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Biodiversity Baseline and Monitoring Trends from 2023 to 2025 in the Goa Sampe Marta Area, Kutai National Park, East Kalimantan, Indonesia

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Abstract:
Background: *The Goa Sampe Marta area in Martadinata Village, Teluk Pandan District, East Kutai Regency, lies inside Kutai National Park and serves as the biodiversity conservation area of PT Pertamina Gas Operation Kalimantan Area. The area has been affected by land conversion, illegal logging, and forest fires. Baseline biodiversity data for the area are needed as a reference for management and monitoring.*
Materials and Methods: *Baseline data were collected from August to September 2023 along three access routes to Goa Sampe Marta. Flora was surveyed through a floristic inventory and a vegetation analysis using nested plots along transects. Birds and insects were surveyed with point counts and free roaming surveys, herpetofauna with Visual Encounter Surveys, and mammals with direct observation, sign surveys, and interviews. Diversity was analysed with the Shannon Wiener index (H'), the Simpson dominance index (D), the Pielou evenness index (J), and the Margalef richness index (R). Conservation status was assigned using the IUCN Red List, the CITES Appendices, and Regulation of the Minister of Environment and Forestry Number P.106 of 2018. Baseline data were compared with monitoring results from 2024 and 2025.*
Results: *The 2023 survey recorded 101 plant species (3,513 individuals), 34 bird species (128 individuals), 62 insect species (215 individuals), 12 herpetofauna species (32 individuals), and 8 mammal species (30 individuals). Recalculated H' values were 4.06 for flora, 3.27 for birds, 3.97 for insects, 2.37 for herpetofauna, and 1.53 for mammals. Grasses and herbs, including several invasive species, dominated the understorey, and oil palm (*Elaeis guineensis*) and Bornean ironwood (*Eusideroxylon zwageri*) dominated the tree layer. Thirteen species of conservation concern were recorded, eight of which are nationally protected, including the Critically Endangered Bornean orangutan (*Pongo pygmaeus*). In 2025 the number of species rose to 63 for birds, 22 for herpetofauna, and 15 for mammals, and the H' value for mammals reached 2.61.*
Conclusion: *The Goa Sampe Marta area provides habitat for protected and threatened animals despite its disturbed vegetation. The increase in faunal diversity from 2023 to 2025 occurred alongside the planting of forest fruit trees, the planting of endemic plants, and the installation of an illegal logging detector based on the Internet of Things. Comparisons between years require a uniform sampling protocol.*
Key Word: *biodiversity baseline; Kutai National Park; Goa Sampe Marta; Shannon Wiener index; conservation status; Bornean orangutan*

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I. INTRODUCTION

Southeast Asia holds very high biodiversity and also experiences a high rate of forest loss[1,2]. Borneo has lost a large share of its lowland forest to logging, plantation development, and fire over the last four decades[3]. Changes in land cover and climate are expected to keep reducing the habitat available to many species on the island[4].

Kutai National Park is the only national park in East Kalimantan Province. The park was designated by Minister of Forestry Decree Number SK.4194/Menhut-VII/KUH/2014 and covers 192,709.55 ha. Its area spans Bontang City, Kutai Kartanegara Regency, and East Kutai Regency, and it contains lowland tropical rain forest and mangrove forest[5]. The park has long been under pressure from encroachment, illegal logging, fire, and surrounding development[6]. The park lost about 15% (272 km^2) of its forest cover after 2000, and about half of this loss coincided with fires during El Niño periods[7]. Fires during prolonged droughts caused heavier damage in logged forests of East Kalimantan[8]. These changes affect wildlife, and Bornean orangutans in the park adjusted their feeding ecology, diet, and daily activity after fire[9].

Law Number 5 of 1990 on the Conservation of Living Natural Resources and Their Ecosystems requires living natural resources to be managed in a balanced and lasting manner. PT Pertamina Gas Operation Kalimantan Area runs a biodiversity conservation programme in the Goa Sampe Marta area of Kutai National Park as part of its environmental management commitment. Support from industries around Bontang for the management of Kutai National Park was reported as early as 1994[6].

Ecological monitoring needs clear initial data to allow changes to be measured over time[10]. Initial data also form the basis for assessing habitat restoration programmes. Baseline data on flora, birds, insects, herpetofauna, and mammals in the Goa Sampe Marta area were collected in 2023 together with the conservation status of each species. The data are compared here with monitoring results from 2024 and 2025 and are accompanied by a description of the conservation programmes run by the company in the same area.

II. MATERIAL AND METHODS

Study design: This study is a descriptive quantitative field survey. Baseline data were collected in 2023. Comparison data were taken from the 2024 and 2025 biodiversity monitoring reports for the same site and from programme documents of PT Pertamina Gas Operation Kalimantan Area.

Study location: The Goa Sampe Marta area lies in Martadinata Village, Teluk Pandan District, East Kutai Regency, inside Kutai National Park. The park extends from 0°07′54″ to 0°33′53″ N and from 116°58′48″ to 117°35′29″ E. The area around the cave is disturbed and fragmented. Part of the land on both sides of the road to the cave has been converted into fields, oil palm gardens, rubber gardens, and open land. In 2023 observations started at the basecamp and followed Route A, which passes the hut of Mr Sampe, the customary elder who looks after the Goa Sampe Marta area. Route B is an alternative path through an oil palm garden. The two routes meet at a junction, from which Route C leads to Goa Sampe Marta (Figure 1). The 2025 monitoring used three habitat types, namely former field, shrubland, and secondary forest (Table 1).

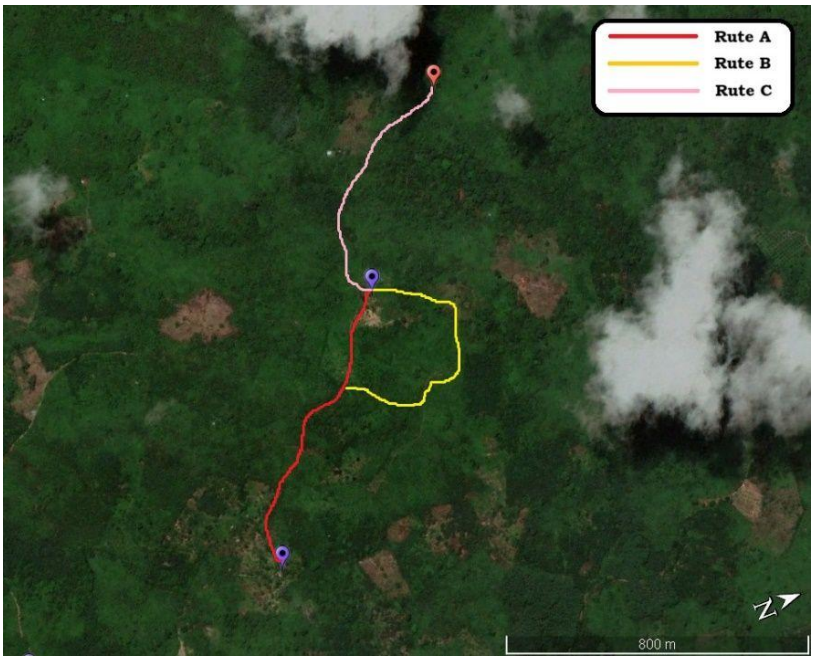


Figure 1. Map of the biodiversity baseline survey area at Goa Sampe Marta, Kutai National Park. The red line shows Route A, the yellow line shows Route B, and the pink line shows Route C.

Table 1. Survey routes and observation points in the Goa Sampe Marta area

Code	Location description	Coordinates	Year
Route A	Basecamp past the hut of Mr Sampe to the junction	Follows the track in Figure 1	2023
Route B	Alternative path through an oil palm garden to the junction	Follows the track in Figure 1	2023
Route C	Junction to the entrance and interior of Goa Sampe Marta	Follows the track in Figure 1	2023
Point A	Former field with mixed fruit trees	0°11′49.39″ N; 117°26′13.25″ E	2025
Point B	Shrubland with pioneer vegetation	0°12′09.06″ N; 117°25′30.15″ E	2025
Point C	Secondary forest	0°12′10.62″ N; 117°25′08.48″ E	2025

Study duration: Baseline data were collected from August to September 2023. The floristic inventory and vegetation analysis were carried out in August 2023. Herpetofauna and mammal surveys were carried out from 30 August to 1 September 2023. Comparison surveys were carried out in 2024 and from 2 to 4 June 2025.

Equipment: The equipment included a Global Positioning System (GPS) receiver, a digital camera with a telephoto lens, binoculars, a tailor tape for measuring stem diameter, a 50 m field tape, an insect net, identification guides, stationery, a grab stick, specimen containers, and gloves. The 2025 survey also used camera traps.

Procedure methodology

Flora: Flora data were collected through a floristic inventory and a vegetation analysis. The inventory used a census at six observation stations along the routes. Every plant individual encountered was recorded by species, family, and number of individuals. Species found outside the plots were recorded through exploration. The vegetation analysis used nested plots along transects, and the measurements did not damage the plants[11]. At each sampling point (T1, T2, and T3) a 40 m transect was laid out and divided into two plots of 20 m × 20 m. Trees were measured in 20 m × 20 m plots, poles in 10 m × 10 m plots, saplings in 5 m × 5 m plots, and seedlings in 2 m × 2 m plots (Figure 2). Stem diameter was measured at breast height, 1.3 m above the ground. Growth stages were defined as trees (diameter ≥ 20 cm), poles (diameter 10 cm to less than 20 cm), saplings (height above 1.5 m and diameter below 10 cm), and seedlings (height below 1.5 m). Plants were identified in the field and checked against plant identification guides.

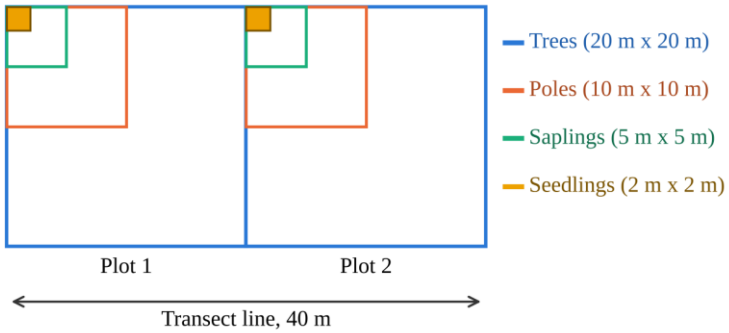


Figure 2. Nested plot design along a transect for the vegetation analysis.

Birds: Birds were surveyed with a combination of point counts and free roaming surveys. At each point count the observer stayed in place and recorded the species and number of birds seen or heard within a radius of about 50 m[12]. In free roaming surveys the observer walked along the trail and recorded all birds encountered. Birds were identified with a field guide to the birds of Borneo, the Burungnesia application, and the iNaturalist website.

Insects: Insects were surveyed with a combination of point counts and free roaming surveys. Each insect was recorded by scientific name, family, and local name. Insects that were difficult to identify were caught with an insect net, photographed, and released. Identification used Indonesian guides to butterflies and beetles and the iNaturalist website.

Herpetofauna: Herpetofauna were surveyed with the Visual Encounter Survey (VES), an active search along trails in terrestrial and aquatic habitats[13]. The search lasted two hours in each habitat type. Night surveys used flashlights directed at places commonly used by herpetofauna, including the interior of the cave. All animals encountered were photographed for identification.

Mammals: Mammals were surveyed through direct sightings and searches for tracks, droppings, and nests at predetermined points. Interviews were held with residents who often work in or near the area to obtain records of mammals seen before the survey.

Statistical analysis

All 2023 index values were recalculated from the number of individuals per species. Index values for 2024 and 2025 were taken from the monitoring reports. The Shannon Wiener index was used to describe community diversity based on the number of species and the distribution of individuals among them[14]. The index was calculated as $H' = -\Sigma\ p_i \ln p_i$, where $p_i = n_i/N$, n_i is the number of individuals of species i, and N is the total number of individuals. Relative abundance was calculated as $Di = (n_i/N) \times 100\%$ to classify species as dominant, subdominant, or not dominant[15]. The Simpson dominance index was calculated as $D = \Sigma\ (n_i/N)^2$[16].

The Pielou evenness index was calculated as J = H′/ln S, where S is the number of species[17]. The Margalef richness index was calculated as R = (S − 1)/ln N[14]. The criteria for each index are given in Table 2.

Vegetation structure was analysed with the Importance Value Index (IVI), the sum of relative density, relative frequency, and relative dominance. Density was calculated from the number of individuals per plot area, frequency from the proportion of plots in which a species occurred, and dominance from the basal area of stems[11].

Table 2. Criteria for the ecological indices

Index	Value range	Category
Shannon Wiener (H′)[18]	H′ ≥ 3.50	Very high
	3.00 ≤ H′ < 3.50	High
	2.50 ≤ H′ < 3.00	Moderate
	2.00 ≤ H′ < 2.50	Low
	H′ < 2.00	Very low
Relative abundance (Di)[15]	Di ≥ 5%	Dominant
	2% ≤ Di < 5%	Subdominant
	Di < 2%	Not dominant
Simpson dominance (D)	0.75 < D ≤ 1.00	High dominance
	0.50 < D ≤ 0.75	Moderate dominance
	0 < D ≤ 0.50	Low dominance
Pielou evenness (J)	J > 0.6	High evenness
	0.3 ≤ J ≤ 0.6	Moderate evenness
	J < 0.3	Low evenness
Margalef richness (R)	R > 5.0	High richness
	3.5 ≤ R ≤ 5.0	Moderate richness
	R < 3.5	Low richness

Conservation status: The conservation status of each species was assigned using three references. The first is the IUCN Red List of Threatened Species, which assesses global extinction risk from quantitative criteria such as rate of population decline, population size, and range size[19]. The second is Appendices I, II, and III of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which regulate international trade in wild plants and animals. The third is Regulation of the Minister of Environment and Forestry Number P.106/MENLHK/SETJEN/KUM.1/12/2018 on Protected Plant and Animal Species.

Monitoring data and conservation programmes: Species numbers, individual numbers, and H′ values for 2024 and 2025 were taken from the biodiversity monitoring reports of PT Pertamina Gas Operation Kalimantan Area. In 2024 and 2025 insect data were split into dragonflies and butterflies. The 2023 insect data were split in the same way to allow comparison. Information on conservation programmes was taken from company programme documents.

III. RESULT

Species composition and ecological indices in 2023

The 2023 baseline recorded 101 plant species from 53 families, 34 bird species from 20 families, 62 insect species from 18 families, 12 herpetofauna species from 6 families, and 8 mammal species from 7 families (Table 3). Diversity was very high for flora and insects, high for birds, low for herpetofauna, and very low for mammals. All groups showed low dominance and high evenness. Species richness was high for flora, birds, and insects and low for herpetofauna and mammals.

Table 3. Number of species, families, and individuals and ecological indices of each taxonomic group in the Goa Sampe Marta area in 2023

Group	Species	Families	Individuals	H′	H′ category	D	J	R
Flora	101	53	3,513	4.06	Very high	0.027	0.88	12.25
Birds	34	20	128	3.27	High	0.046	0.93	6.80
Insects	62	18	215	3.97	Very high	0.022	0.96	11.36
Dragonflies	11	4	40	2.24	Low	0.119	0.93	2.71
Butterflies	34	4	107	3.37	High	0.040	0.95	7.06
Herpetofauna	12	6	32	2.37	Low	0.102	0.95	3.17
Mammals	8	7	30	1.53	Very low	0.309	0.74	2.06

Notes: H′ = Shannon Wiener index; D = Simpson dominance index; J = Pielou evenness index; R = Margalef richness index. Dragonflies and butterflies are subsets of the insect group.

Relative abundance showed different numbers of dominant species among groups (Table 4). Only two plant species were dominant, namely *Eragrostis amabilis* and buffalo grass (*Paspalum conjugatum*). Eleven

plant species were subdominant, including *Praxelis clematidea*, cogongrass (*Imperata cylindrica*), *Selaginella delicatula*, giant reed (*Arundo donax*), and lantana (*Lantana camara*). No insect species was dominant. Most herpetofauna and mammal species were classed as dominant because few individuals were recorded.

Table 4. Dominant species (Di ≥ 5%) and number of species in each relative abundance class in 2023

Group	Dominant species (Di)	Dominant	Subdominant	Not dominant
Flora	*Eragrostis amabilis* (9.54%), *Paspalum conjugatum* (6.12%)	2	11	88
Birds	*Pycnonotus aurigaster* (8.59%), *Passer montanus* (7.81%), *Pericrocotus speciosus*, *Lonchura atricapilla*, *Hirundo tahitica*, *Pycnonotus goiavier* (6.25% each), *Geopelia striata* (5.47%)	7	12	15
Insects	None; highest abundance Rhaphidophoridae sp.1 (4.19%)	0	18	44
Herpetofauna	*Chalcorana* sp. (15.63%), *Hemidactylus platyurus* and *Dendrelaphis caudolineatus* (12.50% each), six other species (6.25% to 9.38%)	9	3	0
Mammals	*Hipposideros diadema* (50.00%), *Callosciurus notatus* (20.00%), *Pongo pygmaeus* (10.00%), *Tupaia minor* (6.67%)	4	4	0

Vegetation structure

The vegetation analysis recorded 114 trees of 11 species, 211 poles of 23 species, 468 saplings of 25 species, and 2,719 seedlings of 74 species. Oil palm (*Elaeis guineensis*) had the highest IVI among trees at 81.51%, with a relative density of 49.12%. Bornean ironwood (*Eusideroxylon zwageri*) had an IVI of 43.10% and the highest relative dominance among trees at 24.55%. Cassava (*Manihot esculenta*) had the highest IVI among poles, giant reed (*Arundo donax*) among saplings, and *Spatholobus littoralis* among seedlings (Table 5).

Table 5. Three species with the highest Importance Value Index (IVI) at each growth stage in 2023

Growth stage	Species	RD (%)	RF (%)	RDo (%)	IVI (%)
Trees (11 species, 114 individuals)	*Elaeis guineensis*	49.12	19.23	13.15	81.51
	Eusideroxylon zwageri	7.02	11.54	24.55	43.10
	Dracontomelon dao	7.89	15.38	11.05	34.33
Poles (23 species, 211 individuals)	*Manihot esculenta*	16.59	10.53	1.63	28.74
	Bambusa sp.	11.37	7.89	3.52	22.79
	Theobroma cacao	9.00	5.26	7.40	21.66
Saplings (25 species, 468 individuals)	*Arundo donax*	16.24	8.33	7.26	31.83
	Phrynium pubinerve	14.32	8.33	1.70	24.34
	Lantana camara	8.76	8.33	6.36	23.45
Seedlings (74 species, 2,719 individuals)	*Spatholobus littoralis*	1.54	3.31	11.73	16.59
	Eragrostis amabilis	12.32	2.65	0.04	15.01
	Imperata cylindrica	4.30	3.31	3.08	10.70

Notes: RD = relative density; RF = relative frequency; RDo = relative dominance; IVI = Importance Value Index.

Conservation status of species in 2023

Thirteen species recorded in 2023 are of conservation concern (Table 6). Eight species are protected under Ministerial Regulation P.106 of 2018, namely six birds, one butterfly, and one mammal. The Bornean orangutan (*Pongo pygmaeus*) is Critically Endangered and listed in CITES Appendix I. The Wreathed Hornbill (*Rhyticeros undulatus*), Javan Myna (*Acridotheres javanicus*), Bornean ironwood (*Eusideroxylon zwageri*), and Beauty Rat Snake (*Elaphe taeniura*) are Vulnerable. West Indian mahogany (*Swietenia mahagoni*) and the Chestnut-bellied Malkoha (*Phaenicophaeus sumatranus*) are Near Threatened. No herpetofauna or plant species is nationally protected. The Brown Barbet (*Calorhamphus fuliginosus*) and Dusky Munia (*Lonchura fuscans*) are endemic to Borneo. Several of these species are shown in Figures 3 to 6.

Table 6. Species of conservation concern recorded in the Goa Sampe Marta area in 2023

No	Species	English name	P.106/2018	CITES	IUCN
1	*Haliastur indus*	Brahminy Kite	Protected	App. II	LC
2	*Ictinaetus malaiensis*	Black Eagle	Protected	App. II	LC
3	*Nisaetus cirrhatus*	Changeable Hawk Eagle	Protected	App. II	LC
4	*Rhyticeros undulatus*	Wreathed Hornbill	Protected	App. II	VU
5	*Rhipidura javanica*	Malaysian Pied Fantail	Protected		LC
6	*Calorhamphus fuliginosus*	Brown Barbet	Protected		LC
7	*Troides amphrysus*	Malayan Birdwing	Protected	App. II	LC
8	*Pongo pygmaeus*	Bornean Orangutan	Protected	App. I	CR
9	*Eusideroxylon zwageri*	Bornean Ironwood	Not protected		VU
10	*Swietenia mahagoni*	West Indian Mahogany	Not protected	App. II	NT
11	*Phaenicophaeus sumatranus*	Chestnut-bellied Malkoha	Not protected		NT
12	*Acridotheres javanicus*	Javan Myna	Not protected		VU
13	*Elaphe taeniura*	Beauty Rat Snake	Not protected		VU

Notes: P.106/2018 = Regulation of the Minister of Environment and Forestry Number P.106/MENLHK/SETJEN/KUM.1/12/2018; App. = Appendix; CR = Critically Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern. Empty cells indicate that the species is not listed.



Figure 3. Protected birds recorded in the Goa Sampe Marta area: (A) Malaysian Pied Fantail (*Rhipidura javanica*), (B) Changeable Hawk Eagle (*Nisaetus cirrhatus*), (C) Brown Barbet (*Calorhamphus fuliginosus*), and (D) Wreathed Hornbill (*Rhyticeros undulatus*). Source: team documentation, 2023.

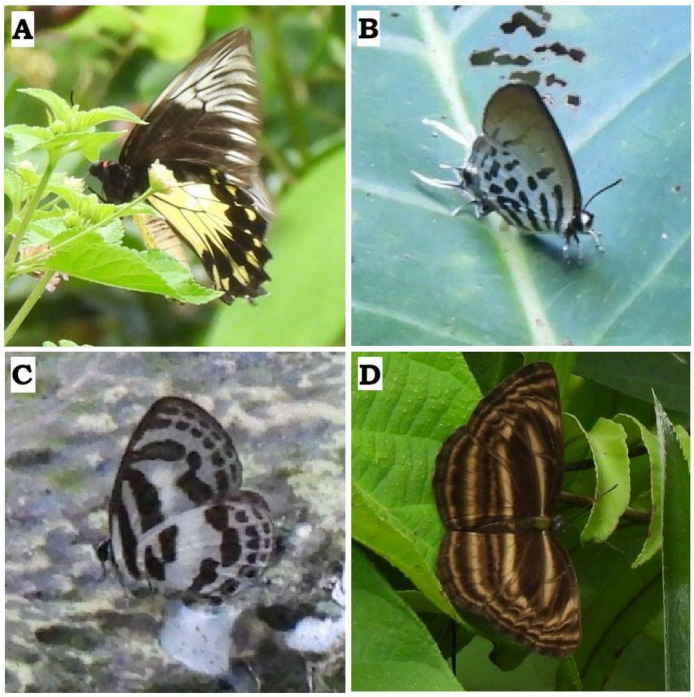


Figure 4. Butterflies recorded in the Goa Sampe Marta area: (A) *Troides amphrysus*, (B) *Drupadia ravindra*, (C) *Discolampa ethion*, and (D) *Neptis omeroda*. Source: team documentation, 2023.



Figure 5. Herpetofauna recorded in the Goa Sampe Marta area: (A) *Eutropis rudis*, (B) *Chalcorana* sp., (C) *Dendrelaphis caudolineatus*, and (D) *Elaphe taeniura*. Source: team documentation, 2023.



Figure 6. (A) Diadem Roundleaf Bat (*Hipposideros diadema*) inside Goa Sampe Marta and (B) an inactive nest of the Bornean orangutan (*Pongo pygmaeus*). Source: team documentation, 2023.

Diversity trends from 2023 to 2025

The number of species of birds, herpetofauna, dragonflies, butterflies, and mammals increased from 2023 to 2025 (Table 7). Bird species rose from 34 to 63 and bird individuals from 128 to 229. Mammal species rose from 8 to 15 and mammal individuals from 30 to 59. The H′ value for mammals increased from 1.53 (very low) to 2.61 (moderate). The H′ value for herpetofauna increased from 2.37 (low) to 2.97 (moderate), and the H′ value for butterflies increased from 3.37 (high) to 4.05 (very high). The H′ value for flora stayed almost constant at 4.06 in 2023, 4.07 in 2024, and 4.08 in 2025 (Figure 7). Far fewer plant individuals were recorded in 2024 and 2025 than in 2023 because the later surveys used only three observation points, whereas the 2023 survey used a full inventory along the routes.

Table 7. Number of species (S), number of individuals (N), and Shannon Wiener index (H′) in 2023, 2024, and 2025

Group	S 2023	S 2024	S 2025	N 2023	N 2024	N 2025	H′ 2023	H′ 2024	H′ 2025
Flora	101	100	100	3,513	434	443	4.06	4.07	4.08
Birds	34	60	63	128	201	229	3.27	3.73	3.86
Herpetofauna	12	22	22	32	41	47	2.37	2.89	2.97
Dragonflies	11	13	16	40	na	66	2.24	2.30	2.61
Butterflies	34	69	72	107	221	207	3.37	3.73	4.05
Mammals	8	12	15	30	53	59	1.53	2.14	2.61

Notes: 2023 values were recalculated from the baseline data; 2024 and 2025 values come from the monitoring reports; na = not available in the report.

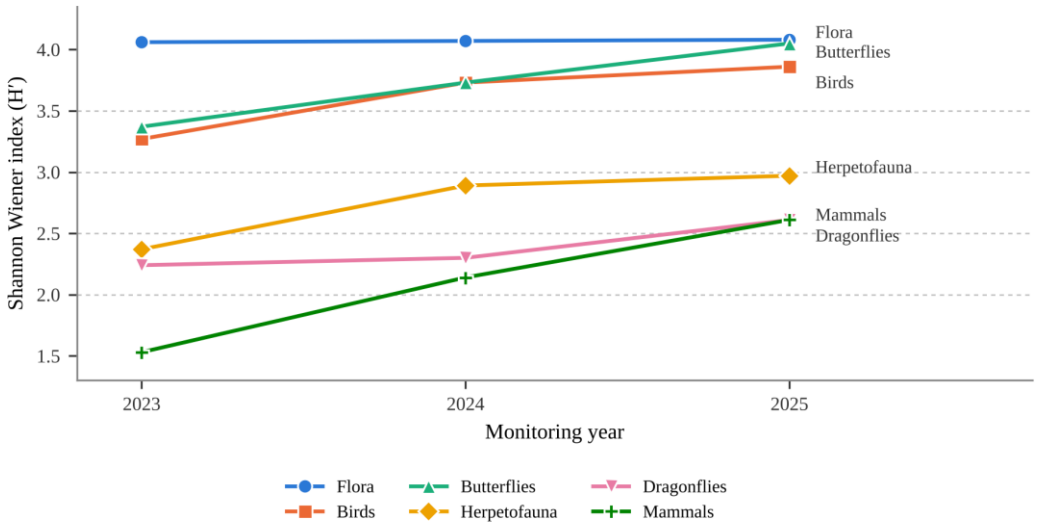


Figure 7. Shannon Wiener index (H′) of each taxonomic group in 2023, 2024, and 2025. Dashed lines mark the category limits of 2.00, 2.50, 3.00, and 3.50.

The 2025 monitoring also recorded species of conservation concern that were not found in 2023 (Table 8). Protected bird species increased to 11, including the Crested Serpent Eagle (*Spilornis cheela*), Red-crowned Barbet (*Psilopogon rafflesii*), Great Slaty Woodpecker (*Mulleripicus pulverulentus*), Blue-crowned Hanging Parrot (*Loriculus galgulus*), and Common Hill Myna (*Gracula religiosa*). The Long-tailed Macaque (*Macaca fascicularis*) and Southern Pig-tailed Macaque (*Macaca nemestrina*) are Endangered. *Aglaia forbesii* is Near Threatened. *Dryobalanops lanceolata*, a dipterocarp endemic to Borneo, was found at the secondary forest point. Orangutan nests were also found in *Macaranga gigantea* trees at the former field point and at the secondary forest point. In 2025 the numbers of individuals and species of birds, herpetofauna, dragonflies, butterflies, and mammals were highest at the secondary forest point and lowest at the former field point.

Table 8. Additional species of conservation concern recorded in the 2025 monitoring

Group	Species	English name	P.106/2018	CITES	IUCN
Flora	*Aglaia forbesii*				NT
Birds	*Spilornis cheela*	Crested Serpent Eagle	Protected	App. II	LC
	Psilopogon rafflesia	Red-crowned Barbet	Protected		NT
	Aethopyga siparaja	Crimson Sunbird	Protected		LC
	Mulleripicus pulverulentus	Great Slaty Woodpecker	Protected		VU
	Loriculus galgulus	Blue-crowned Hanging Parrot	Protected	App. II	LC
	Gracula religiosa	Common Hill Myna	Protected	App. II	LC
	Prinia familiaris	Bar-winged Prinia			NT
	Ducula aenea	Green Imperial Pigeon			NT
	Phaenicophaeus diardi	Black-bellied Malkoha			NT
Herpetofauna	*Gekko gecko*	Tokay Gecko		App. II	LC
	Varanus salvator	Asian Water Monitor		App. II	LC
Mammals	*Macaca fascicularis*	Long-tailed Macaque		App. II	EN
	Macaca nemestrina	Southern Pig-tailed Macaque		App. II	EN
	Rhinolophus sedulous	Lesser Woolly Horseshoe Bat			NT

Notes: EN = Endangered. Other abbreviations follow Table 6. Empty cells indicate that the species is not listed or has no widely used English name.

Conservation programmes in the Goa Sampe Marta area

PT Pertamina Gas Operation Kalimantan Area has run three groups of conservation programmes in the Goa Sampe Marta area since 2023 (Table 9). The forest fruit tree planting programme was carried out with the Kampung Bersama Farmers Group to provide food for orangutans and sun bears. The programme also included outreach that asks visitors not to disturb the forest around the cave. External parties provided 73% of the programme investment and the company provided 27%, as verified by PT Lafirza Global Indonesia. An illegal logging detector based on the Internet of Things (IoT) was installed in 2024 after about 5 ha of forest in Martadinata Village was illegally logged in 2022 and 2023. The device operates 24 hours a day and sends real time information to patrol officers. The innovation has received simple patent certificate Number S00202503560.

Table 9. Conservation programmes of PT Pertamina Gas Operation Kalimantan Area in the Goa Sampe Marta area

Programme	Start year	Area and output	Purpose
Planting of forest fruit trees with the local community	2023	1.5 ha of degraded land; 540 forest fruit tree seedlings	Provide food for orangutans, sun bears, and other animals that eat fruit
Planting of endemic plants as a nature tourism trail	2023	1.5 ha of degraded land; 1,110 endemic plant seedlings	Restore vegetation cover and mark the Goa Sampe Marta tourism trail
Illegal logging detector based on IoT	2024	Forest area of Martadinata Village; sensors operating 24 hours a day	Speed up detection of and response to illegal logging by patrol officers

IV. DISCUSSION

Flora

The 2023 flora composition reflects a disturbed area. The most abundant species were grasses and herbs that grow fast and readily occupy open land. Cogongrass (*Imperata cylindrica*), lantana (*Lantana camara*), *Chromolaena odorata*, and *Clidemia hirta* are known invasive plants in Southeast Asia[20]. Cogongrass can form dense stands that hinder tree regeneration[21]. Lantana has spread across many tropical countries and is difficult to control once established[22]. The presence of these invasive plants needs attention in vegetation restoration programmes.

Cultivated species such as oil palm, cassava, cacao, and bamboo dominated the tree and pole layers. This pattern matches the land use along the routes, which pass gardens and settlements. Oil palm expansion in Southeast Asia reduces biodiversity because it replaces natural forest[23,24]. Forest fragments bordering oil palm

can still hold many native tree species if they are not cleared any more[25]. Bornean ironwood had the highest relative dominance among trees because of its large stem diameter. Bornean ironwood lives for a long time and grows slowly[26]. Its stands give the area particular value because the species is Vulnerable.

The flora H′ value of 4.06 in 2023 is very high because many species were recorded and individuals were fairly evenly distributed. Understorey plants and cultivated species, not native forest trees, contributed most to this high value. The 2024 and 2025 surveys recorded 100 species with a composition different from 2023, because those surveys focused on points that still had woody cover. Native forest species such as *Dryobalanops lanceolata*, *Pterospermum diversifolium*, and *Chisocheton pentandrus* were recorded at the secondary forest point in 2025. Lowland forest in East Kalimantan affected by fire and logging needs a long time to regain the species composition of undisturbed forest[27,28]. Differences in sampling design between years mean that the flora index values cannot be compared directly[29].

Birds

The 2023 bird community was dominated by species common in open habitats and near settlements, such as the Sooty-headed Bulbul (*Pycnonotus aurigaster*), Eurasian Tree Sparrow (*Passer montanus*), Pacific Swallow (*Hirundo tahitica*), and Chestnut Munia (*Lonchura atricapilla*). This composition matches the vegetation of the area, which consists of grassland, fields, oil palm gardens, and secondary forest. Birds are widely used as indicators of environmental condition because their responses to habitat change are easy to observe[30]. Four protected raptor species show that the area still provides prey for top predators[31]. The Wreathed Hornbill disperses the seeds of forest trees with large fruits[32]. Some species recorded in 2025, such as the Common Hill Myna and the Blue-crowned Hanging Parrot, are among the birds commonly traded in Indonesian bird markets[15].

Bird species increased from 34 in 2023 to 63 in 2025. In 2025 the secondary forest point had the most species (49), followed by shrubland (44) and the former field (38). This pattern indicates that secondary forest, with its more complex vegetation structure, provides more varied food and nesting sites.

Insects

Insect diversity in 2023 was very high and no species was dominant. Butterflies formed the largest group with 34 species. Butterfly diversity depends on habitat heterogeneity, including canopy gaps, host plants, and flowering plants[33,34]. The Malayan Birdwing (*Troides amphrysus*) is protected and listed in CITES Appendix II. Dragonflies respond to changes in water conditions and in the surrounding forest cover. A study in the rain forest of East Kalimantan showed that dragonfly composition changed with the degradation of terrestrial habitat[35]. The H′ value for dragonflies rose from 2.24 in 2023 to 2.61 in 2025, and the number of species rose from 11 to 16.

Herpetofauna

The 2023 H′ value for herpetofauna was low because few species and individuals were recorded. The survey lasted only three days with two hours of searching in each habitat type. The VES method is effective for detecting rain forest herpetofauna, but its results depend strongly on search time[13]. The index value is not a sufficient basis for judging that the area cannot support herpetofauna. Amphibians and reptiles are sensitive to habitat change, especially changes in humidity and canopy cover[36]. A VES survey over three nights in Prevab, Kutai National Park, recorded 25 herpetofauna species from 76 individuals, with *Chalcorana raniceps* as the most abundant species[37]. The genus *Chalcorana* was also the most abundant herpetofauna group in the Goa Sampe Marta baseline. In 2025 herpetofauna species increased to 22, including three species endemic to Borneo, namely *Limnonectes leporinus*, *Cyrtodactylus malayanus*, and *Tropidophorus beccarii*. The Beauty Rat Snake (*Elaphe taeniura*) is Vulnerable and was found inside the cave, where it preys on bats.

Mammals

The 2023 mammal community was dominated by the Diadem Roundleaf Bat (*Hipposideros diadema*), which roosts in large numbers inside Goa Sampe Marta. Caves and limestone outcrops are important roosts for bats in Southeast Asia, and their loss can reduce bat diversity[38,39]. Bats that feed on insects help control insect populations, and bats that feed on fruit help pollinate plants and disperse seeds[40]. Protection of the cave interior and entrance from visitor disturbance is an important part of managing the area.

The Bornean orangutan was recorded through sightings, nests, and information from residents. Bornean orangutan populations continue to decline because of forest loss and the killing of animals[41]. Orangutans can still use secondary forest and landscapes bordering plantations where food trees and nesting trees are available[42]. Nest size and the features of nest trees vary among individual orangutans, including those in Kutai National Park[43]. The nests found in *Macaranga gigantea* trees in 2025 show that pioneer trees in the area are also used by orangutans. The H′ value for mammals increased from 1.53 in 2023 to 2.61 in 2025. The 2025 survey added

strip transects, camera traps, and observations in three habitat types. Part of the increase reflects differences in survey effort.

Conservation programmes and monitoring

The planting of forest fruit trees and endemic plants responds to the baseline finding that understorey plants, invasive plants, and cultivated species dominate the area. Planting native trees that grow fast and bear fruit can speed up the recovery of forest cover and attract animals that disperse seeds[44]. Forest restoration on degraded land also restores ecosystem functions such as habitat provision and soil protection[45]. The involvement of a local farmers group agrees with evidence that the success of community-based conservation projects depends on project design and local community characteristics[46]. Detection of illegal logging with acoustic sensors has been tested for recognising chainsaw sounds in forests[47]. This approach is relevant because illegal logging and fire are major causes of forest loss in Kutai National Park[7].

The increase in faunal diversity from 2023 to 2025 cannot be treated as a direct effect of the conservation programmes. Differences in point locations, survey duration, and methods between years affect the number of species recorded[29]. Monitoring over many years requires clear questions, a fixed sampling design, and consistent records of survey effort[10]. Point locations, number of plots, survey duration, and survey timing should be standardised in future monitoring. Survey effort for each taxonomic group should also be recorded to allow a correct assessment of changes in index values.

V. CONCLUSION

The 2023 baseline in the Goa Sampe Marta area recorded 101 plant species, 34 bird species, 62 insect species, 12 herpetofauna species, and 8 mammal species. Diversity was very high for flora and insects, high for birds, low for herpetofauna, and very low for mammals. Grasses, herbs, and invasive plants dominated the understorey, and oil palm and Bornean ironwood dominated the tree layer. The area provided habitat for 13 species of conservation concern in 2023, including the Critically Endangered Bornean orangutan. The 2025 monitoring recorded more species of birds, herpetofauna, dragonflies, butterflies, and mammals, together with additional protected and threatened species. Future monitoring requires a uniform protocol to allow changes in diversity to be linked to the planting of forest fruit trees, the planting of endemic plants, and the detection of illegal logging.

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