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Inventory of butterfly species in Kali Pethuk, Rahtawu Village, Gebog District, Kudus Regency

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A B S T R A C T
Indonesia is recognized for its exceptionally high biodiversity, including diverse insect groups such as butterflies, which act as pollinators and bioindicators of ecosystem health due to their sensitivity to habitat changes. This study aimed to inventory butterfly species in the Kali Pethuk area, Kudus Regency, Central Java, using a field observation method with an exploratory survey approach. Observations were conducted directly along the riverbanks and surrounding vegetation in May, with each session lasting 2–4 hours, employing random sampling. Eight butterfly species from four families: Pieridae, Lycaenidae, Nymphalidae, and Papilionidae were recorded. The diversity index (H') was 1.65, classified as moderate, indicating a reasonably varied butterfly community, while *Eurema* sp. was the most dominant species and the evenness index (E = 0.86) suggested a fairly balanced distribution among species. Data collected included the number of individuals, species richness, and abundance. These findings provide valuable baseline information for understanding local biodiversity, supporting environmental monitoring and conservation planning in riparian ecosystems, and offering a reference for future ecological studies aimed at assessing long-term changes in species composition due to anthropogenic or climatic influences.
Keywords: Inventory of butterfly; Species diversity; Species abundance

1. INTRODUCTION

Indonesia is recognized as the second most megadiverse country in the world after Brazil. The term *megadiversity* refers to countries or regions that possess an exceptionally high level of biodiversity, encompassing genetic variation, species richness, and diverse ecosystems (Yanuar et al., 2011). This biodiversity spans all levels of life, from genetic diversity within species, the number and variety of species, to the ecosystems in which they exist. Insects are the most species-rich animal group, yet many, especially in tropical regions like Indonesia, remain undescribed. Often perceived as pests, they play vital ecological roles. Global declines in insects, particularly in biodiverse tropical forests, are poorly documented, with up to 80% of tropical species still undescribed, highlighting the urgency of studying and conserving these key components of biodiversity (Boyle, et al., 2024). These roles include functioning as pollinators that assist in plant reproduction, decomposers that accelerate organic matter breakdown, natural predators of crop pests, and parasitoids that regulate the populations of other organisms (Haneda et al., 2023).

Butterflies are among the insect groups that play an essential role in maintaining ecological balance (Florida et al., 2015). In addition to functioning as natural pollinators for flowering plants, butterflies possess high aesthetic and educational value and are widely used as indicators in biodiversity studies. Their wide distribution across diverse habitats, ranging from lowland areas to high mountain regions, makes butterflies important indicators representing the state of biodiversity and key ecosystem functions. However, the effective use of butterflies as bioindicators requires a deeper understanding of how their observed responses are linked to environmental factors that influence their diversity, distribution, and species composition (Comay, et al., 2021). Their presence and abundance are highly influenced by various environmental factors such as temperature, humidity, vegetation cover, and the availability of food resources. Therefore, butterflies are considered effective bioindicators of environmental health, as changes in habitat conditions are often reflected in shifts in butterfly composition and population size. In addition to natural factors, anthropogenic activities such as land-use changes, deforestation, pollution, and urbanization also have a significant impact on butterfly populations (Ren et al., 2022). In Indonesia, a tropical country with high biodiversity, it is estimated that there are approximately 1,600 to 2,500 butterfly

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species distributed across various islands and ecosystems. This figure reflects the vast potential for scientific research, conservation efforts, and sustainable utilization.

Currently, biodiversity is facing serious threats, including escalating levels of degradation and loss. One of the primary causes of biodiversity decline is habitat destruction either directly through deforestation and forest fragmentation, or indirectly through pollution and climate change. Such environmental changes negatively affect the survival of various plant and animal species, potentially leading to rarity or even extinction (Sutoyo, 2010). Additionally, excessive exploitation, such as poaching, illegal wildlife trade, and unsustainable use of natural resources, further exacerbates this issue. These challenges have prompted scientists and conservation practitioners to raise public awareness about the importance of environmental preservation. Insects, being highly diverse yet vulnerable to environmental changes, have become a central focus in conservation campaigns. Conservation efforts targeting this group are considered vital due to their key ecological roles and the high number of species yet to be scientifically documented (Cardoso, 2020). Documenting insect diversity, especially butterflies, is a critical first step in biodiversity conservation, providing baseline data to detect ecological changes and guide management. Similar insights come from Great Britain's comprehensive butterfly database, which shows how long-term species records reveal trends and gaps crucial for conservation. This comparison underscores that systematic documentation is essential for understanding community dynamics and informing effective conservation strategies across both local and large-scale contexts (Lobo, et al., 2021).

Kali Pethuk is one of the river ecosystems that has recently developed into a nature-based tourist destination located in Rahtawu Village, Gebog District, Kudus Regency, approximately 21.6 kilometers from the center of Kudus City. This area lies within the Muria mountain range, known for its relatively undisturbed ecosystems and scenic landscapes. The river flowing through this highland terrain offers captivating views, complemented by cool air and a preserved rural atmosphere. In addition to its recreational appeal, Kali Pethuk holds great potential for the development of environmental education programs. Its lush river environment, diverse vegetation, and proximity to forested areas make it an ideal location for outdoor learning, including activities such as river ecosystem exploration, water conservation, and biodiversity education like butterfly observation. Despite this potential, scientific information about the ecological status and biodiversity of Kali Pethuk remains limited, particularly in the context of its integration with nature-based tourism. Most studies within the Muria mountain range have focused on forest biodiversity and watershed management, leaving riverine ecosystems underexplored. There is still a lack of comprehensive data on species diversity, habitat quality, and ecosystem dynamics, which hinders the ability to evaluate the environmental carrying capacity of this area. This research gap makes it challenging to determine whether current and future tourism activities can coexist sustainably with ecosystem conservation, highlighting the urgency and relevance of conducting this study.

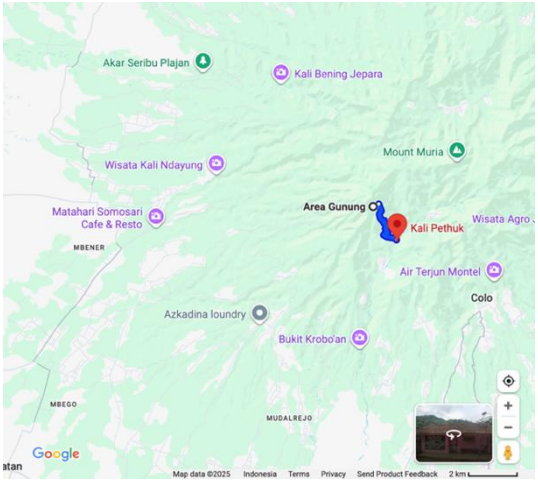

Figure 1. Geographic location of the research site

This research provides significant scientific and practical contributions beyond serving merely as baseline data. Scientifically, it delivers valuable insights into species composition, ecological dynamics, and biodiversity status, which can serve as essential references for future studies and conservation planning. Practically, the findings can be used as measurable indicators of environmental sustainability and ecotourism management**,** assisting stakeholders in monitoring habitat quality, assessing the ecological impacts of tourism, and designing conservation-based tourism strategies. Consequently, the research not only enriches local biodiversity databases but also supports integrated management policies aimed at maintaining ecological balance while promoting sustainable nature-based tourism in Kali Pethuk.

Preliminary surveys indicate that the environmental conditions at Kali Pethuk remain relatively natural, with low levels of human disturbance, as evidenced by the presence of various fauna species, including butterflies. The diversity of butterfly species observed in this area suggests that Kali Pethuk possesses significant ecological potential and is well-suited as a site for research on insect biodiversity. This research is framed against with the comparative study of the ecotourism potential assessment in the Progo River's mangrove ecosystems (Yogyakarta), which applied nested and gridline sampling along with the Tourism Suitability Index (IKW) to evaluate habitat quality and determine suitability zones for recreation (Poedjirahajoe, et al, 2025). Therefore, this location is highly suitable for assessing habitat quality through butterfly inventory, which serves as a critical initial step toward documenting and preserving local insect biodiversity. The findings of this study are expected to provide valuable baseline data for future research, particularly in the fields of environmental conservation, ecological tourism management, and the inventory of other insect groups.

2. MATERIAL AND METHODS

This study employed a field observation method using an exploratory approach. Observations were conducted directly by surveying the river area and the surrounding vegetation. The study site is situated at an elevation of approximately 492 meters above sea level, characterized by a tropical highland riverine ecosystem with relatively lush riparian vegetation and a mix of natural and semi-managed habitats. During the observation periods, the **a**verage ambient temperature was recorded at 27.5 °C, which falls within the optimal thermal range for butterfly activity and survival. The combination of moderate elevation, stable temperature, and diverse vegetation provides favorable microhabitats and adequate floral resources, creating suitable conditions for butterfly feeding, mating, and oviposition.

A random sampling technique was applied to ensure unbiased data collection across different microhabitats along the river corridor. Sampling points were randomly determined within the study area to represent variations in vegetation cover, light intensity, and habitat structure. Sampling was carried out three times during different periods to obtain a more comprehensive representation of species diversity. Butterfly collection was conducted using insect nets to safely capture specimens, as well as smartphone cameras to visually document butterflies without the need for capture, particularly for sensitive or elusive species. Visual documentation also supported the identification and data verification processes. All collected data were subsequently analysed by calculating species diversity indices, species abundance indices, and species evenness indices.

Species identification was based on external morphological characteristics, including wing shape and coloration, body patterns, and overall body size. To enhance the accuracy of identification, reference materials such as identification guidebooks and relevant scientific articles on butterfly taxonomy and classification were used, particularly those focusing on commonly found species in Indonesia, with an emphasis on the Java region. Among these references, the primary guidebook used was *"Lepidoptera Semarang Raya"* by Baskoro et al. (2018)**,** which provides detailed descriptions, diagnostic features, and high-resolution illustrations of butterfly species commonly found in Central Java and surrounding areas. This reference was supplemented by additional scientific literature to ensure precise identification and verification of species records.

Data Analysis

Species Abundance Index (Krebs, 1989)

The species abundance index is used to determine the proportion of each species in the overall community. It is calculated using the following formula:

$$Di = \frac{ni}{N} \times 100\% \quad (1)$$

Where:

Di = Relative abundance index of species *i*

ni = Number of individuals of species *i*

N = Total number of individuals across all species

According to Jorgensen (1974), relative abundance values can be categorized as follows:

Di>5%Di>5%: Dominant species

Di=2–5%Di=2–5%: Sub-dominant species

Di<2%Di<2%: Non-dominant species

Shannon-Wiener Diversity Index

Species diversity was analyzed using the Shannon-Wiener diversity index (Krebs, 1989):

$$H' = -\sum pi \ln pi \quad (2)$$

Where:

$pi = \frac{ni}{N}$

H′ = Shannon-Wiener diversity index

ni = Number of individuals of species *i*

N = Total number of individuals across all species

Based on Magurran (1988), taxonomic diversity is classified into three categories:

High diversity: H′≥3.5H′≥3.5

Moderate diversity: 1.5<H′<3.51.5<H′<3.5

Low diversity: H′≤1.5H′≤1.5

Evenness Index

Species evenness was calculated using the following formula (Krebs, 1989):

$$e = \frac{H'}{\ln S} \quad (3)$$

Where:

e = Evenness index (ranging from 0 to 1)

H′ = Shannon-Wiener diversity index

ln = Natural logarithm

S = Total number of species (taxa)

According to Magurran (1988), the evenness level is categorized as:

High evenness: e > 0.6

Moderate evenness: 0.3 – 0,6

Low evenness: e < 0.3

If the value of e approaches 0, it indicates an uneven distribution in which certain taxa dominate the community. Conversely, if e = 1, it implies that all taxa are evenly distributed and have equal survival chances.

3. RESULTS AND DISCUSSION

The study conducted in the Kali Pethuk area revealed the presence of eight butterfly species belonging to four major families: Pieridae, Lycaenidae, Nymphalidae, and Papilionidae (Table 1). A total of 139 individual butterflies were recorded during the inventory observations, indicating that the Kali Pethuk ecosystem is relatively healthy and supports diverse insect life, particularly butterflies.

A healthy ecosystem is characterized by physical environmental factors that support the life of surrounding biota. One such key factor influencing the presence of insects is temperature, which significantly affects their survival, particularly during the nymphal stage (Sun et al., 2022). Butterflies are well-known biological indicators of environmental quality, and their presence in various species and large numbers is a positive signal of habitat health. This finding aligns with Azahra (2021), who stated that butterflies can serve as effective bioindicators of environmental conditions.

Each identified family included two butterfly species. The Pieridae family was represented by *Eurema* sp. and *Catopsilia* sp., both commonly found in open habitats and shrublands. While butterflies of the genus *Eurema* can become agricultural pests when larvae damage crops and reduce yields, research has shown that their larvae can be controlled using environmentally friendly plant-based extracts (Darmawan et al., 2016). Both *Eurema* and *Catopsilia* act as indicators of habitat health and are important pollinators. From the Lycaenidae family, *Euchrysops cnejus* and *Caleta* sp. were recorded, typically inhabiting areas with low vegetation. The Nymphalidae family included *Hypolimnas bolina* and *Symbrenthia hypselis*, two species known for their striking coloration and significant roles in the food web. Nymphalidae butterflies generally exhibit brown base colors with distinct patterns for each species (Baskoro et al., 2018). According to Kirton (2020), Nymphalidae is one of the most species-rich families within the order Lepidoptera. These butterflies are highly adaptable and are frequently found in shaded habitats with flowering plants (Handayani et al., 2022). This adaptability is attributed to their polyphagous nature, which allows them to feed on various host plants even when their primary host is unavailable (Ridwan, 2015). In high population densities, the larvae of this family can become pests. However, if their presence does not significantly affect agricultural yields, they are not categorized as pests (Martitik, 2025).

Additionally, two butterfly species from the Papilionidae family were observed: *Papilio memnon* and *Troides helena*. The presence of more sensitive or rare species like *Troides helena* highlights areas of high habitat quality and conservation value**.** Papilionidae butterflies were mainly found in open spaces. This corresponds with Ilhamdi et al. (2019), who noted that waterway paths tend to have higher humidity and light intensity due to water flow and canopy openings, creating favorable conditions for high-flying butterfly species such as those from the Papilionidae family. These findings highlight the importance of environmental conservation in the Kali Pethuk area to maintain butterfly diversity. The presence and survival of butterflies are highly dependent on natural habitat conditions. This is consistent with Kurniawan et al. (2020), who emphasized that butterflies are highly sensitive to habitat disturbances and climate change.

Eight butterfly species were recorded at Kali Pethuk, namely *Eurema* sp., *Catopsilia* sp., *Euchrysops cnejus*, *Caleta* sp., *Hypolimnas bolina*, *Symbrenthia hypselis*, *Papilio memnon*, and *Troides helena*, each representing distinct ecological roles within the ecosystem. All of these species are currently classified as Least Concern (LC) on the IUCN Red List, indicating relatively wide distributions and no immediate risk of extinction. However, this conservation status should be interpreted with caution, particularly in tropical butterfly systems, where ecological dynamics differ substantially from temperate regions. Compared to temperate butterfly systems, tropical butterfly ecology remains underrepresented in empirical studies, and the relative scarcity of long-term and population-level data limits our ability to accurately assess conservation priorities. As highlighted in studies of tropical butterfly ecology, the apparent stability of LC-listed species may mask underlying vulnerabilities driven by habitat alteration, resource specialization, and complex species interactions, underscoring the need for localized ecological assessments as a framework for effective conservation in tropical regions (Bonebrake, et al., 2010). Additionally, the observed species composition reflects the structural diversity of the riparian vegetation and microclimatic suitability, suggesting that the moderate elevation (492 masl), average temperature (27.5 °C), and heterogeneous vegetation collectively create optimal conditions for butterfly activity, reproduction, and

feeding. These findings are critical for ongoing biodiversity monitoring, guiding conservation management, and developing ecotourism strategies that maintain ecosystem integrity while supporting species persistence.

Table 1. Species and population of butterfly in Kali Pethuk

No	Class	Order	Family	Species	Obervation			Total
					1	2	3	Σ
1	Insect	Lepidoptera	Pieridae	*Eurema sp*	15	9	21	45
2				*Catopsilia sp*	11	15	16	42
3			Lycanidae	*Euchrysops cnejus*	5	3	17	25
4				*Caleta sp*	3	3	3	9
5			Nymphalidae	*Hypolimnas bolina*		2	2	4
6				*Symbrenthia hypselis*		4	2	6
7			Papilionidae	*Papilio memnon*		3	1	4
8				*Troides helena*	1	2	1	4
Total								139

The diversity index analysis indicates that butterfly diversity in the Kali Pethuk area falls into the moderate category, with a value of 1.65 (Table 2). This suggests that, while the area hosts a fairly wide range of species, some species still dominate the local butterfly community. A moderate diversity level generally reflects a relatively stable ecosystem but also points to the presence of certain species that are more adaptable or competitive than the others. Specifically, an index of 1.65 shows that no single species overwhelmingly dominates the community, yet overall diversity has not reached a high level. The butterfly community at Kali Pethuk shows a balance between species richness and evenness, despite the dominance of *Eurema* sp., typical of ecosystems under mild environmental pressures or light disturbances. Similar studies highlight the need for habitat-specific strategies: enhancing native plants in urban areas, restoring wetlands, and addressing fragmentation in peripheral habitats. Integrating such targeted actions with community engagement helps maintain butterfly diversity and ecological stability across landscapes with varying human impacts (Trivedi, et al., 2024). The pattern observed in Kali Pethuk aligns with the Intermediate Disturbance Hypothesis (IDH), which posits that species diversity is highest at intermediate levels of ecological disturbance. Low levels of disturbance allow highly competitive species to dominate, whereas high levels of disturbance put all species at risk of local extinction. At intermediate disturbance levels, however, species from both early and late successional stages can coexist, leading to higher overall diversity. This concept is supported by Mercado-Gómez et al. (2023), who found that in dry tropical forests, butterfly diversity increases under moderate disturbances, suggesting that mild to moderate environmental changes can enhance diversity by providing habitats suitable for species capable of adapting to varying ecological conditions.

Moreover, the moderate level of butterfly diversity observed in the Kali Pethuk area may be influenced by the limited availability of critical resources, including food sources, host plants, and suitable breeding sites. These resource limitations tend to favour species with higher adaptability and efficiency in resource utilization, allowing them to outcompete less flexible species and establish local dominance. Therefore, it is important to identify butterfly distribution patterns and the factors influencing butterfly diversity and species composition, as

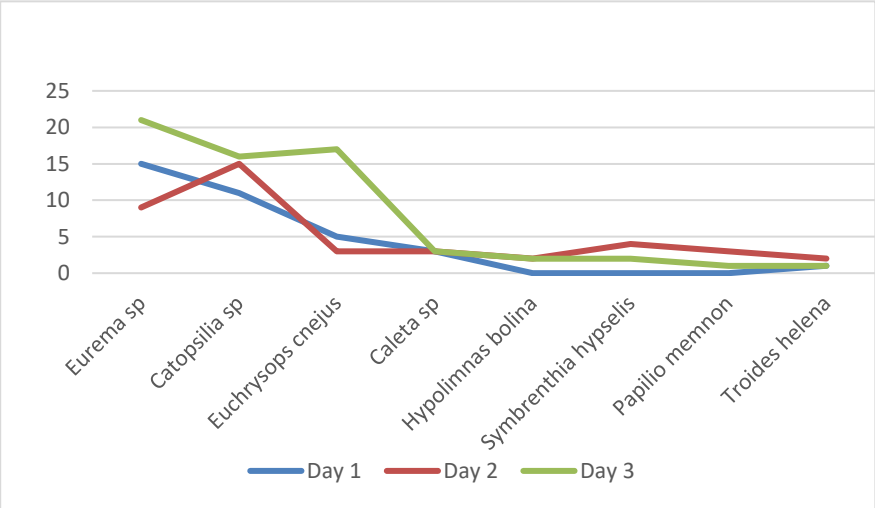

Figure 2. Butterfly species abundance across three observation periods

such information is essential for understanding the ecological dynamics of the habitat and supporting effective conservation planning (Han, et al., 2021). This selective advantage contributes not only to the observed patterns of species dominance but also to the overall structure and stability of the butterfly community. Consequently, the diversity index serves a dual function: it reflects the current ecological balance within the habitat and acts as an early-warning indicator of environmental quality. Tracking community indices over time enables conservationists to detect changes in species composition and identify emerging ecological pressures, supplying critical information for designing targeted and sustainable biodiversity management strategies. In Kali Pethuk, maintaining a balanced distribution of butterfly species alongside high-quality habitats is essential for sustaining species richness and long-term ecosystem functionality. Comparable insights are evident in studies of urban–rural gradients, such as in Purulia district, West Bengal, India, where assessing butterfly diversity and richness indices provided a basis for understanding how habitat variation influences community structure and informs ecosystem management decisions. These comparisons highlight that systematic monitoring of diversity indices, whether in relatively natural or anthropogenically influenced landscapes, is a key tool for predicting ecological changes and implementing effective conservation interventions (Mukherjee and Hossain, 2024).

The analysis of the dominance index in the Kali Pethuk butterfly community indicated that *Eurema* sp. emerged as the most dominant species, with a value of 32.37, reflecting a substantially larger number of individuals relative to other species present in the area. In contrast, *Hypolimnas bolina*, *Papilio memnon*, and *Troides helena* recorded the lowest dominance indices, each with a value of 2.88, highlighting their comparatively lower abundance. Despite the apparent dominance of *Eurema* sp., the overall evenness index remained relatively high at 0.86, indicating that individuals were fairly evenly distributed among the various species. The high evenness of the butterfly community in Kali Pethuk indicates a relatively stable and resilient assemblage, where species can coexist without strong dominance and effectively utilize available resources. This balanced structure reflects the interaction between habitat conditions and resource availability that support community stability. Compared to studies in tropical forest landscapes, primary forests often show non-neutral patterns driven by niche specialization, while disturbed habitats tend to shift communities toward neutral dynamics with higher evenness but reduced species richness. The pattern observed in Kali Pethuk suggests moderate habitat conditions that allow coexistence without the severe species loss typically associated with heavily disturbed environments (Cleary, et al., 2025). Recent studies support these findings. Christianus, et al. (2024) reported that in Lata Hokkaido, Malaysia, *Eurema hecabe*was the dominant species, yet overall butterfly diversity remained high, illustrating a balance between dominance and species richness. Similarly, Nurhayati et al. (2024) found that environmental conditions and habitat modifications influenced butterfly community structure in Bahorok, Sumatra Utara, with moderate disturbances favoring certain dominant species while maintaining diversity. These results indicate that even in communities where a few species dominate, high evenness can reflect a resilient and stable ecosystem, highlighting the importance of considering species interactions and habitat quality in conservation planning.

Table 2. Species diversity, abundance, and evenness index

No	Species	Observation			Total	Species Diversity Index	Abundance Index	Evenness Index
		1	**2**	**3**	**Σ**	**H'**		**e**
1	*Eurema sp*	15	9	21	45	0,37	32,37	0,85
2	*Catopsilia sp*	11	15	16	42	0,36	30,22	
3	*Euchrysops cnejus*	5	3	17	25	0,31	17,99	
4	*Caleta sp*	3	3	3	9	0,18	6,47	
5	*Hypolimnas bolina*		2	2	4	0,1	2,88	
6	*Symbrenthia hypselis*		4	2	6	0,14	4,32	
7	*Papilio memnon*		3	1	4	0,1	2,88	
8	*Troides helena*	1	2	1	4	0,1	2,88	
Total					139	1,65		

Figure 1. *Eurema sp*

Figure 2. *Catopsilia sp*

Figure 3. *Euchrysops cnejus*

Figure 4. *Caleta sp*

Figure 5. *Hypolimnas bolina.*

Figure 6. *Symbrenthia hypselis*

Figure 4. *Papilio memnon*

Figure 5. *Troides Helena*

4. CONCLUSION

This study reveals that the Kali Pethuk area in Kudus Regency exhibits a moderate level of butterfly species diversity, with a total of eight species distributed across four families: Pieridae, Lycaenidae, Nymphalidae, and Papilionidae. *Eurema* sp. was identified as the most dominant species, while the high evenness index value (0.86) indicates a relatively balanced distribution of individuals among species. These findings suggest that the surrounding environment still supports the presence of various butterfly species, highlighting the ecological importance of the area and its potential as a suitable habitat for pollinating insects. This study also provides a valuable foundation for future biodiversity-based conservation efforts and the sustainable management of ecotourism in the region.

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