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Habitat comparison of *Cynopterus* fruit bats at Lampung, Sumatra, Indonesia

Indonesia is home to at least 205 species of bats, over a fifth of the world's total. Chiroptera in the Indonesian island chain belong to nine families and 52 genera (Francis, 2008). Most of these bats are insectivores but the Pteropodidae of sub-Order Yinpterochiroptera are frugivores and nectarivores and, hence, important pollinators of economically significant plants such as petai (*Parkia speciosa*), durian (*Durio zibethinus*), mango (*Mangifera indica*), and kapok (*Ceiba pentandra*); they also disperse seeds of water apple (*Syzygium aqueum*), guava (*Psidium guajava*), and canarium nut (*Canarium* spp.) (Knauth *et al*., 1972; Suyanto, 2001). Not only do these pteropodid bats play roles in agriculture and ecosystem continuity, they also figure in the reproductive success of plants and in the regeneration of disturbed areas (Medellin *et al*., 2000; Bianconi *et al*., 2007; Kunz *et al*., 2011).

Bats of the genus *Cynopterus* are the most common and diverse pteropodids in the Indomalayan Region (Francis, 2008) and new records are still reported from this region. *Cynopterus luzoniensis* was first recorded in Sulawesi (Maryanto & Yani, 2003). These bats are tolerant of habitat disruption and disturbance and so are found in agricultural and urban settings as well as the forest. A generalist approach to diet, a keen nose, good flight ability enabling extensive foraging capability, and adaptability regarding roost locations give *Cynopterus* bats an advantage in surviving well in the habitats they occupy (Corlett, 2004; Castro-Luna *et al*., 2007; Kunz *et al*., 2011, Campbell *et al*., 2006). Nevertheless, there is evidence that this is not the full story because Fenton *et al*. (1992) showed that fruit bat diversity is higher in tropical forest areas where human disturbance level was low. It is this dynamic that we wanted to test for.

Bukit Barisan Selatan National Park (BBSNP) is a tropical rainforest area in the Sumatran lowland 365,800 ha in extent. Illegal logging in the park is especially evident at edges where villages are separated from the forest by the Pemerihan River in West Lampung (Suyadi & Gaveau, 2007). This deterioration in habitat conditions may affect populations of fruit bats that pollinate economically significant trees in nearby plantations. We wanted to evaluate the effect of deforestation on *Cynopterus* fruit bat diversity and numbers with the knowledge that *C. brachyotis*, *C. horsfieldii*, and *C. sphinx* are known pollinating agents (Lasmana, 2008). Research, therefore, was conducted in the BBSNP/agricultural garden ecotone.

Study area (Fig. 1)**:** The study site was located at the edge of BBSNP abutting an adjacent agricultural garden (5°36’54”S, 104°23’34”E). Between the forest and the village was the Pemerihan River as well an asphalt road. The forest edge location will henceforth be referred to as the ‘forest’ and the local farming area will be referred to as the 'agriculture garden'. The forest edge of BBSNP has had a long history of illegal logging by local people and is consequently classified as secondary forest. The agricultural gardens were located between two villages, Pemerihan and Sumberejo, and grew pepper (*Piper* sp.), coffee (*Coffea* sp.), and cocoa (*Theobroma cacao*) on a commercial basis. Three study sites were set up between the two villages. At each study site, two transects totalling 2km were set up at both sides of the edge (1km at agricultural site, 1km at forest edge) with 400m distance between transects.

Mist-netting**:** Fruit bats were captured with mist nets (size 6 x 2.5m and 12 x 2.5m). Mist nets were deployed along the transects at 200m intervals resulting in six plots per transect (1km) at areas with high intensity of bat use. The height of the mist net was adjusted to the height of understorey. Netting deployment was adjusted to habitat situation. In one location, a maximum number of two mist nets were deployed. The nets were combined lengthwise if the plot had a wide opening area. The nets were deployed for 4 hours (18.00–22.00 h) each day. Bats captured were measured (forearm length, thigh length, ear length, and weight), weighed, photographed, identified, then released.

***Habitat measurement*:** Vegetation data was quantified at every mist net location within a 20m radius using the Point-Centered-Quartered (PCQ) method. The 20m radius circular plot was then divided into four quadrants to assist measurement. Within these quadrants we measured understorey density and canopy closure and then averaged the results. We also measured the distance to the mist net of the four nearest trees and their DBH.

Data analysis: To evaluate the different habitat structures of forest and agricultural gardens we used the t-test. To evaluate bat diversity between the two areas we used the Shannon-Wiener (H') index. To evaluate correlation between bats and habitat structures we used Spearman's rho.

***Vegetation Analysis*:** Our results suggest that forests were denser than the agricultural gardens (Table 1). The percent canopy opening was higher in agriculture gardens (46%) than forests (17%) and the percent understorey cover was lower in agriculture gardens (11%) than forests (62%). Both canopy openings and understorey densities were significantly different between the two locations (canopy openness, t = -2.465, P = 0.017; dense understorey density t = 11.678, P <0.001). However, neither forests nor agricultural gardens had any difference in tree DBH (t = -0.396, P = 0.693) or tree distance (t = 1.323, P = 0.19).

***Cynopterus* bat diversity:** 166 *Cynopterus* fruit bats were captured at both forest and agricultural garden locations in 195 hours of capture effort. There were more individuals captured in agricultural gardens (105 individuals) than in forests (61 individuals). *Cynopterus* species diversity was higher in agriculture gardens (H' = 1.11) than in forests (H' = 0.99). Four species of *Cynopterus* bats were apprehended, ie., *C. brachyotis*, *C. horsfieldii*, *C. minutus*, and *C. sphinx* (Fig. 2). All four species of *Cynopterus* are present in both locations although in different proportions. *C. brachyotis* was the commonest species both in the forest and in agriculture gardens. In the latter habitat *C. brachyotis*, *C. horsfieldii*, and *C. sphinx* were the commonest cynopterids whereas *C. minutus* was the commonest species on the forest side. Relationship to habitat structure suggested that only *C. brachyotis* was correlated to more open canopy (Spearman rho 0.466, *P* <0.001) and *C. horsfieldii* was correlated to average tree distance (Spearman rho -0.235, *P*=0.047) showing preference to less spacious habitat. Others showed no correlations to habitat structures (all with P >0.05).

The greater diversity of the *Cynopterus* species in agricultural gardens was likely due to the concentrated availability of food in such locations (Juste & de Val, 1995). Forest settings tended to have patchy tree distribution and more complex vegetation while in agricultural gardens trees were more evenly spaced because they were cultivated (Hylander & Nemomissa 2008).

Table 1: Vegetation structure at forest edge and agricultural gardens adjacent to BBSNP.

Vegetation variables	Location		t-test	
	Forest	Farm	T	Sig. (2-tailed)
Canopy openness (%)	17	46	-2.46	0.02
Understorey density (%)	62	11	11.68	0.00
DBH (cm)	16.08	16.07	-0.39	0.69
Tree distance (m)	2.74	2.34	1.32	0.19

Morphology measurements showed a range for the four species: *C. minutus* (FA = 52.7–69.4mm; W = 20–56mg), *C. brachyotis* (FA = 56.2–72.0mm; W = 22.0–63.5mg), *C. sphinx* (FA = 68.5–74.8mm; W = 48.5–67.0mg), and *C. horsfieldii* (FA = 66.8–78.8mm; W = 41.0–66.5mg). Identification followed Suyanto (2001).

Our results show that *Cynopterus* fruit bats were more prevalent in agricultural gardens adjoining the national park than in the adjacent forest. One cause for this could be that the dense canopy and thicker and lusher understorey in the forest inhibits flight (Hodgkison *et al.*, 2004) of these fruit bats because they have to rely on eyesight for navigation (Knauth *et al*., 1972; Suyanto, 2001; Francis, 2008). Indeed, a thick understorey appears to deter even the more adroit chiropterans that echolocate (Prastianingrum, 2008). Although both forest and agricultural gardens have similar DBH and mean tree distance values, agricultural gardens have a less cluttered understorey in general. Thus vegetation cover is a key factor that could affect bats' flight capability, indirectly affecting their diversity in habitats. Agricultural gardens (13 species) had less tree species than the forest (67 species).

With four medium-sized fruit bat species sharing a given habitat how do they partition resources? It appears that *C. minutus*, with the smallest body, favours the forest, a habitat filled with leaves and twigs and branches, that favours species with smaller wings (Table 2). The larger *C. brachyotis*, on the other hand, is commoner in disturbed areas or those associated with human activities such as farming (Campbell *et al*., 2006; Bumrungsri *et al*., 2007; Jayaraj *et al*., 2012). This is supported by the correlation of *C. brachyotis* distribution with open areas. *C. horsfieldii*, another large species, is also commoner in agriculture gardens adjacent to forest (Campbell *et al*., 2006). It appears then that morphology affects the suitability of a habitat for a given species. Heterogeneity of habitat, therefore, can be a factor in promoting fruit bat species diversity (Hodgkison *et al*., 2004).

Table 2: Comparison of forearm length (FA) mean and individual number of *C. minutus* and *C. brachyotis* between forest and agricultural gardens.

Species	Forest		Agricultural gardens	
	FA mean (mm)	n	FA mean (mm)	n
C. minutus	57	27	58,1	22
C. brachyotis	65,2	28	67,1	61

We observed the overlapping of habitat use but there may be partitioning based on the sizes of fruits exploited that reduces interspecific competition. It has been shown that body size of consumer species is correlated to fruit size (Dumont *et al*., 2003). Small-sized *Cynopterus* species (*C. brachyotis* and *C. minutus*) may tend to pick smaller fruit than the larger cynopterids (*C. horsfieldii* and *C. sphinx*). It was further related to fruit bats' habit of carrying fruit to another perch prior to consumption (Tan *et al*., 2000; Hodgkison *et al.*, 2003). However, the above behaviour was indirectly causing the bats to disperse seed far away from source trees thereby increasing tree reproductive success. *Cynopterus* fruit bats, especially *C. brachyotis*, can be considered as pioneers in regenerating degraded or fragmented areas. Pollen was also effectively translocated by fruit bats (Tan *et al*., 2000).

Nevertheless, in agricultural gardens, human intervention limited the influence of bat dispersal of seeds, fruit, and pollen (Tan *et al*., 2000: Hodgkison *et al*., 2003). In contrast, fruit bats may play a crucial role in the regeneration of fragmented habitats and in sustaining genetic diversity amongst wild plants (Fujita & Tuttle, 1991; Kunz *et al*., 2011). Aside from a limited role in agricultural areas, the ecological services provided by fruit bats can be regarded as beneficial for humans and for the ecosystem. Therefore, both habitats (forest and agricultural gardens) have the potential to sustain the diversity of fruit bats that provide ecological services while sustaining the forest edge of the national park.

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PLATE 24

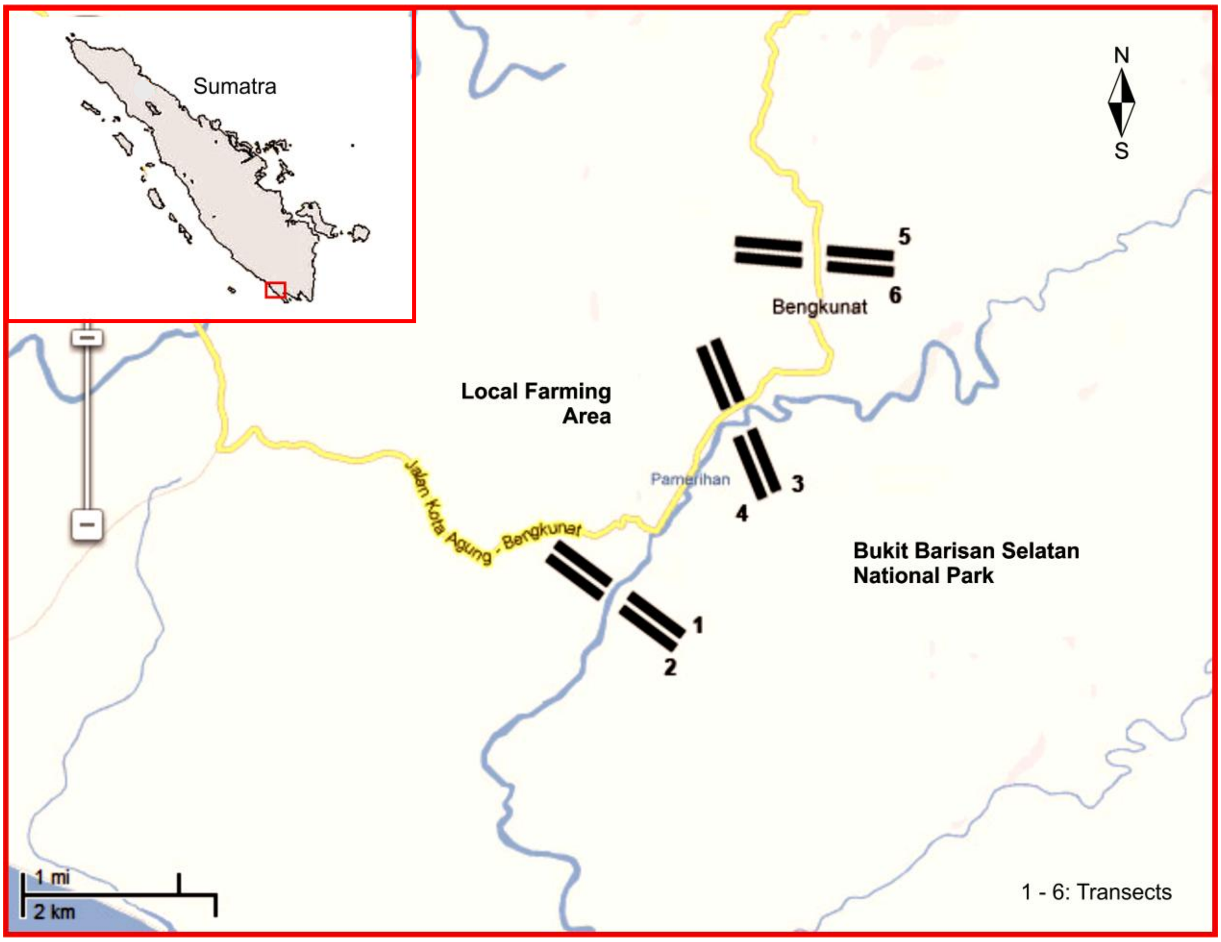

Figure 1: Transect localities at the study site of the BBSNP edge (left upper corner shows Sumatra Island).

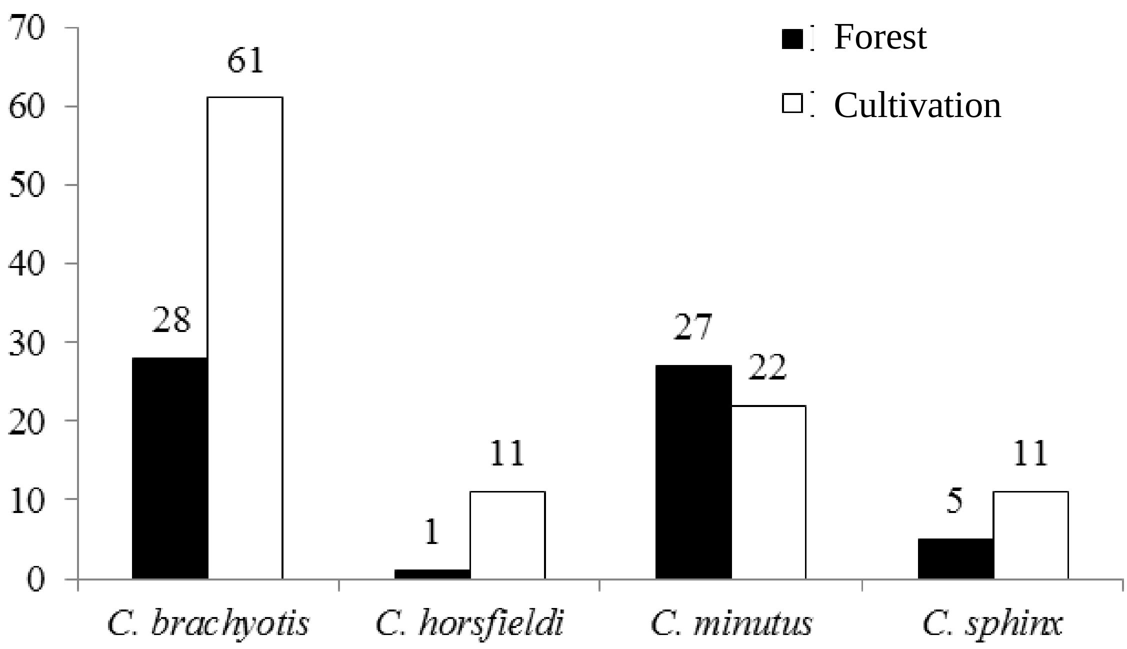

Figure 2: The abundance of *Cynopterus* fruit bats in the forest and surrounding cultivations of BBSNP

PLATE 25

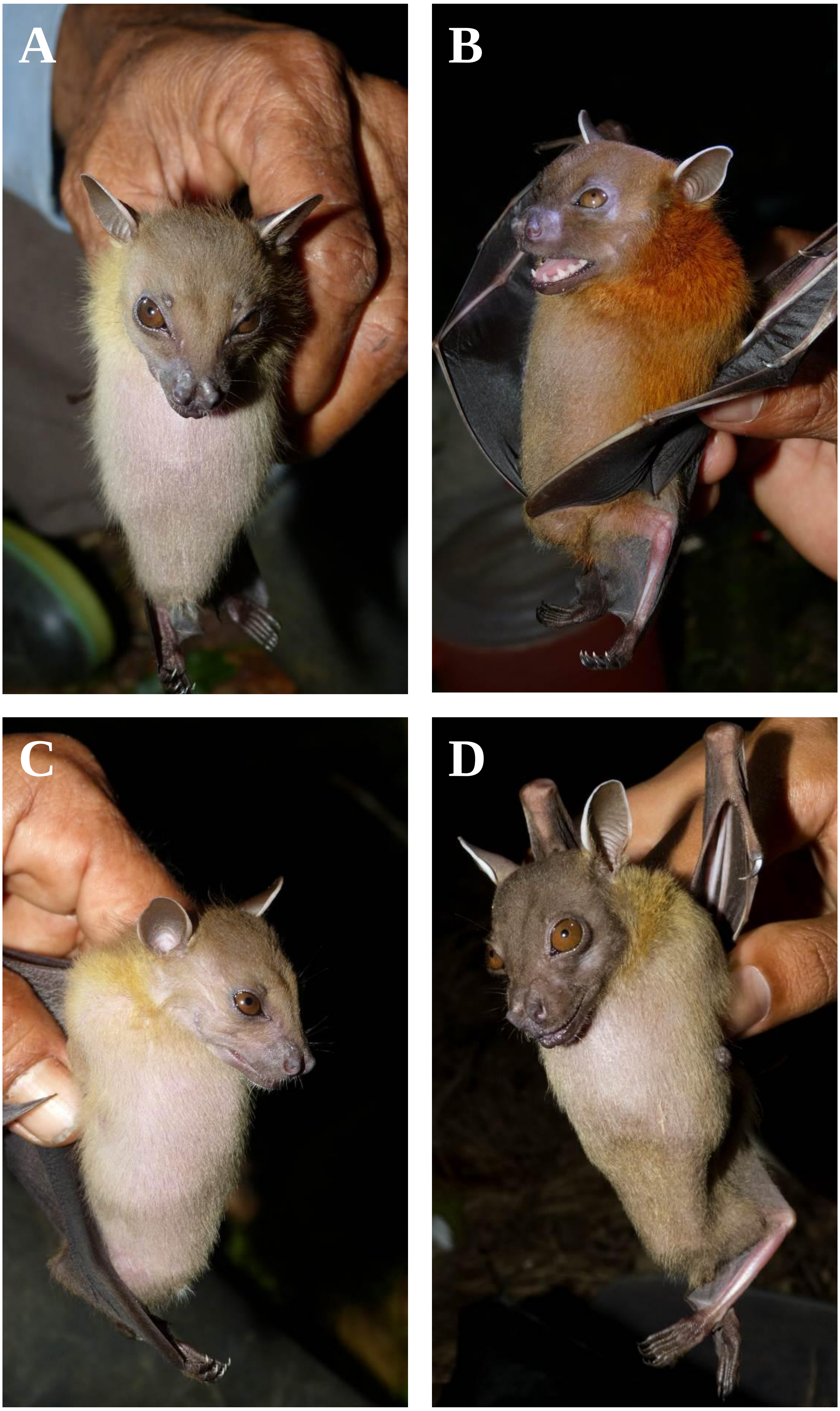

Figure 3: Fruit bats captured at the edge of BBSNP, (**A**) *C. brachyotis*, **(B**) *C. horsfieldii*, (**C**) *C. minutus*, (**D**) *C. sphinx*.