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Survey of the butterflies (Lepidoptera: Rhopalocera) species of the northern coast of East Java, Indonesia

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Abstract. *Arof AS, Barbosa FF. 2024. Survey of the butterflies (Lepidoptera: Rhopalocera) species of the northern coast of East Java, Indonesia. Intl J Trop Drylands 8: 83-94.* The cosmopolitan order Lepidoptera Linnaeus, 1758, is one of the major orders of hexapods and a megadiverse clade of holometabolous insects. Within this order is included, the mostly diurnal butterflies (Lepidoptera: Rhopalocera: Papilionoidea *sensu* Kawahara and Breinholt 2014). The worldwide butterfly species richness is estimated to be ~18,768 species, distributed in ~1,815 genera and seven families. This group presents well-known ecologically important species that may serve as bioindicators. They are relatively well-studied, particularly in temperate biomes, although considerable gaps in information persist in tropical areas. The study area is classified as a tropical and subtropical moist broadleaf forest biome, specifically in the Eastern Java-Bali rain forests ecoregion in the Indo-Malayan realm, and is classified as a critical or endangered biome. More specifically, this area is located on the Java island, East Java province (Oriental Java), northern coast. Also, it is part of Sundaland, which is considered one of the major biodiversity hotspots. From October 2016 to August 2024, twice at a weekly, the authors employed the exploring method along with a visual encounter survey, observing, capturing, and documenting the species encountered to access the species composition. This study covers 126 species belonging to 85 genera, 41 tribes, and 17 subfamilies of five families, and this distribution in the frequency of species among families broadly reflects the global distribution of species of butterflies. This is the first field investigation to study the butterfly richness specifically on the northern coast of East Java. The present study contributes to the knowledge of the butterfly fauna in the Indonesian archipelago. Additionally, this study contributes to future studies of the conservation of biodiversity in this key endangered region. Moreover, this study can be the first step towards future studies focusing on community ecology, population dynamics, and the use of butterflies as bioindicators in the northern coast of East Java.

Keywords: Biodiversity hotspot, butterfly species composition, butterfly species richness, endangered biome, Southeast Asia

INTRODUCTION

Insects, including butterflies, are animals that play a crucial role in ecosystems and human life. They are essential pollinators for many plants, including important food crops, contributing significantly to global agriculture development and biodiversity (Gullan and Cranston 2004; Grimaldi and Engel 2005). Moths and butterflies are classified in the cosmopolitan order Lepidoptera Linnaeus, 1758 (from the Greek *lepídos*, meaning "scale" and *pterón* meaning "wing"). It is one of the major orders of hexapods and a megadiverse clade of holometabolous insects, alongside Coleoptera, Diptera, and Hymenoptera (Misof et al. 2014). The worldwide lepidopteran species richness is estimated to be ~157,424 species, distributed in ~15,578 genera, 126 families, 43 superfamilies, and four suborders (van Nieukerken et al. 2011). They undergo complete metamorphosis through four distinct stages: egg, caterpillar (larva), pupa, and imago (Gullan and Cranston 2004; Grimaldi and Engel 2005).

Within this order is included, the mostly diurnal butterflies (Lepidoptera: Rhopalocera: Papilionoidea *sensu* Kawahara and Breinholt 2014). In the present study the re-definition of the group by the phylogenomic study of Kawahara and Breinholt (2014) was applied, which strongly supported the monophyly of all butterfly families, including the Hesperiidae and Hedylidae families (see also van Nieukerken et al. 2011). The worldwide butterfly species richness is estimated to be ~18,768 species, distributed in ~1,815 genera and seven families: one Neotropical family, Hedylidae; and six worldwide distributed families, Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae, Pieridae, and Riodinidae (van Nieukerken et al. 2011; Lamas 2014). In the Oriental and Australian tropics, it is estimated to presents ~4,500 species of butterflies (Lamas 2014), and specifically, in the Indonesian archipelago, there are ~2,000 species registered (Murwitaningsih et al. 2019).

This group exhibits seasonal and population polymorphism, mimetic rings, and can play important roles in ecosystems around the world, serving both as pollinators and as a food source within the ecological network chains (Gullan and Cranston 2004; Grimaldi and Engel 2005; Rader et al. 2016). Also, they are highly dependent on interactions with host plants to complete their life cycles, which often makes them highly seasonal- and habitat-specific (Robinson et al. 2023). Furthermore, butterflies are recognized as bioindicator species (Ismail et al. 2020) to

evaluate the health of ecosystems and the effects of climate change. This is due to the fact that they are very sensitive and well-responsive to changes in their environment, including habitat loss, an array of abiotic factors, and anthropogenic pressures. Therefore, variations in butterfly population dynamics can reflect disturbances in habitat conditions (Ismail et al. 2020).

Additionally, butterflies are attractive insects with a visual aesthetic appeal, which makes this group popular among the general public (Gullan and Cranston 2004). Consequently, they are a relatively well-studied group globally, particularly in temperate biomes. However, considerable gaps in information and species diversity and distribution persist in tropical biomes (Lewis and Senior 2011; Ismail et al. 2020), including the Indonesian archipelago, which is well-known as a megadiverse region. Several known factors, like biogeographic, climatic, ecological, and geological ones, contributed to the development of a megadiverse fauna and flora in the region, with a high degree of endemic species and complex ecological interactions (Lohman et al. 2011; Koneri et al. 2017; von Rintelen et al. 2017; Murwitaningsih et al. 2019; Kurniawan et al. 2020; Umami et al. 2024).

Climate and vegetation coverage on Java Island, in the Indonesian archipelago, can be described as progressively changing from west to east. In this view, it can be clearly observed that an environmental transition happens from the rainforest regions of western Java to the savanna regions in eastern Java (Umami et al. 2024). The present study is a preliminary survey that aims to present the first species records in the area, with a list of the butterfly species assemblage (*sensu* Stroud et al. 2015), measuring specifically the species richness, of a tropical area belonging to the Eastern Java-Bali Rain Forests Ecoregion in East Java (Indonesia). This region is part of Sundaland (Dixit et al. 2023), which is considered one of the 36 currently recognized biodiversity hotspots, which are regions characterized by a significant presence of endemic species that are severely endangered due to habitat loss (Myers et al. 2000).

MATERIALS AND METHODS

Study area

The study area is classified as a tropical and subtropical moist broadleaf forest biome, specifically in the Eastern Java-Bali rain forests ecoregion (Eco ID: 230; Scientific code: IM0113; ~5,387,175 km) in the Indo-Malayan realm, and is classified as a critical or endangered biome (World Wildlife Fund 2014). Also, it is part of Sundaland, which is considered one of the major global biodiversity hotspots (Myers et al. 2000; https://www.cepf.net/our-work/biodiversity-hotspots).
More specifically, this area is located on the Java Islands, East Java province (Oriental Java), northern coast: Regencies of Bangkalan (07° 03’ S, 112° 56’ E), Gresik (07° 09’ 14” S, 112° 39’ 22” E), Lamongan (07° 07’ S, 112° 25’ E), Sidoarjo (07° 27’ S, 112° 42’ E), and Surabaya City (07° 14’ 45” S, 112° 44’ 16” E). The study area with location sites is presented in a map (Figure 1) generated using the online tool SimpleMappr (Shorthouse 2010). Furthermore, the present study is a preliminary survey that aims to present the first record of the butterfly species assemblage for this study area, since no known species list was previously recorded.

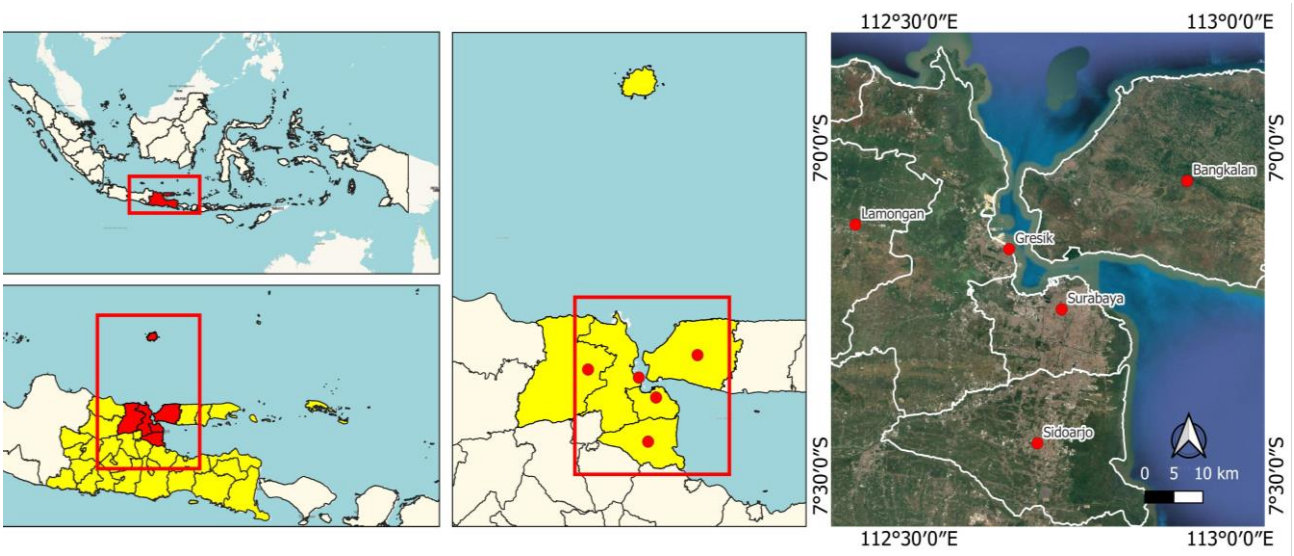

Figure 1. Study area and location sites. Indonesia; Java Island; East Java province (Oriental Java); Northern coast, specifically: Districts of Bangkalan (07° 03’ S, 112° 56’ E), Gresik (07° 09’ 14” S, 112° 39’ 22” E), Lamongan (07° 07’ S, 112° 25’ E), Sidoarjo (07° 27’ S, 112° 42’ E), and Surabaya city (07° 14’ 45” S, 112° 44’ 16” E).

Sampling and photography

From October 2016 to August 2024, twice at a week, the authors employed the exploring method along with a visual encounter survey, observing, capturing, and documenting the species encountered to access the species composition. Surveys, field observations, and collections were in the early morning or into the evening (about ~6 hours for each independent survey). The butterflies were visually registered, not all butterfly specimens were captured, but almost all of them were documented with cellphone cameras for further identification and data analysis. Some specimens were reared in the laboratory with host plants found in the field. In some cases, specimens were frozen (about ~2 days) for further investigation, and finally, some dead specimens were stored (about ~2 days) in a relaxing tube. Then the specimens were pinned and dried for further identification.

The identification of species and their distribution across various families, subfamilies, tribes, and genera was primarily based on identification keys that use traits like the pattern of color and shape of their wings by consulting the available literature for Asian and Australasian butterfly species (D'Abrera 1982, 1985, 1986; Schulze 2013; Braby et al. 2018). Taxonomic names, author, and year were revised via the "Global Butterfly Names: The Lepidoptera Taxome Project" catalog (Lamas 2014), the Google Play app Kupunesia 1.0 for butterflies of Indonesia: https://play.google.com/store/apps/details?id=org.kupunesia (Peggie et al. 2022), and the "Lepidoptera and some other life forms" catalog: https://ftp.funet.fi/pub/sci/bio/life/intro.html. Additionally, a recent study (Umami et al. 2024) was used as a guide concerning butterfly diversity in other East Java locations, in this case, the mountainous site of Kedung Klurak Tourism Area, Mojokerto District, East Java, Indonesia. All photographs are of copyright of Agus Shoumul Arof (@kal_el_arofy) and available at the link: https://figshare.com/s/d10074221b653ce58f6f.

RESULTS AND DISCUSSION

This study registered 126 butterfly species belonging to 85 genera, 41 tribes, 17 subfamilies, five families (Figures 2-8). The Nymphalidae family was the most diverse concerning species richness (51 species; 29 genera; 13 tribes; eight subfamilies), followed by the Lycaenidae family (32 species; 28 genera; 10 tribes; three subfamilies), the Pieridae family (17 species; ten genera; seven tribes; two subfamilies), the Hesperiidae family (16 species; 14 genera; eight tribes; three subfamilies), and finally, the Papilionidae family (ten species; four genera; three tribes; one subfamily) (Table 1). This distribution pattern in species frequency among families broadly reflects the global distribution of species of butterflies, in which Nymphalidae (~6,152 species) and Lycaenidae (~5,201 species) presents globally the biggest number of species, followed by Hesperiidae (~4,133 species), Pieridae (~1,164 species), and Papilionidae (~570 species). The family Riodinidae (~1,532 species) was not sampled in the present survey (van Nieukerken et al. 2011; Lamas 2014).

One species, *Deudorix epijarbas* (Moore, 1857) (Lycaenidae: Theclinae: Deudorigini), the "cornelian" or "hairy line blue", was found as a larva in Rambutan fruits and leaves, *Nephelium lappaceum* L. (Sapindaceae) from an unknown East Java location. This larva was reared until imago, and the identification was confirmed. Since there is no confirmation about the origin of these fruits, the location of this species was scored as "EJ – East Java, with no more specific location defined".

Two species of *Delias* Hübner, [1819] (Pieridae: Pierinae: Pierini) were recorded in the present survey, commonly known as "*jezebels*", which is the most speciose butterfly genus in the world, with ~251 species (Liang et al. 2024). These are *Delias hyparete* (Linnaeus, 1758), the "painted jezebel", and *Delias periboea* (Godart, 1819). This genus is distributed throughout Asia, Australia, and Melanesia with a high degree of endemism, in which numerous species occur on only a few islands or mountains. This high diversity can be explained biogeographically via dispersal events between islands, followed by divergence, the founder effect, and the orogeny of the Central Highlands of New Guinea (Liang et al. 2024). Interestingly, neither of the two species recorded has a high level of endemism; *D. hyparete* is widely distributed in southern Asia, including the Indian subcontinent, southern China, and the Indonesian archipelago; and *D. periboea* is widely distributed in the Indonesian archipelago. The same is true for *Delias belisama* (Cramer, [1779]), registered by Umami et al. (2024), also in East Java, but other locations (see information about the distributions of these species in the "Lepidoptera and some other life forms" catalog https://ftp.funet.fi/pub/sci/bio/life/intro.html).

The species composition recorded in our survey was further compared with the recent study of Umami et al. (2024) concerning butterfly diversity in other East Java locations, in this case, the mountainous site of Kedung Klurak Tourism Area, Mojokerto District, East Java. These authors registered a total of 37 species (see Table 1 from Umami et al. 2024) and the same families that were sampled in our study (Table 1 of the present study). All three Hesperiidae species registered by Umami et al. (2024); *Pelopidas mathias* (Fabricius, 1798), *Potanthus ganda* (Fruhstorfer, 1911), and *Pseudocoladenia dan* (Fabricius, 1787), were not registered in the present study. In the Lycaenidae family, only *Zizula hylax* (Fabricius, 1775) was registered by both Umami et al. (2024) and in the present study. The other four Lycaenidae registered by these authors, *Heliophorus epicles* (Godart, 1823), *Nacaduba kurava* (Moore, 1858), *Taraka hamada* (Druce, 1875), and *Udara dilectus* (Moore, 1879), were not registered in the present study.

Table 1. Species diversity distribution among butterflies (Lepidoptera: Rhopalocera: Papilionoidea) families, subfamilies, tribes, and genera reported for the northern coast of East Java (Indonesia) in the present study among locations: BA: Bangkalan District; GR: Gressik District; LA: Lamongan District; SI: Sidoarjo District; SU: Surabaya City; and EJ: East Java, with no more specific location defined

Family	Subfamily	Tribe	Genus	Species	BA	GR	LA	SI	SU	EJ
Hesperiidae	Coeliadinae	Coeliadini	*Badamia* Moore, [1881]	*Badamia exclamationis* (Fabricius, 1775)		●	●			
			Bibasis Moore, [1881]	*Bibasis sena* (Moore, [1866])		●	●			
			Burara Swinhoe, 1893	*Burara oedipodea* (Swainson, 1820)		●	●			
	Hesperiinae	Ancistroidini	*Udaspes* Moore, [1881]	*Udaspes folus* (Cramer, [1775])		●	●			
		Baorini	*Borbo* Evans, 1949	*Borbo cinnara* (Wallace, 1866)				●		
		Erionotini	*Erionota* Mabille, 1878	*Erionota thrax* (Linnaeus, 1767)	●	●	●	●	●	
			Matapa Moore, [1881]	*Matapa aria* (Moore, [1866])		●			●	
			Suastus Moore, [1881]	*Suastus gremius* (Fabricius, 1798)	●	●	●	●	●	
		Gegenini	*Pelopidas* Walker, 1870	*Pelopidas cf. conjuncta* (Herrich-Schäffer, 1869)		●				
		Taractrocerini	*Potanthus* Scudder, 1872	*Potanthus cf. fettingi* (Möschler, 1878)					●	
			Taractrocera Butler, [1870]	*Taractrocera archias* (Felder, 1860)		●				
				Taractrocera nigrolimbata (Snellen, 1876)				●	●	
			Telicota Moore, [1881]	*Telicota colon* (Fabricius, 1775)		●				
				Telicota sp.		●				
	Pyrginae	Pyrgini	*Caprona* Wallengren, 1857	*Caprona agama* (Moore, [1858])		●				
		Tagiadini	*Tagiades* Hübner, [1819]	*Tagiades japetus* (Stoll, [1781])	●	●	●			
Lycaenidae	Miletinae	Miletini	*Miletus* Hübner, [1819]	*Miletus symethus* (Cramer, [1777])		●				
		Spalgini	*Spalgis* Moore, 1879	*Spalgis epius* (Westwood, 1852)		●				
	Polyommatinae	Lycaenesthini	*Anthene* Doubleday, 1847	*Anthene emolus* (Godart, [1824])		●				
				Anthene lycaenina (Felder, 1868)		●				
		Polyommatini	*Catochrysops* Boisduval, 1832	*Catochrysops panormus* (Felder, 1860)		●				
				Catochrysops strabo (Fabricius, 1793)		●				
			Catopyrops Toxopeus, 1929	*Catopyrops rita* (Grose-Smith, 1895)		●				
			Castalius Hübner, [1819]	*Castalius rosimon* (Fabricius, 1775)		●	●		●	
			Chilades Moore, [1881]	*Chilades pandava* (Horsfield, [1829])		●			●	
			Discolampa Toxopeus, 1929	*Discolampa ethion* (Westwood, 1851)		●				
			Euchrysops Butler, 1900	*Euchrysops cnejus* (Fabricius, 1798)		●				
			Everes Hübner, [1819]	*Everes lacturnus* (Godart, [1824])		●				
			Freyeria Courvoisier, 1920	*Freyeria putli* (Kollar [1844])		●			●	
			Jamides Hübner, [1819]	*Jamides alecto* (Felder, 1860)		●				
				Jamides celeno (Cramer, [1775])		●	●			
			Lampides Hübner, [1819]	*Lampides boeticus* (Linnaeus, 1767)		●	●		●	
			Leptotes Scudder, 1876	*Leptotes plinius* (Fabricius, 1793)		●	●			
			Megisba Moore, [1881]	*Megisba malaya* (Horsfield, [1828])		●				
			Nacaduba Moore, [1881]	*Nacaduba berenice* (Herrich-Schäffer, 1869)		●				
				Nacaduba biocellata (C. & R. Felder, [1865])		●	●			
			Prosotas Druce, 1891	*Prosotas dubiosa* (Semper, [1879])		●			●	
			Zizeeria Chapman, 1910	*Zizeeria karsandra* (Moore, 1865)		●			●	
			Zizina Chapman, 1910	*Zizina otis* (Fabricius, 1787)		●	●	●	●	
			Zizula Chapman, 1910	*Zizula hylax* (Fabricius, 1775)		●	●	●	●	

	Theclinae	Amblypodiina	*Amblypodia* Horsfield, [1829]	*Amblypodia narada* (Horsfield, [1829])		●					
		Arhopalini	*Arhopala* Boisduval, 1832	*Arhopala centaurus* (Fabricius, 1775)		●	●		●		
			Flos Doherty, 1889	*Flos apidanus* (Cramer, [1777])		●					
		Deudorigini	*Deudorix* Hewitson, [1863]	*Deudorix epijarbas* (Moore, 1857)							●
		Hypolycaenini	*Hypolycaena* C. & R. Felder, 1862	*Hypolycaena erylus* (Godart, [1824])		●	●		●		
		Iolaini	*Tajuria* Moore, [1881]	*Tajuria cippus* (Fabricius, 1798)		●					
		Theclini	*Loxura* Horsfield, [1829]	*Loxura atymnus* (Stoll, [1780])		●			●		
			Rapala Moore, [1881]	*Rapala manea* (Hewitson, 1863)		●			●		
Nymphalidae	Biblidinae	Biblidini	*Ariadne* Horsfield, [1829]	*Ariadne ariadne* (Linnaeus, 1763)		●			●		
				Ariadne specularia (Fruhstorfer, 1899)		●					
	Charaxinae	Charaxini	*Polyura* Billberg, 1820	*Polyura alphius* (Staudinger, 1886)		●		●	●		
				Polyura schreiber (Godart, [1824])		●					
	Danainae	Danaini	*Danaus* Kluk, 1780	*Danaus affinis* (Fabricius, 1775)					●		
				Danaus chrysippus (Linnaeus, 1758)	●	●	●	●	●		
				Danaus genutia (Cramer, [1779])		●					
			Euploea Fabricius, 1807	*Euploea climena* (Stoll, [1782])		●					
				Euploea corinna (Macleay, [1780])		●	●	●	●		
				Euploea eleusina (Cramer, [1780])	●	●					
				Euploea mulciber (Cramer, [1777])		●	●	●	●		
				Euploea sylvester (Fabricius, 1793)		●					
			Ideopsis Horsfield, 1857	*Ideopsis juventa* (Cramer, [1777])		●	●				
			Tirumala Moore, [1880]	*Tirumala hamata* (MacLeay, [1826])		●					
				Tirumala limniace (Cramer, [1775])		●					
	Heliconiinae	Acraeini	*Acraea* Fabricius, 1807	*Acraea terpsicore* (Linnaeus, 1758)	●	●	●	●	●		
			Cethosia Fabricius, 1807	*Cethosia penthesilea* (Cramer, [1777])	●	●					
		Vagrantini	*Cupha* Billberg, 1820	*Cupha erymanthis* (Drury, [1773])		●	●		●		
			Phalanta Horsfield, [1829]	*Phalanta phalantha* (Drury, [1773])		●	●	●	●		
			Vindula Hemming, 1934	*Vindula erota* (Fabricius, 1793)		●					
				Vindula dejone (Erichson, 1834)		●					
	Limenitidinae	Adoliadini	*Euthalia* Hübner, [1819]	*Euthalia aconthea* (Cramer, [1777])		●	●	●	●		
				Euthalia adonia (Cramer, [1780])		●			●		
		Limenitidini	*Athyma* Westwood, [1850]	*Athyma nefte* (Cramer, [1780])		●					
				Athyma perius (Linnaeus, 1758)		●					
			Moduza Moore, [1881]	*Moduza procris* (Cramer, [1777])		●	●	●	●		
			Pantoporia Hübner, [1819]	*Pantoporia hordonia* (Stoll, [1790])		●					
		Neptini	*Neptis* Fabricius, 1807	*Neptis hylas* (Linnaeus, 1758)	●	●	●	●	●		
			Phaedyma Felder, 1861	*Phaedyma columella* (Cramer, [1780])	●	●	●	●	●		
	Morphinae	Amathusiini	*Amathusia* Fabricius, 1807	*Amathusia phidippus* (Linnaeus, 1763)		●					
			Discophora Boisduval, [1836]	*Discophora sondaica* Boisduval, 1836		●					
	Nymphalinae	Junoniini	*Junonia* Hübner, [1819]	*Junonia almana* (Linnaeus, 1758)	●	●	●	●	●		
				Junonia atlites (Linnaeus, 1763)		●	●	●	●		
				Junonia erigone (Cramer, [1775])		●			●		
				Junonia hedonia (Linnaeus, 1764)		●	●	●	●		
				Junonia iphita (Cramer, [1779])		●	●		●		
				Junonia orithya (Linnaeus, 1758)	●	●	●	●	●		

				Junonia villida (Fabricius, 1787)		●				
			Yoma Doherty, 1886	*Yoma sabina* (Cramer, [1780])		●				
		Kallimini	*Doleschallia* C. & R. Felder, 1860	*Doleschallia polibete* (Cramer, [1779])		●	●	●	●
			Hypolimnas Hübner, [1819]	*Hypolimnas bolina* (Linnaeus, 1758)	●	●	●	●	●
				Hypolimnas misippus (Linnaeus, 1764)		●		●	●
	Satyrinae	Elymniini	*Elymnias* Hübner, 1818	*Elymnias hypermnestra* (Linnaeus, 1763)		●	●	●	●
			Lethe Hübner, [1819]	*Lethe europa* (Fabricius, 1787)		●			
			Melanitis Fabricius, 1807	*Melanitis leda* (Linnaeus, 1758)	●	●	●	●	●
			Mycalesis Hübner, 1818	*Mycalesis horsfieldii* (Moore, [1892])		●			
				Mycalesis mineus (Linnaeus, 1758)		●	●		●
				Mycalesis perseus (Fabricius, 1775)		●	●		●
			Orsotriaena Wallengren, 1858	*Orsotriaena medus* (Fabricius, 1775)	●	●			
		Ypthimini	*Ypthima* Hübner, 1818	*Ypthima cf. aphnius* (Godart, [1824])		●			
				Ypthima philomela (Linnaeus, 1763)		●			
Papilionidae	Papilioninae	Leptocircini	*Graphium* Scopoli, 1777	*Graphium agamemnon* (Linnaeus, 1758)	●	●	●	●	●
				Graphium antiphates (Cramer, [1775])	●	●	●		
				Graphium doson (C. & R. Felder, 1864)		●	●	●	●
				Graphium sarpedon (Linnaeus, 1758)		●			
		Papilionini	*Papilio* Linnaeus, 1758	*Papilio demoleus* Linnaeus, 1758	●	●	●	●	●
				Papilio memnon Linnaeus, 1758		●	●	●	●
				Papilio peranthus Fabricius, 1787		●			
				Papilio polytes Linnaeus, 1758		●	●	●	●
		Troidini	*Pachliopta* Reakirt, [1865]	*Pachliopta adamas* (Zinken, 1831)		●			
			Troides Hübner, [1819]	*Troides helena* (Linnaeus, 1758)		●			
Pieridae	Coliadinae	Coliadini	*Catopsilia* Hübner, [1819]	*Catopsilia pomona* (Fabricius, 1775)	●	●	●	●	●
				Catopsilia pyranthe (Linnaeus, 1758)		●			●
				Catopsilia scylla (Linnaeus, 1763)				●	●
		Euremini	*Eurema* Hübner, [1819]	*Eurema alitha* (C. & R. Felder, 1862)		●			
				Eurema blanda (Boisduval, 1836)	●				
				Eurema hecabe (Linnaeus, 1758)		●	●		●
	Pierinae	Anthocharini	*Hebomoia* Hübner, [1819]	*Hebomoia glaucippe* (Linnaeus, 1758)		●	●		●
		Leptosiaini	*Leptosia* Hübner, 1818	*Leptosia nina* (Fabricius, 1793)	●	●	●	●	●
		Nepheroniini	*Pareronia* Bingham, 1907	*Pareronia valeria* (Cramer, [1776])		●	●		●
		Pierini	*Appias* Hübner, [1819]	*Appias lyncida* (Cramer, [1777])		●	●	●	●
				Appias olferna Swinhoe, 1890	●	●	●	●	●
			Belenois Hübner, [1819]	*Belenois java* (Linnaeus, 1768)	●	●	●	●	●
			Cepora Billberg, 1820	*Cepora nerissa* (Fabricius, 1775)		●	●	●	●
				Cepora temena (Hewitson, 1861)		●			
			Delias Hübner, [1819]	*Delias hyparete* (Linnaeus, 1758)		●	●	●	●
				Delias periboea (Godart, 1819)		●	●	●	●
		Teracolini	*Ixias* Hübner, [1819]	*Ixias venilia* (Godart, 1819)		●	●	●	●

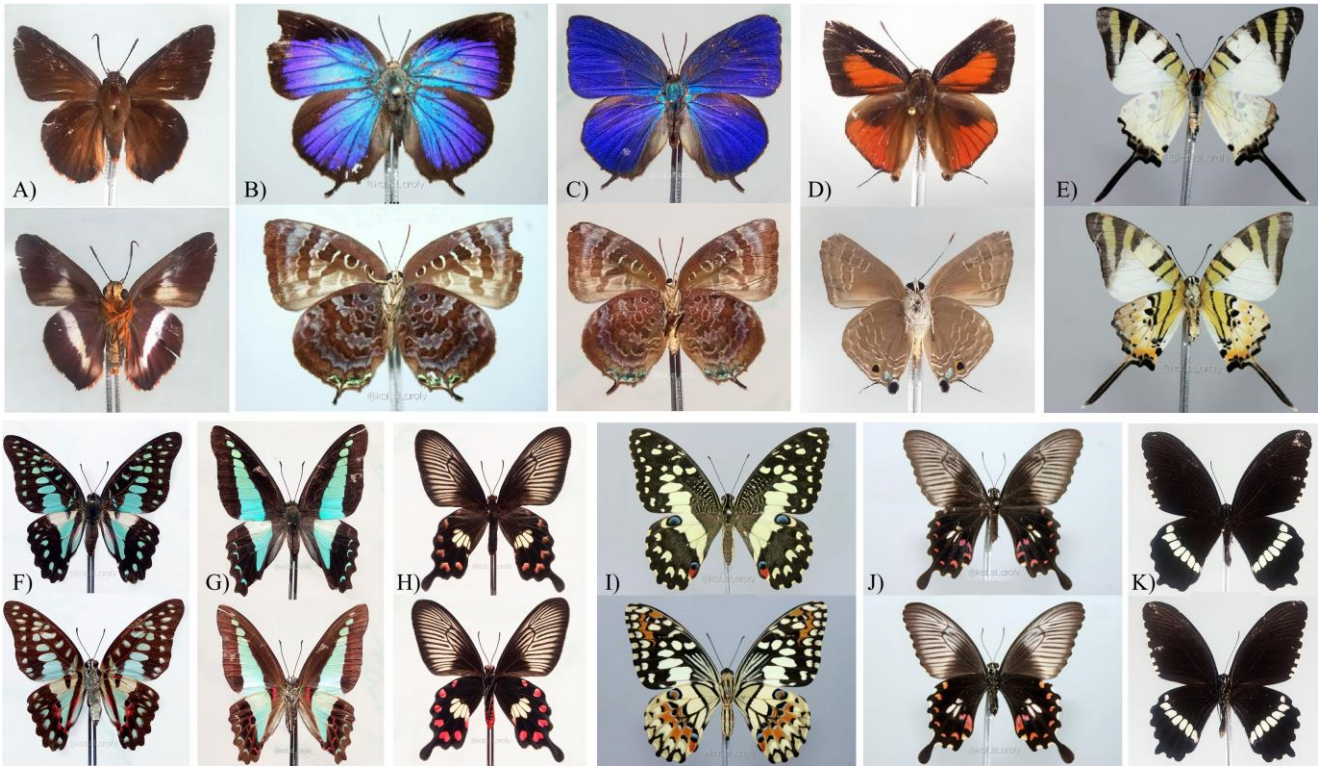

Figure 2. From left to right, top to bottom. Dorsal (image above) and ventral (image below) view. Hesperiidae: A. *Bibasis sena* (Moore, [1866]). Lycaenidae: B. *Arhopala centaurus* (Fabricius, 1775) ♀; C. *Arhopala centaurus* (Fabricius, 1775) ♂; D. *Deudorix epijarbas* (Moore, 1857). Papilionidae: E. *Graphium antiphates* (Cramer, [1775]); F. *Graphium doson* (C. & R. Felder, 1864); G. *Graphium sarpedon* (Linnaeus, 1758); H. *Pachliopta adamas* (Zinken, 1831); I. *Papilio demoleus* Linnaeus, 1758; J. *Papilio polytes* Linnaeus, 1758 ♀; K. *Papilio polytes* Linnaeus, 1758 ♂

Figure 3. From left to right, top to bottom. Dorsal (image above) and ventral (image below) view. Nymphalidae: A. *Acraea terpsicore* (Linnaeus, 1758); B. *Amathusia phidippus* (Linnaeus, 1763); C. *Ariadne ariadne* (Linnaeus, 1763); D. *Athyma perius* (Linnaeus, 1758); E. *Cethosia penthesilea* (Cramer, [1777]); F. *Danaus affinis* (Fabricius, 1775) ♂; G. *Danaus chrysippus* (Linnaeus, 1758) ♂; H. *Elymnias hypermnestra* (Linnaeus, 1763) ♀; I. *Elymnias hypermnestra* (Linnaeus, 1763) ♂; J. *Neptis hylas* (Linnaeus, 1758); K. *Phaedyma columella* (Cramer, [1780]); L. *Polyura alphius* (Staudinger, 1886)

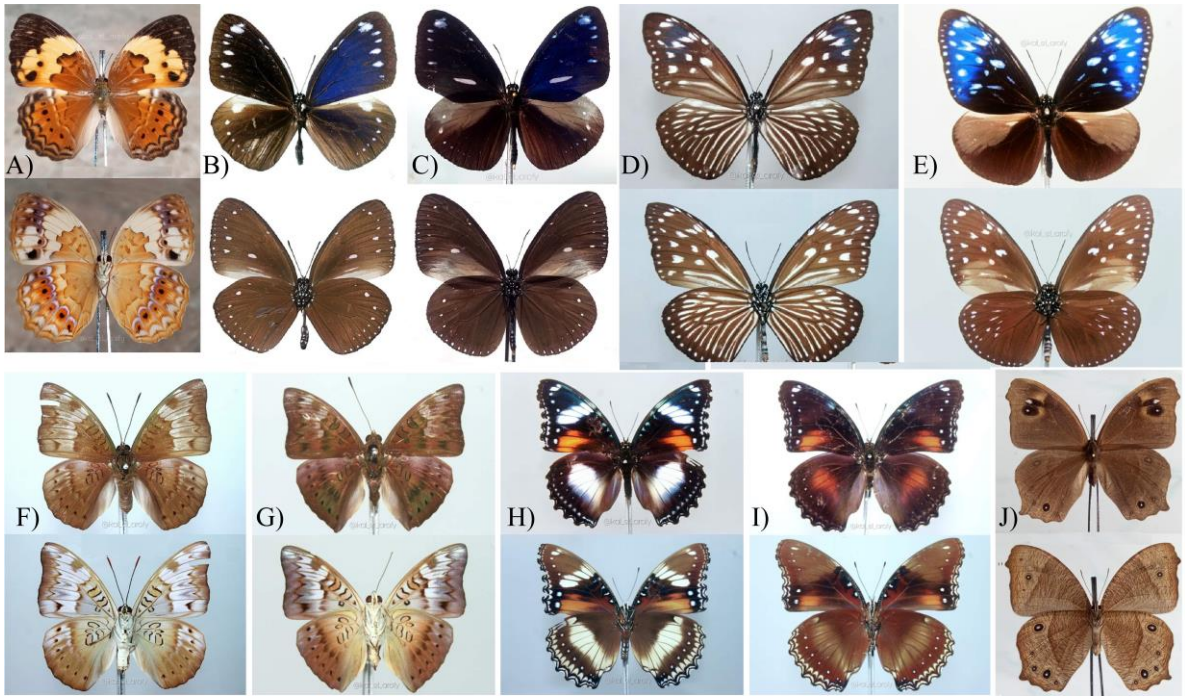

Figure 4. From left to right, top to bottom. Dorsal (image above) and ventral (image below) view. Nymphalidae: A. *Cupha erymanthis* (Drury, [1773]); B. *Euploea eleusina* (Cramer, [1780]) ♀; C. *Euploea eleusina* (Cramer, [1780]) ♂; D. *Euploea mulciber* (Cramer, [1777]) ♀; E. *Euploea mulciber* (Cramer, [1777]) ♂; F. *Euthalia aconthea* (Cramer, [1777]) ♀; G. *Euthalia aconthea* (Cramer, [1777]) ♂; H. *Hypolimnas bolina* (Linnaeus, 1758) ♀; I. *Hypolimnas bolina* (Linnaeus, 1758) ♀; J. *Melanitis leda* (Linnaeus, 1758)

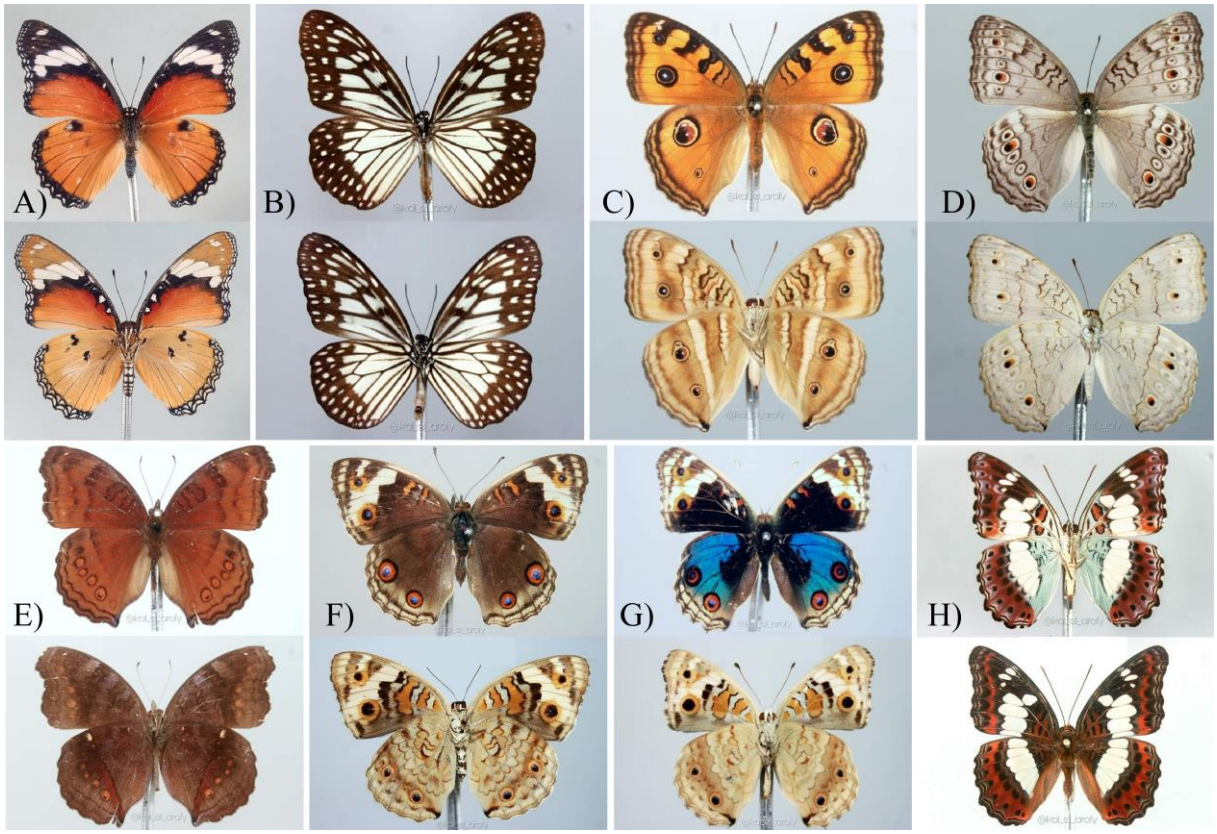

Figure 5. From left to right, top to bottom. Dorsal (image above) and ventral (image below) view. Nymphalidae: A. *Hypolimnas misippus* (Linnaeus, 1764) ♀; B. *Ideopsis juventa* (Cramer, [1777]); C. *Junonia almana* (Linnaeus, 1758); D. *Junonia atlites* (Linnaeus, 1763); E. *Junonia hedonia* (Linnaeus, 1764); F. *Junonia orithya* (Linnaeus, 1758) ♀; G. *Junonia orithya* (Linnaeus, 1758) ♂; H. *Moduza procris* (Cramer, [1777])

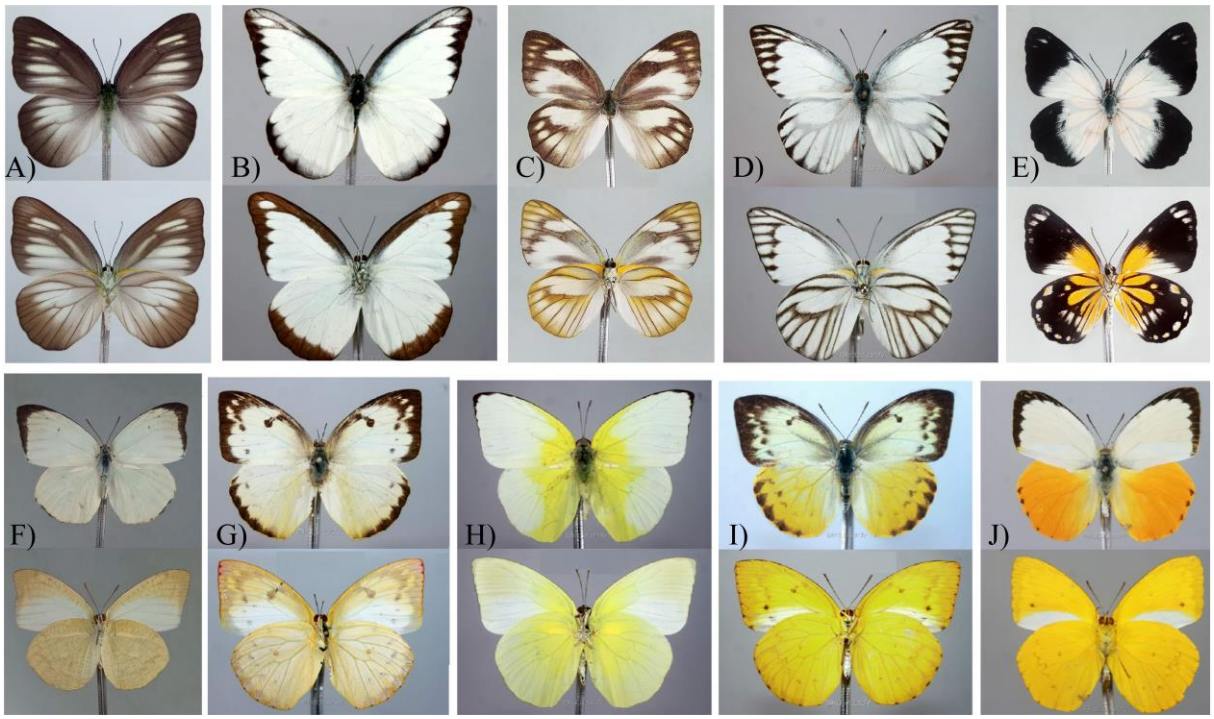

Figure 6. From left to right, top to bottom. Dorsal (image above) and ventral (image below) view. Pieridae: A. *Appias lyncida* (Cramer, [1777]) ♀; B. *Appias lyncida* (Cramer, [1777]) ♂; C. *Appias olferna* Swinhoe, 1890 ♀; D. *Appias olferna* Swinhoe, 1890 ♂; E. *Belenois java* (Linnaeus, 1768)♂; F. *Catopsilia pyranthe* (Linnaeus, 1758); G. *Catopsilia pomona* (Fabricius, 1775) ♀; H. *Catopsilia pomona* (Fabricius, 1775) ♂; I. *Catopsilia scylla* (Linnaeus, 1763) ♀; J. *Catopsilia scylla* (Linnaeus, 1763) ♂

Figure 7. From left to right, top to bottom. Dorsal (image above) and ventral (image below) view. Pieridae: A. *Cepora temena* (Hewitson, 1861) ♀; B. *Cepora temena* (Hewitson, 1861) ♂; C. *Delias hyparete* (Linnaeus, 1758); D. *Delias periboea* (Godart, 1819) ♀; E. *Delias periboea* (Godart, 1819) ♂; F. *Eurema hecabe* (Linnaeus, 1758); G. *Hebomoia glaucippe* (Linnaeus, 1758); H. *Ixias venilia* (Godart, 1819) ♂; I. *Pareronia valeria* (Cramer, [1776]) ♀; J. *Pareronia valeria* (Cramer, [1776]) ♂

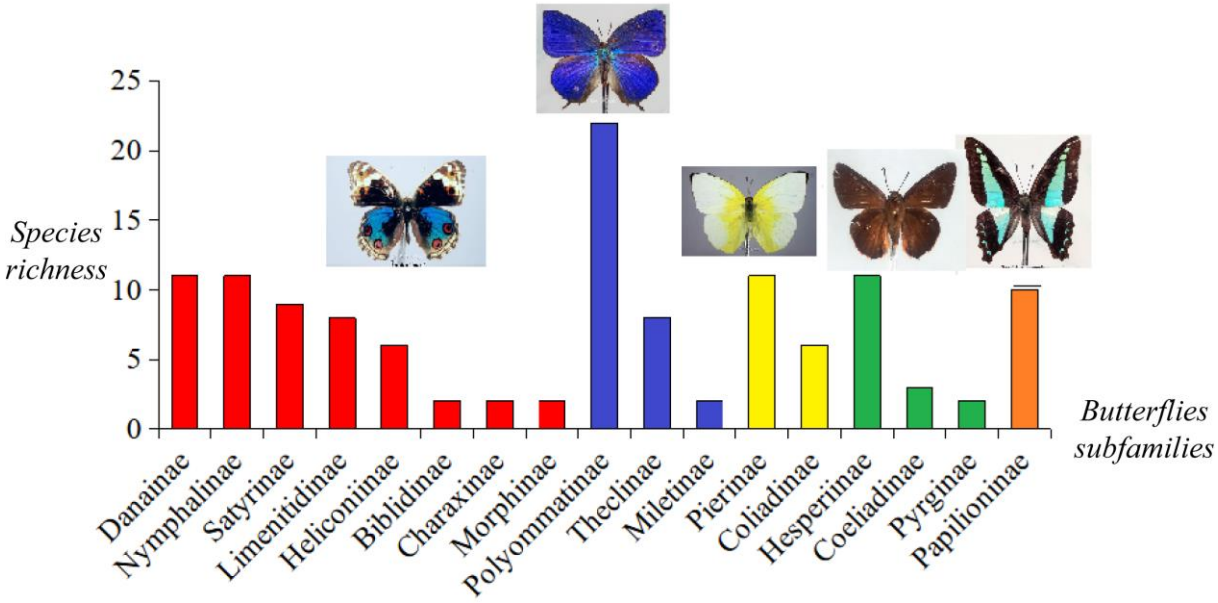

Figure 8. Species diversity (Species richness) distribution among butterflies (Lepidoptera: Rhopalocera: Papilionoidea) families and subfamilies. Red – Nymphalidae, Blue – Lycaenidae, Yellow – Pieridae, Green – Hesperiidae, Orange – Papilionidae, and respective subfamilies were reported for the northern coast of East Java (Indonesia) in the present study

In the case of the Nymphalidae family, ten species were registered by both Umami et al. (2024) and in the present study, *Doleschallia polibete* (Cramer, 1782), *Euploea mulciber* (Cramer, [1777]), *Junonia atlites* (Linnaeus, 1763), *Junonia erigone* (Cramer, [1775]), *Junonia hedonia* (Linnaeus, 1764), *Junonia iphita* (Cramer, 1782), *Neptis hylas* (Linnaeus, 1758), *Orsotriaena medus* (Fabricius, 1775), *Tirumala hamata* (MacLeay, [1826]), and *Mycalesis horsfieldii* (Moore, [1892]). On the other hand, also in the Nymphalidae family, seven species were registered by Umami et al. (2024), but not in the present study, *Chersonesia rahria* (Westwood, 1857), *Lethe confusa* (Aurivillius, 1897), *Neptis vikasi* (Horsfield, 1829), *Parantica aspasia* (Fabricius, 1787), *Tanaecia trigerta* (Moore, 1857), *Ypthima iarba* (Nicéville, 1895), and *Ypthima pandocus* (Moore, 1857).

In the Papilionidae family, all six species registered by these authors, *Graphium agamemnon* (Linnaeus, 1758), *Graphium sarpedon* (Linnaeus, 1758), *Pachliopta adamas* (Zincken, 1831), *Papilio memnon* Linnaeus, 1758, *Papilio polytes* Linnaeus, 1758, and *Troides helena* (Linnaeus, 1758) were also registered in the present study. Finally, in the Pieridae family, five species, *Appias lyncida* (Cramer, 1779), *Eurema blanda* (Boisduval, 1836), *Eurema hecabe* (Linnaeus, 1758), *Hebomoia glaucippe* (Linnaeus, 1758), and *Leptosia nina* (Fabricius, 1793), were registered by both Umami et al. (2024) and in the present study. Only one Pieridae species registered by these authors, *Delias belisama* (Cramer, 1779), was not registered in the present study. Since there is no clear pattern in the species composition among the sampled families when the present survey is compared with the study of Umami et al. (2024), further studies need to be done to explore the real differences in assemblages of butterflies in these several sampled regions of East Java. Perhaps a hypothesis can be generated involving differences in ecological niches (Pocheville 2014) of butterfly species associated with the elevation, reflecting on differences on the species composition, since our study sampled butterflies on the northern coast of East Java and Umami et al. (2024) sampled butterflies in a more mountainous region, but this is speculative since at the moment we lack more precise information about the exact elevation of the sites. Furthermore, both studies diverge in the sampling methods, so further sampling and standardization are necessary for future comparisons.

Despite the speculative nature of this hypothesis regarding the composition of species at different altitudes, previous studies (Rödder et al. 2021) are in accordance. They concluded that more mobile and generalist butterfly species, which have a wide ecological range, are more likely to migrate uphill compared to specialist and sedentary species. These authors identified climatic conditions and topographic factors, such as insolation and solar irradiation, as the main drivers of this altitudinal movement.

Another study in Indonesia (Koneri et al. 2017), specifically in the Tangkoko Nature Reserve (TNR) in North Sulawesi, reached the conclusion that the butterfly community in primary forests shares more similarities with those found on farms, while the butterflies in shrub areas are more closely related to those in secondary forests. Unfortunately, a direct comparison cannot be made since no precise information about soil use and habitat type in the present survey was recorded. Furthermore, the biological diversity of Nymphalidae observed in the Neotropics is primarily a result of low extinction rates rather than high speciation rates or biotic exchanges with other regions that

are infrequent. In contrast, Southeast Asia, including the Indonesian archipelago, is marked by a low speciation rate as well, but the primary source of biological diversity can be attributed to several dispersal events throughout geological time (Chazot et al. 2021).

In addition to the ideas mentioned earlier, other factors may be important and were previously indicated as diversity-driven in butterfly communities as well. In this sense, mutualistic interactions can promote convergent evolution across various ecological axes, often surpassing the influences of phylogenetic history and ecological competition in determining community structure (Doré et al. 2022). This indicates that ecological communities are adapted to a much greater extent than previously assumed. In this sense, it is highlighted that there is a strong connection between phenotypes and ecological interactions, supporting the notion that memetic rings can facilitate ecological speciation (Doré et al. 2022). Finally, these findings can be interpreted as a compelling empirical support for the Müllerian mimicry model at a macroecological scale, especially among the subfamilies Danainae and Ithomiinae of Nymphalidae (Doré et al. 2022).

In the near future, climate change is expected to strongly impact butterfly diversity around the world, including the northern coast of East Java. This will potentially lead to rising sea levels, average temperatures, atmospheric levels of carbon dioxide, and altered rainfall patterns resulting from global and regional climate shifts (Abbass et al. 2022; https://science.nasa.gov/climate-change/). These changes could impact the food resources and host plants available to butterflies and impact their life cycles. Additionally, anthropogenic activities on the northern coast of East Java may further exacerbate the effects of environmental changes that can alter the ecosystem dynamics, posing further threats to butterfly populations (Kurniawan et al. 2020). More specifically, in the studied region, it was noted through personal observation that the butterfly population in the vicinity of Ketanen village in Gresik District has apparently experienced a decline. A limestone hill, between Ketanen and Pantenan villages, previously a notable habitat for butterfly species, has been flattened and transformed into a tourist attraction featuring a swimming pool.

This is the first field investigation to study the butterfly richness specifically on the northern coast of East Java. This study contributes to the knowledge of the butterfly fauna in the Indonesian archipelago, as well as the general diversity of species in Southeast Asia. Additionally, this study contributes to future studies of the conservation of biodiversity in this key endangered region, which is located on the most human-populated island in the world, in the fourth-most-populated country in the world. Moreover, this study can be the first step towards future studies focusing on community ecology, population dynamics and the use of butterflies as bioindicators in the northern coast of East Java.

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