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Distribution and Population Status of *Pteropus medius* and *Pteropus hypomelanus* Flying Foxes (Mammalia: Chiroptera: Pteropodidae) in Myanmar

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ABSTRACT. – Populations of large fruit bats such as flying foxes are declining globally, particularly due to hunting. Monitoring population changes as well as roost characteristics are vital for conservation planning. The distribution and population size of flying foxes (*Pteropus* spp.) in Myanmar were assessed in the Mandalay Region, Sagaing Region, Mon State (Mawlamyine Township and Kyaikami Township), and Tanintharyi Region (Myeik Township, Thayetchaung Township, Thae Phyu Island) from February 2020 to January 2021. The survey found 12 colonies of *P. medius* and 3 colonies of *P. hypomelanus* roosting in 17 tree species. Direct roost counts were used to estimate the population size of these species. The total number of individuals across all study sites was 73,876 for *P. medius* and 20,458 for *P. hypomelanus*. The roosting sites of *P. medius* and *P. hypomelanus* were at an average elevation of 59.25 m and 25 m, respectively, and close to bodies of water. In total, 66% of *P. medius* and 61% of *P. hypomelanus* populations were located within Buddhist temples and public land, respectively. In addition, one-third of their populations occupied private land. Approximately 56% of the total flying fox population was found in areas classified as well-protected and 44% as disturbed. Temples play a crucial role in providing safe roosting habitats for flying foxes in Myanmar as hunting is prohibited in temples. Tall, large canopy trees offer optimum roost sites for flying foxes as they provide more heat dissipation on hot days when flying foxes often experience hyperthermia in full sunlight. Some colonies were found to suffer from hunting or roost tree cutting. Private land is also vital for flying fox survival and conservation efforts need to involve collaboration with private landowners to ensure their protection and survival. This study identifies ecologically important roost characteristics and provides an update on the distribution and population status of *Pteropus* species in Myanmar.

KEYWORDS: distribution, population, *Pteropus medius*, *Pteropus hypomelanus*, conservation status, Myanmar

INTRODUCTION

Flying foxes, genus *Pteropus*, are Old World fruit bats in the family Pteropodidae of the suborder Yinpterochiroptera. Old World fruit bats are found from South Africa to the eastern Mediterranean, the southern coast of the Arabian Peninsula, and eastward to South and Southeast Asia, islands of the Indian Ocean, the Indo-Malayan region, and the northern and western coasts of Australia. Their distribution includes montane and lowland tropical rainforests to open woodland and deserts (Mickleburgh et al., 1992; Koopman, 1994; Francis, 2019; Giannini, 2019). *Pteropus* is the largest genus within the Pteropodidae with 65 species listed, of which 19 species are vulnerable, 2 species are critically endangered, 17 species are endangered, 5 species are data deficient, 6 species are extinct, 10 species are least concern, and 6 species are near threatened (IUCN Red List). They are distributed throughout the Old World tropics and sub-tropics from Africa through southern Asia to Australia and on islands in the Indian and western Pacific Oceans (Mickleburgh et al., 1992).

Flying foxes can be migratory animals and their movement patterns and local distribution are influenced by variations in climate and the flowering and fruiting patterns of their preferred food plants (Nowak, 1994). These large bat species roost in trees in aggregations of several thousand individuals and historically in tens of thousands (Lyon, 1911). Bats play a crucial role as seed dispersers and pollinators for various plant species, particularly those referred to as bat-flower and bat-fruit, which depend on bats for pollination and seed dispersal. Bats are likely to pollinate the flowers of at least 31 genera and may disperse the seeds of most of the fruits they consume. (Marshall, 1983; Marshall, 1985). Human threats disrupting bat-plant interactions in the Old World include hunting, direct persecution, habitat loss and disturbance, invasive species, and climate change. These threats lead to significant ecosystem-level repercussions, affecting pollination and seed dispersal processes. Conservation efforts must address these threats to ensure the survival of bats and maintain the vital ecological roles they play. (Aziz et al., 2021). In many locations, however, flying foxes are targeted using nets because they feed on fruits from farms. They are also hunted for meat by locals for consumption as bushmeat, and the issue of hunting for medicinal purposes affects at least 167 species of bats across various regions, including Africa, Asia, the

islands of Oceania, and partially Central and South America (Mildenstein et al., 2016). The hunting and trade of *P. vampyrus* species among local people continue to be observed in Western Sarawak, Malaysia (Mohd-Azlan et al., 2022). In Asia-Pacific cultures, bats, particularly flying foxes, are commonly eaten as both food and medicine. The decline in bat populations due to hunting is a concerning trend for conservation efforts, as it impacts not only the bats themselves but also the biodiversity and health of the environments they inhabit (Low et al., 2023). By the end of the 21st century, nearly one-quarter of Southeast Asian fruit bat (Pteropodidae) species are predicted to become globally extinct, and flying foxes in the genera *Pteropus* and *Acerodon* are particularly at risk (Lane et al., 2006).

Among 12 species of Pteropodidae in Myanmar, there are four *Pteropus* species. These species are *P. giganteus*, *P. vampyrus*, *P. intermedius*, and *P. hypomelanus* (Bates and Harrison, 1997). According to (Mildenstein et al, 2022) assessment, *P. vampyrus* population was 'Decreasing' and listed as 'Endangered' on the IUCN Red List of Threatened Species. Its population is not likely to be found in Myanmar also depending on our current survey, only two species of *Pteropus* were confirmed in Myanmar which were *P. medius* and *P. hypomelanus* (Hsu Lae Win et al. unpublished manuscript). Although there is no official data on declining fruit bat populations, local villagers have reported that some colonies seem to have been eliminated due to eradication efforts that is to completely remove a harmful species, disease, or problem from a specific area to prevent ongoing damage, protect ecosystems, public health, agriculture, or economies, and often to save native species or human lives, also habitat destruction, and over-harvesting for human consumption. To safeguard declining populations, it is crucial to gather adequate information about the current status and population trends of flying foxes (Mickleburgh et al., 1992; Stewart et al., 2024). Therefore, conducting colony surveys is considered an important initial step in determining management priorities and strategies for protection, and it can provide a basis for evaluating the success of conservation programs (Mohd-Azlan et al., 2001).

Habitats chosen by *Pteropus* species for roosting vary greatly both ecologically and geographically (Pierson and Rainey, 1992; Mildenstein et al., 2005). Although habitat selection is an important feature of flying fox behavior and population dynamics, it has not received much research attention apart from a few earlier studies (Fretwell and Lucas, 1970; Bell et al., 1994). Flying foxes in Myanmar were noted to roost in arboreal areas of towns (Oo et al., 2017). Flying foxes were also noted to roost in rain trees (*Albizia saman*) at a particular site for up to 50 years. For conservation purposes, learning the roost site characteristics of flying foxes will help inform conservation strategies for maintaining current populations through the protection of potential roost sites.

The aim of this study is to document the population size of flying foxes in Myanmar and describe the characteristics of their roosting sites. We hypothesized that, in this human-dominated landscape, these bats are confined to large canopy trees within the vicinity of temples as it may protect them from poaching and disturbance. Data collected on the current population status of flying fox colonies will serve as baseline information for monitoring and conservation efforts. Additionally, understanding their preferred roosting characteristics can aid in flying fox management. This knowledge will help improve strategies for the conservation of *Pteropus* species in Myanmar.

MATERIALS AND METHODS

Study sites

This study was conducted from February 2020 to January 2021. Myanmar is situated from 9˚32'N to 28˚31'N latitude, and 92˚10'E to 101˚11'E longitude (Fig. 1, see supplementary material 1). Myanmar has a tropical monsoon climate, which is divided into three seasons. These seasons include the monsoon or rainy season, which lasts from May to October, the winter season from November to February, and the summer or hot season, which occurs in March and April (Aung et al., 2017). Myanmar is separated into seven states, seven regions, one union territory, and 330 townships. Our study area includes Upper Myanmar (Sagaing Region), Central Myanmar (Mandalay Region), Southeast Myanmar (Mon State), and Southern Myanmar (Tanintharyi Region), altogether contributing to 27% of the country's total area.

The Sagaing region in upper Myanmar is situated in the tropical wet and dry or savanna climate. There are expansive forests filled with Acacia thorn-type shrubs, as well as many dry-land vegetation types like the Euphorbia scrub found in semi-desert areas. Additionally, there are numerous *Mangifera indica* (mango) and *Prunus domestica* (plum) orchards in this region, which can serve as a source of food and roosts for bats (Aung, 2006). The Mandalay region is located in the arid region of central Myanmar and has a semi-tropical climate. It extends not only in the central region of Myanmar, but also on the eastern side of the Ayeyarwady River in the Mandalay Plain. Rainfall decreases after the monsoon ends, the water level of the Ayeyarwady river naturally recedes after the rainy

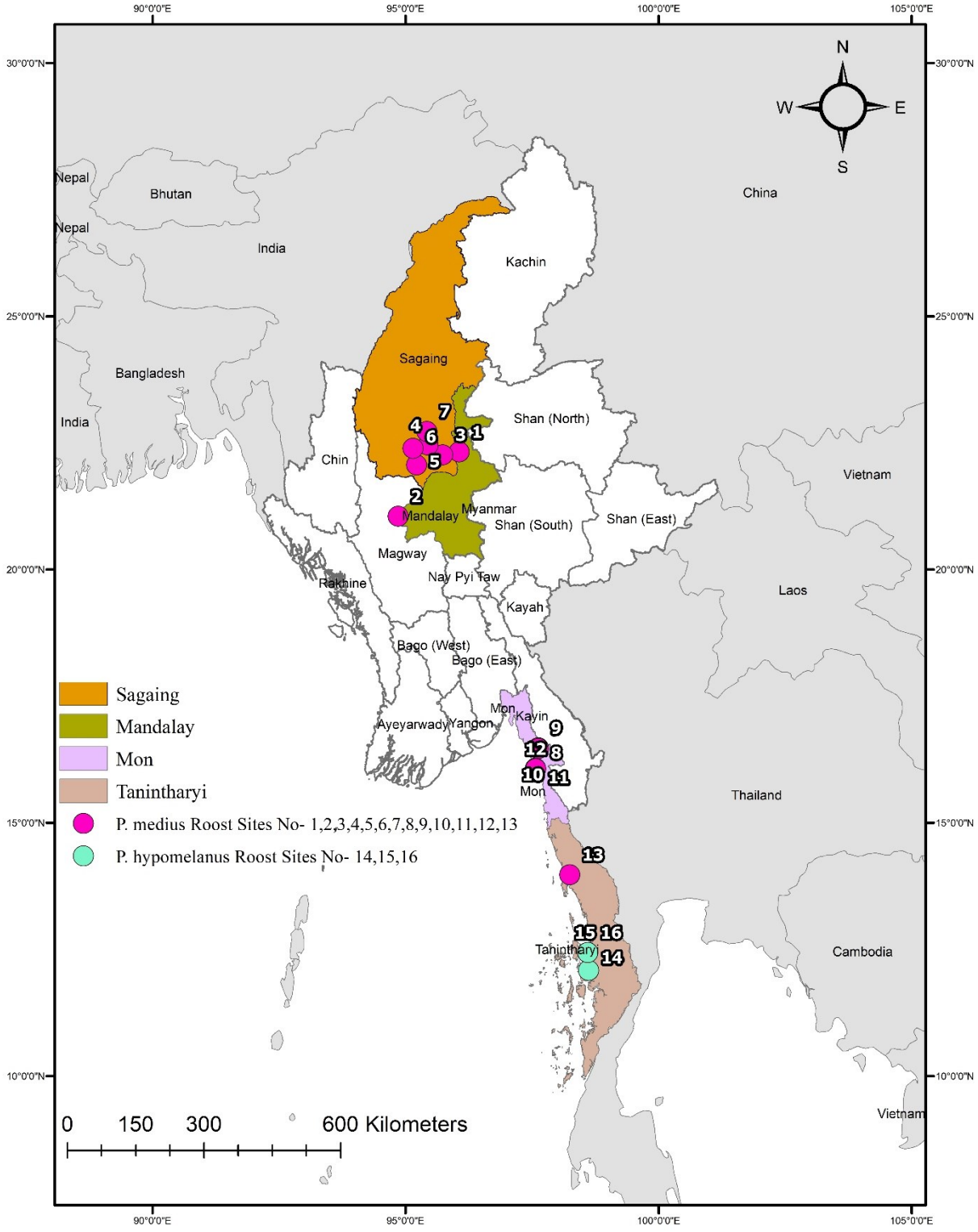

FIGURE 1. Roosting sites of *Pteropus* spp. (No. 1–16; see supplementary material 1).

season, typically around October to November each year. After the river water receded, the sedimentary zone between the research location and the main river transformed into an area suitable for growing different types of crops. Mandalay is characterized by the prevalence of xerophytic trees such as *Tamarindus indica* (tamarind), *Borassus flabellifer* (toddy palm), *Albizzia lebbek* (lebbeck tree), *Bombax ceiba* (cotton tree), and *Azadirachta indica* (neem). Additionally, there are numerous fruit-bearing trees such as *Mangifera indica* (mango), *Ficus religiosa* (sacred fig), *Ficus racemosa* (cluster fig tree), *Psidium guajava*

(guava), and *Musa paradisiaca* (banana) in both the study area and nearby environments which also provide abundant shelters and food sources for flying foxes (Oo, 2009). The Mandalay and Sagaing regions are within the Dry Zone, consisting mostly of agricultural lands (57%) and forests (27%), as well as wetlands, sandy areas, and human settlements. Although it is limited in water, the Dry Zone contains 40% of the country's overall agricultural land (Yee and Nawata, 2014). Mon State is characterized by a tropical climate and heavy rainfall sustains abundant evergreen forests in the area. The majority of land is devoted to growing rice and cultivating rubber trees (*Hevea brasiliensis*), and several other significant crops and fruits such as betel leaves (*Piper betle*), coconut (*Cocos nucifera*), oil palm (*Elaeis guineensis*), durian (*Durio zibethinus*), mango (*Mangifera indica*), mangosteen (*Garcinia mangostana*), pomelo (*Citrus maxima*) and rambutan (*Nephelium lappaceum*). This region also provides great resources for bats, such as comfortable habitats and abundant nourishment. The Tanintharyi Region is situated in the southern part of the country with a tropical and humid climate. In this area, most land has been converted to the cultivation of oil palm (*Elaeis guineensis*) and rubber (*Hevea brasiliensis*). This land use change has led to increased pressure on the forests in the area, which are among the limited remaining forests of significant conservation value in Southeast Asia (Donald et al., 2015). A narrow coastal plain characterises this region and has many islands covered in forests. These lands have been cultivated with tree crops like rubber (*Hevea brasiliensis*), as well as fruits such as durian (*Durio zibethinus*), mangosteen (*Garcinia mangostana*), and rambutan (*Nephelium lappaceum*). These tree crops also provide a suitable habitat and food source for bats (Aye et al., 2007).

Study species

Pteropus medius is distributed in the western part of Myanmar, especially Bagan and Mandalay where there are large populations (Bates et al., 2000). This bat has a widespread distribution extending from Pakistan, Nepal, India, and the Maldives to Myanmar, with presumably large populations. It is also known from a single record from Tsinghai, China. However, in several locations, this species has been hunted for meat and medicine (Molur et al., 2008). *Pteropus hypomelanus* ranges from the Maldives and the Andaman Islands to southern Myanmar, Thailand, India, Indonesia, Malaysia, Vietnam, the Solomon Islands, Papua New Guinea and the Philippines (Tsang, 2020). A major problem of this species is that it comprises several subspecies with complex distributions such that exact subspecific limits have not been drawn. It is known to be threatened by deforestation and habitat disturbance (Francis, 2008). *Pteropus vampyrus* is also distributed in southern Myanmar. It is often confused with *P. hypomelanus* because they overlap in range in Tanintharyi and its archipelagos (Bates et al., 2008). Although, *Pteropus vampyrus* species population was not distributed in southern Myanmar based on our survey and previous records (Aye et al., 2007). They are distributed in Cambodia, Indonesia, Malaysia, the Philippines, Thailand and Vietnam. It is listed by the IUCN Red List as 'Endangered (EN)' because it is in significant decline due to overhunting in much of its range and ongoing degradation of its primary forest habitat (Mildenstein et al., 2022).

Species verification

Flying foxes were captured using a mist net (10x3 or 6x3 m^2) placed in the canopy of their colony or feeding area. Nets were set up using long poles or by hanging ropes on the branches of tall trees in the upper canopy, which were approximately 30 to 35 meters high. Nets were positioned between two trees that were spaced around 10 to 15 meters apart at each location where mist netting was conducted. The nets were put up close to the colony of bats early in the morning to catch them as they came back to their roosting place at sunrise (Sheherazade and Tsang, 2018). Nets were set at places where flying foxes search for food right before sunset. Additionally, dead bats that had fallen to the ground were collected. The specimens were kept in ethanol, with the skull extracted and placed in the Zoological Collection of Myiek University (MUZC) in Myanmar. Species identification was based on morphological descriptions following Francis (2008; 2019) and Bates and Harrison (1997). Morphological characters were obtained from both external and craniodental features. The taxonomic status of flying foxes was verified based on morphology and genetic data collected from 16 roosting sites in Myanmar.

Roost counts and identification of preferred roost trees

Local villagers, townspeople, monks from the monastery, and nuns from the nunnery were interviewed to gather information about the locations of flying foxes and their foraging areas. Direct roost counts were conducted according to Kunz et al. (1996). Roost counts were conducted during the daytime, and the population size of flying foxes roosting in trees within each study site was recorded. The number of bats that roosted in each tree was counted using a pair of binoculars and a handheld tally counter. Altogether, four observers were involved in counting, each assigned to a different section of the study area. Often, it was impossible to count each individual bat when

they roosted in large numbers on a large tree. In such cases, the number of bats per cluster was first carefully counted and then multiplied by the number of clusters on the tree. Moreover, two observers separately conducted the procedure, and the mean was taken to estimate the number of bats. The total number of individuals in the observed roost trees was taken as the estimated population size of the bats roosting in the study area. The roost trees occupied by bats were identified according to Kress et al. (2003).

Roost characteristics

We employed ArcGIS and Google Earth tools to describe and map out the surrounding habitat space accessible to *P. medius* and *P. hypomelanus*. GPS data of the observed roosting sites were placed on Google Earth and then used to create the AOI (area of interest) to determine the roosting areas of bat species, placing the layer of roosting sites over Google Earth images. Then, we measured the area of a roost using a polygon and evaluated the distance from any point to the closest river or body of water, as well as the nearest temple, which was computed using Google Earth. Afterwards, the shapefile was transformed into an ArcMap to construct a map layer that showed the location of each roosting site and it was placed on top of a map that displayed rivers and water bodies, Buddhist temples, and elevation in raster format. Next, we obtained data values from various points on a raster dataset in ArcGIS.

Identification of disturbance category

Sixteen study sites were surveyed in the study area (Fig. 2). Local villagers, townspeople, monks from the monastery, and nuns from the nunnery were interviewed. A total of 61 interviewers participated in the discussions. The purpose of these interviews was to determine the population history of the colony and identify local threats to each population. We categorized each site as either (i) well-protected (hunting prohibited by law or religion), (ii) low threat or moderate disturbance (e.g., locals engaged in bat watching and shot at bats with air guns, rubber rings, or small stones while they roosted or flew overhead), and (iii) high threat or obvious disturbance (e.g., hunting using traps, consumption of flying foxes, and selling them to market vendors).

RESULTS

Population estimates

In our study, a total of 15 *Pteropus* colonies in 16 roost sites were located in the 3 regions and 1 state of Myanmar (Fig. 1). In the Mandalay Region, we found 2 colonies of *P. medius,* and a total of 24,810 individuals were recorded. In the Sagaing Region, we observed 44,844 individual bats belonging to 4 colonies of *P. medius*. In the Mon State, we found 5 colonies with a total of 3,329 individuals of *P. medius*. Additionally, in the Tanintharyi Region, we found a single colony of *P. medius* consisting of a total of 893 flying foxes. As a result, the largest colonies were near the lake located in the Sagaing Region at site 6 (36,750 bats), and the smallest colonies were in a Hindu temple located in Mon State at site 9 (488 bats). Overall, the total population count from 12 colonies was 73,876 *P. medius* bats based on three regions and one state (Table 1). Among these colonies, a total of 48,363 bats (66% of the population) inhabit Buddhist or Hindu temples for shelter. The total roost area was 53,453 m^2, and the mean roost size was 4,454.42 ± 5,303.59 m^2 (range: 275 - 19,824 m^2) (Table 2).

Pteropus hypomelanus was found at 3 roosting sites and a total of 20,458 individuals was estimated in the Tanintharyi Region (Table 1). The largest colony was on Thae Phyu Island located in the Kyun Su Township at site 14 (7,969 bats), and the second and third largest were located in Myeik Township at sites 16 and 15 (7,251 bats and 5238 bats). Overall, 12,489 out of 20,458 bats (61% of the population) roosted mainly in public land close to the Buddhist temples. The whole roost area was 24,963 m^2, and the average roost size was 8,321 ± 8,420.14 m^2 (range: 2,455 - 17,969 m^2) (Table 2).

Characteristics of roosts: From the 15 roost sites observed in Myanmar in our study, seven are new roosts while 8 roosts were identified by previous surveys of Aung (2006) and Oo et al. (2017). *Pteropus medius* roosting sites were situated at low elevations (59.25 ± 41.42 m asl, range 9–130 m) and were an average of 1,931.86 ± 3,439.05 m away from the closest water body (range 72.61–11,350.17 m). Colonies were very close to Buddhist and Hindu temples (46.02 ± 49.87, range 6.24–147.05 m) (Table 2). A total of 88 roosting trees were observed to host *P. medius*, including 13 tree species: *Albizzia lebbek* (RT 1, n = 11), *Azadirachta indica* (RT 3, n = 10), *Bombax ceiba* (RT 4, n = 4), *Borassus flabellifer* (RT 5, n = 4), *Dipterocarpus turbinatus* (RT 6, n = 3), *Ficus glometata* (RT 7, n = 1), *Ficus racemosa* (RT 8, n = 1), *Ficus virens* (RT 9, n = 10), *Interocarpus turbinatus* (RT 10, n = 1), *Pterocarpus macrocarpus* (RT 12, n = 2), *Samanea saman* (RT 13, n = 6), *Tamarindus indica* (RT 14, n = 30), *Ziziphus jujuba* (RT 17, n= 5) (Table 3).

The roosting sites of *P. hypomelanus* were found at relatively low altitudes, at an average of 25 ± 8.54 m above sea level (ranging from 16 to 33 m). The average distance from these roosting sites to the closest water body was 228.74 ± 178.85 m (ranging from 24.92 to 359.46 m). Colonies were approximately 96.92 ± 87.24 m, with a range of 121.62 to 169.15 m, apart from the

TABLE 1. The population size of flying foxes, *Pteropus medius*, from the current study compared to previous studies.

Site no.	Locality	Region/ State	Current population (X)	Previous population (Y)	Population increased/decreased (between X and Y) (%)
1	Myweponkan village, Madayar Township	Mandalay Region	609	–	–
2	Nyaung Hla Village, Nyaung Oo Township		24201	24135 (May Myo Nyunt, 2007)	0.3
3	Shwe Sedi Pagoda Precinct, Hpayarpyan village, Wetlet Township	Sagaing Region	3270	5314 (Moe Moe Aung, 2006)	-39
4	Hintha Taw Ya Monastery, Hintha Village, Ayardaw Township		0	2500 (Khin Than Oo, 2009)	-100
5	Mohnyin Sambuddhe Pagoda Precinct, Mye Ne' Village, Monywa Township		3813	1600 (Khin Than Oo, 2009)	138
6	Kanmagyi Lake, Budalin Township		36750	525 (Khin Than Oo, 2009)	6900
7	Ywatharlay Monastery,Ywatharlay Kokkozu village, Ye U Township		1011	1800 (Khin Than Oo, 2009)	-44
8	Mawyawady Park, Set Kal Gone Quarter, Mawlamyine Township	Mon State	502	–	–
9	Sai Bar Bar Hindu Temple (1), Set Kal Gone Quarter, Mawlamyine Township		488	–	–
10	Hindu Temple (2), Bo Gone Quarter, Mawlamyine Township		703	–	–
11	Police Station, Kyaikhami Township		810	–	–
12	Shwe Kyin Monastery, Kyaikhami Township		826	–	–
13	Tauk Htain Taung Monastery, Nyaung Zin Village, Thayetchaung Township	Tanintharyi Region	893	1621 (Khin Swe Oo, 2017)	-45
14	Thae Phyu Island		7969	–	–
15	Seik Nge Quarter, Myeik Township		5238	5105 (Hsu Lae Win, 2016)	3
16	Zaydan Quarter, Myeik Township		7251	9242 (Hsu Lae Win, 2016)	-22

nearest Buddhist or Hindu temple (Table 2). *Pteropus hypomelanus* were observed roosting on 26 trees comprising 7 tree species : *Artocarpus heterophyllus* (RT 2, n = 9), *Ficus glometata* (RT 7, n = 1), *Mangifera indica* (RT 11, n = 5), *Pterocarpus macrocarpus* (RT 12, n = 2), *Samanea saman* (RT 13, n = 6), *Terminalia bellerica* (RT 15, n = 1), and *Xylia dolabriformis* (RT 16, n = 2) (Table 3).

When combining data from both flying fox species, a total of 114 roost trees belonging to 17 tree species were observed. The most common roost tree species was *Tamarindus indica* (n = 30) (26% of total roost trees), which typically harbored populations between 30,000 and 35,000 bats, followed by *Albizzia lebbek* (n = 11) (10% of total roost trees) and *Samanea saman* (n = 12) (10% of total roost trees), which had the second highest bat populations, typically between 10,000 and 15,000 individuals (Table 4).

Moreover, 9 of the 12 colonies of *P. medius* species (75%) were located within religious temples, while colonies located on private property and common property/ public land were 2 (17%) and 1 (8%) respectively. Additionally, *P. hypomelanus* species, 1 out of 3 roosts (33%) and 2 (67%) were situated in the private property and common property type (Table 5).

Protection and disturbance status of bat colonies

Based on interviewing locals, we categorized each flying fox colony as either well-protected, moderate disturbance or high disturbance. In the well-protected category, most of the colonies were within conservation areas, including sites 2, 3, 5, 7, 14, 15, and 16 (47% of bat colonies), and 56% of the total population was able to roost safely because the bats are fully protected from habitat loss by monks, nuns, local villagers, townspeople and islanders. These groups have prohibited animal hunting either by law or because of religious reasons. The moderate disturbance category included sites 10, 11, and 12 (20% of bat colonies) and 2% of the total population. Finally, 5 colonies fell under the high disturbance category, which were at sites 1, 6, 8, 9, 13 (33% of bat colonies), and they comprised 42% of the total population (Fig. 2) (Table 6).

TABLE 2. Roost characteristics of *Pteropus medius* and *P. hypomelanus*.

Bat species	Region/ State	Sites no.	Population	Roost area (m2)	Elevation (m)	Distance to water body (m)	Distance to temple (m)
P. medius	Mandalay Region	1	609	3253	79	78.81	56
		2	24201	4655	64	80.75	147.05
	Sagaing Region	3	3270	4114	90	11350.17	45.37
		5	3813	3617	92	6355.18	80.86
		6	36750	19824	130	72.61	46.09
		7	1011	5247	111	1083.49	13.96
	Mon State	8	502	1842	15	316.44	–
		9	488	529	19	464.03	6.24
		10	703	766	9	513.4	7.38
		11	810	1762	20	299.38	–
		12	826	275	26	778.98	20.49
	Tanintharyi Region	13	893	7569	56	1789.1	128.78
	Total		73876	53453	–	–	–
	Mean		6156.33	4454.42	59.25	1931.86	46.02
	Standard deviation		11720.96	5303.59	41.42	3439.05	49.87
P. hypomelanus	Tanintharyi Region	14	7969	17969	16	24.92	–
		15	5238	2455	26	301.85	121.62
		16	7251	4539	33	359.46	169.15
	Total		20458	24963	–	–	–
	Mean		6819.33	8321	25	228.74	96.92
	Standard deviation		1415.75	8420.14	8.54	178.85	87.24

Population changes

Compared to previous records of each flying fox colony in the last decade, 4 colonies of *P. medius* were found to have decreased, including sites 3 (-39%), 4 (-100%), 7 (-44%), and 13 (-45%), while one colony of *P. hypomelanus* (site 16) also decreased (-22%). On the other hand, two colonies of *P. medius* were found to have increased in size, namely, site 5 (138%) and site 6 (6900%). The populations at sites 2 and 15 were relatively stable (Table 1).

DISCUSSIONS

Our field survey observed that the roosting sites of *P. medius* and *P. hypomelanus* are mostly situated in or close to Buddhist and Hindu temples or around government buildings. Buddhist and Hindu temples provide shelter and protection for bats, as reported in Thailand and elsewhere (Boonkird et al., 2006; Chaiyes et al., 2017; Duengkae et al., 2019). Large canopy trees are usually preserved in temples due to spiritual beliefs. Moreover, hunting and other types of disturbance are prohibited (Boonkird et al., 2006). Thus, temples play a crucial role in providing safe roosting habitats for flying foxes. A rapid assessment of flying fox (*Pteropus* spp.) colonies in Cambodia stated that most of the roost sites were situated inside or within the vicinity of religious or government buildings (Ravon et al., 2014). Additionally, roosting preference by island flying foxes was observed to be mostly dependent on foraging and roosting resource availability (Win, 2016). Palmer and Woinarski (1999) and Granek (2002) reported that *P. livingstonii* and *P. alecto* preferred to roost near bodies of water to remain within humid environments and regulate temperature. Our field observations have shown that most roosting sites of *P. medius* and all *P. hypomelanus* roosts are typically found near a body of water or a river. The average distance between roost site and the nearest body of water was found to be 1,932 m for *P. medius*, and 229 m for the Island flying fox *P. hypomelanus* (Table 2). The availability of water near the bat roost is crucial for thermoregulation, as flying foxes drink and dip their bellies in water to cope with heat during the day (Welbergen et al., 2014).

TABLE 3. Population estimates and roost species of *Pteropus medius* and *P. hypomelanus* in each roosting site.

Site no.	Locality	Region/ State	Species	Population	Roost tree species (n)
1	Myweponkan village, Madayar Township	Mandalay Region	*P. medius*	609	RT4 (3)
2	Nyaung Hla Village, Nyaung Oo Township	Mandalay Region	*P. medius*	24201	RT1, RT3, RT4, RT5, RT8, RT14 (11), (1), (1), (2), (1), (3) = 19
3	Shwe Sedi Pagoda Precinct, Hpayarpyan village, Wetlet Township	Sagaing Region	*P. medius*	3270	RT9, RT13, RT14, RT 17 (1), (1), (6), (5) = 13
4	Hintha Taw Ya Monastery, Hintha Village, Ayardaw Township	Sagaing Region	*P. medius*	-	-
5	Mohnyin Sambuddhe Pagoda Precinct, Mye Ne' Village, Monywa Township	Sagaing Region	*P. medius*	3813	RT3 (8)
6	Kanmagyi Lake, Budalin Township	Sagaing Region	*P. medius*	36750	RT5, RT13, RT14 (1), (3), (19) = 23
7	Ywatharlay Monastery,Ywatharlay Kokkozu village, Ye U Township	Sagaing Region	*P. medius*	1011	RT3, RT5, RT9, RT13, RT14 (1), (1), (1), (2), (2) = 7
8	Mawyawady Park, Set Kal Gone Quarter, Mawlamyine Township	Mon State	*P. medius*	502	RT9, RT12 (2), (1) = 3
9	Sai Bar Bar Hindu Temple (1), Set Kal Gone Quarter, Mawlamyine Township	Mon State	*P. medius*	488	RT9 (1)
10	Hindu Temple (2), Bo Gone Quarter, Mawlamyine Township	Mon State	*P. medius*	703	RT6 (2)
11	Police Station, Kyaikhami Township	Mon State	*P. medius*	810	RT9, RT10, RT12 (1), (1), (1) = 3
12	Shwe Kyin Monastery, Kyaikhami Township	Mon State	*P. medius*	826	RT6 (1)
13	Tauk Htain Taung Monastery, Nyaung Zin Village, Thayetchaung Township	Tanintharyi Region	*P. medius*	893	RT7, RT9
14	Thae Phyu Island	Tanintharyi Region	*P. hypomelanus*	7969	RT2, RT 11, RT12 (2), (5), (9) = 16
15	Seik Nge Quarter, Myeik Township	Tanintharyi Region	*P. hypomelanus*	5238	RT13 (3)
16	Zaydan Quarter, Myeik Township	Tanintharyi Region	*P. hypomelanus*	7251	RT 7, RT 13, RT 15, RT 16 (3), (1), (2), (1) = 7

Indian flying foxes tend to choose certain trees for roosting, including *Albizia lebbeck, Bombax ceiba, Ficus racemosa, Holoptelea integrifolia, Syzygium cumini, Terminalia arjuna, Mangifera indica,* and *Tamarindus indica.* These roost trees selected by bats had expansive canopies and were out of reach to humans and many predators (Kumar et al., 2017). The tallest and largest trees were the primary roosting sites of *P. medius* (Aung, 2013; Nyunt, 2007; Oo, 2009). In this study, it was observed that they roosted prominently on the terminal branches and twigs of the larger trees (Fig. 3), and the trees chosen for roosting are big trees consisting primarily of *Azadirachta indica*, *Borassus flabellifer,* and *Tamarindus indica*. These particular species are characterized by their height and large canopies, and they are commonly found in the Sagaing and Mandalay regions. *Ficus virens* and *Pterocarpus macrocarpus* were also found to be tall and sizeable trees in both Mon state and Tanintharyi region, where our study took place. Vonhof and Barclay (1996) and Betts (1998) suggested several advantages of roosting in tall, large trees. First, they are easier for bats to locate due to increased visibility. Second, they decrease the chance of being

TABLE 4. Bat population on types of roost trees used by *Pteropus medius* and *P. hypomelanus* within the study area.

Family	Roost Trees species	Common Name	Roost Tree species (No.)	Roost Tree spp (n)	Bat Population (n)
Mimosaceae	*Albizzia lebbek,* Benth.	Lebbeck tree	RT 1	11	14011
Moraceae	*Artocarpus heterophyllus* Lam.	Jackfruit	RT 2	9	4483
Meliaceae	*Azadirachta indica* A. Juss.	Neem	RT 3	10	4284
Bombacaceae	*Bombax ceiba,* L.	Cotton tree	RT 4	4	809
Arecaceae	*Borassus flabellifer,* L.	Toddy palm	RT 5	4	5560
Dipterocarpaceae	*Dipterocarpus turbinatus* C.F.Gaertn.	Gorjon tree	RT 6	3	1529
Moraceae	*Ficus glomerata* Roxb	Fig tree	RT 7	2	1215
Moraceae	*Ficus racemosa* L.	Cluster fig tree	RT 8	1	1592
Moraceae	*Ficus virens*, Aiton	White fig tree	RT 9	10	3992
Moraceae	*Interocarpus turbinatus* C.F.Gaertn.	Lofty tree	RT 10	1	290
Anacardiaceae	*Mangifera indica* L.	Mango	RT 11	5	2490
Fabaceae	*Pterocarpus macrocarpus,* Kurz.	Burma padauk	RT 12	4	1498
Mimosaceae	*Samanea saman,* (Jacq.) Merr.	Rain tree	RT 13	12	13721
Caesalpiniaceae	*Tamarindus indica* L.	Tamarind	RT 14	30	32940
Combretaceae	*Terminalia bellerica,* (Gaertn.) Roxb.	Beleric	RT 15	1	1036
Mimosaceae	*Xylia dolabriformis,* Benth.	Burma ironwood	RT 16	2	2071
Rhamnaceae	*Ziziphus jujuba* Lam.	Jujube	RT 17	5	2813
			Total	114	94334

preyed upon. Third, they help maintain an ideal microclimate. Tall trees offer more heat dissipation on hot days when flying foxes often experience hyperthermia in full sunlight (Pierson and Rainey, 1992; Granek, 2002; Gulraiz et al., 2015). As a result, these bats appear to prefer roosting in larger trees more often than would be anticipated based on their presence in the overall forest habitat. Roosting in tall, large trees reduce the chance of predation, but which do not offer absolute protection, especially against highly adapted predators like birds such as larger falcons (e.g. *Falco peregrinus* and *Falco biarmicus*) that are capable of successful predation of even larger bats of the family Pteropodidae (Clunie, 1972, Worthy and Anderson, 2009). Moreover, large bats (mainly Pteropodidae) are also usually caught by eagles (Welbergen, 2006; Fam and Nijman, 2011). Bird species capable of catching and eating bats are opportunistic hunters, and the specific bat species attacked vary among bird groups (Mikula et al., 2016).

The population in each colony was found to be stable, increasing, or decreasing compared to previous records. In the present study, particular colonies such as sites 1, 6 and 13 are under serious threat due to hunting for selling and consumption. Across Malaysia Borneo, most communities generally believe that consuming flying fox meat and liver is considered the best cure for general malaise and respiratory ailments (Mohd-Azlan et al., 2022). In our study, some communities believe that eating fruit bats can cure a range of ailments, like asthma, kidney complaints, and even tiredness, based on the local people's reports. Also, sites 3 and 7 faced hunting pressure; fortunately, hunting is strictly prohibited by monks in this area. Loss of roost trees is another reason for flying fox declines. Aung (2006) reported that cutting trees for firewood also causes the flying fox population to decline. At site 4, a flying fox colony was previously reported in a prior study (Oo, 2009), but we recorded that flying foxes have since abandoned this site as their roost trees were cut down for firewood by villagers. Sewall et al. (2007) reported that human pressures on Livingstone's flying fox habitats are decreasing mainly due to increased land requirements for agriculture and the widespread use of wood for fuel and construction. This suggests the rainforest, an important habitat for this critically endangered species, is directly damaged by human activities, remarkably firewood collection. Aziz et al. (2017) mentioned that flying foxes are facing significant extinction risk because of a lack of conservation attention, especially when they are considered pests. However, in some cases where several roosting sites are within flight of each other, population fluctuations in each colony may reflect

TABLE 5. *Pteropus medius* and *P. hypomelanus* distribution by property type.

Species	Property type	No. of roosts	Percentage of all roosts	Total population (mean)	Percentage of total population	Remarks
P. medius	Religious Temple	9	75	48363 (5374)	66	Mandalay Region, Sagaing Region, Tanintharyi Region
	Private property	2	17	24703 (12352)	33	Mandalay Region, Mon State
	Common property/ public land	1	8	810 (203)	1	Mon State
P. hypomelanus	Private property	1	33	7969 (1328)	39	Tanintharyi Region
	Common property/ public land	2	67	12489 (6245)	61	Tanintharyi Region

movement between colonies. For example, studies of *P. lylei* in central Thailand found that bats frequently moved among a network of roost sites, some of which are separated by relatively long distances, as this species does not form distinct colonies (Hondo, 2010; Weber et al., 2015). Weber et al. (2015) reported that Lylei flying foxes tend to forage in agricultural landscapes within a radius of about 20 km from their day roosts. Population fluctuations may also be due to changes in the availability of resources, such as flowers and fruit (Eby, 1991; Parry-Jones and Augee, 1992; Eby and Lunney, 2002). Thus, to improve the accuracy of population changes, it is best to perform roost counts during the same time period as much as possible.

We also found that there are stable populations in site 2 (0.3% change) and site 15 (3% change), relative to previous records (Nyunt, 2007; Win, 2016). Based on interviews with locals, site 2 has been used over the past 30 years as a permanent roost site of *P. medius*, and bats remain year-round. This colony is in close proximity to the Ayeyarwaddy River, which provides not only water but also abundant food resources such as Figs (*Ficus species*), Guava (*Psidium guajava*), Mango (*Mangifera indica*), and and Banana (*Musa sapientum*). Site 15 is a roost site of *P. hypomelanus* in Myeik Township, Tanintharyi region, where they also roost year-round. This Island flying fox roost is very close to the Andaman Sea (0.43 km) and is in the vicinity of an urban area where there is plenty of food. Parry-Jones and Augee (2001) and Tait et al. (2014) reported that a growing number of *Pteropus* species are adapting well to urban environments. It has been suggested that the increase in availability and stability of food resources is the main driving force behind this trend (Meade et al., 2021).

In the present study, 33% of the *P. medius* population and 39% of the *P. hypomelanus* population are located on private property. Chaiyes et al. (2017) stated that some bat roosts found on private property have areas of untouched natural forest and lower bat population densities compared to those found in temples. Although there is a risk of potential land use change depending on land ownership, private property is an essential refuge for bats. Therefore, flying fox conservation efforts may need to involve collaboration with private landowners to ensure their protection and survival. Additionally, public property can also be an appropriate and important roosting habitat for bats as it can provide undisturbed land. Around 1% of the whole population of *P. medius* and 61% of the total population of *P. hypomelanus* were found to roost on public property. Aziz et al. (2016) stated that island flying foxes feed on cultivated fruit in villages, where they also roost, even though wild food is available nearby. This leads to conflicts with villagers who grow the fruit for their consumption. Additionally, Aziz et al. (2017) on Tioman Island, Malaysia, where Island flying foxes consume durian flowers because pollen from the durian (*D. zibethinus*) has been detected in the droppings of flying foxes, and camera traps placed in durian trees have been verified. Shherazade et al. (2019) stated that bats are the primary pollinators for durian, highlighting their essential contribution to local agriculture and the economy. Chaiyes et al. (2017) stated that landowners of both private and public property can play an important role in conserving these important refuges for bats. By recognizing and saving these areas, flying foxes have assured places to roost that are protected from high risks (e.g., hunting and disturbance).

Overall, all types of property are important to consider for an effective management plan when it comes to flying fox conservation.

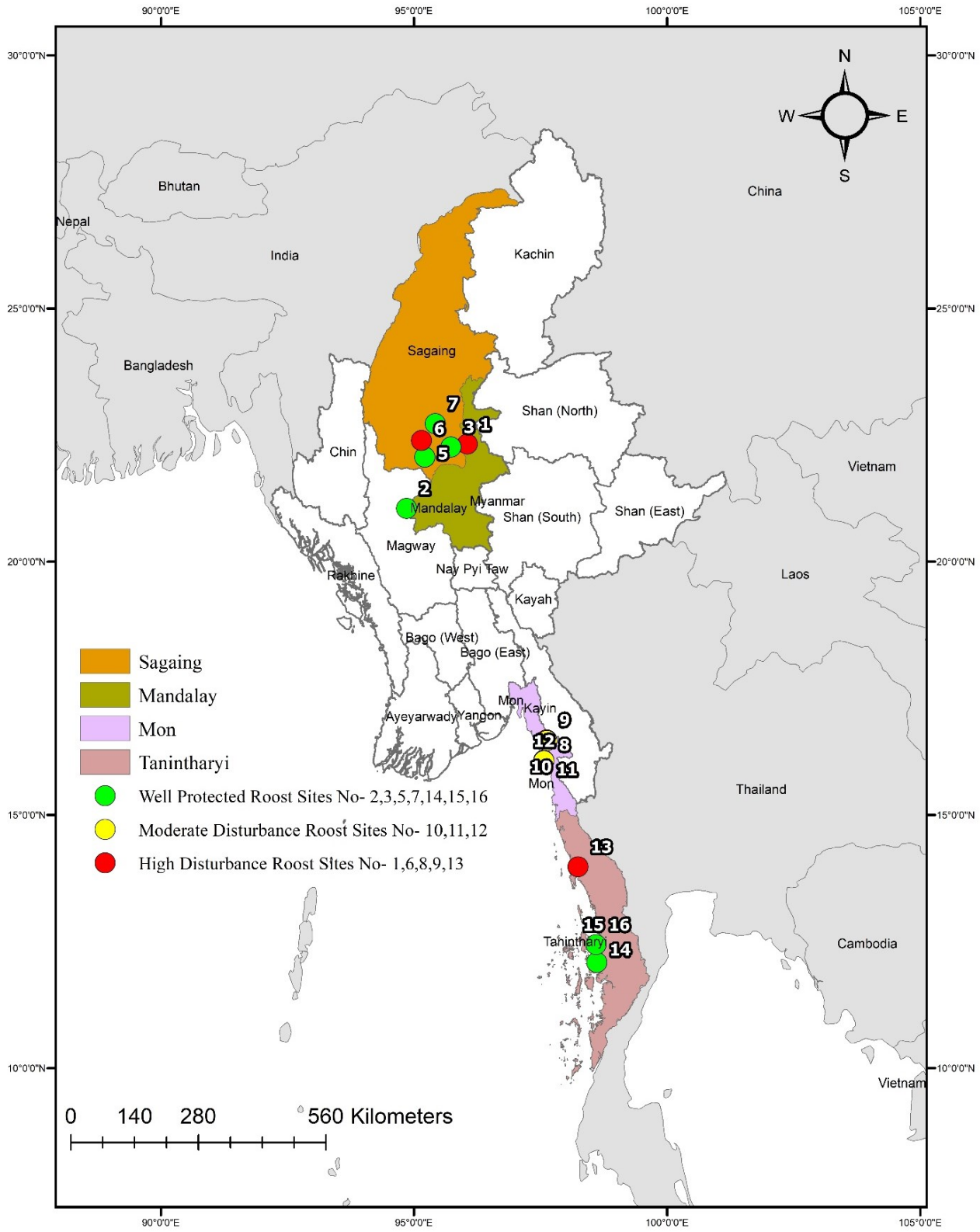

FIGURE 2. Disturbance status of bat colonies.

CONCLUSIONS

This study contributes information on the roost distribution and population sizes of *P. medius* and *P. hypomelanus* in Myanmar. A total of 94,334 *Pteropus* bats were discovered in one state and three regions in Myanmar, distributed across 15 roosting sites. Both *Pteropus* species were found occupying a total of 114 roost trees which belonged to 17 different species of trees. The population of *P. medius* was

TABLE 6. Disturbance status of bat colonies.

Category	Bat colonies	Percentage of bat colonies	Total population	Percentage of total population	Species	Remarks
Well-protected	7	47	52753	56	*P. medius, P.hypomelanus*	Site No. 2, 3, 5, 7, 14, 15, 16
Some disturbance	3	20	2339	2	*P. medius*	Site No. 10, 11, 12
Obvious disturbance	5	33	39242	42	*P. medius*	Site No. 1, 6, 8, 9, 13
Overall	15	100	94334	100		

FIGURE 3. *Pteropus* bats roost in the twigs and foliage of roosting trees.

recorded on 13 species of roost trees that supported 73,876 bats. *Pteropus hypomelanus* was recorded on 7 species of roost trees that supported 20,458 bats. The most common roost tree species was *Tamarindus indica* (26% of total roost trees). The data also revealed that 75% of *P. medius* roosts are located within temples and contain 66% of the total *P. medius* population. Temples can provide a safe place for bats by providing them with good shelter and high protection. Furthermore, 67% of the *P. hypomelanus* roosts are found in the public property with 61% of the total population of *P. hypomelanus*. This sort of property

may provide disturbance-free land that is appropriate for use as roosts and can therefore also provide important shelter for bats. Around 56% of the total population is found at sites categorized as well-protected categories and 44% of the total population is found at sites under some degree of disturbance. In our study area, hunting is mostly prohibited by monks, however, in certain places of Myanmar, most *Pteropus* species are being seriously threatened by poaching. Therefore, it is crucial to prevent illegal hunting and promote public awareness to protect the flying fox population in Myanmar.

Myanmar is extremely biodiverse and has already worsened pressures on critical ecosystems because its civil war has been happening since 2021. Not only Myanmar's civil war but also natural disasters such as flooding and severe earthquakes have significantly endangered its rich biodiversity, threatening critical habitats and numerous species. Flying Foxes in Myanmar are also threatened by the widespread deforestation that disrupts their colonies. Many of Myanmar's bat surveys and protection efforts have stalled since 2021. Scientists and conservationists have been forced to suspend fieldwork, leaving bat populations unmonitored and unprotected. Therefore, there is an urgent need to conserve and understand the ecosystem services of Myanmar flying foxes. Our study hopes to give attention and support to Myanmar's flying foxes conservation efforts from international bat research organisations.

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LITERATURE CITED

Aung L.L., Zin, E.E., Theingi, P., Elvera, N., Aung, P.P., Han, T.T., Oo, Y. and Skaland, R.G. 2017. Myanmar Climate Report, Department of Meteorology and Hydrology Myanmar, Ministry of Transport and Communications, Government of the Republic of the Union of Myanmar. Yangon, 105 pp.

Aung, M.M. 2006. Autecology of Indian Flying Fox, *Pteropus giganteus* Brunnich, 1782 within Shwe Sedi Pagoda Precinct, Hpa Yar Pyan Village, Wetlet Township. PhD. Thesis. Department of Zoology, Mandalay University.

Aung, M.M. 2013. Autecology of *Pteropus giganteus* from Myanmar- Feeding, Reproductive and Roosting Ecology. LAP Lambert Academic Publishing House, Germany, 84 pp.

Aye, N.N., Lin, T.T. and Htwe, M. M. 2007. Study on some bat species in Myeik Environs. Departmental Research, Department of Zoology, Myeik University.

Aziz, S. A., Olival, K. J., Bumrungsri, S., Richards, G. C., Racey, P. A. 2016. The Conflict Between Pteropodid Bats and Fruit Growers: Species, Legislation and Mitigation. In: Voigt, C., Kingston, T. (eds) Bats in the Anthropocene: Conservation of Bats in a Changing World.

Aziz, S. A., Clements, G. R., Giam, X., Forget, P. M. and Campos-Arceiz, A. 2017. Coexistence and conflict between the island flying fox (Pteropus hypomelanus) and humans on Tioman Island, Peninsular Malaysia. Human Ecology, 45 (3), 377–389. https://doi.org/10.1007/s10745-017-9905-6.

Aziz, S. A., Clements, G. R., Peng, L. Y., Campos-Arceiz, A., McConkey, K. R., Forget, P., Gan, H. M. 2017. Elucidating the diet of the island flying fox (*Pteropus hypomelanus*) in Peninsular Malaysia through Illumina Next-Generation Sequencing. PeerJ5: e3176.

Aziz, S. A., McConkey, K. R., Tanalgo, K., Sritongchuay, T., Low, M. R., Yong, J. Y., Mildenstein, T. L., Nuevo-Diego, C. E., Lim, V. C. and Racey, P. A. 2021. The critical importance of old world fruit bats for healthy ecosystems and economies. Frontiers in Ecology and Evolution, 9, Article 641411.

Bates, P.J.J. and Harrison, D.L. 1997. Bats of the Indian Subcontinent. Harrison Zoological Museum. Kent, 258 pp.

Bates, P.J.J., New, T., Pearch, M.J., Swe, K.M., Bu, S.S.H. and Tun, T. 2000. A review of bat research in Myanmar (Burma) and results of a recent survey. Acta Chiropterologica, 2: 53–82.

Bates, P., Francis, C., Gumal, M., Bumrungsri, S., Walston, J., Heaney, L. and Mildenstein, T. 2008. *Pteropus vampyrus.* The IUCN Red List of Threatened Species. Available from: http://doi.org/10.2305/IUCN.UK.2008.RLTS, (31 December 2023).

Bell, S.S, McCoy, E.D. and Mushinski, H.R. 1994. Habitat Structure: The Physical Arrangement of Object in Space. Chapman and Hall. London, 100 pp.

Betts, B.J. 1998. Roosts used by maternity colonies of Silver-Haired Bats in Northeastern Oregon. Journal of Mammalogy, 79: 643–650.

Boonkird, K., Wanghongsa, S., Wacharapluesadee, S. and Hemachudha, T. 2006. On the roost selection of Lyle's Flying Fox, *Pteropus lylei* at Wat Luang Pormmawas, Chon Buri province. Wildlife Yearbook, 7: 120–131.

Chaiyes, A., Duengkae, P., Wacharapluesadee, S., Pongpattananurak, N., Olival, K.J. and Hemachudha, T. 2017. Assessing the distribution, roosting site characteristics, and population of *Pteropus lylei* in Thailand. Raffles Bulletin of Zoology, 65: 670–680.

Clunie, F. 1972. A contribution to the natural history of the Fiji peregrine. Notornis 19: 302–321.

Donald, P.F., Round, P.D., Dai We Aung, T., Grindley, M., Steinmetz, R., Shwe, N. M. and Buchanan, G.M. 2015. Social reform and a growing crisis for southern Myanmar's unique forests. Conservation Biology, 29: 1485–1488.

Duengkae, P., Srikhunmuang, P., Chaiyes, A., Suksavate, W., Pongpattananurak, N., Wacharapluesadee, S., Hemachudha, T., 2019. Patch metrics of roosting site selection by Lyle's flying fox

(*Pteropus lylei* Andersen, 1908) in a human-dominated landscape in Thailand. Folia Oecologica, 46: 63- 73.

Eby, P. 1991. Seasonal movements of Grey-headed Flying-foxes, *Pteropus poliocephalus* (Chiroptera: Pteropodidae), from two maternity roosts in Northern New South Wales. Wildlife Research, 18: 547–559.

Eby, P. and Lunney, D. 2002. Managing the Grey-headed Flying Fox *Pteropus poliocephalus* as a threatened species in NSW: adjusting to a long-term vision, pp. 273–284. In: Eby, P and Lunney, D. (Eds.). Managing the grey-headed Flying Fox as a threatened species in NSW. Mosman, NSW: Royal Zoological Society of New South Wales. New South Wales, 286 pp.

Fam, S. D. and Nijman, V. 2011. Spizaetus hawk- eagles as predators of arboreal colobines. Primates 52: 105–110.

Francis, C. 2008. A Guide to the Mammals of South-East Asia. Princeton University Press. United Kingdom, 392 pp.

Francis, C. 2019. Field guide to the mammals of Southeast Asia (2nd edition). Bloomsbury Publishing. London, 416 pp.

Fretwell, S.D. and Lucas, H.L. 1970. On territorial behaviour and other factors influencing habitat distribution in birds. Acta Biotheoretica, 19: 16–36.

Giannini, N.P. 2019. Pteropodidae (Old World Fruit Bat). In: Wilson, D.E. and Mittermeier, R.A. (Eds). Handbook of the Mammals of the World - Volume 9. Lynx Edicions in association with Conservation International and IUCN. Barcelona, 16–61.

Granek, E. 2002. Conservation of *Pteropus livingstonii* based on roost site habitat characteristics on Anjouan and Moheli, Comoros Islands. Biological Conservation, 108(1): 93–100.

Gulraiz, T.L., Javid, A., Mahmood-Ul-Hassan, M., Maqbool, A., Ashraf, S., Hussain, M. and Daud, S. 2015. Roost characteristics and habitat preferences of Indian Flying Fox (*Pteropus giganteus*) in urban areas of Lahore, Pakistan. Turkish Journal of Zoology, 39: 388–394.

Hondo, E., Inoue, N., Maeda, K., Rerkamnuaychoke, W. and Duengkae, P. 2010. Movement of Lyle's Flying Fox (*Pteropus lylei*) in Central Thailand. Journal of Wildlife in Thailand, 17: 55–63.

IUCN. 2023. The IUCN Red List of Threatened Species. Version 2023-1. Available from: https://www.iucnredlist.org/en, (31 December 2023).

Koopman, K. 1994. Handbook of Zoology, Band/Volume VIII Mammalia. Chiroptera: Systematics Teilband/Part 60. Walter de Gruyter Press. New York, 217 pp.

Kress, W.J., Defilipps, R.A., Farr, E. and Kyi, Y.Y. 2003. A Checklist of the Trees, Shrubs, Herbs and Climbers of Myanmar. Contributions from the United States National Herbarium, Vol. 45. Smithsonian Institution. Washington, D.C., 590 pp.

Kumar, R., Prasad, D. N. and Elangovan, V. 2017. An update on distribution of the Indian Flying Fox, *Pteropus giganteus* in Uttar Pradesh, India. Trends in Biosciences, 10(37): 7794–7801.

Kunz, T. H., Thomas, D. W., Richards, G. C., Tidemann, C. R., Pierson, E. D. and Racey, P. A. 1996. Observational techniques for bats, pp. 105-114. In: Wilson D.E., F. R. Cole, J. D. Nichols, R. Rudran & M. S. Foster (eds.). *Measuring and Monitoring Biological Diversity: Standard Methods for Manuals*. Smithsonian Institution Press, Washington D. C., USA, 440pp.

Lane, D.J.W., Kingston, T. and Lee, B.P.Y.H. 2006. Dramatic decline in bat species richness in Singapore, with implications for Southeast Asia. Biological Conservation, 131: 584–593.

Low, M. R., Hoong, W. Z., Shen, Z., Murugavel, B., Mariner, N., Paguntalan, L. M., Tanalgo, K., Aung, M. M., Sheherazade, Bansa, L. A., Sritongchuay, T., Preble, J. H., and Azia, S. A. 2023. Bane or Blessing? Reviewing Cultural Values of Bats across the Asia-Pacific Region. Journal of Ethnobiology, 41 (1), 18- 34. https://doi.org/10.2993/0278-0771-41.1.18 (Original work published 2021).

Lyon, M.W., Jr. 1911. Mammals collected by Dr W. L. Abbott on Borneo and some of the small adjacent islands. Proceeding of US National Museum, 40 (1809): 53–146.

Marshall, A. G. 1983. Bats, flowers and fruit: evolutionary relationships in the Old World. Biological Journal of the Linnean Society, 20 (1), 115- 135.

Marshall, A. G. 1985. Old World phytophagous bats (Megachiroptera) and their food plants: A survey. Zoological Journal of the Linnean Society, 83 (4), 351- 369.

Meade, J., Martin, J. M. and Welbergen, J. A. 2021. Fast food in the city? Nomadic Flying Foxes commute less and hang around for longer in urban areas. Behaviour Ecology, 32: 1151–1162.

Mickleburgh, S.P., Hutson, A.M. and Racey, P.A. 1992. Old World Fruit Bats. An Action Plan for their Conservation. IUCN/SSC Chiroptera Specialist Group. Gland, 263 pp.

Mikula, P., Morelli, F., Lucan, R. K., Jones, D. N. and Tryjanowski, P. 2016. Bats as prey of diurnal birds: A global perspective. Mammal Review, 46 (3), 160–172.

Mildenstein, T. L., Stier, S. C., Nuevo-Diego, C. E. and Mills, L. S. 2005. Habitat selection of endangered and endemic large Flying Foxes in Subic Bay, Philippines. Biology Conservation, 126: 93–102.

Mildenstein, T., Tanshi, I., Racey, P. A. 2016. Exploitation of Bats for Bushmeat and Medicine, In: Voigt, C., Kingston, T. (eds) Bats in the Anthropocene: Conservation of Bats in a Changing World. Springer, Cham.

Mildenstein, T., Abdul Aziz, S., Paguntalan, L., Jakosalem, P. G., Mohd-Azlan J., Tagtag, A., Bansa, L., Reintar, A. R., Struebig, M., Fredriksson, G., Lee, B., Thong, V. D. and Sheherazade. 2022. Pteropus vampyrus. The IUCN Red List of Threatened Species 2022: e.T18766A22088824.

Mohd-Azlan, J., Zubaid, A. and Kunz, T.H. 2001. Distribution, Relative Abundance, and Conservation Status of the Large Flying Fox, *Pteropus vampyrus,* in Peninsular Malaysia. Acta Chiropterologica, 3(2): 149–162.

Mohd-Azlan, J., Yong, J. Y., Hazzrol, N. N. M., Pengiran, P., Atong, A. and Aziz, S. A. 2022. Local hunting practices and perceptions regarding the distribution and ecological role of the Large Flying Fox (Chiroptera: Pteropodidae: *Pteropus vampyrus*) in western Sarawak, Malaysian Borneo, Journal of Threatened Taxa 14 (1): 20387- 20399.

Molur, S., Srinivasulu, C., Bates, P. and Francis, C. 2008. *Pteropus medius*. The IUCN Red List of Threatened Species 2008: e.T18725A8511108. Available from: https://www.iucnredlist.org/, (31 December 2023).

Nowak, R. 1994. Walker's Bats of the World. The Johns Hopkins University Press. Baltimore, 287 pp.

Nyunt, M.M. 2007. Ecology and Seasonal Abundance of Indian Flying Fox *Pteropus giganteus,* (Brunnich, 1782) in Nyaung Hla Village, Nyaung Oo Township. PhD. Thesis. Mandalay University.

Oo, K.T. 2009. Distribution, Seasonal Occurrence and Roosting of Indian Flying Fox *Pteropus giganteus* Brunnich, 1782 in Monywa Township and its Environs. PhD. Thesis. Mandalay University.

Oo, K.S., Win, H.L., Bates, P.J.J. and Pearch, M. 2017. The ecology and distribution of Flying Foxes (Chiroptera: Pteropodidae: *Pteropus*) in Tanintharyi Region, Myanmar with a first mainland record of *Pteropus hypomelanus geminorum* from Myeik. Journal of Threatened Taxa, 9(8): 10528–10537.

Palmer, C. and Woinarski, J.C.Z. 1999. Seasonal roosts and foraging movements of the Black Flying Fox (*Pteropus alecto*) in the Northern Territory: resource tracking in a landscape mosaic. Wildlife Research, 26(6): 823–838.

Parry-Jones, K.A. and Augee, M.L. 1992. Movements of Grey-headed flying foxes (*Pteropus poliocephalus*) to and from a colony site on the central coast of New South Wales. Wildlife Research, 19: 331–340.

Parry-Jones, K.A. and Augee, M.L. 2001. Factors affecting the occupation of a colony site in Sydney, New South Wales by the Grey-headed Flying Fox *Pteropus poliocephalus* (Pteropodidae). Australian Ecology, 26:47–55.

Pierson, E. D. and Rainey, W. E. 1992. The Biology of Flying Foxes of the Genus *Pteropus*: a review. In: Wilson, D.E. and Graham, G.L. (Eds.). Pacific Island Flying-foxes: Proceedings of an International Conservation Conference, US Department of the Interior, Fish and Wildlife Service. Washington, DC, **90 (23):** 111–121.

Ravon, S., Furey, N.M., Hul, V. and Cappelle, J. 2014. A rapid assessment of Flying Fox (*Pteropus spp*) colonies in Cambodia. Cambodian Journal of Natural History, 1: 14–18.

Sewall, B. J., Granek, E. F., Carroll, J. B., Feistner, A. T. C., Masfeiled, W., Moutui, M. F. E., Trewhella, W. J., Young, R. J., and Said, I. 2007. Conservation Action Plan for Livingstone's Flying Fox *Pteropus livingstonii*. Mutsamudu, Anjouan, Union of the Comores: Action Comores (antenne Anjouan).

Sheherazade and Tsang, S.M. 2018. Roost of Gray Flying Foxes (*Pteropus griseus*) in Indonesia and records of a new hunting threat. Diversity, 10(3): 102.

Sheherazade, Ober, H. K., Tsang, S. M. 2019. Contributions of bats to the local economy through durian pollination in Sulawesi, Indonesia. Biotropica. 2019; 00:1-10.

Stewart, A.B., Srilopan, S., Wayo, K., Hassa, P., Dudash, M. R., Bumrungsri, S. 2024. Bat pollinators: a decade of monitoring reveals declining visitation rates for some species in Thailand. Zoological Letters, 10(1): 5.

Tait, J., Perotto-Baldivieso, H.L., McKeown, A. and Westcott, D.A. 2014. Are Flying Foxes coming to town? Urbanisation of the Spectacled Flying Fox (*Pteropus conspicillatus*) in Australia. PLoS ONE, 9: e109810.

Tsang, S. M. 2020. *Pteropus hypomelanus*. The IUCN Red List of Threatened Species 2020: e.T18729A22081642.

Vonhof, M.J. and Barclay, R.M.R. 1996. Roost-site selection and roosting ecology of forest- dwelling bats in Southern British Columbia. Canadian Journal of Zoology, 74: 1797–1805.

Weber, N., Duengkae, P., Fahr, J., Dechmann, D.K.N., Phengsakul, P., Khumbucha, W., Siriaroonrat, B., Wacharapluesadee, S., Maneeorn, P., Wikelskiand, M. and Newman, S. 2015. High-resolution GPS tracking of Lyle's Flying Fox between temples and orchards in central Thailand. The Journal of Wildlife Management, 79(6): 957–968.

Welbergen, J. A. 2006. Timing of the evening emergence from day roosts of the grey-headed flying fox, *Pteropus poliocephalus*: the effects of predation risk, foraging needs, and social context. Behavioral Ecology and Sociobiology 60: 311–322.

Welbergen, J. A., Booth, C. and Martin, J. 2014. Killer climate: Tens of thousands of Flying Foxes dead in a day, The conversation. Australia, 5. Available from: https://www.iucnredlist.org/, (31 December 2023).

Win, H.L. 2016. Population and Roosting Preference of Small Island Flying Fox *Pteropus hypomelanus geminorum* (Miller, 1903) in Myeik, Tanintharyi Region. M. Res. Thesis, Department of Zoology, Myeik University.

Worthy, T. H. and Anderson, A. 2009. Results of palaeofaunal research. In: Clark G, Anderson A (eds) The Prehistory of Early Fiji, Terra Australis 31, 41–62. Australian National University, Canberra, Australia.

Yee, M. S. and Nawata, E. 2014. Land use and farming systems in Dry Zone, Myanmar. Tropical Agriculature Development, 58(4): 169–179.