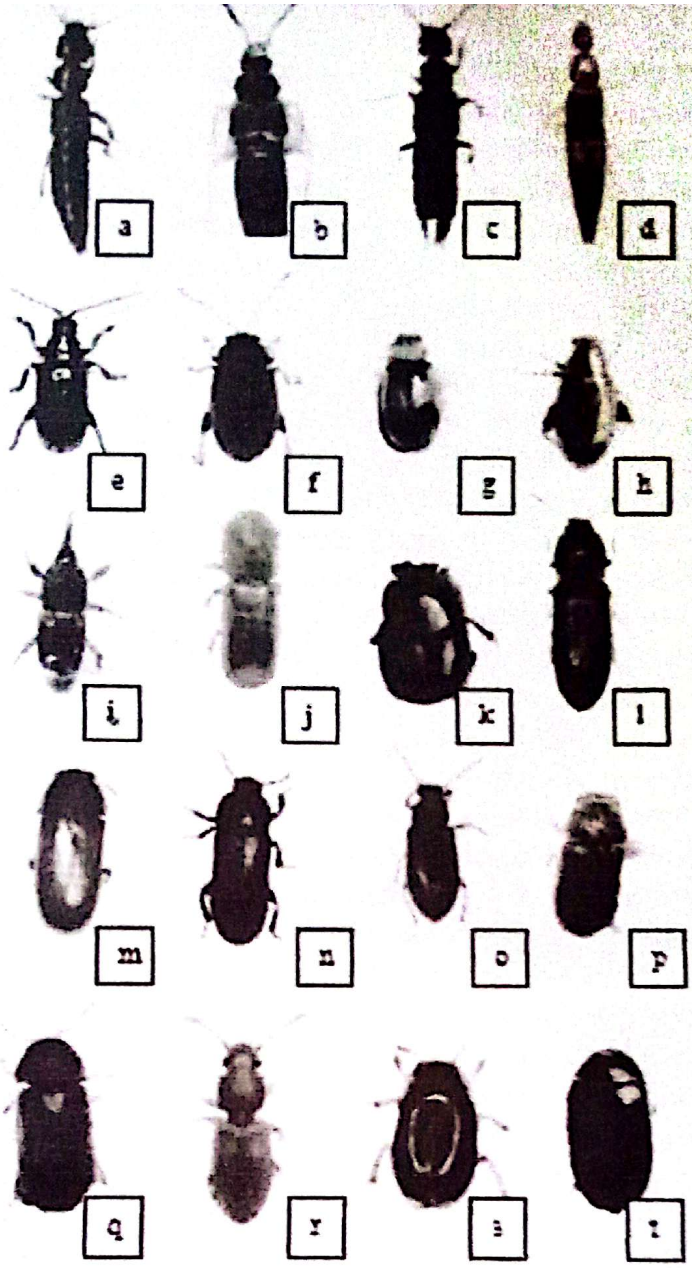


**Fig 4.** Family of Coleoptera in Silokek Geopark Ecotourism Area; a-d. Staphylinidae: a. *Achenomorphus corticinus*, b. *Atheta klagesi*, c. *Ochthephilum fracticorne*, d. *Diochus schaumii*, e-h. Chrysomelidae: e. *Agelastica alni*, f. *Epitrix fuscula*, g. *Monolepta australis*, h. *Chaetocnema hortensis*, i-j. Curculionidae: i. *Sitophilus oryzae*, j. *Xyleborus glabratus*, k. Scarabanidae: *Onitis* sp, l. Elateridae: *Pheletes aenoniger*, m-o. Tenebrionidae: m. *Corticeus* sp, n. *Tenebrio molitor*, o. *Telesicles cordatus*, p-q. Ptinidae: p. *Lasioderma serricorne*, q. *Stegobium paniceum*, r. Silvanidae: *Ahasverus advena*, s. Leiodidae: *Leiodes appalachiana*, t. Dermestidae: *Attagenus unicolor*.

Staphylinidae, commonly known as rove beetles, are characterized by distinctive morphological features, including a slender and elongated body shape [9]. Their elytra, or forewings, are short and do not extend to cover the entire abdomen [10]. These beetles are further characterized by long, slender, and sharp mandibles, often crossing in front of their head. Their coloration typically ranges from shades of orange, brown, to black. Staphylinidae inhabit diverse environments, including the spaces under rocks, other ground objects, and

various plant types. Predation is the primary mode of sustenance for the majority of Staphylinidae, as they feed on small insects and mites [7].
It is noteworthy that their prevalence in forest ecosystems contradicts findings in other studies, which suggest a more common occurrence of this family in agricultural settings, such as yam plantations and rice fields. In this study, it was observed that within the forest area, 15 individuals belonging to 6 different species were found. Conversely, in the rubber-plant plantation, 9 individuals from 8 distinct species were identified. In the rice field, a single individual from a single species was discovered. Moreover, during the research conducted in the coffee plantations in East Java, a total of 69 individuals from this particular family were recorded [6].
This disparity raises questions regarding their dominance in forest ecosystems. However, other investigations reveal that the abundance of Staphylinidae is influenced by several factors. They exhibit a remarkable capacity to thrive in various conditions, including fire-scarred areas and locales with high humidity levels [6]. Additionally, their population size can be influenced by the phenology of plants and the availability of prey. The high presence of these insects, particularly in forest ecosystems, can be attributed to the even distribution of available resources in this habitat. Solitary in nature, Staphylinidae manage to secure resources consistently in forest ecosystems, which accounts for their elevated presence in such environments [11]. This adaptability is further reinforced by their ability to inhabit areas with a temperature range of 28°C and 96% humidity [4].
Curculionidae, commonly known as weevils, are distinctive for their elongated head that bears a striking resemblance to a snout [12]. A characteristic feature of this family is their behavior when disturbed; they quickly retract their limbs and may even simulate death. These beetles exhibit a compact and short body structure [13]. The findings of this study reveal that Curculionidae were most frequently observed in rubber-plant plantation ecosystems and rice field ecosystems. This observation aligns with the natural tendencies of this family, as they are specialized and well-adapted to both wet and dry seasons, making them monophagous insects. Monophagous insects possess a unique characteristic that limits their ability to thrive and reproduce to a single host plant species [6]. In rubber-plant plantations and rice field ecosystems, the presence of similar plant species is notable, as these two ecosystems adhere to a monocultural system. In contrast, forest ecosystems exhibit a significantly greater variety of plant species.
Ptinidae is comprised of small beetles, typically measuring between 2 and 5 mm in length. They are characterized by a unique appearance that, in some cases, resembles spiders [12]. These beetles have narrow and rounded thoraxes, along with globular abdomens. While some members of this family have smooth and shiny elytra, others exhibit dense pubescence. Ptinidae are known to feed on dried stored products, skins, carcasses, and are often considered as pests. Ptinidae tend to be more prevalent in regions with temperate temperatures and climates [2]. In this study, both species from this family were exclusively found in rubber-plant plantation and rice field ecosystems. The high presence of this family in these ecosystems is likely attributed to the availability of food sources that meet their quality and quantity requirements. It is suspected that the plant species and plant carcass types present in both ecosystems are well-suited for this family, contributing to their elevated population levels.
In a previous study conducted on coffee plantations in East Java, Staphylinidae emerged as one of the families with the highest composition, alongside the families Anthicidae and Coccinidae [6]. Furthermore, research carried out in the Bawakaraeng Feather Mountain Forest following a fire incident also highlighted Staphylinidae as one of the families with a significant composition, although it was surpassed in composition by the Tenebrioidae family [2]. These two studies collectively indicate that Staphylinidae is a family commonly

encountered across various ecosystem conditions. Therefore, the results obtained in the present study, where Staphylinidae stands as the family with the highest composition, are consistent with these findings.

It can be observed from Table 1 that the identified species exhibit various biological habits. The majority of these species, totaling 16, exhibit predatory behavior, followed by herbivores (pests) comprising 14 species, detritivores represented by 7 species, and Myophagus with a total of 3 species. The prevalence of Coleoptera with a strong inclination towards predatory behavior suggests their potential for use in pest control. This potential is further substantiated when comparing Coleoptera's predatory biology with herbivores (pests), where the number of herbivorous species is fewer than the number of predators. This implies that the presence of predators influences Coleoptera, with mutual interactions between the two. Additionally, the diversity of vegetation in each location can impact the populations of both predators and herbivores [6]. In locations with suitable vegetation for Coleoptera herbivores, the population of herbivores tends to increase, subsequently leading to an increase in predator populations [14]. The limited number of detritivore insects found in the three habitats may be attributed to environmental pressures, such as excessively open soil surfaces or thin litter layers. In all three locations, the soil conditions indicate thin, waterlogged litter layers, which may restrict the abundance of Coleoptera species exhibiting detritivores habits. The scarcity of Coleoptera species with Myophagus biology in these three habitats can be attributed to the limited availability of food sources. Coleoptera species with this biological trait prefer to feed on fungal species, which are absent in these habitats [14].

In terms of the genus distribution, the genus *Atheta* stands out as the most abundant, comprising 4 species and 14 individuals. Following closely are the genera *Quedius* and *Tribolium*, each with 2 species and 2 individuals. Notably, these three genera belong to two distinct families, with *Atheta* and *Quedius* belonging to the family Staphylinidae, while *Tribolium* is categorized under the family Tenebrionidae. *Tribolium*, a genus within the Coleoptera order, is well-known for its pest status, particularly in relation to rice crops [7]. Beetles from this genus typically favor dark, moist environments and are commonly found in homogenous or uniform habitats. On the other hand, the genus *Quedius* is recognized for its ability to adapt to specific habitat conditions [4]. Research on this genus remains challenging due to the unclear distribution of its species and an incomplete understanding of its preferred habitats. Nevertheless, based on existing studies, it is believed that the genus *Quedius* can thrive in homogeneous ecosystem conditions and tends to exhibit resilience in high-temperature and high-humidity environments.

The most abundant species included *Atheta transfuga* with 11 individuals, *Xyleborus glabratus* with seven individuals, and *Lasioderma serricorne* and *Stegobium paniceum*, each accounting for six individuals. *Atheta transfuga* is primarily used to assist in the control of shore flies, fungus gnats, and other small arthropods in the soil or planting media (see fungus gnats) [12]. They also play a role in controlling the soil stages of thrips and feed on most other small soil organisms, such as moth flies, springtails, and root mealybugs. While most native *Xyleborus glabratus* target dead and dying trees, some of them initiate attacks on healthy redbay trees. These beetles drill through the bark and inoculate the tree's xylem with their symbiotic fungi. *Lasioderma serricorne* is a pest of tobacco, both in refined cigarette packaging and when stored in hogsheads and bales. Additionally, it is a minor pest of oilcake, oilseeds, cereals, dried fruit, sage, flour, and certain animal products [10].

Notably, agroforestry areas exhibited the highest diversity, hosting a diverse array of 23 species and 37 individuals. In contrast, forests presented 14 species comprising 25 individuals, and rice fields showcased 12 species with 19 individuals. The variation in the number of individuals, species, and families found in each transect can be attributed to differences in environmental factors. These differences are especially noticeable in the distinct geographical coordinates and varying elevations of each transect. The intensity of light in each transect also plays a significant role in determining the presence of insects in that location. Besides environmental factors, variations in vegetation conditions in each transect contribute to differences in the insect populations observed. For instance, the forest transect boasts a more diverse range of vegetation compared to the other two locations. In the forest transect, we found as many as 22 plant species representing 15 different families. In contrast, the garden transect revealed 6 plant species from 6 different families, and the rice field transect featured 7 species from 7 different families. The results also show the difference value in the diversity index of the three transects, where the highest diversity index is found in the Rubber-plant plantation transect, in line with the calculation results on the composition, where in this transect the diversity value is calculated at 2.86. This value is followed by the rice field transect with a calculation value of 2.26 and forest with a calculation value of 2.1. The measured diversity index of the type of Coleoptera as a whole at this study location showed a high diversity value (H'>3), and in each transect showed a moderate diversity index value (1<H'<3).

**Table 2. Coleoptera diversity index and environmental factor value by transect**

| Location | Forest | Rubber-plant Plantation | Rice Field |
|---|---|---|---|
| Number of individual Species | 25 | 36 | 17 |
| H' | 2,10835 | 2,8613 | 2,26239 |
| Temperature | 27,4 | 26,4 | 29,3 |
| Light intensity | 58,3 | 51,4 | 62,8 |
| Humidity | 81,6 | 80,4 | 84,7 |
| Altitude | 185,6 | 171 | 158,3 |

The variation in diversity index values, whether high or low, can be attributed to several factors, with the primary influences being the distribution of species and the dominance of each species. High diversity index values suggest that species within the order are evenly distributed across all three locations and can be found in various sites. However, this result seems to contradict, which suggests that communities near human settlements may experience disturbances, ultimately affecting the number of species in those communities [15]. Based on this statement, one might expect that the transects in gardens and rice fields, which are habitats with significant human activities, would theoretically have lower diversity index and evenness values compared to forest transects [11]. Surprisingly, in this research, the opposite was observed, with the highest diversity index found in the rubber plantation area and rice fields.

The high and low values of diversity indices play a crucial role in determining the stability of the community [3]. Hence, species with low diversity index values often have less stable or unstable communities in each transect due to the dominance of specific species within each order. Conversely, orders with high diversity index values indicate stable communities, as species within each order are evenly distributed, and there is no dominance of particular species. Lower species richness reduces the level of competition, allowing certain adaptable organisms to thrive and dominate ethe communities. This dominance of particular species lowers the evenness index of species composition and, in turn, results in a low diversity index [13].

The presence of each family within the Coleoptera order is closely tied to habitat conditions and several key limiting factors affecting the survival of each individual within each family. These factors include low temperatures, unsuitable conditions for nesting, limited food sources, and insufficient areas for roaming. In the Silokek Geopark Ecotourism Area, where average temperatures range from 28-31°C, the composition of Coleopterans is high and evenly distributed. This aligns with the air temperature range for soil mesofauna, including insects, falls between 29.6-32.1°C [13]. The effective temperature range for insects is a minimum of 15°C, an optimum of 25°C, and a maximum of 45°C. Coleoptera are poikilothermic organisms, meaning their body temperature is significantly influenced by environmental temperatures.

Humidity also plays a significant role in determining the presence of insects in an area. The measured humidity levels in the three transects ranged from 80-85%, with the highest humidity recorded in the rice field transect, followed by the forest and garden transects. Insects typically exhibit their optimal tolerance range within the highest point of 73-100% humidity [12]. However, it's worth noting that higher humidity levels can lead to reduced insect diversity. This is evident in the lower number of individuals and composition of each order in the rice field transects compared to the other two. Different insect species have varying tolerance ranges for air humidity, which can affect their development. Good air humidity falls within the range of 85-95%, supporting insects in their survival [16].

In general, higher altitudes are associated with higher air humidity levels. The altitude of a location is also linked to air temperature, with higher elevations typically resulting in lower air temperatures [16]. The altitude of a location plays a crucial role and is often a limiting factor, affecting various aspects of insect life, including metabolic processes, feeding activities, and development [12]. Light intensity is another factor influencing insect species' existence. Light is a major factor affecting insect behavior, including lifespan, egg-laying patterns, and flight direction, as many insects exhibit positive reactions to light [10]. Light can determine whether insects are active during the morning or at night, affecting their invasive activity (diurnal, nocturnal, crepuscular) and behavior (attraction to or avoidance of light) [9].

The wide variety of families within the Coleoptera Order at the study site can be attributed to the availability of food sources, such as plant leaves, flowers, and prey insects found on the soil surface. This observation aligns with the notion that the Coleoptera order can be found in nearly every habitat type and exhibits diverse dietary preferences, including plant and animal materials. The functional roles of Coleoptera can be categorized into four groups: predators, herbivores, mycophagus (fungus-eaters), and detritivores (consumers of organic matter and scavengers) [16]. Nevertheless, it's essential to recognize that most Coleoptera species are either predators or pests for nearby plants, leading to antagonistic interactions between the Hymenoptera and Coleoptera orders [17].

## 4. Conclusion

This study marks the first research endeavor to explore the presence of Coleoptera in the Silokek Geopark Ecotourism Area, laying the groundwork for potential future investigations. In essence, it offers significant contributions by shedding light on the diversity and distribution of Coleoptera species in this particular environment. The high biodiversity within the Coleoptera Order presents promising opportunities for employing these insects as effective agents for pest control in agricultural settings. This study underscores the necessity of comprehending the intricate relationships that exist between these species and their surrounding ecosystem. In doing so, it uncovers their various ecological roles and underscores their potential implications in the fields of pest control and habitat management. These findings pave the way for further research and the development of more extensive studies in this area.

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