FIELD EXPEDITION

REPORT OF ORANGUTAN AND WILDLIFE SURVEY

IN TAWAI FOREST RESERVE (MAY 2025)

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Executive Summary

Despite challenging field conditions, including heavy and frequent rainfalls and steep terrain that constrained survey operations and limited data collection effectiveness, our expedition documented the presence of critical wildlife populations and habitat use patterns within the study area.

The distribution of orangutan nests showed marked spatial clustering, with the majority concentrated along the RW 3 (20 nests) and Line 7 (6 nests), both positioned on opposite sides of the proposed highway alignment. Nest occurrence was notably sparse along other survey transects. The central corridor where these two high-density areas are located appears to constitute critical habitat for the local orangutan population. The proposed highway alignment will bisect this essential habitat zone, effectively fragmenting the existing orangutan population into two isolated subpopulations. This fragmentation poses significant threats to population viability and long-term survival prospects. While orangutans are capable of terrestrial locomotion and could theoretically traverse a highway, the risk of vehicle collisions is a real threat. Such incidents pose a risk to human safety, orangutan conservation, and may lead to negative publicity on a national or international level when orangutans become roadkill casualties.

The broader ecological impacts of the proposed highway extend across all wildlife taxa within this unique ecosystem. Forest fragmentation and direct habitat destruction will trigger cascading effects, including increased mortality of multiple species, not just orangutans, loss of forest-dependent endemic and protected species, and degradation of ecosystem connectivity. The development will also facilitate increased human access to previously remote areas, potentially enabling expanded poaching and other illegal activities in once-remote and inaccessible areas. This road will impact not only the surrounding areas of the linear infrastructure but the integrity of the entire Tawai FR. Last, but not least, this new fragmentation process will also significantly elevate the risks of human-wildlife conflict involving elephants and orangutans.

Although proposed mitigation measures aim to reduce the highway's environmental impacts, these interventions cannot fully offset the fundamental ecological damage inherent in bisecting the Tawai forest ecosystems. The PBH will inevitably compromise the biological integrity of this irreplaceable habitat, resulting in substantial wildlife population losses that cannot be adequately compensated for through mitigation alone.

Background Information

Understanding the distribution and size of orangutan populations in Sabah is crucial for effective conservation strategies for the species. Over time, the Sabah Wildlife Department (SWD) and its collaborators have conducted multiple surveys in the State to establish reliable size estimates of the orangutan populations across Sabah. Continuous monitoring of population size and dynamics is essential for evaluating the sustainability of orangutan populations in Sabah and assessing the effectiveness of conservation efforts by the SWD and other stakeholders.

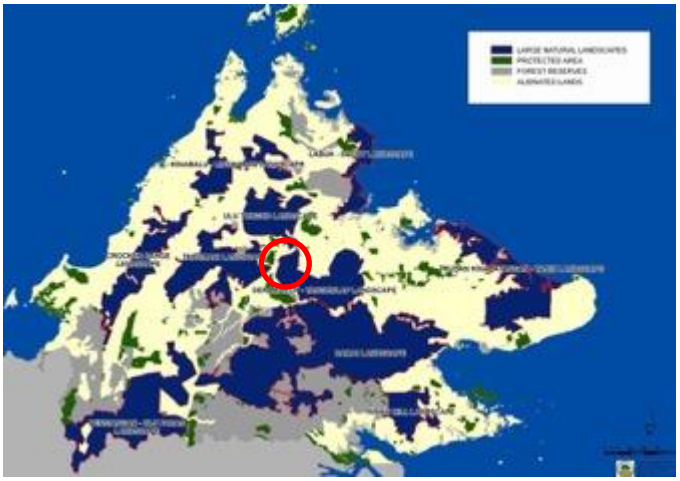
The Overall project funded by MPOGCF and entitled "Orang-utan surveys in Sabah" follows the following objectives (see detailed proposal):

- Surveying orangutan nests in key protected and non-protected areas in Sabah.
- Finalizing what we know about orangutan metapopulation in Kinabatangan.
- Collecting practical and detailed information using mixed bio-social methods to document orangutan conservation status in at least two other agricultural landscapes.
- This project is a vehicle for relevant stakeholders' capacity building and training platform.

This report summarizes the results of the field expedition conducted under the MPOGCF project, which took place in the Tawai Forest Reserve between May 20th and May 29th, 2025 (seven days of fieldwork and two days of travel).

In addition to the Hutan orangutan team, who was in charge of orangutan surveys, Hutan also sent the Wildlife Survey and Protection Team to collect data about other wildlife taxa and to cover more ground in the field. This Final Report presents the results of all field activities carried out during the survey.

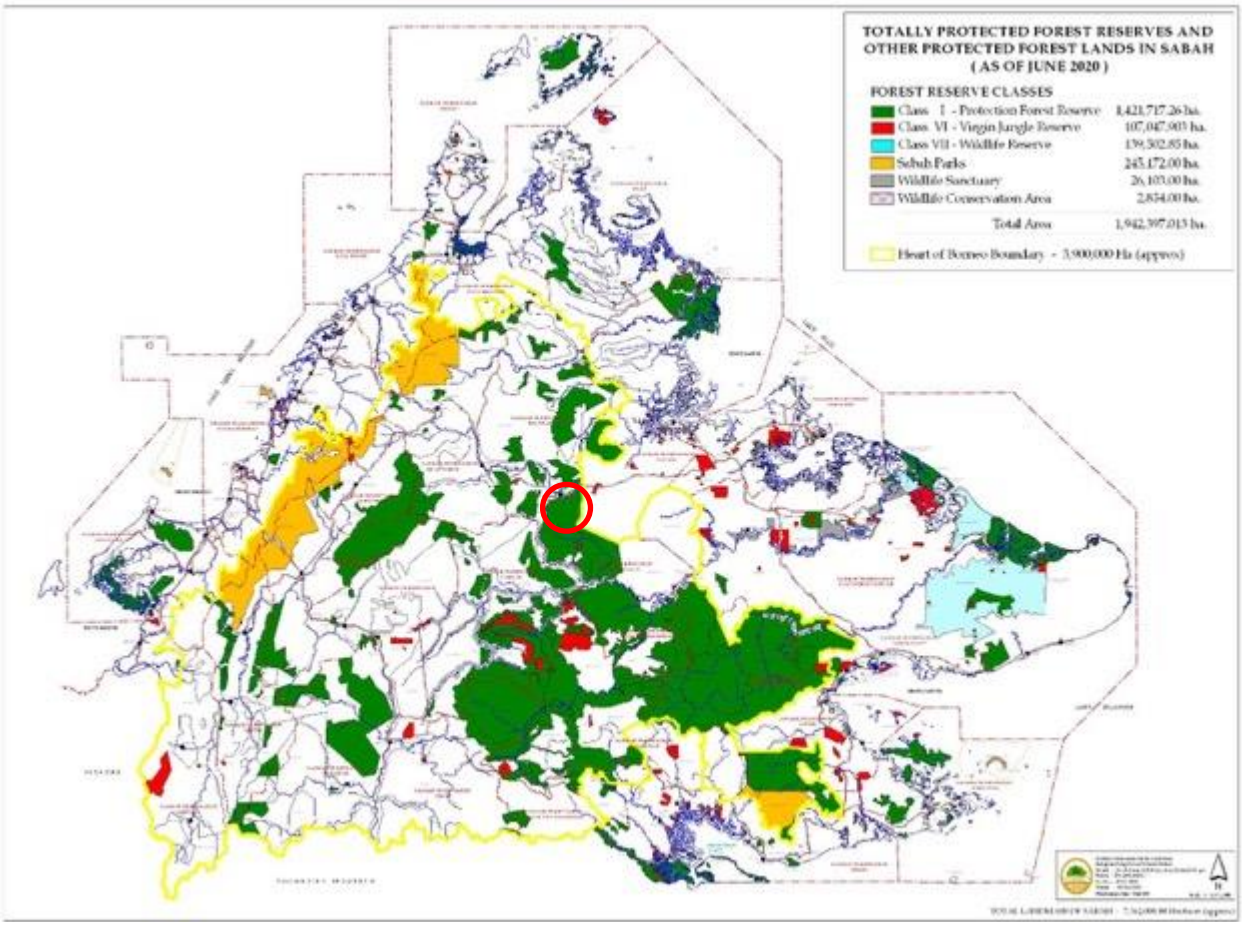
Background information about Tawai Reserve and its orangutan population



Tawai Forest Reserve is a Class I Protection Forest Reserve located in Telupid District that covers an area of 22,697 ha. Tawai is part of the larger "Deramakot-Tangkulap landscape", and is connected to FMU 17 also called Tangkulap-Pinangah on its southern side: Map 1 and 2 (Tawai is circled in red).

The landscape is mostly hilly and consists primarily of ultramafic, upper mixed dipterocarp and kerangas forests. Kerangas forests (or heath forests, literally meaning "land which cannot grow rice") are found on nutrient-poor, acidic, sandy soils produced by siliceous parent rocks. Kerangas forests are characterized by small to medium-size trees with a low and dense canopy with a uniform height including several species belonging to the Dipterocarpaceae, Myrtaceae (*Syzygium sp.*), and Sapotaceae families.

Tawai FR has been badly damaged by fires of human origin in the past, and signs of encroachments are still occurring today.



Maps 1 and 2 showing the location of Tawai FR in Sabah

Tawai FR and the Pan Borneo Highway project

The Sabah State Government has designated a new route through Tawai Forest Reserve as part of the Pan Borneo Highway Project. This proposed alignment crosses 15 kilometers of critical habitat for elephant and other protected species like orangutans within a steep-sided valley ecosystem. The construction will create additional habitat fragmentation for wildlife populations in Tawai Forest Reserve, compounding existing pressures on already vulnerable animal communities.

Habitat fragmentation, disturbance, and wildlife displacement resulting from the highway will intensify human-wildlife conflicts in the region. Beyond these immediate impacts, the road infrastructure will contribute to wildlife mortality through road kills and facilitate increased human access to previously remote forest areas. This enhanced accessibility raises serious concerns about secondary threats including wildfire risks, poaching, illegal logging operations, and other forms of forest encroachment.

The Pan Borneo Highway's proposed route through Tawai Forest Reserve exemplifies the complex conservation challenges facing Sabah, where critical infrastructure development objectives must be weighed against the urgent need to protect the state's rapidly declining wildlife populations and their remaining natural habitats.

Kerangas forests exhibit limited fruit productivity and scarce food resources for wildlife, which accounts for the characteristically low animal biomass in this forest type. While orangutans do occur in kerangas ecosystems, their populations remain sparse, as they depend heavily on adjacent forest types for sustenance.

A 2001 aerial helicopter survey by Hutan and the SWD estimated orangutan density at approximately 0.1 individuals per km², with nests concentrated primarily in the eastern lowlands near boundaries with other land-use types (Figure 1).

No updated population estimates have been conducted since this survey. In order to mitigate the possible side effects of the construction of the Pan Borneo Highway across Tawai, it is urgent to carry out new orangutan surveys to document the distribution and abundance of the species in this FR.

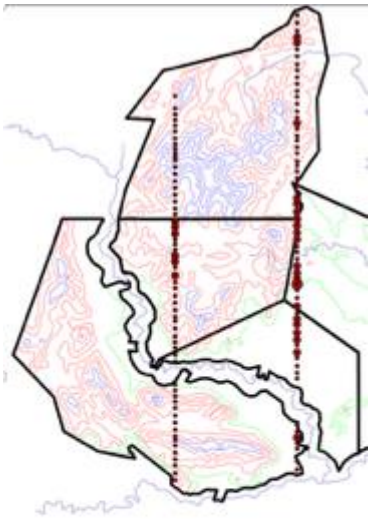


Figure 1: Number of orangutan nests detected from helicopter transects during the 2001 aerial survey

Methodology

During fieldwork, we employed standardized field methodologies specifically designed for orangutan surveys, adhering to established protocols in Sabah (Ancrenaz, 2013).

- **Reconnaissance Walks (RWs) :** Reconnaissance walks follow terrain-adapted routes rather than predetermined transects. This flexible approach enables the teams to navigate challenging terrain features, allowing for coverage of greater distances and more extensive areas within limited timeframes. While density estimation is not possible from RW observations, we can calculate linear encounter rates expressed as the number of nests detected per kilometer walked.
- **Botanical Monitoring:** We established botanical monitoring plots (100m × 20m) at each RW location to assess forest condition and composition. Within each plot, we counted and identified all trees with a diameter at breast height (DBH) exceeding 20cm. Forest structure parameters, including canopy openness, small tree presence, and climber abundance, were evaluated using a standardized scoring system ranging from 0 (minimum/absent) to 3 (maximum).
- **Ancillary Data Collection:** Comprehensive environmental data collection included weather conditions, human presence indicators, forest disturbance signs, and topographical features that might influence wildlife observations and distribution patterns.
- **Camera trap surveys**: We deployed ten camera traps (Model Reconyx Hyperfire Professional 2). All cameras were mounted on trees at an average height of 30 – 60 cm above ground level. We placed the cameras on three to five-meter-wide observed wildlife tracks. Each camera was configured to take three photos per trigger, with three minutes of a quiet period, followed by 45 seconds of video recording. The cameras were deployed in April 2025 and were retrieved in July 2025 by the team. Unfortunately, one camera was found to be faulty and did not obtain any recordings, and one of the camera traps was declared lost due to the clearing of the area in the location (CT04) for Pan Borneo development.
- **Passive recording for wildlife acoustics (Bioacoustics):** A total of five Audiomoth devices were deployed in Tawai FR (as shown in Map 1) to record the acoustic patterns. The devices were mounted on trees within Tawai FR at a 100 cm height, between 150 – 200 m altitude and located 100 – 150 m away from road access. We ensured that the deployment was far from noise factors such as vehicles, waterbodies (rivers) and human activities. We configured the Audiomoth devices to actively record their surroundings in four different periods: 0500 – 0800 hrs, 1100 – 1400 hrs, 1700 – 2000 hrs and 2300 – 0200 hrs. We used a frequency of no more than 48 kHz, and the devices were active for 60 seconds every 300 seconds (5 minutes). We left the devices on-site for five days, and they were retrieved. One device was found to be faulty and did not obtain any recordings.
- **Passive and Active Recording for Bats:** Two locations were selected for active recording and passive recording of bats' echolocation calls beyond human hearing range. For active recording, we used the Pettersson M500 device in ultrasonic mode with a frequency limit of 160 kHz. This active recording started the moment the first frequency contact was detected and lasted for 30 minutes. As for passive recording, we used the Song Meter Mini Bat device with a frequency limit of 120 kHz. This passive recording was conducted by deploying a device to record from 1800 hours to 0600 hours for five consecutive days. The device was collected afterwards.

- **Small Mammal trapping and release:** In Tawai FR, we established five transects, each 100 m long, for small mammal trapping. Within a 100 m length, ten wire-mesh live traps were placed at a ten-meter distance. We baited each trap with either banana or palm mesocarp fruit. The traps were checked at 0800 hrs and 1500 hrs for five consecutive mornings and evenings. We identified the trapped individuals at the species level and recorded additional information for each capture (gender, physical condition, size) before releasing them on the spot. The map below shows the locations where we deployed the traps. On average, the transects established for small mammals were 20 to 50 m away from road access. Certain areas have dense shrubs as an understory and little canopy cover.
- **Frog Survey:** Because of weather conditions, we only managed to conduct a 400–meter transect line for frog survey along the river found within the Tawai Rainforest Camp of Tawai FR. The survey, conducted from 1900 hours to 2015 hours, involved detecting frog species by direct sighting or calls along the transect. The 400-meter distance was divided into 10 sections of 40 meters each (0 – 40 m, 40 – 80 m, 80 – 120 m, 120 – 160 m, 160 – 200 m, 200 – 240 m, 240 – 280 m, 280 – 320 m, 320 – 360 m, 360 – 400 m). The species encountered were recorded for each section.
- **Bird Survey:** Bird surveys were usually conducted simultaneously with recce walk, we employed 15-species Mackinnon List (ML) method. This rapid assessment is suggested to be a cost-effective method of conducting bird surveys in the tropics. We grouped both visual and auditory observations into the 15 – species consecutive list of species. The species accumulation curve was generated by adding the species recorded on previous lists to the total number of species. However, during the expedition, the number of efforts to conduct the bird survey during the recce was hindered by the rainy weather. Several days were spent observing birds from basecamp and fixed locations during daytime.
- **Gibbon survey**: we employed the method of 'triangulation', which involves listening and mapping the locations where gibbon songs (long or short) were heard in the forest. We used this method to estimate the number of gibbon groups in the forest. To precisely identify the location and number of gibbon groups within a forest area, we had two listening posts that recorded the calls simultaneously. The recording started exactly at 0600 hrs and 0800 hrs, recording the number of songs and call types every five minutes by detected groups. We conducted this data recording for three consecutive days.
- **Drone Surveys:** We conducted two distinct types of unmanned aerial vehicle (UAV) surveys:
    - *Daytime Operations*: Drones conducted nest counts along aerial line transects and during random flight patterns. All flights were recorded for subsequent video analysis at the field camp to identify and quantify orangutan nests. These aerial surveys provided critical landscape overviews that informed ground survey planning and optimization.
    - *Nocturnal Thermal Surveys:* Thermal imaging technology enabled direct detection of orangutans in their nests during nighttime flights. These surveys followed systematic linear transects within 800m × 800m quadrats.
    - *Technical Specifications:* all drone operations were conducted with a Mavic 3 thermal (night surveys) or a Matrice 30 (day surveys) at a standardized altitude of 70 meters with flight speeds maintained at 8 m/s. Data collection protocols included recording the types of findings, GPS coordinates, timestamps, and behavioral observations for all detected orangutan signs and individuals.

Results

- Weather limitations

Weather conditions and site accessibility posed significant challenges during field work operations. The persistent and heavy rainfall further restricted field operations during the expedition, allowing survey teams to enter the forest for only four days. Heavy rain conditions present multiple safety hazards, including increased risk of falling branches and other forest debris. Additionally, the reduced light availability during rainy periods significantly impairs the ability to properly observe and document orangutan nests. Conducting orangutan surveys under these conditions would introduce serious observational bias into the data collection process. Last, the heavy rainfall in the evening precluded most surveys from taking place, including drone flights, frog or night surveys, for example. The weather encountered during field work significantly hampered our efforts.

- Study Area and Context

Our surveys were concentrated on the northern side of Tawai Forest Reserve, targeting the area anticipated to experience the greatest impact from the Pan Borneo Highway development project. Most survey trails originated from adjacent human settlements and villages. The proximity of these communities to the forest boundaries contributed significantly to the disturbance and degradation patterns observed throughout our recces.

Figure 2: map showing the location of the recce walks and camera traps during the Tawai Expedition

I. RESULTS FOR ORANGUTAN SURVEYS

1. Ground Recce Walks

We walked a total of 10.113 km of recce walks along 10 different routes, yielding a total of 34 orangutan nests or 3.36 nests/km. We did not record any orangutan direct sightings or calls: Table 1.

Food resources were more abundant in dipterocarp forest characterized by taller trees and a more diverse species composition, particularly on ridge tops, compared to kerangas forests where trees were numerous but small and orangutan food sources were scarce. Areas dominated by climbing bamboos (*Dinochloa spp.*) also provided limited food resources, and orangutan nests were particularly scarce in these areas.

Date	RW Name	Length (km)	General Location	Bot. Plot	Wildlife	Forest Condition
20.05	RW 1 (145-152)	0.800	About 500 m from existing road / Human activities nearby	146-148 149-151	None but signs of people's wastes	Existing trail located close to the existing road /Degraded and infested with climbing bamboos / Steep slope / After 600m: kerangas / Small trees but closed canopy.
	RW 2 (548-552)	0.983		549-550 565-566	None	Steep slope /Small trees / Closed canopy
21.05	L 3 (154-161)	0.700	1.5 km from Kg Gambaron / Close to current road development	156-158 168-169	IS: bear, elephant /Sign of illegal logging	Degraded / Small trees / Semi-inundated
	L 4 (553-567)	0.833	From Sg Labuk estate development	558-559	IS: elephant, sambar deer OU nests: 3	Degraded place / Semi inundated at the beginning / Slope / Trees ++ but small size / Bushes ++ / Climbing bamboos ++
23.05	RW 3 (569-599)	1.200	2 km from the road / Go south	572-575 590-592	IS: rusa, bear people OU nests: 20	Poor close to start but nice after 200m / Slope
	RW 5 (165-170)	1.900	2 km from the road / Go south	None	IS: elephant	Climbing bamboos ++ / Slope/ Small trees ++ / OU food -
24.05	L 7 (171-186)	1.000	2.5 km from the road / Go north	175-175 184-186	IS: rusa, barking deer, illegal logging OU nests: 6	Open area and bushes ++ on slope / Ridge (>600m): nice forest with OU food + / Close to the new development area
	L 8 (600-610)	1.220	2.5 km from the road / Go north	603-606	IS: great argus, rhino hornbill DS: moonrat OU nests: 4	Close to the new development area
26.05	Line 3 (191-199)	0.677	2 km from Eastern Tawai / Go south	195-197	IS: elephant, human OU Nest: 1	Climbing bamboos ++
	Tawai10 (135-155)	0.800			IS: elephant, sambar deer	
TOTAL		**9.313**			**OU nests: 34**	

Table 1: List of recce walks carried out during the Tabin Orangutan Surveys

- Nest Distribution and Age Classification

The vertical distribution of nests reflected the forest's structural characteristics (most trees of small size and small circumference) with the majority (81%) located between 10-20 meters above ground level. A smaller proportion occurred at lower elevations below 10 meters (8%, n=2) and higher elevations between 20-30 meters (11%, n=3). This distribution pattern mirrors the forest composition, which contains relatively few tall canopy trees. All nests were either old (Class III: 3 - Class IV: 18 nests) or very old (Class V: 13 nests). The absence of fresh or recently constructed nests suggests a limited resident orangutan population, particularly breeding females, within the surveyed areas. Nevertheless, the presence of aged nests indicates periodic orangutan utilization of these habitats, likely coinciding with seasonal peaks in fruit and food resource availability.

- Forest Composition and Structure

Botanical analysis across 13 plots along the recces totalled 184 trees exceeding 20 cm diameter at breast height (DBH). The size distribution revealed a predominance of smaller trees, with the 20-30 cm DBH class comprising 47.8% of the sample, followed by 30-40 cm (34.8%), 40-50 cm (3.2%), and 50-60 cm (1.1%) classes. Dipterocarpaceae dominated the forest composition, representing 50.5% of all recorded trees. Within this family, Seraya (*Shorea* spp.) was most prevalent at 28.8%, followed by Kapur (*Dryobalanops* spp.) at 10.3%, Keruing (*Dipterocarpus*spp.) at 6.0%, and Urat mata (*Parashorea* spp.) at 3.8%. Dipterocarps were found across all forest types, including kerangas forests where they typically exhibited reduced stature compared to other habitats. Pioneer tree species occurred infrequently, with only scattered *Ficus* spp. and *Macaranga* spp. individuals observed. Trees representing preferred orangutan food sources were notably scarce, including *Ficus* sp. (Moraceae), *Garcinia* sp. (Guttiferaea), *Lithocarpus* sp. (Fagaceae), and *Syzigium* sp. (Myrtaceae).

- Structural Assessment

Rapid forest structure evaluation using standardized scoring methods revealed predominantly semi-closed to closed canopy conditions (mean score: 1.97 ± 0.70, range: 1.0-3.0) and a relatively uniform canopy structure. These characteristics are typical of kerangas forests. Small trees and shrubs were abundant throughout the survey area (mean score: 2.67 ± 0.65, range: 1.0-3.0). Climbing vegetation was frequently encountered (mean score: 1.60 ± 0.78), particularly in degraded areas dominated by climbing bamboos (*Dinochloa* sp.). Overall, and bamboo-infested zones especially, contained minimal orangutan food resources explaining the relatively low orangutan abundance in surveyed areas.

Signs of human disturbances including hunting trails or illegal logging were relatively common along the trails. We only recorded a few signs of animal's presence, including sunbear, elephants of sambar deer. However the forest soil conditions were not optimal for detecting wildlife tracks.

- Summary

The botanical assessment revealed a heterogeneous landscape comprising of disturbed forests along the slopes near Tawai Forest Reserve boundaries, interspersed with nutrient-poor kerangas forests offering limited wildlife food resources, and some lowland dipterocarp stands in better condition concentrated primarily on ridge tops. Degraded areas were frequently colonized by climbing vegetation, especially climbing bamboos, which further reduced habitat quality for wildlife.

The distribution of orangutan nests showed marked spatial clustering, with the majority concentrated along the RW 3 (20 nests) and Line 7 (6 nests), both positioned on opposite sides of the proposed highway alignment. Nest occurrence was notably sparse along other survey transects. The central corridor where these two high-density areas are located appears to constitute critical habitat for the local orangutan population. The proposed highway alignment will bisect this essential habitat zone, effectively fragmenting the existing orangutan population into two isolated subpopulations. This fragmentation poses significant threats to population viability and long-term survival prospects. While orangutans are capable of terrestrial locomotion and could theoretically traverse a highway, the risk of vehicle collisions is a real threat. Such incidents will create a risk to human safety, orangutan conservation and national or international negative publicity when orangutans will become roadkill casualties.

2. Deployment of camera traps

The team deployed a total of ten camera traps during the survey. We decided to leave these camera traps for a period of two months. We will retrieve these cameras toward the end of July 2025. Camera trap results will be then added to this preliminary report to give a more exhaustive picture of the entire survey results.

3. Results from drone surveys above the forest during the day

During daytime, we deployed a Matrice 30 drone to survey orangutan nests along predetermined line transects above the forest canopy. However, adverse weather conditions significantly hindered our data collection efforts, forcing us to cancel numerous flights due to persistent rainfall. Additionally, poor connectivity limited the drone's operational range to below 1 km (mostly) from the launch point, further constraining our survey coverage.

The area we surveyed with the drone was a strip of about 1 km each side of the existing road: Figure 3.

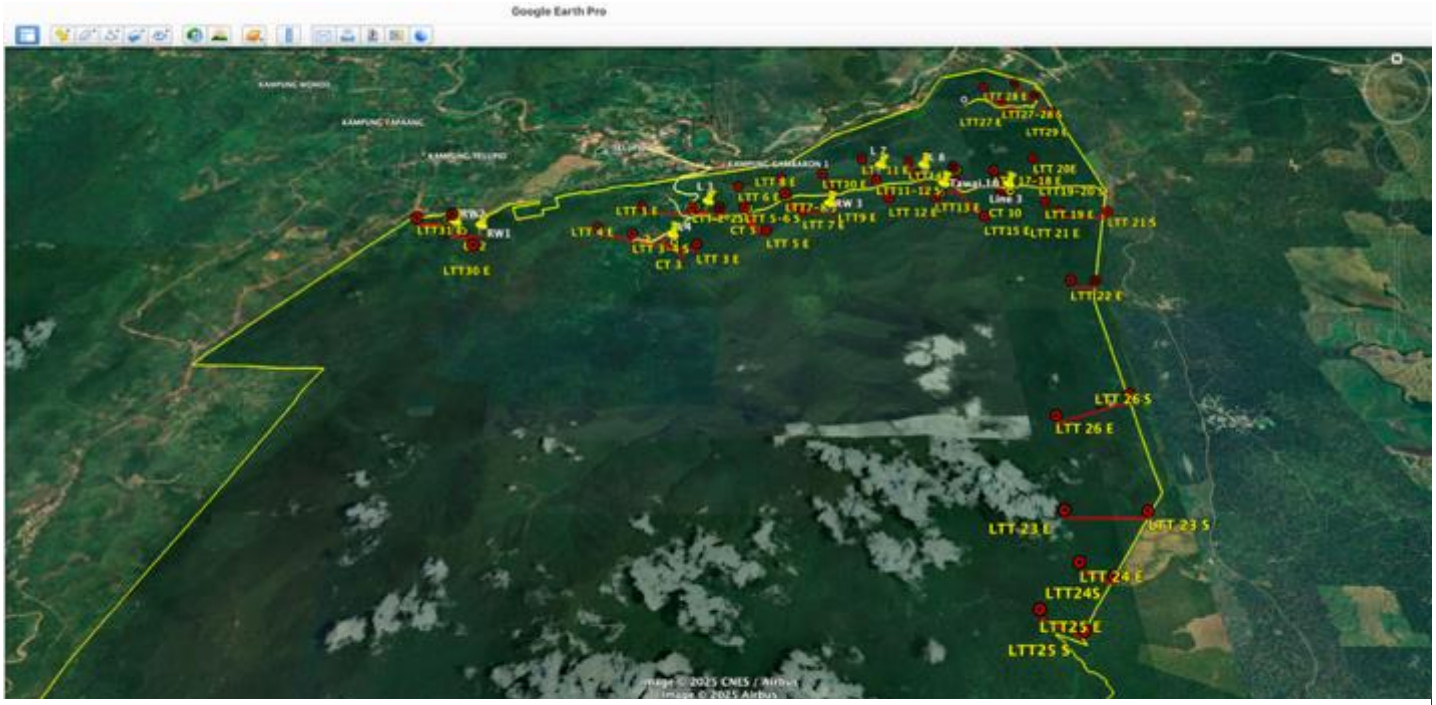


Figure 3: Map showing the location of the drone transects

Despite weather conditions, we successfully conducted 32 drone flights covering a total distance of 22,727 km, during which we identified 11 orangutan nests. These observations yielded an overall nest density index of 0.48 nests/km of flight (Table 2). A notable cluster of six nests was discovered in Transect 26, situated on the southeastern side of Tawai Forest Reserve. All detected nests were classified as old to very old (Class IV or V).

Date	Nb Transect	Distance transect (km)	Starting Line	Bearing	Nb Nests	Forest Condition
20.05.25	LTT1	0.814	N:5.606584 - E:117.140096	W	None	First half: very disturbed Second half: better (canopy: 20-30 m)
	LTT2	0.549		E	None	Forest in good shape dominated by Dipterocarps
	LTT3	0.864	N:5.599990 E:117.134330	E	None	Disturbed along the road (200 m)
	LTT4	1.200		W	None	Steep – Forest ok
21.05.25	LTT5	0.849	N:5.606537 E:117.149825	SE	None	Very steep – Nice Diptero forest
	LTT6	0.600		NW	None	Steep – Nice Diptero forest
22.05.25	LTT7	0.652	N:5.610795 E:117.157434	SE	1 at 616 m	Steep / Degraded forest close to the road
	LTT8	0.500		NW	None	Steep – Nice Diptero forest
	LTT9	0.447	N:5.612315 E:117.166317	SE	None	Steep – OK forest
	LTT10	0.523		NW	None	Steep – OK forest
23.05.25	LTT11	0.700	N:5.614748 E:117.174697	NW	None	Very steep – Mixed degraded forest and OK forest
	LTT12	0.600		SE	None	Very degraded forest
	LTT13	0.792	N:5.616656 E:117.182666	SE	None	Steep – OK forest
	LTT14	0.450		NW	None	Very steep
	LTT15	1.200	N:5.614319 E:117.189693	SE	1 at 352 (Class IV) 1 at 442 (IV)	Very steep / Degraded forest infested with climbing bamboos
	LTT16	0.500		NW	None	
	LTT17	0.400	N:5.614699 E:117.3197308	SSE	None	
	LTT18	0.350		N	None	
	LTT19	0.700	N:5.614625 E:117.205378	SE	None	
	LTT20	0.725		NW	None	
24.05.25	LTT21	0.770	N:5.605145 E:117.216237	W	None	Steep but nice forest
	LTT22	0.657	N:5.586366 E:117.209987	W	None	Steep but nice forest)except 200 m of oil palm at the edge)
	LTT23	1.400	N:5.524833 E:117.199858	W	None	Nice forest – Small rivers
	LTT25	0.700	N:5.519428 E:117.188577	NNW	1 nest	Nice forest
	LTT26	1.500	N:5.559343 E:117.209779	SW	6 nests: 1 at 890 m/5 at 1500 (hilltop)	Very steep – Nice forest
25.05.25	LTT27	0.451	N:5.641082 E:117.202508	SE	None	Nice forest but short trees (<20m)
	LTT28	0.678		NW	None	
	LTT29	0.724	N:5.643336 E:117.209614	SE	None	
	LTT30	0.622		NW	None	
28.05.25	LTBC1	1.100	N:5.604220 E:117.096459	SE	1 nest Class IV	Degraded Forest / Climbing bamboos
	LTBC2	0.710		W	None	

Table 2: Date, location, length and number of orangutan nests recorded during drone transect flights during daytime.

We then looked at a possible correlation between kilometric indexes from RW and aerial indexes derived from drone line transect flights that were flown in the same area where ground recces were walked: Table 3.

RW nb	Ground kilometric index	Drone transect nb	Aerial kilometric index
Line 4	3.60	LTT3	0
RW 3	16.7	LTT7	1.52
Line 7	6.00	LTT11	0
Line 8	3.33	LTT14	0
Line 3	1.48	LTT17	0
Average	6.22	Average	0.30
SD	6.07	SD	0.68

Table 3: Ground and aerial kilometric indexes of RW and drone transects carried out in similar areas

A t-test shows no statistical difference between the samples ($t=2.441$; $df=4$, $p>0.05$). However, the ground method shows a mean index of 6.22 nest/km, while the aerial method shows a mean index of 0.30 nest/km. In Tawai FR, the ground method appeared to detect substantially more nests per kilometer than the aerial method. The box plot (Figure 4) clearly shows the dramatic difference between methods. The ground method has much higher values and greater variability, while the aerial method is clustered near zero with only one outlier at 1.52. **However, because of the very small sample size (n=5), results should be interpreted cautiously.**

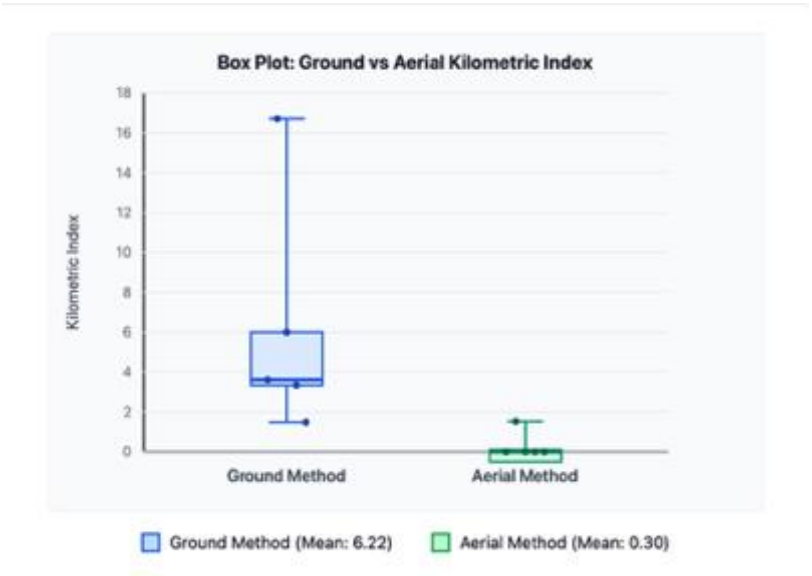


Figure 4: Box plots comparing aerial and ground nest kilometric indexes

The relatively low nest detection rate with drones can be attributed to the challenging terrain conditions encountered during many flights. Indeed, the steep to very steep topography and slopes forced our pilot to operate the drone at altitudes significantly higher than the standard 70-100 meters above the canopy, which reduced the probability of nest detection.

Results from reconnaissance walks and drone transects do not provide direct orangutan abundance estimates. Table 4 presents a summary of results from recent orangutan surveys conducted under the MPOGCF project. As the field team continues to conduct surveys in different areas and adds new data to our dataset, we will be able to refine our methodology for deriving orangutan densities from drone surveys. Based on the preliminary results currently

available from other forest reserves, we can hypothesize that orangutan density in Tawai Forest Reserve is less than 0.5 individuals per km², when we compare the kilometric indexes obtained from the ground and from the drone to other values obtained in other survey areas. Of course this guess estimate is only an approximation of the true orangutan abundance in Tawai FR. However our results confirm that orangutans occur in Tawai but at very low densities.

Location	Nest Kilometric Index (nest/km)		Orangutan Density (ind./km²)
	Ground RW	Drone	
Deramakot	20.0	9.13	2.26
Lot 8 LKWS	-	3.32	0.5
Lot 9 LKWS	-	3.11	0.96
Tabin WR (west)	5.81	5.23	-
Tawai FR	6.22	0.31	-

Table 4: Nest kilometric indexes obtained during ground RWs and drone transects during previous field expeditions and resulting orangutan densities

Because of the steep conditions encountered in Tawai FR and because it was raining most of the evenings, the team could not conduct any thermal drone survey at night.

Figure 5: Drone pictures showing overdegraded areas in Tawai FR (above) and orangutan nests (below)

II. SURVEY RESULTS FOR OTHER WILDLIFE TAXA

- **1. Camera Trapping**

The eight camera traps yielded a sampling effort of 495.48 days in Tawai FR, and a total of 545 wildlife images were retrieved after a two-month period. These photos derived 162 independent detection events of 15 species and four other taxa that we could not identify down to species level (Mousedeers, rodents, treeshrews and an unidentified bird). A total of eight species are listed in the IUCN Red List as Endangered (Long-tailed macaque, Pig-tailed macaque, Bornean clouded leopard and Bornean elephant) and five as Vulnerable (Bornean bearded pig, Great argus, Crested fireback and Sambar deer). Two species are fully protected in Sabah (Annex I WCE 1997): the clouded leopard and the Bornean elephant.

Pig-tailed macaques were the commonest capture and yielded 33.3% (54 out of 162) of the independent detection events, followed by Great argus with 16.05% (26 independent events), and mousedeers (*Tragulus sp.*): 15.4%. Detection events for other species were lower than 10%: Figure 6.

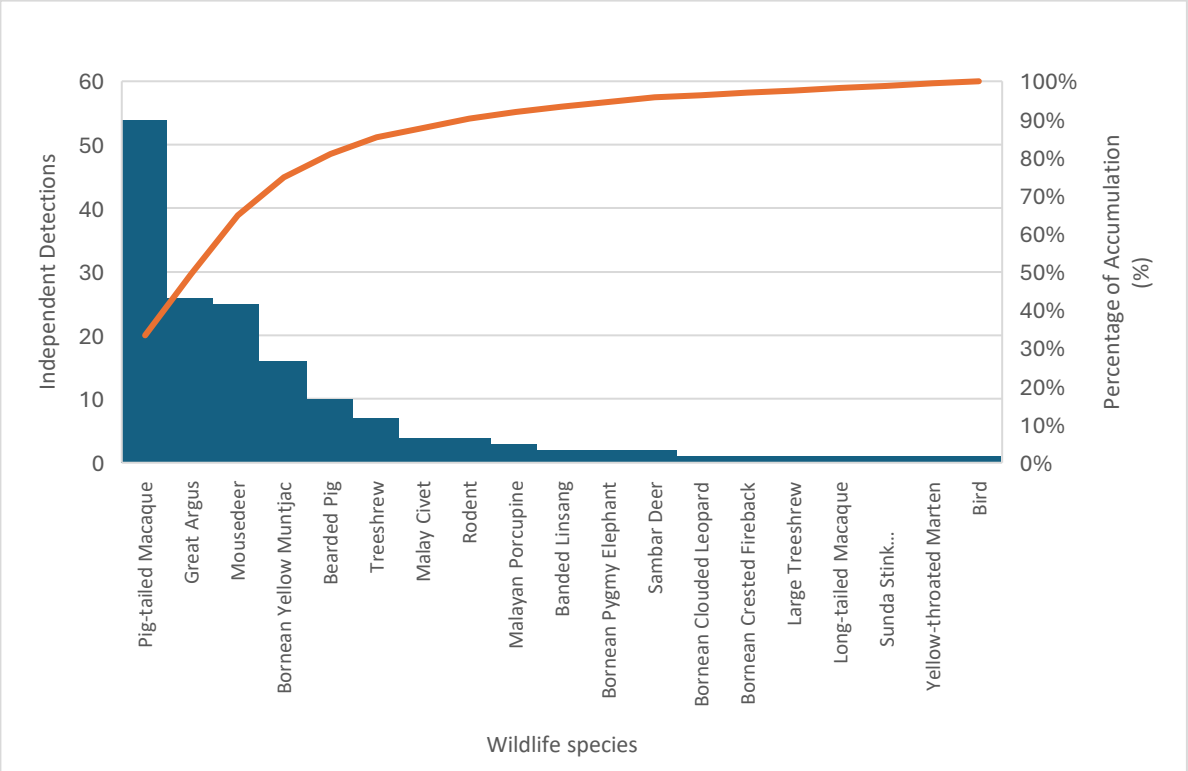


Figure 6: Number of independent detection events from eight camera traps deployed for two months at Tawai FR (April – July 2025)

Interestingly, wild boars were captured in two of our cameras, indicating a slow recovery from the outbreak of African Swine Flu that wiped out most of the population a few years ago[1]. Detection was near an active wallow. This type of HCV must be strictly protected, as it attracts

[1] Lieb, Z.E., Meijaard.e., Brodie, J.F., Shabrani, A., ... Ancrenaz, M.,... Luskin, M.S. 2025. Mapping multiple wild pig species' population dynamics in Southeast Asia during the African Swine Fever outbreak. *Conservation Letters* https://doi.org/10.1111/conl.13105

both game species and hunters. The construction of the PBH will make this wallow easily accessible to hunters, which in turn will create a real threat to sustain many species in the area. The abundance of great argus detection is significant since this bird species is increasingly rare in the forests of Sabah. We can assume that the PBH will be a major threat to this species, as the great argus is being hunted by poachers for its meat and feathers.

The detection of one clouded leopard in our cameras is a significant finding, although we cannot draw any inference about the local population from a single detection. Clouded leopards are wide-ranging predators, and the PBH is posing a real threat to the survival of the individuals who roam in this part of Tawai FR. Indeed, roadkill is a major threat to this species. Banded linsang is also an interesting finding, given the scarcity of this species in most forests across Borneo. We didn't capture any picture of sun bear, but signs of presence were regularly observed by the field teams (Table 1).The carnivore community in Tawai is diverse and contains rare species of conservation concern. **Most of these carnivores, currently living in Tawai close to the area where PBH is built, will be victims of roadkill after the PBH is in use.**

Figure 7: Four carnivore species were detected with camera traps: Clouded leopard (top-left); Banded linsang (bottom left); Yellow-throated marten (top right); Malay civet (bottom right)

Figure 9: A camera trap placed near an active wallow indicated regular use by Bornean elephants and wild boars

Our camera traps yielded a relative abundance of Cervids, which are prime game species for hunters (see pictures). These pictures confirm the observations made during field surveys: see Table 1.

It is to be expected that the construction of the PBH will attract and provide easy access to currently remote areas to hunters and poachers. The result will be a decline of game species populations, as it has been observed in other forest reserves in Sabah wafter road construction.

Our camera trap efforts did not detect any orangutans using the ground for movement.

- **2. Small mammals**

Table 5 below provides the list of small mammals captured throughout the survey: in tital, we captured and released 31 small mammal individuals belonging to four species around Tawai FR, with two identified recaptures.

Local Name	Scientific Name	Transect				
		SM01	SM02	SM03	SM04	SM05
Muller rat	*Sundamys muelleri*	0	2	0	0	1
Plain tresshrew	*Tupaia longipes*	2	2	0	3	0
Rajah maxomys	*Maxomys rajah*	2	1	0	1	0
Tioman rat	*Rattus tiomanicus*	3	5	2	4	1
Total captures		**7**	**10**	**2**	**8**	**2**

Table 4. List of small mammal captures from five established transects around Tawai FR during the expedition period (the recaptured individuals were discarded from this count).

Overall, the species captured during our trapping sessions are commonly associated with the environmental conditions characterising degraded forests and forest edges. The Tioman rat is the

most common rat in disturbed habitats, including degraded forests, plantations, and village edges. This species accounted for up to 51.7% of the total captures (n = 15 out of 29 captures). Rajah maxomys is a common forest rat throughout Borneo, and is especially found in disturbed forests, while the mueller rat is a large rat that is attracted by forest edge ecological conditions. The presence of these three rat species indicates the level of disturbance of the area where trapping took place. Plain treeshrews are a diurnal species also commonly found in disturbed habitats. These species are only slightly influenced by canopy cover. The relatively low number of species captured could be related to the bad weather conditions encountered during field surveys.

- **3. Frog surveys**

The only survey we were able to complete was conducted after the rain along an existing trail that progressively elevates behind the basecamp in Tawai Rainforest Camp. The habitat is a disturbed mixed dipterocarp forest, characterized by sudden occurrences of fallen logs, vines, and the presence of abundant leaf litter on the forest floor. The trail used for the survey is disturbed and regularly used by visitors. The trail follows a river, which, at the time of our survey, was characterized by strong current flow due to recent rains, with occasional rocks and boulders. We recorded five species of frogs along the transects: Table 5.

No	Frog name	Scientific Name	Notes
1	Kuhl's Creek frog	*Limnonectes kuhlii*	Forest
2	Black-spotted foot-flagging frog	*Staurois guttatus*	Forest
3	Slender torrent frog	*Meristogenys jerboa*	Forest
4	Spiny slender toad	*Ansonia spinulifer*	Forest, Plantation
5	Cinnamon tree frog	*Nyctixalus pictus*	Forest

Table 5: List of frog species encountered during the surveys

We failed to detect frogs in five out of ten of the 40 m transect segments, and every species was only detected once in a segment along the trail. Overall, the frog community sampled the night of our survey was not very diverse nor abundant. Three species are commonly found in rocky streams or riverbanks of primary and secondary forests, including the Kuhl's Creek frog (*Limnonectes kuhlii*), Slender torrent frog (*Meristogenys jerboa*), and Black-spotted foot-flagging frog (*Staurois guttatus*). The Spiny slender toad (*Ansonia spinulifer*) inhabits shrubs along the swift streams and rivers. On the other hand, the Cinnamon tree frog (*Nyctixalus pictus*) prefers higher grounds on shrubs or small trees about a metre to three metres tall.

- **4. Bird surveys**

During the entire expedition, we completed 19 Mackinnon lists (ML), totalling 272 observations. The total number of species recorded was 96, belonging to 39 families.

Eight bird species are endemic to Borneo, including: Bornean black magpie (*Patysmurus aterrimus*), White-crowned shama (*Copsychus stricklandii*), Yellow-rumped flowerpecker (*Prionochilus xanthopygius*), Blue-headed pitta (*Hydronis baudii*), Blue-banded pitta (*Erythropitta arquata*) – Near Threatened due to deforestation rates in Borneo (IUCN), Bornean black-capped babbler (*Pellorneum capistratoides*), Bornean bristlehead (*Pityriasis gymnocephala*) – Near Threatened species due to an estimated 2.5% loss of its lowland forest habitat across Borneo (IUCN Red List), Dusky munia (*Lonchura fuscans*), and the Sabah partridge (*Tropicoperdix graydoni*). The documentation of

eight endemic species is significant given that Borneo is home to only 37 endemic bird species: this represents about 20% of Borneo's endemic avifauna at this location.

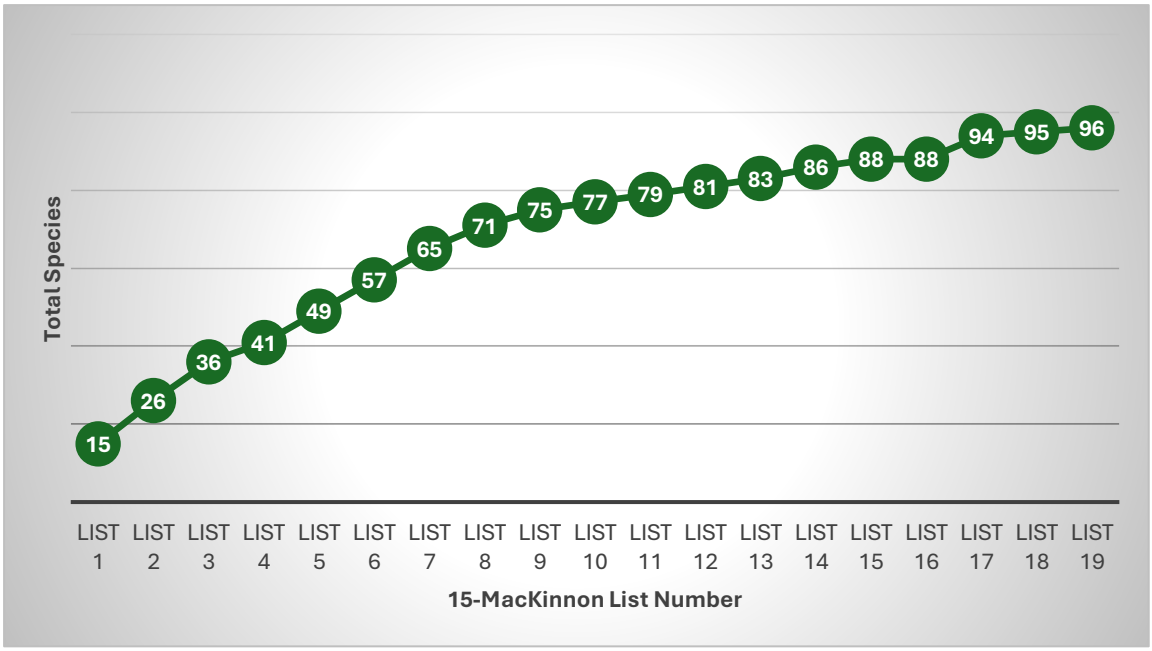


Figure 10: Species accumulation curve of bird species during the Tawai Field Expedition

Figure 10 shows that the number of species increases with increased sampling effort during the expedition:

The species accumulation curve starts to reach a plateau after ML nb 9, but we still note a steady and regular increase in the number of bird species with the completion of successive ML (each of them totalling 15 different species records). The species accumulation curve indicates that additional bird species would be detected with more extensive surveys, especially deeper in the forest interior. Indeed, most of our observations were conducted along the forest edge and within a strip of a few hundred meters within Tawai FR, which influenced the diversity of the bird community recorded during our surveys (Table 6).

No	Species	Scientific Name	Frequency
1	Black Hornbill	*Anthracoceros malayanus*	9
2	Plaintive Cuckoo	*Cacomantis merulinus*	9
3	Cream-vented Bulbul	*Pycnonotus simplex*	8
4	Malaysian Pied Fantail	*Rhipidura javanica*	8
5	Yellow-vented Bulbul	*Pycnonotus goiavier*	8
6	Black-and-yellow Broadbill	*Eurylaimus ochromalus*	6
7	Blue-crowned Hanging Parrot	*Loriculus galgulus*	6
8	Hill Myna	*Gracula religiosa*	6
9	Orange-bellied Flowerpecker	*Dicaeum trigonostigma*	6
10	Ashy Tailorbird	*Orthotomus ruficeps*	5
11	Black-and-red Broadbill	*Cymbirhynchus macrorhynchos*	5
12	Black-eared Barbet	*Psilopogon duvaucelii*	5
13	Black-headed Bulbul	*Microtarsus melanocephalos*	5
14	Bornean Black Magpie	*Platysmurus aterrimus*	5

15	Crimson Sunbird	*Aethopyga siparaja*	5
16	Lesser Green Leafbird	*Chloropsis cyanopogon*	5
17	Scarlet-breasted Flowerpecker	*Prionochilus thoracicus*	5
18	Banded Kingfisher	*Lacedo pulchella*	4
19	Blue-throated Bee-eater	*Merops viridis*	4
20	Brown-throated Sunbird	*Anthreptes malacensis*	4
21	Fluffy-backed Tit-Babbler	*Macronus ptilosus*	4
22	Red-eyed Bulbul	*Pycnonotus brunneus*	4
23	Rhinoceros Hornbill	*Buceros rhinoceros*	4
24	White-crowned Shama	*Copsychus stricklandii*	4
25	Yellow-rumped Flowerpecker	*Prionochilus xanthopygius*	4
26	Black-winged Flycather-shrike	*Hemipus hirundinaceus*	3
27	Crested Serpent Eagle	*Spilornis cheela*	3
28	Eurasian Tree Sparrow	*Passer montanus*	3
29	Gray-bellied Bulbul	*Rubigula cyaniventris*	3
30	Great Argus	*Argusianus argus*	3
31	Greater Coucal	*Centropus sinensis*	3
32	Greater Green Leafbird	*Chloropsis sonnerati*	3
33	Green Iora	*Aegithina viridissima*	3
34	Javan Myna	*Acridotheres javanicus*	3
35	Little Spiderhunter	*Arachnothera longirostra*	3
36	Olive-winged Bulbul	*Pycnonotus plumosus*	3
37	Oriental Dollarbird	*Eurystomus orientalis*	3
38	Pacific Swallow	*Hirundo javanica*	3
39	Pale-faced Bulbul	*Pycnonotus leucops*	3
40	Raffles's Malkoha	*Rhinortha chlorophaea*	3
41	Ruby-cheeked Sunbird	*Chalcoparia singalensis*	3
42	Spectacled Bulbul	*Rubigula erythropthalmos*	3
43	Square-tailed Drongo-Cuckoo	*Surniculus lugubris*	3
44	Blue-headed Pitta	*Hydrornis baudii*	2
45	Blyth's Paradise-Flycatcher	*Terpsiphone affinis*	2
46	Bold-striped Tit-Babbler	*Mixornis bornensis*	2
47	Bornean Black-capped Babbler	*Pellorneum capistratoides*	2
48	Changeable Hawk Eagle	*Nisaetus cirrhatus*	2
49	Charlotte's Bulbul	*Iole charlottae*	2
50	Chestnut-bellied Malkoha	*Phaenicophaeus sumatranus*	2
51	Copper-throated Sunbird	*Leptocoma calcostetha*	2
52	Crested Myna	*Acridotheres cristatellus*	2
53	Gray-hooded Babbler	*Cyanoderma bicolor*	2
54	Great Slaty Woodpecker	*Mulleripicus pulverulentus*	2
55	Grey-cheeked Bulbul	*Alophoixus tephrogenys*	2
56	Hooded Pitta	*Pitta sordida*	2
57	Jambu Fruit Dove	*Ptilinopus jambu*	2
58	Large-tailed Nightjar	*Caprimulgus macrurus*	2
59	Long-billed Spiderhunter	*Arachnothera robusta*	2
60	Ornate Sunbird	*Cinnyris ornatus*	2
61	Rufous-backed Dwarf-Kingfisher	*Ceyx rufidorsa*	2
62	Rufous-tailed Tailorbird	*Orthotomus sericeus*	2
63	Rufous-winged Philentoma	*Philentoma pyrhoptera*	2
64	Scarlet Minivet	*Pericrocotus speciosus*	2
65	Scarlet-rumped Trogon	*Harpactes duvaucelii*	2
66	Silver-rumped Spinetail	*Rhaphidura leucopygialis*	2
67	Ventriloquial Oriole	*Oriolus consobrinus*	2
68	Whiskered Treeswift	*Hemiprocne comata*	2
69	White-bellied Erpornis	*Erpornis zantholeuca*	2
70	White-bellied Woodpecker	*Dryocopus javensis*	2
71	Asian Emerald Dove	*Chalcophaps indica*	1
72	Black Eagle	*Ictinaetus malaiensis*	1
73	Black-bellied Malkoha	*Phaenicophaeus diardi*	1

74	Black-naped Monarch	*Hypothymis azurea*	1
75	Blue-banded Pitta	*Erythropitta arquata*	1
76	Bristlehead	*Pityriasis gymnocephala*	1
77	Brown Fulvetta	*Alcippe brunneicauda*	1
78	Brown-backed Needletail	*Hirundapus giganteus*	1
79	Chestnut Munia	*Lonchura atricapilla*	1
80	Common Iora	*Aegithina tiphia*	1
81	Dusky Munia	*Lonchura fuscans*	1
82	Gray-chinned Minivet	*Pericrocotus solaris*	1
83	Gray-headed Babbler	*Stachyris poliocephala*	1
84	Hook-billed Bulbul	*Setornis criniger*	1
85	Indian Cuckoo	*Cuculus micropterus*	1
86	Oriental Bay-Owl	*Phodilus badius*	1
87	Purple-naped Spiderhunter	*Kurochkinegramma hypogrammicum*	1
88	Rufous-crowned Babbler	*Malacopteron magnum*	1
89	Sabah Partridge	*Tropicoperdix graydoni*	1
90	Scaly-crowned Babbler	*Malacopteron cinereum*	1
91	Short-tailed Babbler	*Pellorneum malaccense*	1
92	Sooty-capped Babbler	*Malacopteron affine*	1
93	Streaked Bulbul	*Ixos malaccensis*	1
94	Sunda Scimitar-Babbler	*Pomatorhinus bornensis*	1
95	Temminck's Sunbird	*Aethopyga temminckii*	1
96	Van Hasselt's Sunbird	*Leptocoma brasiliana*	1

Table 7: List of the 96 bird species identified during our surveys in Tawai FR, and frequency of appearance in the 19 completed MLs

Bird species with the highest detection frequencies are either noisy species that are easily heard from a distance (black hornbill, plaintive cuckoo, hanging parrot, hill myna, etc.) or small species common in disturbed and edge ecological conditions (tailorbird, black-eared barbet, fantail, etc.). The relative abundance of bulbuls and sunbirds/flowerpeckers (Pycnonotidae and Nectariniidae) families, with 12 and 10 species, respectively, can be partially explained by the abundance of ornamental flowers found around the base camp and near communication towers. We recorded several forest-specialist species, including, for example, argus pheasant, slaty woodpecker, pitta, bristlehead, partridge, etc. Some of these larger species are particularly sensitive to habitat fragmentation and degradation, serving as indicators of ecosystem health. Monitoring their presence and relative abundance could inform the potential impact of this new linear infrastructure on birds and the ecosystem. Babblers (Pellorneidae and Timaliidae families) and cuckoos (Cuculidae) were also present, with 5 and six species respectively. Most of these birds above forage for insects, flowers and seeds in the undergrowth or understory area at the forest edge.

Further surveys deep into the forest interior would presumably reveal additional conservation-significant bird species and provide a more comprehensive and accurate assessment of the reserve's importance for birds. The forests of Tawai appear to be an important refuge for Borneo's unique avifauna, currently jeopardized by the development of the PBH.

- **5. Additional results from ad hoc surveys**

A list of species recorded during field activities and not included in specific surveys is presented below:

Primates:	Long-tailed macaque	*Macaca fascicularis*
	Western tarsier	*Cephalopachus bancanus*

	Sunda slow loris	*Nycticebus coucang*
	Red leaf monkey	*Presbytis rubicunda*
	Bornean gibbon	*Hylobates funereus*
Carnivores:	Sun bear	*Helarctos malayanus*
Rodents:	Plantain squirrel	*Callosciurus notatus*
	Moonrat	*Echinosorex gymnurus*
Reptiles:	Water monitor lizard	*Varanus salvator*
	Sumatran cobra	*Naja sumatrana*
	Comb-crested Agamid	*Gonocephalus loigaster*

Discussion

Most of our survey area during the Tawai Field Expedition was concentrated along the existing road, which is planned for upgrading as part of the Borneo Highway Initiative. This area is expected to undergo heavy disturbances and changes, making it crucial to document the status of orangutan and other wildlife populations as baseline data.

The terrain throughout most of the existing road corridor is characterized by steep to very steep topography. Many places already showed signs of human-related degradation (timber extraction, agriculture, trails). Some of the flatter areas were planted with oil palms. Degraded sites were characterized by small-diameter pioneer trees, open canopy structure, and extensive invasion by woody climbers and climbing bamboos. In contrast, better-preserved forests were found at greater distances from the road, particularly on steep slopes, indicating reduced human pressure on these less accessible sites. The forest composition in these areas was dominated by dipterocarps and other trees of uniform size and height, creating a homogeneous canopy structure, characteristic of kerangas and ultrabasic forests.

The survey confirms the widespread orangutan presence throughout Tawai Forest Reserve, albeit at low population densities. Orangutan signs were predominantly found on the eastern side of Tawai Forest Reserve, consistent with findings from the 2001 surveys. The species is also present in the flatter, lower-elevation areas bordering the current road on both sides of the proposed highway corridor. The distribution of orangutan nests identified during our surveys showed marked spatial clustering, with the majority concentrated along the RW 3 (20 nests) and Line 7 (6 nests), both positioned on opposite sides of the proposed highway alignment. Nest occurrence was notably sparse along other survey transects. We failed to detect orangutan pictures in our camera traps, which prevented us from identifying the type of sex/age classes present in the survey area.

Signs of ungulates (elephants, wild boars, sambar, and barking deer) were widespread across the study area but relatively uncommon. This relative scarcity can be attributed to three main factors: (1) the difficulty of detecting animal signs in Tawai ecosystems due to steep slopes, dry forest floors, and limited visibility caused by climbing bamboos and ground vegetation; (2) hunting and other illegal activities: indeed regular signs of illegal human penetration and poaching were systematically detected during our fieldwork ; and (3) the characteristically low forest productivity of Tawai ecosystems.

Two fully protected carnivore species (clouded leopard and sunbear) were present in the survey area. The risk of collision with vehicles and roadkill is a real and major threat to sustaining these animals and populations of iconic species in Tawai.

The detection of several Near-Threatened and endemic bird species, particularly the bristlehead and blue-banded pitta, suggests that Tawai FR is a critical habitat that requires enhanced protection measures. The bird diversity reveals a healthy community that could be used to develop tourism products. The forests of Tawai appear to be an important refuge for Borneo's unique avifauna, currently jeopardized by the development of the PBH.

This highway development will pose a significant threat to maintaining a viable orangutan population in Tawai due to anticipated disturbances from highway construction, traffic, and other disturbances. Because of the highway, we can anticipate an increase in wildlife damage to people's crops, especially on the northern side of the highway, which will lead to increased conflicts and possible retaliatory killing. This situation is becoming a real threat to the survival of the remaining orangutan population in the area. Additional risks related to the highway will include increased accessibility for people and associated illegal activities, increased risks of fire, and increased disturbances to local ecosystems and wildlife (including orangutans).

Additional threats created by the PBH project in Tawai are real:

- **Habitat destruction**: This will impact smaller species that occupy smaller home ranges (birds and small mammals in particular)
- **Creation of forest edges**: Negative impact on forest-dependent animal species that are rare and declining in Sabah, being replaced by resilient and generalist species that are common.
- **Habitat fragmentation**: This will impact many species, whose populations will be split into two separate subpopulations on both sides of the highway (e.g., small mammals, reptiles).
- **Road kill**: the highway will result in many road kills (despite any mitigation measures that must be implemented), and this will threaten the survival of Endangered and Fully Protected species like clouded leopards or orangutans. Collisions with elephants or other large species could also result in human casualties.
- **Increased damages and conflicts**: This road will indirectly result in an increase in damages by elephants, monkeys, or orangutans on local people's crops, as is the case everywhere in Sabah in similar conditions. Identifying who will be responsible for potential compensation is urgent to mitigate these conflicts.
- **Poaching and illegal activities**: This highway will provide a unique opportunity for poachers and other illicit users to access what was previously remote and difficult to reach. Our surveys revealed the widespread presence of poaching signs. Hunting pressure will increase when the PBH is complete, jeopardizing even further the ecological integrity of Tawai, the local livelihood, and the potential development of tourism products.

Concluding remarks

Despite challenging field conditions, including heavy and frequent rainfalls and steep terrain that constrained survey operations and limited data collection effectiveness, our expedition documented the presence of critical wildlife populations and habitat use patterns within the study area.

Our surveys identified a central corridor of relevant conservation value for orangutans, characterized by the highest recorded orangutan abundance and activity for the area. This habitat represents a core area for the local orangutan population, supporting a complex network of features for movement and foraging activities. The proposed highway alignment will bisect this critical habitat, creating a real barrier that will fragment the existing orangutan population into two isolated subpopulations.

The ecological consequences of population fragmentation extend beyond immediate habitat loss. Isolated subpopulations experience reduced genetic diversity, limited access to resources, and decreased resilience to environmental stressors, all of which compromise their long-term viability. While orangutans possess terrestrial locomotion capabilities that could theoretically enable highway crossing, potential collisions with vehicles represents a severe and unacceptable risk of mortality. Orangutan-vehicle collisions would not only threaten individual survival but also pose safety hazards to human road users and generate significant negative publicity that could damage national and international conservation efforts.

The broader ecological impacts of the proposed highway extend across all wildlife taxa within this unique ecosystem. Forest fragmentation and direct habitat destruction will trigger cascading effects, including increased mortality of multiple species, not just orangutans, loss of forest-dependent endemic and protected species, and degradation of ecosystem connectivity. The development will also facilitate increased human access to previously remote areas, potentially enabling expanded poaching and other illegal activities in once-remote and inaccessible areas. This road will impact not only the surrounding areas of the linear infrastructure but the integrity of the entire Tawai FR. Last, but not least, this new fragmentation process will also significantly elevate the risks of human-wildlife conflict involving elephants and orangutans.

Although proposed mitigation measures aim to reduce the highway's environmental impacts, these interventions cannot fully offset the fundamental ecological damage inherent in bisecting the Tawai forest ecosystems. The PBH will inevitably compromise the biological integrity of this irreplaceable habitat, resulting in substantial wildlife population losses that cannot be adequately compensated for through mitigation alone.

Figure 8: Aerial view of the current road to be upgraded under the an Borneo Highway Project: this road will dissect the forest and animal populations (orangutans, elephants and other) and jeopardize the long-term viability of these unique ecosystems.

Annex I: Brief Specifics of the Field Expedition carried out in Tawai Wildlife Reserve

Location: Tawai Forest Reserve
Date: 20.05.2025 to 29.05.2025

Staff/freelance personnel involved:

- Hartiman Bin Abdul Rahman, OURS, Hutan
- Suhaimi Bin Bahrani, OURS, Hutan
- Azli Bin Etin, OURS, Hutan
- Herman Bin Suali, OURS, Hutan
- Mohd Daisah Bin Kapar, OURS, Hutan
- Waslee Bin Maharan, OURS, Hutan
- Bahrani Bin Elahan, OURS, Hutan
- Muhd Azizi Sulaiman Bin Bahrani, OURS, Hutan
- Muhammad Asim Addin Bin Zainal Abidin, OURS, Hutan
- Khairul Mizan Bin Johry, OURS, Hutan
- Shahri bin Jamrin, OURS, Hutan
- Hardiman bin Abdul Rahman, OURS, Hutan
- Mohd Faisal bin Asmara, OURS, Hutan
- Noraini binti Waslee, OURS, Hutan
- Hamisah binti Elahan, OURS, Hutan
- Vhielcey Villey, OURS, Hutan

Adjacent area type: Oil palm plantations

Types of activities conducted:

- Aerial drone line transects
- Ground Reconnaissance Walks (Recces or RW)
- Botanical plots assessment
- Camera trapping
- Bioacoustics (deployment of audiomoths)

Annex II: Description of Botanical Plots: Number and size of Trees

Table A: Number, size, tree species and botanical scores within each botanical plot in Tawai FR.

Plot	Tree species	DBH (cm)					Score (from 0 to 3)			Misc.
		20-30	30-40	40-50	50-60	>60	Canopy	Small trees (<20 cm)	Climbers	
549-550	Kerangas									Climbing bamboos +
	Rangas									
	Ficus									
	Unknown									
TOTAL							**2**	**3**	**2**	
146-148	Unknown	2								Climbing bamboos +
	Nyatoh	3								
	Bangkulat	2	1							
	Resak	1								
	Ficus	1								
TOTAL		**9**	**1**				**2**	**2**	**1**	
149-151	Kapur	2	2			1				Orangutan food +
	Nyatoh		2							
	Sendaman	2								
	Bangkulat		1							
	Seraya	2	1	2						
	Selangan batu	1								
	Buak-buak	4	1							
	Sental				1					
	Keruing	1				1				
	Unknown			1						
	Selangan	1								
	Obah		1							
	Urat mata	1								
	Kunau-kunau	1								
TOTAL		**15**	**8**	**3**	**1**	**2**	**1**	**2**	**1**	
558-559	Togop			2						OU food ++
	Urat mata			2						
	Unknown			1						
	Unknown				1					
TOTAL		**0**	**0**	**5**	**1**	**0**	**1**	**3**	**3**	
565-566	Seraya		1							Climbing bamboos +++
	Unknown	10								
	Unknown	3								No OU food
	Unknown	5								

TOTAL		**18**	**0**	**0**	**0**	**0**	**3**	**3**	**3**	
168-169	Kapur		2							OU food +
	Seraya	3	4							
	Obah J	1								
	Merbau	1								
TOTAL		**5**	**4**				**2**	**3**	**1**	
572-575	Seraya		2							
	Kapur		2							
	Unknown	4								
	Unknown		3							
	Unknown	4								
	Unknown		4							
	Unknown			2						
TOTAL		**8**	**11**	**2**			**2**	**3**	**1.3**	
590-592	Urat mata			1						Climbing bamboos ++
	Unknown	1		1						
	Unknown	1		1						
	Unknown	1		1						
	Unknown	1								
	Unknown	1								
	Unknown	1								
TOTAL		**6**	**0**	**4**			**3**	**3**	**2**	
184-186	Keruing		6	1						No OU food
	Seraya	8	4		1					
	Kapur		1							
	Kayu malam		2							
TOTAL		**8**	**13**	**1**	**1**		**2.6**	**3**	**1**	
175-176	Seraya sp	4	5							OU food ++
	Urat mata	1								
	Kapur	1	2	1						
	Keruing		2							
	Mempening Babi		2	1						
	Dara-Dara	1								
	Minyak beruk	1								
	Nyatoh	1								
TOTAL		**9**	**11**	**2**	**0**		**2**	**1**	**1**	
603-606	Perepat burung	1								
	Ficus	1								
	Kandis	1								
	Kapur		2							
	Seraya		3							

	Urat mata		1							
	Unknown	2	**1**							
TOTAL		**5**	**7**				**1**	**3**	**2**	
195-197	Seraya		5	6	2					Climbing bamboos ++
	Perapat Burung	2								
	Obah	2								
	Kayu malam	1								
	Kapur			3						
	Unknown		1							
	Urat mata				1					
TOTAL		**5**	**6**	**9**	**3**		**2**	**3**	**1**	
Average scores							**1.97**	**2.67**	**1.60**	

Table B: DBH and total of tree species across all botanical plots:

- Lines highlighted in yellow are tree species belonging to the Dipterocarp family)
- Lines highlighted in green are tree species that are part of the regular orangutan diet as documented in Lower Kinabatangan

Vernacular name	DBH						
	20-30	30-40	40-50	50-60	>60	Total	Percentage
Bangkulat	2	2				4	2.2%
Buak-buak	4	1				5	2.7%
Dara-Dara	1					1	0.5%
Ficus	2					2	1.1%
Kandis	1					1	0.5%
Kapur	3	11	4		1	19	10.3%
Kayu malam	1	2				3	1.6%
Kerangas						0	0.0%
Keruing	1	8	1		1	11	6.0%
Kunau-kunau	1					1	0.5%
Mempening Babi		2	1			3	1.6%
Merbau	1					1	0.5%
Minyak beruk	1					1	0.5%
Nyatoh	4	2				6	3.3%
Obah	3	1				4	2.2%
Perepat burung	3					3	1.6%
Rangas						0	0.0%
Resak	1					1	0.5%
Selangan	1					1	0.5%
Selangan batu	1					1	0.5%
Sendaman	2					2	1.1%
Sental				1		1	0.5%
Seraya	17	25	8	3		53	28.8%
Togop			2			2	1.1%
Unknown	36	9	5	1		51	27.7%
Urat mata	2	1	3	1		7	3.8%
TOTAL	88	64	24	6	2	184	2.2%
Percentage	47.8%	34.8%	13.0%	3.3%	0.1%		