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A comparative study of insect diversity and distribution across elevations at Denai Cadamba, UiTM Puncak Alam, Malaysia

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Abstract. *Fathiah KN, Alhafiza IMDP, Amin IN, Nadiah MYN, Khairiyah MHS, Akmal AWN, Norhafizah MZ. 2024. A comparative study of insect diversity and distribution across elevations at Denai Cadamba, UiTM Puncak Alam, Malaysia. Biodiversitas 25: 3473-3479.* Insects play a significant role in shaping the ecosystem community and are beneficial to mankind in many ways. They are known for many roles such as pollinators, bioindicators, scavengers, and vectors for diseases. A study on the diversity and distribution of class Insecta was conducted using two Malaise traps at the hiking trail of Denai Cadamba, UiTM Puncak Alam, Malaysia as no study has been done here before. Two study sites with two different elevations were chosen: low elevation (70 meters above sea level/masl) and high elevation (110 masl). A total of 2476 individuals from 335 morphospecies belonging to 13 orders were collected. The orders identified were Diptera, Lepidoptera, Hymenoptera, Coleoptera, Hemiptera, Collembola, Thysanoptera, Orthoptera, Blattodea, Microcoryphia, Isoptera, Mantodea, and Psocoptera. Diptera was the most common order sampled, while Microcoryphia and Psocoptera recorded the least number, with only two individuals found each. The Shannon-Wiener Diversity Index (H′) showed that the higher elevation (trap 2) has a higher diversity with H′=1.362 compared to the lower elevation (trap 1) with H′=1.017. The Evenness Index (E′) and Margalef Richness Index (R′) were also higher for trap 2 with the values E′=0.300 and R′=1.635 respectively, while for trap 1, the values were E′=0.276 and the R′=1.315, respectively. Mann-Whitney test showed that there was a significant difference in the insect distribution between the low elevation and the high elevation with $P<0.05$. In general, this study found that the order distribution differs across the elevations. This might be due to the rainy season, sunlight exposure, warmer conditions, less human disturbance, and type of vegetation. The data obtained in this study can be used as a baseline for future research while serving as an educational purpose to create awareness among the public about insect conservation and management.

Keywords: Abundance, distribution, diversity indices, hiking trail, insects

INTRODUCTION

Insects are the most extensive and diverse group under the kingdom Animalia whose respective phylum is Arthropoda. This phylum comprises all animals which are having segmented bodies and exoskeletons (Triplehorn et al. 2005). Arthropoda can be further divided into four classes: Arachnida, Crustacea, Hexapoda, and Myriapoda. Insects belong to the class Hexapoda or Insecta (Springer and Holley 2012) and have distinct characteristics from other classes under the phylum Arthropoda. Insects have a three-part segmented body (head, thorax, and abdomen), three pairs of legs, a pair of antennae, a pair of compound eyes, and two pairs of wings. However, some insects, like ants and fleas, do not exhibit all these characteristics (Moore 2015).

The class Insecta has 30 orders (Moore 2015) with approximately one million known species. Globally, insect diversity is estimated to reach as high as 80 million; despite this, only about 20% of insects have been named and characterized. Insects make up more than 58% of all known species in the world (Tihelka et al. 2021), with the most abundant insects from the orders Coleoptera (beetles), Lepidoptera (butterflies and moths), Hymenoptera (ants, bees, wasps), and Diptera (true flies) (Wigglesworth 2022). Insects role as keystone species has attracted researchers to study more about their distribution and abundance across the world. Habitat restoration, sustainable agricultural practices, and minimization of pesticides are the current conservation practices used to acknowledge the critical importance of insect biodiversity (Hallmann et al. 2017). Their distribution can be affected by biotic and abiotic components such as competition, temperature, and humidity (Naman et al. 2019).

Even though insects are small, their roles in the ecosystem are diverse and crucial; for instance, insects are important for pollination (Abd Aziz et al. 2021; Hatta et al. 2023), carbon sequestration in soil (Bardgett and Van Der Putten 2014), organic matter recycling, and water filtration (Dangles and Casas 2019). Insects play an implicit but consequential role in supporting carbon sequestration by enhancing soil health through decomposition and have various ecological functions, thereby contributing to climate change mitigation efforts (Bardgett and Van Der Putten 2014). Due to this reason, insects play an indirect role in some of the strategies implemented to achieve the Sustainable Development Goals (SDGs) that are centred on potential sources to solve some current global challenges (Dangles and Casas 2019).

Human activities and urbanization have led to the decline of insect populations, a situation largely unnoticed due to the apparent abundance of insects. Construction and urbanization are rapidly occurring in Puncak Alam areas, including UiTM Puncak Alam. Denai Cadamba, which is situated in UiTM Puncak Alam, is open to the public for hiking, and this tourism activity might threaten the habitat of insects. Remarkably, the insect population in Denai Cadamba, a unique opportunity for study, has not been documented.

This study is of paramount importance as it not only provides crucial information about insect distribution and abundance at Denai Cadamba, UiTM Puncak Alam but also assesses the health of an ecosystem and assesses potential threats to biodiversity. It will provide beneficial information for future research as no comprehensive study has been carried out on class Insecta in Puncak Alam. In addition, this study also helps guide further studies and the development of effective conservation strategies. These strategies will play a significant role in mitigating the negative impacts of recreation and urbanization on the ecosystem in Puncak Alam.

From this study, we sought to understand the distribution and abundance of class Insecta at Denai Cadamba, UiTM Puncak Alam. This research will provide a list of insect orders present in the Denai Cadamba hiking trail and observe how biotic factors, and abiotic factors affect their distributions. This information can help researchers with future research and give insight into the diversity and abundance of the class Insecta at Denai Cadamba, UiTM Puncak Alam.

MATERIALS AND METHODS

Study site

This study was conducted at Denai Cadamba Forest, UiTM Puncak Alam (Figure 1). Located in Puncak Alam, Malaysia (3.23708°N, 101.42381°E), it is one of the hiking trails that UiTM Puncak Alam students frequently use for extracurricular activities. Denai Cadamba features an easy-to-moderate hiking trail, making it suitable for all ages. The relatively gentle hill provides one of the best views in the area. Because of their easily accessible and gradually varying elevation gradients, these hiking trails were chosen as study sites to examine the impact of elevation on insect diversity.

Sampling methods

In this study, Malaise traps were used to capture the insects from both elevations. The traps were installed for two weeks starting from 3 to 17 December 2022. The Malaise traps were positioned in flat, open areas measuring at least 2×1.5 m. The peak of each trap was oriented towards a light source, and the lower edges were firmly anchored to the ground using pegs while the roof corners were fastened to nearby trees to ensure a tight and secure setup (Evans 2016). The samples collected from each Malaise trap were sorted into their respective order by observing their morphology. Each morphospecies was counted, and the data obtained were used to analyze the distribution and abundance of each order present.

Two Malaise traps (Figure 2) were set up at two different elevations: low elevation (around 70 masl) and high elevation (around 110 masl). A killing bottle with 70% alcohol was placed at the upper part of the Malaise trap to kill and preserve the samples. The collected samples were preserved with 70% alcohol and then classified according to their order. The identified samples were pinned using insect pins in temporary storage boxes according to their respective order, along with details such as order, date, and name.

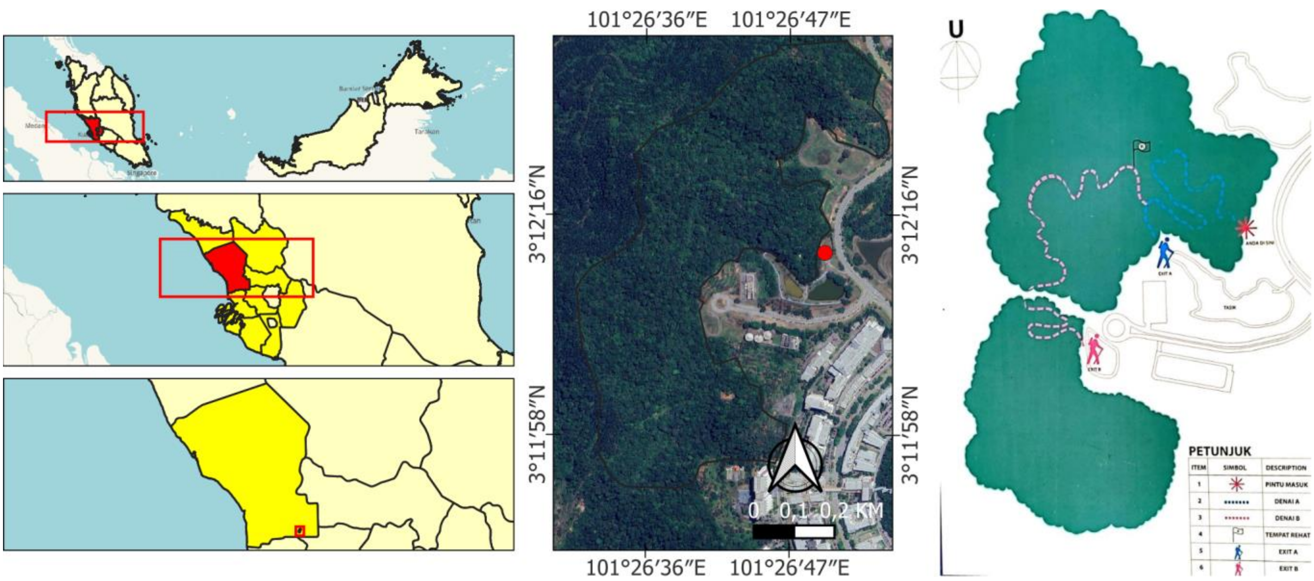

Figure 1. Denai Cadamba Forest, UiTM Puncak Alam Tasik 5 entrance, Kuala Selangor, Selangor, Malaysia

The samples were pinned using the entomological pin. The morphological and physical characteristics of the specimens were observed and compared to the reference book, Borror and DeLong's Introduction to the Study of Insects (7th Edition), for order identification purposes.

Data analysis

All the data were analyzed by using Statistical Product and Service Solutions (SPSS) and Paleontological Statistics (PAST) software. Shannon-Wiener Diversity Index, Evenness Index, and Margalef Richness Index were used to measure biodiversity index (Pudzi et al. 2017). The normality test and Mann-Whitney test were performed to determine the differences in insect distribution between the two different elevations.

RESULTS AND DISCUSSION

Throughout this study, 2476 individuals from 13 orders from class Insecta and 335 morphospecies were collected from two different elevations at Denai Cadamba hiking trail, UiTM Puncak Alam. Figure 3 shows the percentage of insects collected based on the orders present.

The most abundant order of insects collected was Diptera (true flies) at 65%, followed by Lepidoptera (butterflies and moths) at 10%, Hymenoptera (ants, bees, and wasps) at 9%, and Coleoptera (beetles) at 6%. Meanwhile, the other 10 orders were recorded at 5% or lower: Hemiptera (true bugs) with 114 individuals (5%), Collembola (springtails) with 107 individuals (4%), Thysanoptera (thrips) with 20 individuals (1%), and Blattodea (cockroaches) with 12 individuals (1%). Five orders were recorded under 10 individuals, which were Microcoryphia (bristletails), Orthoptera (grasshoppers and crickets), Isoptera (termites), Mantodea (mantises), and Psocoptera (booklice and barklice) (Figure 3).

These results were obtained despite having only two study sites; this is probably due to the use of Malaise traps for insect collection, as it stands out as the most effective trapping method compared to the other methods such as pitfalls, light traps, Berlese funnels, and sweep nets (Hatta et al. 2022). Diptera dominated the insect distribution with 64% in the study area. This result was expected as Diptera are known as one of the most species-rich insect orders (Huang et al. 2022). Diptera are important as pollinators, scavengers, and predators (Pudzi et al. 2017). Similar to dipterans, lepidopterans, and hymenopterans are also known as populous orders. They are also important pollinators: adult Lepidoptera and Hymenoptera are nectar feeders, so pollen grains from stamen can attach to their bodies and be transferred to another flower stigma (Electric Power Research Institute 2022). Pollination is always one of the highlights when discussing the interaction between insects and plants (Hatta et al. 2021). Adamidis et al. (2019) reported the importance of the pollinator's role in enhancing crop yield production and shortening the growing season.

Figure 2. Townes-style Malaise traps for insect collection

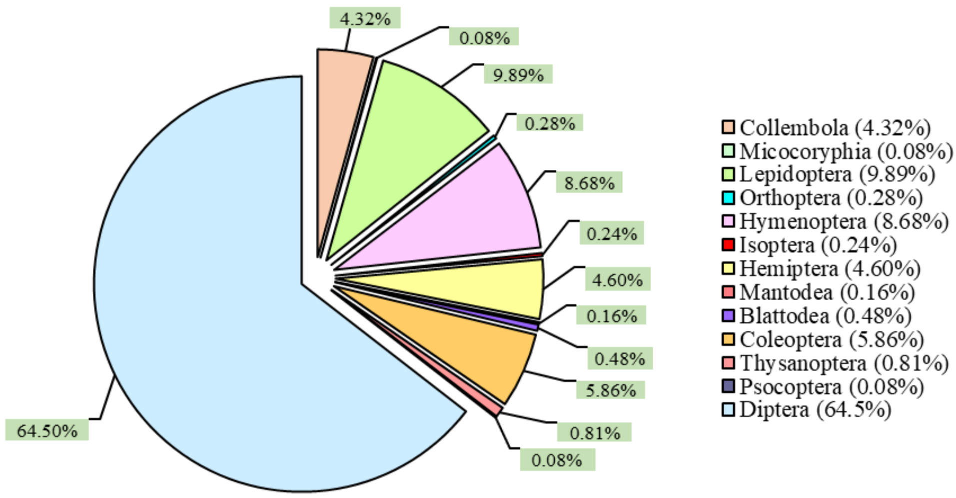

Figure 3. Percentage of insects collected based on orders found

The fourth highest order in overall number was Coleoptera, an order known for 350,000 species (Smithsonian 2023). Yet, their number was lower than the number of Diptera collected in this study. Likewise, Hatta et al. (2022) recorded 53 individuals of Coleoptera at Tuba Island Reserve Forest and 101 individuals of Coleoptera at Gunung Datuk, Negeri Sembilan (Pudzi et al. 2017), while the number of Diptera collected was 5,450 individuals and 1,028 individuals respectively. As both studies only used Malaise trap for collecting samples, it indicates that the number of Coleoptera individuals collected in this study does not reflect the whole population of Coleoptera at the study site. This is because Coleoptera are flying animals that can maneuver; besides that, their flying behavior varies between species because of their diverse eating habits (Harada et al. 2021). It can also be said that the Malaise trap is not the best trap to catch Coleoptera compared to the pitfall trap for ground-dwelling beetles and the pan trap for some flying beetles (Montgomery et al. 2021).

Meanwhile, the least commonly found orders were Microcoryphia and Psocoptera, where only two individuals with two morphospecies were collected from each order. The association of Microcoryphia and Psocoptera as moisture-dependent insects is the likely explanation for this situation as a laboratory study showed that the optimal relative humidity for psocids is approximately 80% (Mattsson 2021). These insects live under barks, logs, and leaf litter and play an important role as decomposers for decaying leaves (Mendes 2018).

Abundance

Table 1 shows the abundance of insects at Denai Cadamba, UiTM Puncak Alam at different elevations. Trap 1 was set at a lower elevation (around 70 masl), and trap 2 was set at a higher elevation (around 110 masl).

A total of 940 individuals were collected at the lower elevation (trap 1) with 10 orders, while 1,536 individuals were collected at the higher elevation (trap 2) with 12 orders (Table 1). Insect populations tend to be more abundant and diverse in lower elevation regions compared to higher altitudes (Khairiyah et al. 2013; Pudzi et al. 2017). However, this study shows that the higher elevation recorded more insects than the lower elevation, a finding that challenges existing knowledge. The small difference in elevation (only a 40 m difference in altitude between the traps) has limited the extent of ecological variation observed between the two sites. Limited temperature variations, similar vegetation types, minor microclimate differences, and overlap of insect species might have attributed to this finding (Hodkinson 2005). Lower elevations are often more accessible and may experience greater human activity, such as hiking or development, which can impact insect populations. This research underscores the importance of considering all factors, including human activity, in ecological studies. Higher elevations might be more remote and less disturbed, allowing for different species to flourish (Hamer and Hill 2000).

Diptera dominated Denai Cadamba as the most abundant order for both traps even though higher elevation (931 individuals) captured one-third more individuals than lower elevation (666 individuals). Sampling was done in mid-December, during rainy season in Malaysia. Rainfall is one of the important factors that influence Diptera diversity and abundance, as wet seasons are associated with high populations, especially mosquitoes (Nurin-Zulkifli et al. 2015). Midges and gnats are also expected to appear more in a swarm during the rainy period (Townsend 2018). This statement is supported by the study done by Hatta et al. (2022) where 93% of the total sample consisted of Diptera species and the dominant gnat family because the sampling period occurred during the southwest monsoon at Tuba Island, Malaysia.

For Lepidoptera, there was a slight difference where higher elevation had more individuals than lower elevation, with 131 and 114 individuals, respectively. This is probably because higher elevation trap placement received more sunlight compared to lower elevation placement, which makes higher elevation more favorable as some Lepidoptera are positively phototactic where they are attracted to light (Park and Lee 2017). This is proven by an experiment on bagworm reaction towards the light, where bagworm larvae aggregated at the focus point of the light intensity and shifted as the light source placement was shifted (Tripathy and Panda 2022). Vieira et al. (2022) also observed a higher number of Lepidoptera individuals at higher elevations compared to lower elevations, which contradicted what they expected. Similarly, Shrestha et al. (2020) found the same result: they elucidated that species richness notably increased with elevation. The presence of more shrubs with less forest and specific plant species might have attracted more Lepidoptera at the higher elevations. Lepidoptera play a role as biological indicators as they are sensitive to environmental changes, have short life cycles, and are easy to sample (Henriques et al. 2019).

Table 1. Abundance of insects at different elevations of Denai Cadamba

Order	Morpho-species	Trap		Total individual
		1 (70 m)	2 (110 m)	
Diptera	83	666 (57)	931 (71)	1597
Lepidoptera	68	114 (51)	131 (37)	245
Hymenoptera	78	39 (21)	176 (62)	215
Coleoptera	48	23 (13)	122 (44)	145
Hemiptera	30	3 (3)	111 (27)	114
Collembola	4	86 (4)	21 (4)	107
Thysanoptera	2	1 (1)	19 (2)	20
Blattodea	8	3 (3)	9 (5)	12
Orthoptera	6	3 (2)	4 (4)	7
Isoptera	3	0	6 (3)	6
Mantodea	1	0	4 (1)	4
Microcoryphia	2	2 (2)	0	2
Psocoptera	2	0	2 (2)	2
Total individual		940	1536	2476
		38%	62%	
Total order	13	10	12	
Total morphospecies	335	157	262	

Note: The value in the bracket is the total number of morphospecies

Table 2. Diversity indices of insects at Denai Cadamba, UiTM Puncak Alam

Elevation	H′	E′	R′
Lower	1.017	0.277	1.315
Higher	1.362	0.300	1.635

Hymenoptera, a widely studied order due to their keystone species function, was recorded as the third most abundant order in this study. This result is similar to a previous study by Pudzi et al. (2017) conducted at Gunung Datuk, Negeri Sembilan, and they found that Hymenoptera was the second highest order. However, the pattern shown by lower elevation and higher elevation contradicted the results obtained by their study where in this study, Hymenoptera caught in trap 2 (higher elevation) were more abundant than in lower elevation (trap 1). This is probably due to the temperature at higher elevations being warmer than at lower elevations, as the trap at higher elevation was placed at one of the peaks that were directly exposed to the sunlight. Temperature exerts a strong influence on ectothermic organisms, restricting their foraging to specific temperature ranges and impacting their metabolic activities, population growth, and diversification (Mayr et al. 2020).

Next, Coleoptera showed higher abundance at the higher elevation (trap 2) with 122 individuals compared to 23 individuals at the lower elevation (trap 1). This might be because the trap at the lower elevation was located at the forest entrance compared to where the trap at the higher elevation was placed. This placement could have deterred the beetles since their distribution is influenced by various factors, including human-induced disturbances and multiple environmental factors (Musthafa and Abdullah 2019).

Hemiptera were recorded as the sixth and fifth-highest individuals collected for lower and higher elevations, respectively. Hemiptera were more abundant in higher elevations compared to lower elevations (Table 1) because they are associated with plant feeding (Jocson et al. 2019); direct sunlight provides optimal conditions for plants to grow. Additionally, even though Hemiptera are found in both aquatic and terrestrial environments, they have a greater diversity in warm and shallow waters as these conditions provide abundant vegetation as their food source (EcoSpark 2023).

Next in line is Collembola, where there was also a huge difference between the number of individuals at lower elevations (86 individuals) and higher elevations (21 individuals), where 4 morphospecies were found in both traps (Table 1). This difference might be because the microhabitat surrounding the lower elevation has an abundance of leaf litter on the ground and shady trees, making this place damp and suitable for Collembola. Collembola are decomposers; they mineralize organic matter that is important in the nutrient cycle (Sandrine 2019).

From the overall finding, we concluded that the abundance of class Insecta at Denai Cadamba, UiTM Puncak Alam, was different between traps. Because the data collected in this study were not normally distributed, a non-parametric test was conducted to measure the distribution difference of class Insecta between the elevations. Mann-Whitney Test shows that the distribution of orders across elevation has a significant difference (Mdn=795701.500, df=1, $P<0.05$). Furthermore, the rainy season can also be a factor that influences insect abundance; flying in rainy conditions is challenging for insects as it reduces flight efficiency and consumes more energy (Lawson and Rands 2019). This understanding can help us appreciate the resilience and adaptability of these creatures.

Species diversity, evenness, and richness

Paleontological Statistics (PAST) software was used to analyze the diversity indices of class Insecta at Denai Cadamba, UiTM Puncak Alam. The statistical measures used in this study were the Shannon-Wiener Diversity Index (H′), Evenness Index (E′), and Margalef Richness Index (R′). Table 2 shows the diversity indices that represent insect diversity at Denai Cadamba, UiTM Puncak Alam.

Insect diversity was relatively higher in higher elevations (H′=1.362) compared to lower elevations (H′=1.017). Lower human disturbance and higher exposure to light might be the factors behind these results. In most ecological studies, the diversity values generally fall between 1.5 and 3.5 (Magurran 2004). The Evenness Index shows whether any certain species dominates the selected ecosystem or relatively has the same proportion of individuals, where a higher E′ value indicates less domination of certain species (Sholiqin et al. 2021). The value of the Evenness Index for trap 1 (E′=0.276) was lower than for trap 2 (E′=0.300), which indicates more order domination occurs in trap 1. This low E′ value was mostly contributed by the higher number of Diptera present in both traps than in the other orders. For the Margalef Richness Index, higher elevation also recorded a higher value, showing that higher elevation has higher species richness than lower elevation. A higher number of morphospecies present alongside a higher number of individuals collected might explain trap 2 species richness.

In conclusion, in conclusion, a total of 2476 individuals of insects were collected at Denai Cadamba, UiTM Puncak Alam. The insects were sorted and identified revealing a diverse array of 13 orders and 335 morphospecies. The orders present and identified in this study were Diptera (true flies), Lepidoptera (butterflies and moths), Hymenoptera (ants, bees, and wasps), Coleoptera (beetles), Hemiptera (true bugs), Collembola (springtails), Thysanoptera (thrips), Orthoptera (grasshoppers and crickets), Isoptera (termites), Blattodea (cockroaches), Mantodea (mantises), Microcoryphia (bristletails), and Psocoptera (booklice and barklice). The total number of individuals at the higher elevation (1,536 individuals) was higher than in the lower elevation (940 individuals), with 262 morphospecies from the higher elevation and 157 morphospecies found in the lower elevation. Diptera was the most commonly found order at these two elevations, with 83 morphospecies from 1,597 individuals. Conversely, the least number belonged to Psocoptera and

Microcoryphia, each with two morphospecies and two individuals. The result revealed significant differences in the insect distribution between trap 1 (lower elevation) and trap 2 (higher elevation), potentially influenced by several factors such as sunlight exposure, temperature, human disturbance, and the type of vegetation present.

For future studies, it is recommended to increase the number of traps and prolong the sampling period to ensure more samples are collected and obtain more precise and accurate data to reflect the ecosystem conditions of the research locations. It is also recommended to determine whether human disturbance has a direct impact on the study by installing a trap near the track of the hiking trail and a trap that is far away from the track. Equally important is to avoid the rainy season during the sampling period, as it may result in a low number of samples collected, thereby affecting the accuracy of the data.

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