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The diversity of small mammals in a mixed fruit orchard at Bukit Bekong limestone massif, Merapoh, Pahang, Malaysia.

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Abstract. The increasing forest fragmentation due to human encroachment has isolated and scattered forest patches and limestone karsts. Agroforestry has been touted as a sustainable solution for the agriculture sector to yield crops and also provide alternative habitats for wildlife outside protected areas and linking forest patches and isolated limestone karsts. This initial survey was conducted to evaluate small mammals (bats and non-volant) assemblages present in a mixed fruit orchard bordering Bukit Bekong limestone massif in Merapoh, Pahang. We captured 193 individuals from 28 species (13 for bats & 15 for non-volant) using mist nets, harp traps and cage traps. This orchard contains *Nycteris tragata* and *Kerivoula pellucida*, listed as Near Threatened plus *Maxomys rajah* as Vulnerable in the IUCN Red List, revealing the fact that this small area in comparison to protected areas possesses unprecedented conservation value. Furthermore, 15 out of 28 small mammal species captured are habitat generalist may provide a cause of concern for the loss of forest specialists. Nonetheless, our results show that less intensively managed agroforest like mixed fruit orchard can also support forest specialists that are sensitive to disturbance. Moreover, the presence of limestone karst nearby contributes to bat diversity, especially cave-roosting bats. In summary, the diversity of small mammals in agroforest is worth to be studied as the species accumulation curve in this one mixed fruit orchard has yet to reach an asymptote. We hope future biodiversity data in agroforest will be incorporated in agriculture management strategies to stimulate sustainable agriculture and promoting mammal diversity.

1. Introduction

The role of forest reserves and national parks are a no-brainer for wildlife conservation. Nevertheless, this approach alone is not adequate to meet conservation goals, especially in the ever-increasing human encroachment activities, whether illegally or legally into these pristine ecosystems. Other conservation strategies need to be implemented to complement protected areas (forest reserve and national park) for more efficient and sustainable biodiversity conservation [2]. One such strategy is the biodiversity assessment and management of agroforestry system. Agroforestry is the practice of incorporating shade trees (native or foreign) with crops [1]. This system has been touted as a sustainable solution to the standard monoculture agriculture model in which this modified human habitat acts as a buffer zone and refuge for wildlife outside protected areas plus providing additional resources for mammals [1], [14],



[20]. Many mammalian carnivores (Carnivora) uses agroforest as corridors linking forest patches [3]. The abundance of small mammals was greater in agroforests near these forest patches [2]. The conservation values of agroforestry cannot be denied but can be greatly reduced with higher intensity of management practices aiming to increase crop yield [21]. Low-impact agroforestry contributes to bat diversity by serving as foraging sites and commuting pathways [25]. Thus, there is a need to find the right balance to accomplish both conservation and agriculture goals sustainably and realistically.

On the other hand, limestone karst landscapes, widely regarded as arks of biodiversity, are becoming increasingly isolated and fragmented by agriculture [23]. Agroforestry systems near limestone karst can connect those fragmented landscapes and reduce pressure on limestone forest [1]. Furthermore, limestone karst provides a permanent shelter for bats that are synonymously known to associate with caves as one of their roosting sites. The largest cluster of bats usually found inside caves. Caves minimised risks of predation and shelter bats from incompatible weather conditions. On the contrary, there are non-volant mammal species endemic to limestone karst, known examples including *Leopoldamys neilli* and *Niviventer hinpoon* in Thailand [10]. Notably, the sighting of *Petaurista petaurista* on a steep limestone wall in Merapoh, Malaysia shows us there is more to discover on the biodiversity in this ecosystem and how the fauna utilise the karst ecologically [12]. In this initial survey, we studied the species diversity and abundance of small mammals consisting of bats and non-volant mammals in a mixed fruit orchard at Bukit Bekong, Merapoh, Pahang, Malaysia. The diversity information on the small mammals found in this mixed fruit orchard then used to classify their foraging strategies and original habitat for a more precise look at how these mammals utilise the agroforestry system. We hypothesised (a) Fruit trees in the orchard attract a higher diversity of frugivores (b) A more significant number of generalist species in the mixed fruit orchard than forest specialists.

2. Materials and Method

2.1. Study Area

Merapoh is a small town located next to the Pahang-Kelantan border about 30 km from Gua Musang in Kelantan and 80.7 km from Kuala Lipis in Pahang. Surrounded by a large number of limestone hills of the Gua Musang Formation, the Merapoh cave system consisting of 85 explored caves believed to be 130 million years old along with many more unexplored caves waiting to be discovered. The abundance of limestone hills in Merapoh and the vicinity of Taman Negara Pahang Sungai Relau and several forest reserves including Persit Forest Reserve, Sungai Yu Forest Reserve and Tanum Forest Reserve have blessed the area rich in biodiversity, particularly karst flora and fauna [12]. The sampling site is located in a mixed fruit orchard agroforestry system that borders Bukit Bekong limestone massif (4° 41' 37.75" N, 102° 1' 13.96" E). This orchard consists of fruit trees like durian, cocoa and rambutan plus native forest trees including figs. Bukit Bekong limestone massif is roughly 0.211km² in size and approximately located 5 km away from the entrance to Taman Negara Sungai Relau [11]. This survey was conducted in the mixed fruit orchard in 2 phases: Phase 1 (20th July-20th August for 30 days) and Phase 2 (25 January 2020 till 9 February 2020 for 12 days).

2.2 Methodology

This survey was conducted for 42 days/nights in which small non-volant mammal sampling transpired in Phase 1 and Phase 2 during the day while bat sampling only occurred in Phase 2 at night. Bats were captured using two mist nets and two harp traps which were placed along forest trails, orchard walkways and near the limestone wall. The traps were checked hourly throughout the night from 7:00 pm till 11:00 pm. Bat species identification was attributed to [9] and [4]. Selected bat captures were also collected as voucher specimens euthanized and preserved in ethanol. These were deposited at Natural Resource Museum Universiti Malaysia Kelantan's Jeli Campus. Furthermore, 80 collapsible cage traps baited

with banana and langsung were used to capture small non-volant mammals. The cage traps were set up on a grid of 10m x 10m per trap in the mixed fruit orchard agroforestry system. The trap location remained fixed for the entire sampling duration. All traps were observed and checked two times daily, at 10:00 am and 5:00 pm. Small non-volant mammal captures were identified up to species level, referring to [4]. Nail varnish was applied to the small mammal toe before releasing it back to its natural habitat for tagging purposes. Lastly, standard body measurements and weight of selected representatives of each species were taken for record purposes. Results are presented in the form of species composition at both sites with assessments of these mammals' most recent conservation status in the IUCN Red List of Threatened Species [5] and Red List of Mammals for Peninsular Malaysia Version 2.0 [18]. Species accumulation curve of small mammals was created to look at the adequacy of sampling effort over time.

3. Results and Discussion

A total of 193 individuals consisting of 28 species from nine families were recorded at the mixed fruit orchard in Merapoh. Bats had the highest individual count and species diversity compared to non-volant small mammals. The most abundant species caught is *Rhinolophus affinis* amounting to 28 individuals. By comparison, *Macroglossus minimus*, *Nycteris tragata*, *Kerivoula pellucida*, *Murina suilla* and *Paradoxurus hermaphroditus* were recorded as singletons. *Callosciurus erythraeus* was included in the species diversity data as confirmed observations. Among the species captured, *Nycteris tragata* and *Kerivoula pellucida* are listed as Near Threatened while *Maxomys rajah* is listed as Vulnerable in the IUCN Red List. Moreover, *M. minimus* and *R. pusillus* are listed as Data Deficient in the Red List of Mammals for Peninsular Malaysia Version 2. Also, both *C. erythraeus* and *Rattus tanezumi* are not assessed in the Red List of Mammals for Peninsular Malaysia Version 2 [18]. Table 1 shows the species composition of small mammals in this survey.

The species accumulation curve for small mammals in the mixed fruit orchard is shown in Figure 1. The curve has yet to reach asymptote level in 42 trapping days/nights indicating there possibly be more species to be found and recorded. The exponential increase of the curve after 30 days was due to the absence of bat sampling effort in Phase 1 (20 Jul-20 Aug 2019). Correspondingly, Phase 2 sampling (25 Jan-9 Feb 2020) was unable to recapture some of the small mammals recorded in Phase 1 which are *C. erythraeus*, *Lariscus insignis*, *M. rajah*, *Sundamys muelleri* and *Sundasciurus lowii*. We can infer the lack of these Phase 1 small mammals was due to inadequate sampling efforts in Phase 2 and the fruiting season during Phase 1 may attract more small mammals to the orchard.

In general, fruit trees in the orchard do attract frugivores as 67.86% of the small mammal species captured in this survey are either primary frugivores (Pteropodid bats) like *Cynopterus brachyotis* or opportunistic frugivores (squirrels and mice) such as *Callosciurus notatus* and *M. surifer* [4], [9], [17]. The mixed fruit orchard is similar to fruit gardens which attract a greater abundance and higher diversity of frugivorous mammals than natural forest as the annual fruiting events guarantee fruit availability compared to infrequent mass fruiting events in tropical forests [14]. Looking from the farmers' perspective, the attraction of these frugivorous mammals will only cause further damage to fruit crops, even though they provide essential ecosystem services like seed dispersal and pollination. One study provided a solution in planting wild native fruit tree *Muntingia calabura* to sway *C. sphinx* away from eating fruit crops as a non-destructive method to manage pests [22]. Likewise, keeping native plants among commercial fruit trees in orchards and plantations may bring about similar effects while simultaneously reduce the agricultural impact on natural forests.

Furthermore, previous studies have shown that agroforestry systems are dominated by habitat generalist species and lacking forest specialists like in natural forest [2], Sullivan & Sullivan 2006; [14]. This survey supports this pattern with 15 out of the 28 small mammal species captured occur in various habitats and able to adapt in disturbed areas. Examples of habitat generalist from this survey include *C. brachyotis*, *C. notatus*, *R. affinis*, *Tupaia glis* and *R. tiomanicus*. *C. brachyotis* can be classified into two different lineages; *C. brachyotis* which was formerly known as the "Sunda" lineage and commonly found in various habitats including disturbed ones, and *C. cf. brachyotis* 'Forest' which

is restricted to primary forest and old secondary forest [4], [6], [7]. There might be convergence between these two lineages in our capture as the forest patch at the top and fringes Bukit Bekong limestone massif is still intact. Since the mixed fruit orchard is located beside a limestone massif, there are still a high number of forest specialists and cave-roosting bats (13 out of 28) in our species capture. Forest specialist such as *Balionycteris seimundi* and *Rhinosciurus laticaudatus* possibly come from forest patches in the vicinity of the limestone or the forest on top of karst itself. Subsequently, it is not a surprise that more than half of the bat species captured are cave-roosting bats with the vicinity of the Bukit Bekong limestone massif. Examples of cave-roosting bats from this survey include *R. affinis*, *Hipposideros larvatus* and *N. tragata*. Aside from bats, non-volant mammals also utilise limestones like *R. tiomanicus* in Bukit Sarang, Bintulu, Sarawak and *S. muelleri* in Gua Ikan, Gunung Stong State Park, Kelantan [7], [26].

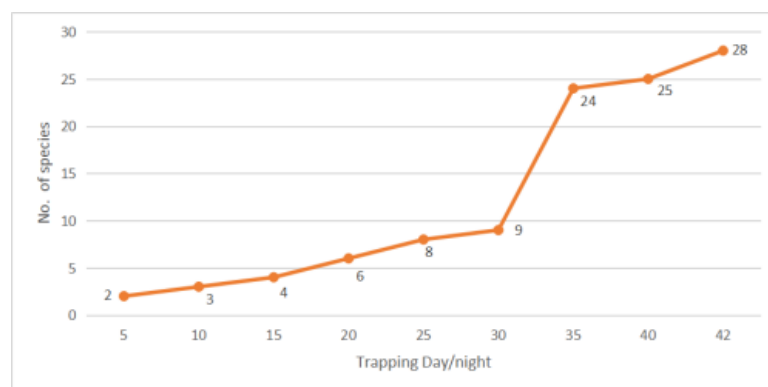


Figure 1. Small mammals species accumulation curve over time in the mixed fruit orchard

Most of the species captured in this survey such as *R. luctus*, *Murina suilla* and *Leopoldamys sabanus* can also be found in protected areas in Hulu Terengganu including Hutan Simpan Tembat and Taman Negara Terengganu [16]. Another comparison can be made with other agricultural modified habitats to get a clearer picture of mammal diversity on these types of habitat. Above all, this simple comparison highlight the unprecedented conservation value of this mixed fruit orchard and possibly other agroforests. The conservation of small mammals generally depends on protected areas, overlooking forest patches, limestone karst outcrops and agriculture modified habitats due to the lack of biodiversity data. Many studies conducted in Merapoh mostly refer to the Taman Negara section, not the town and collection of villages in the area [15], [8]. It is worth noting that this initial survey was conducted in a single mixed fruit orchard at one limestone massif, obtaining quite a high species diversity count (28 species in 42 trapping day/night). To reiterate, Merapoh has a total of 85 explored caves located in approximately 42 limestone massif, not fully explored in which some are near villagers' houses and agricultural lands such as orchards, rubber plantations, oil palm plantations and gardens. In a previous bat diversity study conducted at an undisclosed limestone massif in Merapoh, six bat species were recorded in which they were *C. brachyotis*, *C. horsfieldii*, *B. seimundi*, *Megaderma spasma*, *R. affinis* and *Myotis horsfieldii* [19]. Therefore, further surveys should be conducted in these agroecosystems and limestone karst outcrops to not only add to the biodiversity data for conservation efforts but to be used as tools to educate and empower local communities to practice sustainable agroforestry for the benefit of both locals; humans and animals.

Table 1. Small mammal species composition in mixed fruit orchard agroforestry system

No	Family Species	20 Jul - 20 Aug	25 Jan - 9 Feb	Total	IUCN Red List (2020)	PERHILITAN (2017)
Scandentia						
Tupaiaidae						
1	<i>Tupaia glis</i>	10	16	26	LC	LC
Chiroptera						
Pteropodidae						
2	<i>Balionycteris seimundi</i>	-	4	4	LC	LC
3	<i>Cynopterus brachyotis</i>	-	9	9	LC	LC
4	<i>Cynopterus sphinx</i>	-	2	2	LC	LC
5	<i>Macroglossus minimus</i>	-	1	1	LC	DD
Nycteridae						
6	<i>Nycteris tragata</i>	-	1	1	NT	LC
Rhinolophidae						
7	<i>Rhinolophus affinis</i>	-	28	28	LC	LC
8	<i>Rhinolophus luctus</i>	-	1	1	LC	LC
9	<i>Rhinolophus pusillus</i>	-	17	17	LC	DD
Hipposideridae						
10	<i>Hipposideros cf. bicolor</i>	-	12	12	LC	LC
11	<i>Hipposideros cineraceus</i>	-	2	2	LC	LC
12	<i>Hipposideros larvatus</i>	-	25	25	LC	LC
Vespertilionidae						
13	<i>Kerivoula pellucida</i>	-	1	1	NT	LC
	<i>Murina suilla</i>	-	1	1	LC	LC
Sciuridae						
15	<i>Callosciurus caniceps</i>	1	5	6	LC	LC
	<i>Callosciurus erythraeus</i> *	1	-	1	LC	NA
16	<i>Callosciurus nigrovittatus</i>	-	2	2	LC	LC
17	<i>Callosciurus notatus</i>	3	6	9	LC	LC
18	<i>Lariscus insignis</i>	2	-	2	LC	LC
19	<i>Rhinosciurus laticaudatus</i>	-	2	2	NT	LC
20	<i>Sundasciurus lowii</i>	4	-	4	LC	LC
Muridae						
22	<i>Leopoldamys sabanus</i>	-	2	2	LC	LC
	<i>Maxomys rajah</i>	3	-	3	VU	LC
23	<i>Maxomys surifer</i>	3	3	6	LC	LC
24	<i>Rattus tanezumi</i>	-	16	16	LC	NA
25	<i>Rattus tiomanicus</i>	-	7	7	LC	LC
26	<i>Sundamys muelleri</i>	2	-	2	LC	LC
Viveridae						
28	<i>Paradoxurus hermaphroditus</i>	-	1	1	LC	LC
Total individuals		29	164	193	-	-
Total species		9	23	28	-	-

Keys; *: Observed, NA: Not Assessed

Conclusion

This initial survey managed to record 28 new species locality records of small mammals (bats and non-volant) in Merapoh, at a single mixed fruit orchard near Bukit Bekong limestone massif. These findings indicate that there is conservation value in agriculture modified habitats, particularly agroforestry. We believe there is a need to document fauna on agricultural lands to supplement conservation efforts in already existing protected areas like national parks and forest reserve. Equally important, limestone karst outcrops serve as bat population reservoirs even in a fragmented forest landscape. The biodiversity data collected can be used to propose agriculture management strategies in conjunction with conservation goals to stimulate sustainable agriculture and promote mammal diversity.

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