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Morphology, abundance and population status of flying foxes in the mangrove ecosystem of Barangay Bukid, Jose Abad Santos, Davao Occidental, Philippines

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ABSTRACT

Flying foxes (*Pteropus* spp.) are keystone pollinators and seed dispersers whose populations are increasingly threatened by habitat degradation and human disturbance. This study assessed the morphology, abundance, population status, and habitat associations of flying foxes in the mangrove ecosystem of Barangay Bukid, Jose Abad Santos, Davao Occidental, Philippines, to provide baseline information for conservation planning. Field investigations conducted from January to June 2025 employed roost-site surveys, direct observations, photographic documentation, acoustic monitoring, and vegetation assessment. A total of 11,920 flying foxes were recorded, comprising 10,955 Island flying foxes (*Pteropus hypomelanus*) and 965 Large flying foxes (*Pteropus vampyrus*), roosting on 626 mangrove trees within a 962-m² area. Nine mangrove species were identified, with *Rhizophora mucronata*, *Sonneratia alba*, and *Rhizophora apiculata* exhibiting the highest Importance Value Indices, indicating their dominant role in supporting communal roosts. The mangrove forest exhibited moderate species diversity (H′= 1.962) and high evenness (J′= 0.893), indicating a structurally stable habitat conducive to sustaining mixed-species colonies. Field observations further indicated active reproduction, preference for mature *Rhizophora* stands, and sensitivity to anthropogenic disturbance, emphasizing the ecological dependence of flying foxes on intact mangrove ecosystems. The presence of a large mixed colony, including the nationally threatened *P. vampyrus*, highlights the exceptional conservation value of Barangay Bukid. These findings provide strong scientific evidence for declaring the area a Critical Habitat and underscore the need for long-term protection and sustainable management of its mangrove ecosystem.

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INTRODUCTION

Flying foxes (genus *Pteropus*) are among the most ecologically significant vertebrates inhabiting tropical and subtropical ecosystems. Widely distributed across the Indo-Pacific region, these highly mobile fruit bats act as essential pollinators and seed dispersers, supporting the reproductive cycles of over 300 plant species, many of which are keystone taxa in forest and coastal habitats. Their ecological role is particularly crucial on islands, where plant communities have evolved specialized traits for chiropterophily, including nocturnal flowering, musky scents, and high nectar production. Globally, flying foxes are severely threatened by deforestation, hunting, and persecution due to perceived crop damage (Fleming and Racey, 2010).

These threats are exacerbated by their low reproductive rates, typically producing only one offspring per year, and their dependence on large, contiguous foraging areas (Epstein *et al.*, 2009). As a result, several Pteropus species are classified as Vulnerable or Endangered by the IUCN (2023), underscoring the urgent need for focused conservation efforts.

In the Philippines, a recognized global biodiversity hotspot, flying fox populations have declined markedly due to habitat fragmentation, mangrove clearance, and targeted hunting. The lowland mangroves of Davao Occidental present a potential refuge for these species; however, comprehensive faunal data for the area remain lacking (DENR-CENRO Malita, 2019).

Although informal reports from the DENR indicate a substantial local population, there is a critical absence of baseline data necessary for effective conservation management (Ang, 2022). Despite their ecological importance, flying foxes are often underrepresented in conservation strategies. Although protected under the Wildlife Resources Conservation and Protection Act (RA 9147), enforcement remains inconsistent at the local level. Moreover, empirical research on their population status and roosting ecology is limited, with most information derived from opportunistic sightings rather than systematic surveys. These challenges highlight the importance of designating Critical Habitats under DENR Administrative Order No. 2007-02 to ensure the survival of these species (DENR, 2007).

This study addresses these knowledge gaps by comprehensively assessing the composition, abundance, and ecological roles of flying fox species in Barangay Bukid, Jose Abad Santos, Davao Occidental. By integrating field surveys, local ecological knowledge, and spatial analysis, the research aims to: (1) identify the resident bat species; (2) assess their population status and relative abundance; (3) characterize the structure of the local mangrove community; and (4) evaluate the ecological significance of flying foxes to provide robust evidence for habitat protection.

Ultimately, this work supports the achievement of UN Sustainable Development Goals 14 and 15 by supplying the data necessary to restore terrestrial ecosystems and promote sustainable livelihoods in coastal communities.

MATERIALS AND METHODS

Research locale

This study integrated field surveys, direct observations, and community engagement from January to June 2025 to assess flying fox populations and their ecological context in Barangay Bukid, Jose Abad Santos, Davao Occidental (Fig. 1). Methods followed the Manual on Biodiversity Assessment and Monitoring System for Terrestrial Ecosystems (BMB-DENR, 2017) and DENR-BMB protocols. Fig. 2 shows the actual survey transects within the flying fox sanctuary.

Field sampling methods

All fieldwork complied with Wildlife Gratuitous Permit No. R11-2026-003 (DENR Regional Office XI). Authorization was obtained from the Municipality of Jose Abad Santos and MENRO. Surveys focused on mangroves and other forests that support megabat populations. Sampling sites were delineated with MENRO and local community members based on habitat suitability, safety, and accessibility. Spatial data were mapped and analyzed using QGIS (2024).

Fig. 1. QGIS mapping of the study area

Fig. 2. QGIS Mapping on the species distribution of Barangay Bukid's flying fox sanctuary

Morphological identification of flying foxes

Roost-site surveys, direct observations, photographic documentation, and acoustic monitoring were conducted at roosting sites during dawn and dusk to maximize detection while minimizing disturbance (Kunz and Parsons, 2009; O'Malley *et al.*, 2006; Dimaculangan *et al.*, 2019). Binoculars and spotting scopes aided in documenting morphological characteristics, roosting behavior, and colony composition. Photographs enabled species verification (Ingle and Heaney, 1992). A few individuals were examined directly with community assistance, and interviews provided local knowledge on flying fox occurrence.

Acoustic data collected with digital recorders complemented visual observations (Sedlock *et al.*, 2014; Dimaculangan *et al.*, 2019). Species were identified using Ingle and Heaney (1992) and validated by an expert Chiropterologist Dr. Krizler C. Tanalgo.

Assessment of abundance and population status

Abundance and distribution were assessed using complete counts along line transects perpendicular to the shoreline, with sampling stations and 10 × 10 m quadrats established according to standard protocols (Kunz and Parsons, 2009; English *et al.*, 1997; Kent, 2012).

Assessment of their ecological characteristics and behavior

Preferred roosting trees were identified, and their physical characteristics, height, diameter at breast height (DBH), density, and canopy cover, were measured, as these influence roost-site selection (Kunz and Parsons, 2009; Stier and Mildenstein, 2005). Roost site elevation and proximity to human settlements were recorded to assess habitat suitability and disturbance. Foraging and reproductive behaviors were documented through direct observation and standard field methods (Altmann, 1974; Kunz and Parsons, 2009). Mangrove habitat characterization included systematic species identification and assessment of floristic composition and structure using standard survey methods and expert verification (Cintrón and Schaeffer-Novelli, 1984; English *et al.*, 1997; Primavera *et al.*, 2004).

Species classification followed Primavera *et al.* (2016). Botanical nomenclature was verified using World Flora Online (WFO, 2026) and the IUCN (2023) Red List (2023–1). Community structure metrics, including basal area, stems per hectare, relative density, frequency, dominance, importance value (IV), Shannon diversity, and evenness, were calculated (English *et al.*, 1997; Odum and Barrett, 2005), and identifications were validated by a taxonomist. Botanical nomenclature was verified using the World Flora Online (WFO, 2026) database and the IUCN Red List (2023–1).

Mangrove community structure was analyzed by calculating basal area, stems per hectare, relative density, frequency, dominance, and importance value (IV). The Shannon Index of Biodiversity and species evenness were determined using formulas from English *et al.* (1997) and Odum and Barrett (2005). All identifications were validated by taxonomist Dr. Angelo B. Agduma.

Population estimation

Population size was estimated using direct roost counts during dusk emergence, with binoculars and high-resolution photographic counts. Photographs were georeferenced and analyzed in QGIS. Repeated counts across multiple days were averaged to obtain final estimates (Kunz and Parsons, 2009; O'Shea *et al.*, 2016; Dimaculangan *et al.*, 2019; Westcott *et al.*, 2015).

Habitat assessment and roost characterization

The habitat assessment involved comprehensive surveys of vegetation structure, dominant plant species, and the availability of suitable roosting trees within the mangrove ecosystem following established ecological habitat assessment procedures (Brower, Zar and von Ende, 1998; Kent, 2012). Vegetation characteristics were documented to describe the habitat's composition and structural attributes that may influence the occurrence and distribution of flying fox populations. Key roost characteristics, including tree species preference, roost height, canopy cover, and proximity to water sources, were systematically recorded to evaluate habitat suitability and roost selection by flying foxes. These habitat attributes are widely recognized as important determinants of bat roost selection and colony persistence (Kunz and Parsons, 2009; Fleming and Racey, 2010).

To characterize the microclimatic conditions at each roosting site, environmental parameters, including air temperature, relative humidity, and light intensity, were measured with portable environmental meters, following standard ecological field survey techniques (Sutherland, 2006). These environmental variables were recorded to determine their potential influence on roost-site selection and habitat quality. Spatial coordinates of all identified roosting sites were collected using a mobile-integrated Geographic Information System (GIS). The spatial data were subsequently used to map the distribution of flying fox roosts and examine their spatial relationships with important habitat features, including vegetation composition, canopy structure, and nearby water sources. GIS-based habitat mapping and spatial analysis are widely used to evaluate wildlife habitat distribution and landscape relationships (Morrison, Marcot and Mannan, 2012; ESRI, 2023).

Threats and conservation status assessment

The assessment of threats to flying fox populations employed a combination of qualitative social science methods and direct field observations. Semi-structured interviews and informal discussions were conducted with local community members, hunters, and farmers to identify major anthropogenic threats affecting flying fox populations, including hunting, habitat destruction, agricultural expansion, and pesticide use.

The information gathered from interviews was supplemented by direct observations of human activities within and adjacent to known roosting and foraging sites to verify reported threats and assess their potential impacts on flying fox populations. Direct field observations are a standard component of ecological census and wildlife monitoring, providing complementary evidence for evaluating habitat disturbance and other anthropogenic pressures (Sutherland, 2006; Kunz and Parsons, 2009).

To determine the conservation status of each flying fox species recorded during the study, classifications were verified using the International Union for Conservation of Nature (IUCN, 2023) Red List of Threatened Species (Pacheco-Fabig and Coll, 2023) and the Updated National List of Threatened Philippine Fauna issued by the Department of Environment and Natural Resources (DENR Administrative Order No. 2019-09) (DENR, 2019).

Furthermore, informal discussions with local stakeholders were undertaken to assess community perceptions, attitudes, and awareness regarding flying fox conservation. These discussions provided valuable insights into the social dimensions influencing conservation efforts, including local beliefs, resource dependence, and community willingness to participate in conservation initiatives (Newing *et al.*, 2011; Cunningham, 2001).

Data analysis

Vegetation data were analyzed to characterize the structure and composition of the mangrove community. Basal area (BA), standard basal area (SBA), tree density, seedling density, relative dominance (RDo), relative density (RD), relative frequency (RF), and Importance Value Index (IVI) were calculated using standard phytosociological methods described by Mueller-Dombois and Ellenberg (1974), Cintrón and Schaeffer-Novelli (1984), and Krebs (1999). Species diversity was determined using the Shannon–Wiener Diversity Index (H′) following Shannon and Weaver (1949) and Magurran (2004). Descriptive statistics were used to summarize vegetation attributes, and all analyses were performed using Microsoft Excel and PAST version 4.0 (Hammer *et al.*, 2001).

RESULTS AND DISCUSSION

Morphological identification of the flying fox species present in the area

A total of 11,920 flying foxes were recorded in the study area, with the population predominantly consisting of Island flying foxes (*Pteropus hypomelanus*, 10,955 individuals) and a smaller proportion of Large flying foxes (*Pteropus vampyrus*, 965 individuals). The Endangered status of *P. vampyrus* (DENR Administrative Order 2019-09) highlights the urgent need to designate Critical Habitats, exemplified by the proposed protected area in Nopol Hills, Barangay Mabuhay, General Santos City, which supports an estimated 7,000 flying foxes. Recent research by Ramos and Nemenzo Calica (2025) in Luban, Mati, Davao Oriental, has clarified that a previously misidentified colony consists of a mixed population of *P. hypomelanus* and *P. vampyrus*, totaling at least 11,920 individuals (Table 1).

A clear spatial pattern emerged in this study: transects without flying foxes were consistently located in areas where human households encroached upon the mangrove habitat. This finding suggests that the colony is highly sensitive to anthropogenic disturbances such as noise, artificial light, and continuous human activity. As shown in Table 1, *P. hypomelanus* overwhelmingly dominates the population, while *P. vampyrus* occurs at much lower densities. The distribution of individuals is highly dispersed, with a notable concentration between stations 5 and 13, identifying this zone as the primary roosting area.

Table 2 lists the mangrove species identified within the study area, which include *Rhizophora mucronata* (Bakauan-babae), *Rhizophora apiculata* (Bakauan-lalaki), *Bruguiera gymnorrhiza* (Pototan), and *Ceriops* sp. (Tungog), all belonging to the Rhizophoraceae family. Other recorded species include *Sonneratia alba* (Pagatpat), Pemphis acidula (Bantigue), *Aegiceras floridum* (Tinduk-tindukan), *Xylocarpus rumphii* (Tabigi), and *Scaevola taccada* (Naupaka). According to Agduma *et al.* (2023), *Aegiceras floridum* is categorized as Near Threatened (NT) by the IUCN (2023), while the remaining species are classified as Least Concern (LC) (Fig. 3).

Table 1. Distribution and abundance of flying foxes recorded across sampling transects in Barangay Bukid, Jose Abad Santos, Davao Occidental

Transect	Stations	*P. hypomelanus*	*P. vampyrus*	Total	Roost trees	Habitat/Ecological observations
T1	1–10	735	1	736	66	Interior mangrove
T2	11–21	2,079	133	2,212	45	High-density roost
T3	22	0	0	0	25	No bats observed
T4	23–31	585	97	682	126	Seafront habitat
T5	32–38	1,918	248	2,166	21	Dense roosting colony
T6	39–41	1,151	147	1,298	26	Interior mangrove
T7	42–48	433	85	518	17	Small colony
T8	49–58	1,570	215	1,785	20	Nursing females with pups
T9	59	0	0	0	93	Adjacent to 10 houses
T10	60–63	31	28	59	51	Sparse population
T11	64–69	384	0	384	87	Moderate colony
T12	70–76	1,636	6	1,642	23	A nursing female observed
T13	77	549	5	554	26	Mating area: two houses
Total	77	10,955	965	11,920	626	Mixed-species colony

Table 2. Mangrove species composition recorded in Barangay Bukid Flying Fox Sanctuary, Jose Abad Santos, Davao Occidental

Scientific name	Common name	Family	Botanical authority	IUCN status	Philippine status
Rhizophora mucronata	Bakauan-babae	Rhizophoraceae	Lam.	LC	OWS
Rhizophora apiculata	Bakauan-lalaki	Rhizophoraceae	Blume	LC	OWS
Sonneratia alba	Pagatpat	Lythraceae	Sm.	LC	OWS
Bruguiera gymnorrhiza	Pototan	Rhizophoraceae	(L.) Lam.	LC	OWS
Ceriops sp.	Tungog	Rhizophoraceae	—	NE	OWS
Pemphis acidula	Bantigue	Lythraceae	J.R.Forst. & G.Forst.	LC	EN
Aegiceras floridum	Tinduk-tindukan	Primulaceae	Roem. & Schult.	NT	OWS
Xylocarpus rumphii	Tabigi	Meliaceae	(Kostel.) Mabb.	LC	OWS
Scaevola taccada	Naupaka	Goodeniaceae	(Gaertn.) Roxb.	LC	OWS

LC = Least Concern; NT = Near Threatened; NE = Not Evaluated; EN = Endangered; OWS = Other Wildlife Species

According to the Philippine National List of Threatened Flora (DENR Administrative Order No. 2017-11), *Pemphis acidula* is classified as Endangered (EN), while the other species in this study are categorized as Other Wildlife Species (OWS). The roosting preferences of *Pteropus hypomelanus* and *Pteropus vampyrus* are closely associated with these mangrove ecosystems. Mangrove forests dominated by Rhizophora species are critical roosting sites for large flying fox colonies in the Philippines. Additionally, bat-mediated pollination of *Sonneratia alba* exemplifies the ecological interdependence between bats and mangrove flora. Our findings show that 11,920 flying foxes utilize 626 individual mangrove trees as roosts, highlighting the exceptional density and conservation significance of this coastal ecosystem.

A total of 626 mangrove trees, representing nine species, were documented in the study area. Flying foxes preferentially roosted in zones dominated by locally threatened species, notably *Aegiceras floridum* (Near Threatened, NT) and *Pemphis acidula* (Endangered, EN), as recognized by the Philippine National List of Threatened Flora. Consistent with Pototan et al. (2021), Rhizophoraceae was the most species-rich family observed.

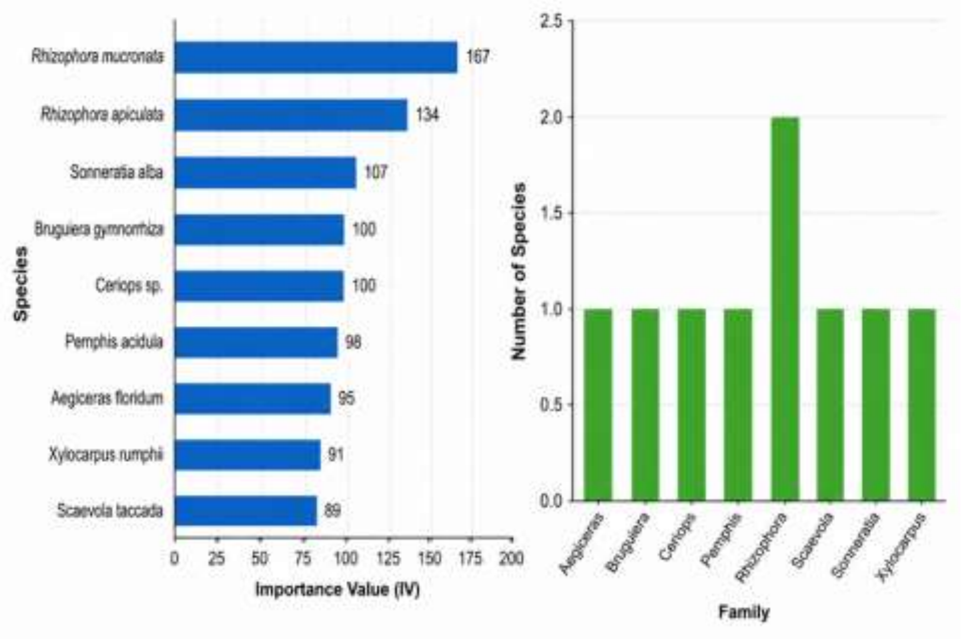

Fig. 3. Mangrove species and families

Table 3A shows that the community structure of the mangrove forest in Barangay Bukid, Jose Abad Santos, is dominated by *Rhizophora mucronata* (IVI = 59.79), followed by *Sonneratia alba* (IVI = 47.50) and *Rhizophora apiculata* (IVI = 42.46). These species exhibited the highest relative density, frequency, and dominance, indicating that they are the principal structural components of the sanctuary. The remaining mangrove species occurred at lower importance values and contributed to overall habitat heterogeneity rather than canopy dominance (English *et al.*, 1997).

The prevalence of mature Rhizophora and Sonneratia stands creates optimal roosting habitats for flying foxes, as these species offer large trunks, broad canopies, and stable branches that can support communal colonies. These structural features enhance roost availability, reduce thermal stress, and foster colony stability, ultimately influencing the distribution and persistence of flying fox populations within the sanctuary (Primavera *et al.*, 2004; Ramos and Nemenzo Calica, 2025).

Overall, the vegetation structure indicates that the mangrove forest remains suitable for sustaining robust flying fox populations. Conservation of mature Rhizophora and Sonneratia stands should be prioritized, as their degradation would diminish suitable roosting sites and adversely affect the abundance and spatial distribution of flying foxes in Jose Abad Santos.

The mangrove forest at the Barangay Bukid Flying Fox Sanctuary exhibited moderate species diversity (H′ = 1.962), high species richness (S = 9), and high evenness (J′ = 0.893) (Table 3B), reflecting a stable and structurally diverse habitat. Although Rhizophora and Sonneratia were dominant, the relatively balanced distribution of individuals among species indicates a well-developed mangrove community capable of providing diverse roosting resources for flying foxes. Such habitat complexity supports the large body size, broad wingspan, and colonial roosting behavior of these species while offering protection from environmental stressors and predators (Tanalgo and Hughes, 2019).

High mangrove diversity and evenness enhance habitat connectivity and increase the availability of suitable roosting sites across the sanctuary, facilitating a broader distribution of flying fox colonies in response to roost availability and seasonal variation (Pierson and Rainey, 1992; Epstein *et al.*, 2009). The balanced vegetation structure signifies a resilient ecosystem capable of supporting stable flying fox populations by improving roost availability, reducing intraspecific competition, and promoting conditions favorable for colony persistence and recruitment. These results highlight the critical importance of conserving the mangrove community to ensure the long-term viability of flying fox populations in Barangay Bukid, Jose Abad Santos (Aziz *et al.*, 2017; Aziz *et al.*, 2021).

Table 3A. Community structure of mangroves in Barangay Bukid's Flying Fox Sanctuary, Jose Abad Santos, Davao Occidental

Species	BA (cm^2)	SBA (m^2 ha^{-1})	TD (trees ha^{-1})	SD (seedlings ha^{-1})	RDo (%)	RF (%)	RD (%)	IVI
Rhizophora mucronata	26,156.11	0.805	48.92	55.56	18.30	16.05	25.44	59.79
Rhizophora apiculata	24,352.80	0.749	22.77	50.23	17.04	13.58	11.84	42.46
Sonneratia alba	16,306.29	0.502	40.92	55.56	11.41	14.81	21.28	47.50
Bruguiera gymnorrhiza	15,322.20	0.472	13.23	50.29	10.72	9.88	6.88	27.48
Ceriops sp.	13,476.12	0.415	11.69	46.21	9.43	8.64	6.08	24.15
Pemphis acidula	12,235.11	0.376	10.46	35.42	8.56	7.41	5.44	21.41
Aegiceras floridum	10,234.76	0.315	8.92	30.81	7.16	6.17	4.64	17.97
Xylocarpus rumphii	9,324.34	0.287	14.15	29.55	6.52	11.11	7.36	24.99
Scaevola taccada	8,532.12	0.263	21.23	25.90	5.97	12.35	11.04	29.36
Total	142,939.85	4.398	192.31	—	100.00	100.00	100.00	300.00

BA: Basal Area; SBA: Standard Basal Area; TD: Tree Density; SD: Seedling Density, RD: Relative Dominance; RF: Relative Frequency. Rd: Relative Density, IV: Importance Value; SD: Species Diversity

Table 3B. Community diversity indices of mangroves in the Barangay Bukid Flying Fox Sanctuary, Jose Abad Santos, Davao Occidental

Diversity	Value	Interpretation
S	9	Nine mangrove species were recorded, indicating relatively high floristic richness and a heterogeneous mangrove community.
H′	1.962	Indicates moderate species diversity (H′= 1–3), suggesting a moderately complex and relatively stable mangrove community with several coexisting species but a few dominant taxa.
J′	0.893	Indicates high evenness (J′ > 0.80), reflecting a well-balanced distribution of individuals among species despite the ecological dominance of Rhizophora and Sonneratia.

S= Species Richness, H′=Shannon–Wiener Diversity Index, J′=Pielou's Evenness Index

Ecological and morphological profile of flying foxes

Assessments indicate that flying foxes favor small islands and coastal regions, frequently establishing roosts within undisturbed mangrove forests. The Large flying fox (*Pteropus vampyrus*) and the Island flying fox (*Pteropus hypomelanus*) often occupy the same roosting sites, forming mixed-species colonies (Heaney *et al.*, 1991). During the day, they congregate in the densest sections of the mangrove canopy. These roosts serve as essential sanctuaries for grooming, social vocalization, and maternal care (Markus and Blackshaw, 2002). Undisturbed sites are preferred as they offer protection from predators and proximity to foraging grounds.

Flying foxes are highly efficient foragers, utilizing an acute sense of smell to locate ripe fruit and specialized long tongues to access nectar. By moving between trees, they act as primary pollinators and seed dispersers, facilitating forest regeneration and the survival of diverse mangrove taxa (McConkey and Drake, 2006).

However, they are highly sensitive to anthropogenic noise and structural disturbances, such as falling branches. Their auditory range is similar to that of humans, but they are particularly agitated by impulsive sounds, those that are sudden or sharp. In response to such disturbances, the colony exhibits increased vocalization, including squawking and chattering; this serves as a collective alarm signal to warn the densely packed roost of potential threats.

Morphological adaptations and measurements

The morphometric measurements (Table 4) reveal distinct size differences between the two flying fox species. *Pteropus vampyrus* exhibited greater body length, wingspan, body weight, and wing chord than P. hypomelanus, reflecting adaptations that influence flight performance, energetic requirements, and roost selection (Kunz and Parsons, 2009; Stier and Mildenstein, 2005).

These morphological differences influence habitat use within the mangrove ecosystem. The larger *P. vampyrus* depends on mature mangrove trees with strong branches and extensive canopy cover, whereas the smaller *P. hypomelanus* can utilize a broader range of roosting substrates. Such niche differentiation reduces interspecific competition and facilitates the coexistence of both species within the sanctuary (Pierson and Rainey, 1992; Epstein *et al.*, 2009).

Table 4. Morphometric parameters of *P. vampyrus* and *P. hypomelanus*

Morphometrics	*P. vampyrus*	*P. hypomelanus*
Total length (from the tip of the nose to the tail)	29 cm	19.2 cm
Tail-vent length	No tail	Short tail
Body weight	600 grams	469 grams
Wing cord	26 cm	13 cm
Bill or culmen length	2 cm	1 .2 cm
Gape Height	2 cm	1.2 cm
Width of gape	1 cm	.087 cm
Tarsus length	9 cm	7 cm
Lower leg bone	10 cm	8.9 cm
Claws length	4.5 cm	3.1 cm
Claws width	1.3 cm	0.97
Size	Large	Medium
Wing span	117 cm	70 cm

The availability of mature mangrove stands capable of supporting both large- and medium-sized flying foxes indicates that the sanctuary provides suitable habitat for mixed-species colonies. The higher abundance of *P. hypomelanus* may reflect its greater ecological flexibility, while the lower abundance of *P. vampyrus* suggests a stronger dependence on large, undisturbed roost trees. These findings highlight the importance of conserving mature stands of Rhizophora and Sonneratia to maintain stable flying fox populations and ensure the long-term persistence of both species (Mildenstein *et al.*, 2005; Aziz *et al.*, 2021).

Habitat availability and quality

Flying foxes depend on structurally intact mangrove forests for daytime roosting, with roost-site selection strongly influenced by forest composition, canopy structure, and the availability of large mature trees (Kunz and Parsons, 2009; Aziz *et al.*, 2021). In Barangay Bukid, Pteropus hypomelanus and *Pteropus vampyrus* predominantly roosted *on Rhizophora mucronata* (Bakauan-babae) and *Rhizophora apiculata* (Bakauan-lalaki), whereas *Sonneratia alba* (Pagatpat) was used less frequently, likely because of the reduction of mature individuals caused by tree cutting within portions of the study area. Similar preferences for mature Rhizophora stands have been documented in Philippine flying fox populations, where these trees provide suitable structural support and protection for large communal colonies (Mildenstein *et al.*, 2005; Ramos and Nemenzo Calica, 2025).

The dense canopy, extensive branching architecture, and robust prop-root systems of Rhizophora species provide stable roosting substrates that support the weight of numerous individuals while reducing exposure to aerial predators and human disturbance

(Stier and Mildenstein, 2005; Aziz *et al.*, 2021). Their proximity to tidal waterways further enhances roost security by limiting access by terrestrial predators and reducing human encroachment (Epstein *et al.*, 2009; Fleming and Racey, 2010). Dense canopy cover also moderates the roost microclimate by reducing solar radiation, buffering temperature fluctuations, and minimizing thermal stress during daytime roosting, thereby improving habitat suitability for large fruit bat colonies (Kunz and Parsons, 2009; Aziz *et al.*, 2017).

In addition to providing suitable roosting habitat, mangrove species such as Rhizophora and Sonneratia contribute important floral resources that support nectar feeding and pollination by flying foxes. By transferring pollen and dispersing seeds, flying foxes facilitate forest regeneration, maintain genetic connectivity among plant populations, and enhance the ecological resilience of coastal ecosystems (McConkey and Drake, 2006; Aziz *et al.*, 2017; Aziz *et al.*, 2021). The dominance of mature Rhizophora stands and the relatively low levels of anthropogenic disturbance observed within the sanctuary likely contribute to the high abundance and long-term persistence of the mixed-species flying fox colony recorded in Barangay Bukid.

Population demographics and dynamics

The Flying fox colony in Barangay Bukid is exceptionally large, with an estimated population reaching 11,920 individuals. We have observed that these colonies use two distinct types of roosting locations: one group prefers trees with dense foliage (Fig. 4A), while another occupies more exposed branches where leaves are absent (Fig. 4B).

Fig. 4A. Flying fox roosting in trees with dense leaves (*P. hypomelanus*)

Fig. 4B. Flying fox occupies more exposed branches where leaves are absent (*P. vampyrus*).

Reproductive status

Repeated field observations documented a consistently large colony of Pteropus hypomelanus and *Pteropus vampyrus* roosting within the mangrove canopy throughout the study period, suggesting that the site functions as an important and stable roosting habitat (Aziz *et al.*, 2021; Mildenstein *et al.*, 2005). Although direct photographic evidence of parturition was not obtained because of dense canopy cover and the cryptic nature of birthing events, the frequent occurrence of females carrying dependent young and the presence of nursery groups provide evidence of active reproduction within the colony (Kunz and Parsons, 2009; Pierson and Rainey, 1992). Field observations indicated that births were most common between April and June, consistent with the seasonal reproductive patterns reported for Philippine flying foxes and other tropical *Pteropus* species (Heideman, 1987; Stier and Mildenstein, 2005).

During the breeding season, adult males established and defended small territories within communal roosts through vocalizations, wing displays, and agonistic interactions to secure mating opportunities (Markus and Blackshaw, 2002). Females typically produced a single offspring following a gestation period of approximately five to seven months, reflecting the low reproductive rate characteristic of Old-World fruit bats (Fleming and Racey, 2010). Neonates remained attached to their mothers during early foraging flights, then were left in nursery aggregations within the roost as they developed. Juveniles generally attained volant capability and independent foraging between three and five months of age, depending on species and environmental conditions (Kunz and Parsons, 2009; Pierson and Rainey, 1992).

Mortality factors

Both anthropogenic activities and climate change represent significant threats to flying fox populations. Specifically, the destruction of vital mangrove ecosystems deprives these species of essential roosting and foraging grounds (Ramos and Nemenzo Calica, 2025). In Barangay Bukid, however, the colony appears relatively resilient to human interference due to active community-led conservation. Residents frequently intervene to prevent hunting and illegal mangrove cutting, which reduces the likelihood of colony displacement. This localized protection contrasts with broader trends; for instance, a 2020 report in the Journal of Threatened Taxa noted that slow reproductive rates make these bats exceptionally vulnerable to overhunting.

Furthermore, in adjacent areas, flying foxes are often perceived as agricultural pests due to damage to fruit crops, which can lead to human-wildlife conflict (Jumao-as *et al.*, 2023). During the study, researchers discovered a deceased Pteropus vampyrus suspended from a mangrove branch. Upon retrieval and examination, the specimen was confirmed dead with no discernible vital signs. The incident was immediately reported to the Municipal Environment and Natural Resources Office (MENRO) for a necropsy. Preliminary physical examination revealed a localized mass in the lower right abdomen, which may have resulted from an injury sustained during foraging, possibly from a traditional trap known locally as a "Pintik (slingshot). The fresh state of the carcass suggested that the mortality event had occurred shortly before discovery.

Daily activity patterns

During daylight hours, the flying foxes in the study area remain largely inactive within their dense, communal roosts. This period is dedicated primarily to rest, social interaction, and self-maintenance behaviors such as grooming and wing-flapping for thermoregulation (Suresh, 2021; Hengjan *et al.*, 2017). As dusk approaches, the colony initiates a coordinated mass departure from the roosts (Tsoar *et al.*, 2011), marking the beginning of their nocturnal foraging for the fruits and nectar abundant within the mangrove ecosystem.

These bats rely on keen eyesight and an acute sense of smell to locate food sources (Tsoar *et al.*, 2011). They use sophisticated mental maps of their foraging grounds that can extend several kilometers from their primary roost (Tsoar *et al.*, 2011; Harten *et al.*, 2024). During this study, a synchronized flight pattern was observed, with the colony consistently heading North. This suggests that their most reliable or abundant food sources are currently located in that direction (Harten *et al.*, 2024). Rather than flying aimlessly, the colony follows established commuting routes, likely utilizing prominent landmarks as aerial guides (Yovel and Ulanovsky, 2017).

This synchronized group flight provides safety in numbers against potential nocturnal predators and facilitates collective intelligence: when individuals discover productive food sources, the wider colony benefits from the shared information. Their return to the roost at dawn completes a daily cycle essential not only to their survival but also to their critical ecological roles as seed dispersers and pollinators within the coastal ecosystem.

Social behavior of the flying fox

Within the undisturbed mangrove forest of Barangay Bukid, the social behavior of flying foxes is a complex and dynamic aspect of their daily lives. Although resting and sleep are the predominant activities during daylight hours, these periods are punctuated by near-constant vocalizations, which are essential for maintaining social cohesion within the communal roost (Welbergen, 2005). Individual bats engage in meticulous grooming for hygiene and thermoregulation, often accompanied by wing-flapping to dissipate heat on warmer days (S. Suresh, 2021). Territoriality is particularly pronounced among males during the breeding season. They actively defend small sections of the roost using vocal displays, wing-spreading, and occasional physical altercations to attract mates (Markus and Blackshaw, 2002). Courtship and mating occur within these defended territories, involving a complex sequence of male approaches and female receptivity. Following successful breeding, maternal care becomes paramount; mothers meticulously tend to their single pup, carrying it during initial foraging flights before eventually leaving it in designated "crèche" or nursery areas within the roost while they forage (Jumao-as *et al.*, 2023). Collectively, these intricate social interactions shape the daily rhythms and reproductive success of the colony.

Evaluation of their contribution to the environment, such as pollination and seed dispersal

Flying foxes are vital to our local ecosystems, playing a crucial role as pollinators and seed dispersers. As they forage, these bats effectively pollinate many plants, including economically important fruit trees, and widely distribute seeds, thereby aiding forest regeneration and biodiversity (Tsoar *et al.*, 2011). Their consistent activity highlights their irreplaceable contribution to maintaining a healthy environment.

Exploration of their potential role in promoting local ecotourism

Beyond their ecological roles, flying foxes also hold significant potential for promoting local ecotourism. Observing these large, active colonies in Barangay Bukid can be a compelling draw for nature enthusiasts and tourists alike, offering unique wildlife-viewing experiences. This can create opportunities for sustainable tourism initiatives that benefit local communities and raise awareness for conservation, as highlighted by recent studies on the economic value of wildlife tourism (Ramos and Nemenzo Calica, 2025).

CONCLUSION

The presence of *Pteropus hypomelanus* and *Pteropus vampyrus* in the mangrove ecosystems of Barangay Bukid, Jose Abad Santos, Davao Occidental highlights the critical ecological value of this habitat and the urgent need for its protection. These flying foxes are keystone species that sustain tropical ecosystems through pollination and seed dispersal. Both face significant threats: *P. hypomelanus* is listed as Near Threatened and *P. vampyrus* as Endangered by the IUCN (2023), a status echoed by the DENR and the Biodiversity Management Bureau of the Philippines. The Barangay Bukid colony is substantial, with about 10,955 *P. hypomelanus* and 965 *P. vampyrus*, and active breeding is evident from the presence of mating adults and nursing pups.

The diverse mangrove forest enhances coastal resilience and sustains biodiversity, meeting the criteria for Critical Habitat designation under DENR Administrative Order No. 2007-02 due to the presence of threatened species, particularly P. vampyrus. Formal protection is essential to prevent further declines caused by habitat loss, hunting, and human disturbance. Immediate conservation action and formal declaration as a Critical Habitat are strongly recommended to safeguard this vital roosting and foraging site.

To secure the long-term survival of these flying foxes and the integrity of the mangrove ecosystem, a multi-faceted conservation strategy is needed. First, the proponents advocate for the formal designation of Barangay Bukid as a Critical Habitat under DENR and BMB guidelines to protect the essential roosting and foraging grounds of *P. hypomelanus* and *P. vampyrus*. The DENR should also initiate comprehensive documentation of biodiversity in collaboration with local government units and research partners to inform broader conservation strategies.

To reduce reliance on extractive use of mangrove resources, TESDA, BFAR, and DTI, in partnership with the CCEF, should implement sustainable livelihood programs. These efforts should be complemented by DENR- and BMB-led habitat restoration projects, including the planting of native flowering and fruiting trees to expand food sources. Finally, developing community-based ecotourism, led by the CCEF and DTI, can empower residents as eco-guides and artisans through training in sustainable tourism, product development, and business management, fostering a resilient, conservation-oriented local economy.

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