Abundance, diversity and daily activity of terrestrial mammal and bird species in disturbed and undisturbed limestone habitats using camera trapping, Central Thailand

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Abstract: *Pla-ard M, Hoonheang W, Kaewdee B, Panganta T, Charaspet K, Khoiesri N, Paansri P, Kanka P, Chanachai Y, Thongbanthum J, Bangthong P, Sukmasuang R. 2021. Abundance, diversity and daily activity of terrestrial mammal and bird species in disturbed and undisturbed limestone habitats using camera trapping, Central Thailand. Biodiversitas 22: 3620-3631.* This study on the abundance, diversity and daily activity of terrestrial mammal and bird species was conducted in the limestone mountainous area of Central Thailand, located on the east of Dong Phaya Yen-Khao Yai forest complex. Camera traps were placed in both habitats disturbed by limestone mining and undisturbed habitat areas. From the study, a total of 38 species of mammals and birds from 27 families in 13 orders were recorded, including 15 species of mammals from 6 orders, 12 families and 23 species of birds from 14 families in 7 orders. Fifteen species of mammals were recorded in the undisturbed area and 11 were recorded in the disturbed area, with the Malayan Pangolin, Small Indian Civet and Grey-bellied Squirrel found in the undisturbed area. However, the number of bird species in the limestone mining area was larger than in the undisturbed area. It was also found that there was no difference in the overall abundance and diversity of mammalian species between disturbed and undisturbed areas, which is not in accordance with the hypothesis. But in the case of wild birds, the relative abundance of wild birds was found to differ significantly between areas. A high number was found in the areas with mining activities, although there was no difference in the diversity index of the two areas. However, it was found that when the combined data was analyzed, there was a significant difference in the daily activity of both mammals and wild birds in both areas. Many rare wildlife species were recorded during this study, for example, the Malayan Pangolin, Serow, Northern Pig-tailed Macaque, Rufous Limestone-babbler, Golden Jackal, Leopard Cat, Large-toothed Ferret Badger, Small Asian Mongoose, Common Palm Civet, Small Indian Civet, Malayan Porcupine. The key measure proposed is to preserve some natural habitats within the areas with mining activities, as wildlife remains in the area.

Keywords: karstic habitat, species diversity, relative abundance, activity pattern, time partitioning

INTRODUCTION

Limestone or karst mountains are sedimentary rocks formed by the accumulation of carbonates from marine organisms, together with changes of the Earth's crust, a geological evolutionary process that has happened for millions of years)Clements et al. 2006). In Asia, Karstic habitat covers an area of approximately 8.35 million km²)Grismer et al. 2021). Karst mountains of Southeast Asia cover an area of 460,000 km² or 10% of the total area)Day and Urich 2000(. Limestone or karstic habitats are originally rare terrestrial ecosystems. The size of Thailand's limestone mountain topography still lacks actual research data. However, it was found that the limestone mountain areas are widely distributed, from the north, west, central, east and down to the south of Thailand, but are not connected together as a large mountain range. Large areas of connected limestone mountains are found in the Western Forest Complex and around the Dong Phaya Yen-Khao Yai Forest Complex)Latinne et al. 2011), especially on the east

of the Dong Phaya Yen-Khao Yai forest complex which is a natural world heritage site and one of the most important limestone habitats)Clements et al. 2006).

Limestone mountains (Karstic habitat) are inhabited by many endemic living organisms including flora (Phutthai and Hughes 2017), wildlife and insects)Hughes 2017(. They are also areas with regular new species records)Liu et al. 2015(, especially rodents)Latinne et al. 2011), bats)Balete et al. 2013), birds (e.g. Alström et al. 2010), reptiles)e.g. Luu et al. 2016, 2017; Hughes 2017; Nazarov et al. 2018; Grismer et al. 2018, 2021), amphibians)Dehling 2011), fishes, invertebrates (Haase and Schilthuizen 2007) and many species of insects (Grinang 2013). There are still many living organisms within the limestone mountains that have not yet been studied)Chung et al. 2014). This is why it is a very important area for biodiversity conservation. At the same time, the limestone mountains are heavily threatened from many factors, including the expansion of agricultural land along the plains between the valleys and along the waterways, the expansion of the community,

construction of transport routes, drought conditions with water shortages during the dry season, forest fires and human activities within the area such as poaching, collecting forest products, logging and construction in the area)Woxvold et al. 2009; Lillo et al. 2019).

The significant threats to limestone mountain habitats arise from their use as feedstock for the cement industry, both for domestic construction and export. As well as the industrial sites within limestone mountains in various countries of Asia, one of the world's large cement industrial sites, especially in the People's Republic of China)Hughes 2017) which has the largest area of limestone mountain coverage in Asia. In Thailand, the allowance of the mining concessions accounts for approximately 20% of the total limestone mountain area (Latinne et al. 2011). The nature of making an industrial source is to open up the area, which severely threatens the survival of living creatures as well as this unique habitat (Hughes 2017).

The limestone mountain habitat of Saraburi Province is a part of the largest continuous limestone mountain range in Thailand (Latinne et al. 2011). It is also an important source of raw materials that have been constantly used in the cement industry for a long time. The cement concessionaire has carried out a project to restore natural resources in the area after the mining. The restoration includes soil amendment and planting trees, as well as protecting some areas for the preservation of local wild animals and plants (Siam Cement Group 2017) which follows the International Union for Conservation of Nature (IUCN) criteria (2014). However, there have been only a few follow-up studies.

Studies on the diversity, abundance and evenness of wildlife can indicate the direct response of wildlife to the environment)Tu et al. 2020). There have been few studies on the diversity of wildlife in limestone mountain ranges using camera traps. There has never been a wildlife diversity study using camera traps in limestone mountain habitats that have not been previously disturbed by mining. The results of the study can therefore be used as information for area management, species and wildlife population conservation, a measure of their integrity, leading to the success of further operations in the area.

In this study, the main hypothesis is that, when considering the diversity, abundance and activity of the wildlife, there will be a difference in the response of wildlife between the limestone habitats disturbed by mining and undisturbed areas. Undisturbed areas are expected to have greater diversity and abundance of wildlife than disturbed areas. Also, the activities of wildlife, especially mammals, in disturbed areas change to avoid human activities. The results obtained, in addition to knowing the species diversity and the numbers of wildlife in limestone habitats from camera traps which have been very little studied, the activity patterns of the wildlife that relate to the environment in the limestone mountains can also be used for efficient environmental management,

especially reducing the disturbance, to be suitable for the conservation of wildlife in limestone mountain habitats)Dias-Silva et al. 2018). The objectives of this study are: (i) To study the species and abundance of wildlife in the areas of the disturbed and undisturbed habitats, both combined and separate, and (ii) To study the activity patterns of the wildlife in the area, to understand the conditions of wildlife resources that still inhabit the limestone mountains, even though they are outside the protected area, for the benefit of proper conservation and restoration in the future.

MATERIALS AND METHODS

Study area

The study area was located in Kang Koi, Saraburi province following the eastern border of Dong Phaya Yen-Khao Yai Forest Complex, a world natural heritage site)UNESCO 2021), with a highway passing through between the study area and Dong Phaya Yen-Khao Yai Forest Complex. The study area was divided into two areas. The first area was an intact undisturbed limestone habitat covering an area of approximately 5.15 km^2 located between 14°40'52.2"-14°40'40.8" N and 101°05'51.7"-101°06'38.0"E approximately. The second area was a limestone quarry with ongoing mining activities from 1969 until the present and having an area of approximately 4.12 km^2 located between 14°39'54.1-14°39'41.6"N and 101°02'58.7-101°03'25.6"E approximately)Siam Cement Group 2017). The study area and camera trap locations are shown in Figure 1.

The general condition of both study areas is limestone mountains with an elevation of 10-252 m above sea level and a slope of 35-70 degrees. Limestone vegetation is extremely diverse in community types and very rich in endemic taxa (Hua 2002) as with this study area many flora species is specific to the limestone forest ecology, for example, *Phyllanthus mirabilis, Toona calcicole, Erythrina calcicole, Dracaena loureiroi, Dracaena kaweesakii, Cycas petrae, Santisukia kerrii, Toxicodendron calcicole, Ehretia laevis, Ficus anastomosans, Ficus glaberima, Ficus alongensis, Ficus pubipetiola, Mitrephora tomentosa, Garuga floribunda, etc.* Shrub species found are for example *Euphorbia antiquorum, Dracaena loureirin, Dracaena cochinchinensis, Dracaena jayniana, Dracaena kaweesakii, etc.*)Department of National Parks, Wildlife and Plant Conservation 2018). In this limestone mountain study area, there have been reports of the presence of the Rufous Limestone-babbler (*Turdinus calcicola*) which is an endemic species of the Saraburi limestone mountain (BirdLife International 2021). This indicates the long evolutionary natural history of this limestone mountain study area with remnant populations of wild bird species in the ecosystem.
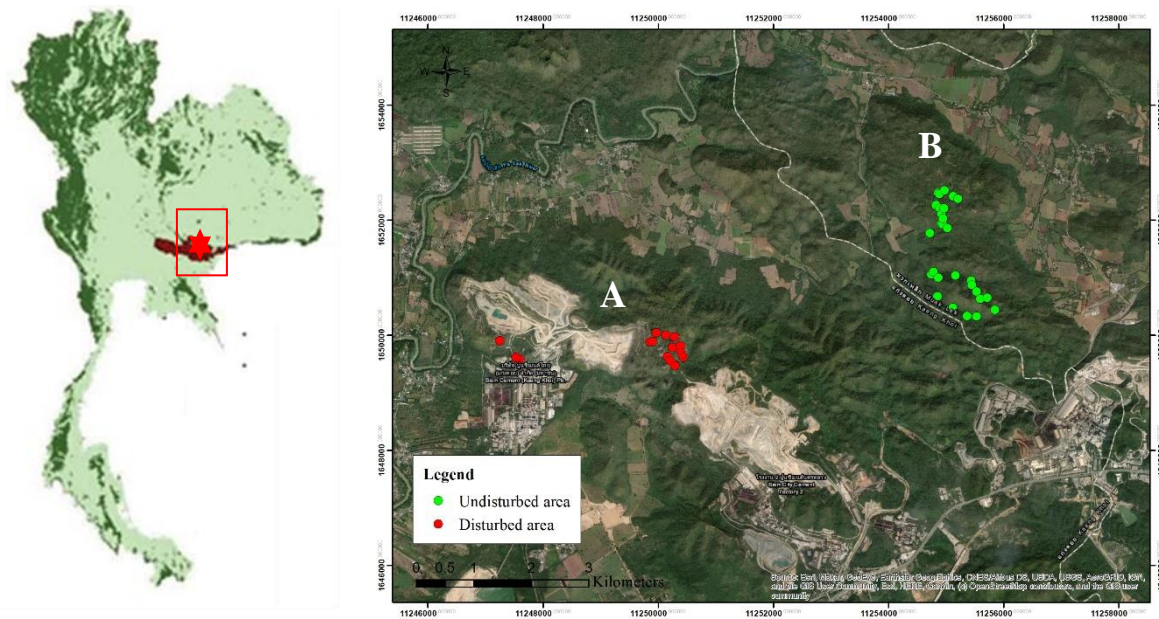
Figure 1. Map shows location of the study sites, red star, disturbed area (A) undisturbed area (B), and camera trap locations, red dots and green dots in each site in Kaeng Khoi District, Saraburi Province, Thailand. Source: Google Earth (2021)

The study area has a tropical savanna climate (Aw), following Köppen climate classification (Chen and Chen 2013), which has low precipitation and is dry. Based on the meteorological data of Saraburi province in the past 69 years, between 1951-2019, the seasons can be divided into 3 seasons including winter from mid-October to mid-February, the hot season from mid-February to mid-May, with hot and humid weather and the hottest month being April and the rainy season starts from mid-May to mid-October. The month with the highest precipitation is September. The average annual temperature is around 28-30 °C. The annual precipitation is between 1,200-1,400 mm with an average rainfall of 70-90 days per year (Department of Meteorological 2020).

Data collection

Field surveys were performed in the forests of both study areas. The first area chosen for the camera trap survey study was the disturbed area, which was conducted during November 2015-September 2016. For the undisturbed area, the camera trap survey was performed during November 2019-September 2020 due to the difficult conditions of the area with rough limestone terrain and being hard to access by using automatic camera traps, Bushnell Trophy Cam HD Essential E2 12MP Trail Camera sets. After selecting the appropriate camera trap location for the wildlife survey, the cameras were deployed systematically by placing them approximately 100-200 meters apart. This was performed following the recommendations of Jansen et al. (2014) on carrying out sample plots for long-term forest ecology studies to intensively study the interactions of wildlife in the ecosystem, and human activities)Keim et al. 2019). Eight to twelve cameras were placed in each study trip. A total of 16 camera trap locations were studied in the disturbed study area and 24 in the undisturbed area, which is related to the size of

the study area, adding up to a total of 40 locations. Photos were automatically captured when the sensor system detecting movement both during daytime and nighttime. The camera traps were placed over a period of 1 year in each area. This is consistent with Kays et al. (2020) who recommended that to monitor the diversity of wildlife within an area, a total of 40-60 camera trap locations should be used throughout the study period.

The camera traps were placed approximately 30 cm above the ground and set to work 24 hours, with 10-second interval between triggers)Jansen et al. 2014(. The GPS locations of the camera traps and the environmental conditions of the area were recorded. Some locations were changed due to the disturbance of the cameras.

The cameras were serviced monthly by downloading data from the memory cards and changing batteries throughout the twelve-month duration. The cameras were first placed within the disturbed area with limestone mining activities and once the data collection in the first area was complete, they were then moved to the second area and deployed for another 12 months. The images were downloaded from the memory cards into the computer and classified using Camera Trap Manager)Zaragozi et al. 2015(. The data was then imported into the Microsoft Excel program for data analysis.

Data analysis

Species identification

Only clearly identifiable images with the date and time shown on the images were classified. The mammalian species recorded were identified following Lekagul and McNeely)1988(and the wild bird species were identified following Lekagul and Round (1991). The common name, scientific name, taxonomic order and conservation status according to the IUCN (2021) were examined. This study uses the selection criterion for the images recorded from

the camera traps by selecting only the images that are independent of each other. The criteria for independence of animal images include: (1) Consecutive images of different animals, which may be the same or different species; (2) Consecutive images of the same animal, the same species with a time interval of more than 30 minutes and (3) Nonconsecutive images of the same animal or the same species)O'Brien et al. 2003(.

Diversity and evenness indices

The diversity of wildlife species was calculated using the Shannon-Weiner Index (H))Krebs 2014(of each species and overall following the formula,

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

Where: p_i = S/N
S = number of individuals of one species
N = total number of all individuals in the sample
In = logarithm to base e

The evenness index (E) (Pielou 1966) was calculated using the following formula

E = H/In S

Where:
H = Shannon-Wiener diversity index
S = total number of species in the sample

To use as an index for measuring the diversity of mammals and wild bird species in each area and overall)Harisha and Hosetti 2009), the wildlife diversity index was then compared between the disturbed and undisturbed areas using the Mann-Whitney U test, at the significance level of P<0.05.

Relative abundance

The relative abundance index (RAI) of each species recorded by the camera traps was calculated using the ratio between the presence of the image and the total number of trap nights, which is a widely used method e.g., according to the publications of Ouboter and Kadosoe (2016), Palmer et al. (2018) and Steinbeiser et al. (2019). The calculation uses the formula presented below.

$$\text{Relative abundance (\%)} = \frac{\text{trap success} \times 100}{\text{trap night}}$$

The %RAI of each species were compared between the disturbed and the undisturbed limestone habitat area using the Mann-Whitney U test, at the significance level of P<0.05.

Activity pattern

The information on the overall wildlife activity and the activity period of each species obtained from the camera traps was summarized. The time period was divided into daytime from 06:01-17:59 and nighttime from 18:00-06:00. The values were used to generate graphs of the activity

pattern of the wildlife species. The species were classified into 5 groups according to the time shown in the photograph)Kronfeld-Schor et al. 2013(. That is, if the number of images during the day is more than 85%, that animal will be grouped as strongly diurnal. If the number of daytime images is between 61-84%, it will be grouped as mostly diurnal. If the numbers of night and daytime images fall within 40-60%, it will be grouped as cathemeral. If the number of nighttime images is between 61-84%, it will be grouped as mostly nocturnal. If the number of images during the night was between 40-60%, the animal was classified to belong to a group with activities that overlapped between day and night (cathemeral). And if the number of images during the night is more than 85%, the animal will be grouped as strongly nocturnal (van Schaik and Griffiths 1996) (Table 1). The classification was done only on the species that were recorded more than 20 times (Cremonesi et al. 2021).

Active time

The analysis of the average active time of the wild animals were recorded by the camera traps from ~~independent images)O'Brien et al. 2003)~~ at 95% confidence interval was performed with ORIANA version 4.02 program (Kovach Computing Services 2011). Mardia-Watson-Wheeler Tests U^2 test)Mardia 1972) was used to test the difference of the time of presence between the 2 areas, at the significance level P < 0.05.

RESULTS AND DISCUSSION

Mammals

A total of 15 mammalian species from 6 orders, 12 families were recorded in the study area including Serow)*Capricornis sumatraensis*), Golden Jackal)*Canis aureus*), Northern Pig-tailed Macaque)*Macaca nemestrina*), Leopard Cat)*Prionailurus bengalensis*), Small Asian Mongoose)*Herpestes javanicus*), Malayan Porcupine)*Hystrix brachyura*), Large-toothed Ferret Badger)*Melogale personata*), Variable Squirrel)*Callosciurus finlaysoni*), Indochinese Ground Squirrel)*Menetes berdmorei*), Northern Tree Shrew)*Tupaia belangeri*), Common Palm Civet)*Paradoxurus hermaphroditus*), Small Indian Civet (*Viverricula indica*), Malayan Pangolin (*Manis javanica*), Grey-bellied Squirrel (*Callosciurus caniceps*) and rodent species that could not be identified from the photographs. The species with the largest distribution when considering from the highest number of locations present are Northern Pig-tailed Macaque (97.5%), Serow (85.0%) followed by Common Palm Civet (52.5%), Golden Jackal (52.0%), Variable Squirrel, Malayan Porcupine and Small Indian Civet, in this order.

When calculating the overall diversity index of mammalian species, it was found that in the limestone habitat study area, the Shannon-Weiner Index was 2.10 and the evenness index was 3.18.

The relative abundance index (%RAI) of the mammals was 26.96%. The species with the highest abundance was the Northern Pig-tailed Macaque with the value of 6.47%,

followed by Serow)6.40%), Variable Squirrel (3.22%), Indochinese Ground Squirrel (2.95%), Golden Jackal (2.03%) and Small Indian Civet (1.90%). From the species of mammals recorded in this study, one species: the Malayan Pangolin, is categorized as critically endangered and two species including serow and Northern Pig-tailed Macaque are categorized as vulnerable. Detailed information is shown in Table 1.

Wild birds

From the study, 23 species of wild birds from 14 families, 7 orders were recorded including Red Junglefowl (*Gallus gallus*), Eastern spotted Dove (*Streptopelia chinensis*), Blue-winged Pitta (*Pitta moluccensis*), Grey-capped Emerald Dove (*Chalcophaps indica*), White-rumped Shama (*Kittacincla malabarica*), Greater Coucal (*Centropus sinensis*), White-crested Laughingthrush (*Garrulax leucolophus*), Oriental Honey-buzzard (*Pernis ptilorhynchus*), Shikra (*Accipiter badius*), Black-capped Bulbul (*Pycnonotus melanicterus*), Red-wattled Lapwing (*Vanellus indicus*), Blue Rock-thrush (*Monticola solitarius*), Malayan Night-heron (*Gorsachius melanolophus*), Rufous Limestone-babbler (*Turdinus calcicola*), Black Drongo (*Dicrurus macrocercus*), Streak-eared Bulbul (*Pycnonotus blanfordi*), Sooty-headed Bulbul (*Pycnonotus aurigaster*), Blue Whistling-thrush (*Myophonus caeruleus*), Lesser Necklaced Laughingthrush (*Garrulax monileger*), Common Hoopoe (*Upupa epops*), Asian Brown Flycatcher (*Muscicapa dauurica*), Racket-tailed Treepie (*Crypsirina temia*) and Crested Goshawk (*Accipiter trivirgatus*).

When calculating the overall diversity index of the wild birds in the limestone mountain study area, it was found that the Shannon-Weiner Index was 2.65 and the evenness index was 2.08.

From the 23 species of birds recorded by the camera traps, the %RAI of each species from high to low included Red Junglefowl (3.20%), Eastern Spotted Dove (1.40%), Blue-winged Pitta and Grey-capped Emerald dove (0.44%), White-rumped Shama (0.32%), Greater Coucal (0.27%), White-crested Laughing Thrush (0.25%), Oriental Honey-buzzard (0.22%), Shikra (0.22%), Black-capped Bulbul (0.22%), Rufous Limestone-babbler (0.06%), etc. The distribution of birds from high to low for example are Red Junglefowl (65.0%), Grey-capped Emerald dove (25%), White-crested Laughing Thrush (22.5%), White-rumped Shama (20.0%), The Rufous Limestone-babbler, which is an endemic species, was found to have a 5.0% distribution.

From the wild birds recorded in this study, 22 species are listed in the least concern category and one, the Rufous Limestone-babbler is categorized as vulnerable as shown in Table 2.

Comparison between the disturbed and undisturbed habitat

Mammals

Results of the study from dividing the study area according to the disturbance characteristics of the limestone mountain area showed that, in the habitat undisturbed from limestone mining activities, 15 species of mammals were recorded. The important species, for example, are Serow, Northern Pig-tailed Macaque, Malayan Pangolin, Golden Jackal, Leopard Cat, Large-toothed Ferret Badger and Small Indian Civet. The species found only in the undisturbed habitat include the Small Indian Civet, Malayan Pangolin and Grey-bellied Squirrel. The Shannon-Wiener index was 2.05, the species evenness index was 2.85 and the %RAI was 29.31%.

Meanwhile, in the area disturbed by limestone mining activities, 12 species of mammals were recorded which were the same species as recorded in the undisturbed area. The Shannon-Wiener index was 1.89 and the species evenness index was 3.77. Comparison of the diversity of wild mammals between the undisturbed and disturbed areas, using the Mann-Whitney U test, showed that there was no significant difference)Z-0.70753, P= 0.4777).

The overall %RAI of wildlife was 24.64. When comparing the %RAI of the undisturbed and disturbed areas using the Mann-Whitney U test, it was found that there was no significant difference between the two areas)Z=1.73, P=.09). This means that even in limestone habitats with mining activities, the abundance of wildlife is still as rich as in the undisturbed or natural areas.

Wild birds

A total of 19 species of wild birds were found in the disturbed area and 11 species in the undisturbed area. The species found only in the undisturbed area were the Oriental Honey-buzzard, Racket-tailed Treepie, Malayan Night Heron and Common Hoopoe. The overall %RAI of the birds in the disturbed area was 8.70%, while the %RAI of the birds in the undisturbed area was 6.20%, slightly lower than the disturbed area. The Rufous Limestone-babbler, which is an important endemic species, was found only in the disturbed area. This shows the importance of conserving the area, even though limestone mining concessions are given.

When comparing the %RAI between the undisturbed and the disturbed area using the Mann-Whitney U test, it was found that there was a significant difference between the two areas (Z=-2.19692, P=0.0278). This means that wild birds species use the limestone areas even with mining activities, especially the ground foraging species.

Table 1. Activity pattern classification of the animals based on % number of images during day and night times gained from camera trap data.

Activity pattern	% Number of images during day and night		
	40-60%	61-84%	>85%
Day time	Cathemeral	Mostly diurnal	Strongly diurnal
Nighttime	Cathemeral	Mostly nocturnal	Strongly nocturnal

Table 2. The abundance of mammals and wild birds found in the limestone mountain area of Saraburi province, Thailand from 40 camera trap locations with a total of 6,308 trap nights

Common name	Scientific name	IUCN (2021)	Limestone study area		
			NOP	NOL)%)	%RAI
Mammalia					
Order Artiodactyla					
Family Bovidae					
Serow	*Capricornis sumatraensis*	VU	404	34(85.0)	6.40
Order Carnivora					
Family Canidae					
Golden Jackal	*Canis aureus*	LC	128	21(52.5)	2.03
Family Felidae					
Leopard Cat	*Prionailurus bengalensis*	LC	20	13(32.5)	0.32
Family Herpestidae					
Small Asian Mongoose	*Herpestes javanicus*	LC	31	16(40.0)	0.49
Family Mustelidae					
Large-toothed Ferret Badger	*Melogale personata*	LC	2	2(5.0)	0.03
Family Viverridae					
Common Palm Civet	*Paradoxurus hermaphroditus*	LC	90	21(52.5)	1.43
Small Indian Civet	*Viverricula indica*	LC	120	16(40.0)	1.90
Order Primate					
Family Cercopithecidae					
Northern Pig-tailed Macaque	*Macaca leonina*	VU	408	35(87.5)	6.47
Order Rodentia					
Family Muridae					
Rat	Murid spp.	-	26	7(17.5)	0.41
Family Hystricidae					
Malayan Porcupine	*Hystrix brachyura*	LC	58	16(40.0)	0.92
Family Sciuridae					
Variable Squirrel	*Callosciurus finlaysoni*	LC	203	20(50.0)	3.22
Indochinese Ground Squirrel	*Menetes berdmorei*	LC	186	16(40.0)	2.95
Grey-bellied Squirrel	*Callosciurus caniceps*	-	7	5(12.5)	0.11
Order Scandentia					
Family Tupaiidae					
Northern Treeshrew	*Tupaia belangeri*	LC	16	5(12.5)	0.25
Order Pholidota					
Family Manidae					
Malayan Pangolin	*Manis javanica*	CR	2	2(5.0)	0.03
Wild birds					
Order Galliformes					
Family Phasianidae					
Red Junglefowl	*Gallus gallus*	LC	202	26(65.0)	3.20
Order Passeriformes					
Family Pittidae					
Blue-winged Pitta	*Pitta moluccensis*	LC	28	3(7.5)	0.44
Family Pycnonotidae					
Streak-eared Bulbul	*Pycnonotus blanfordi*	LC	3	1(2.5)	0.05
Sooty-headed Bulbul	*Pycnonotus aurigaster*	LC	2	1(2.5)	0.03
Black-capped Bulbul	*Pycnonotus melanicterus*	LC	6	3(7.5)	0.10
Family Leiothrichidae					
White-crested Laughingthrush	*Garrulax leucolophus*	LC	16	9(22.5)	0.25
Lesser Necklaced Laughingthrush	*Garrulax monileger*	LC	2	2(5.0)	0.03
Family Muscicapidae					
White-rumped Shama	*Kittacincla malabarica*	LC	20	8(20.0)	0.32
Blue Rock-thrush	*Monticola solitarius*	LC	5	3(7.5)	0.08
Asian Brown Flycatcher	*Muscicapa dauurica*	LC	1	1(2.5)	0.02
Blue Whistling-thrush	*Myophonus caeruleus*	LC	2	2(5.0)	0.03
Family Pellorneidae					
Rufous Limestone-babbler	*Turdinus calcicola*	VU	4	2(5.0)	0.06
Family Dicruridae					
Black Drongo	*Dicrurus macrocercus*	LC	4	1(2.5)	0.06
Family Corvidae					
Racket-tailed Treepie	*Crypsirina temia*	LC	1	1(2.5)	0.02
Order Columbidae					
Family Columbidae					
Grey-capped Emerald Dove	*Chalcophaps indica*	LC	28	10(25.0)	0.44
Eastern Spotted Dove	*Streptopelia chinensis*	LC	88	4(10.0)	1.40

			NOP	NOL	RAI
Order Cuculiformes					
Family Cuculidae					
Greater coucal	*Centropus sinensis*	LC	17	4(10.0)	0.27
Order Charadriiformes					
Family Charadriidae					
Red-wattled Lapwing	*Vanellus indicus*	LC	6	1(2.5)	0.10
Order Accipitriformes					
Family Accipitridae					
Crested Goshawk	*Accipiter trivirgatus*	LC	1	1(2.5)	0.02
Oriental Honey-buzzard	*Pernis ptilorhynchus*	LC	14	3(7.5)	0.22
Shikra	*Accipiter badius*	LC	14	1(2.5)	0.22
Oder Pelecaniformes					
Family Ardeidae					
Malayan Night-heron	*Gorsachius melanolophus*	LC	5	2(5.0)	0.08
Order Bucerotiformes					
Family Upupidae					
Common Hoopoe	*Upupa epops*	LC	2	2(5.0)	0.03
Sum			**471**	**91**	**7.47**

Note: NOP: number of photos, NOL = number of camera trap locations found, RAI: relative abundance index

When considering the diversity of wild birds in the undisturbed habitat. The diversity index calculated with the Shannon-Weiner index was 1.2083, while the evenness of the species in the area following the species evenness index was 1.8851. And in the disturbed habitat, the Shannon-Weiner index was 2.1412 and the species evenness index was 1.8406. Results from the different test on the diversity of birds in the undisturbed and disturbed habitat using the Mann-Whitney U test showed no difference between the two areas)Z-0.12911, P= 0.89656). Details are shown in Tables 3-4.

Activity pattern

The activity patterns were considered in the mammalian species, which had more than 20 images recorded by camera traps. The species were categorized into 4 groups following their activity pattern which are: (i) Strongly nocturnal including Common Palm Civet, Small Indian Civet and Malayan Porcupine; (ii) Mostly nocturnal including Serow, Golden Jackal and Leopard Cat; (iii) Mostly diurnal including Indochinese Ground Squirrel and (iv) Strongly diurnal including Small Asian Mongoose, Northern Pig-tailed Macaque and Variable Squirrel.

When compared between the undisturbed and disturbed areas, it was found that the overall activity in both areas was mostly nocturnal, with variation in some species. For example, the Serows in the disturbed area have mostly nocturnal activities due to the avoidance of human activities, whereas in the undisturbed area, their activities are cathemeral, as there is no human disturbance during the daytime.

Twenty-three species of ground foraging birds were recorded in this study, all of which were recorded during the daytime. Therefore, the activity patterns of all species of wild birds were strongly diurnal, with the exception of the Malayan Night Heron, which had a total of 5 images recorded showing the activity pattern to be cathemeral, as shown in Table 4.

Difference in the time of presence

When considering the comparison of the average activity time of some species of mammals and Red Junglefowl, a ground foraging bird species with enough images to test the difference between undisturbed and disturbed habitat, it was found that there was no difference in the activity cycle of the Small Indian Mongoose, Common Palm Civet, Leopard Cat and Red Junglefowl between the two areas. Although the differences could not be considered from the classified time of presence in both areas when considering only the activity patterns, as shown in Table 5, when the overall data was analyzed, it was found that the time-of-presence of mammals and wild birds recorded from the camera traps in both areas were significantly different)Mardia-Watson-Wheeler Tests P<0.01), as shown in Table 6.

Discussion

Camera traps enable photographic data of mammals and birds in remote areas. They can record images at a natural recording rate, which cannot be carried out with direct observation from the researcher, especially in hard-to-reach areas such as in the middle of the limestone mountains (Cloyed et al. 2017). Results from this study on the diversity of mammals and wild birds in the limestone mountains show we were able to record 15 species of mammals from 6 orders with 12 families and 23 species of wild birds from 14 families in 7 orders, adding up to a total of 38 wildlife species from 27 families and 13 orders. This result is similar to the study by Mo et al. (2019) who studied mammals and birds in Jianfengling District, Hainan Island and reported 15 species of mammals and 33 species of birds. Shi et al. (2017) conducted a study using 83 camera trap locations with 10,961 trap days in Wolong National Nature Reserve, Sichuan Province, China during 2014-2016 and found 32 species of mammals and 59 species of birds. Sukmasuang et al. (2020) reported 23 species of mammals and 10 species of wild birds from camera trap surveys in 21 locations with 3,172 trap nights along the highway that passes through Khao Yai and Thap Lan National Parks.

Table 3. The abundance of mammals and wild birds found in the limestone mountain concession area at Kaeng Khoi District, Saraburi Province from 24 camera trap locations with a total of 3,121 traps nights in the undisturbed natural habitat and 16 camera trap locations, 3,187 trap nights in the limestone mining area

Common name	Undisturbed limestone				Disturbed limestone			
	NOP	NOL (%)	%RAI	-pi ln pi	NOP	NOL (%)	%RAI	-pi ln pi
Mammalia								
Serow	128	19 (79)	4.1	0.275	276	15 (94)	8.66	0.368
Northern Pig-tailed Macaque	253	22 (92)	8.11	0.355	155	13 (81)	4.86	0.32
Indochinese Ground Squirrel	91	9 (37)	2.92	0.230	95	7 (44)	2.98	0.255
Variable Squirrel	116	12 (50)	3.72	0.262	87	8 (50)	2.73	0.244
Common Palm Civet	14	9 (37)	0.45	0.064	76	12 (75)	2.38	0.226
Rat	3	3 (12)	0.1	0.019	23	4 (25)	0.72	0.103
Small Asian Mongoose	13	10 (42)	0.42	0.061	18	6 (37)	0.56	0.086
Malayan Porcupine	41	10 (42)	1.31	0.139	17	6 (37)	0.53	0.083
Golden Jackal	113	16 (67)	3.62	0.258	15	5 (31)	0.47	0.076
Northern Treeshrew	1	1 (4)	0.03	0.007	15	4 (25)	0.47	0.076
Leopard Cat	12	8 (33)	0.38	0.056	8	5 (31)	0.25	0.047
Large-toothed Ferret Badger	1	1 (4)	0.03	0.007	1	1 (6)	0.03	0.008
Small Indian Civet	120	16 (67)	3.84	0.266	0	0	0	0
Malayan Pangolin	2	2 (8)	0.06	0.013	0	0	0	0
Grey-bellied Squirrel	7	5 (20)	0.22	0.037	0	0	0	0
Sum	915		29.31	2.05	786		24.64	1.89
Aves								
Eastern Spotted Dove	1	1 (4)	0.03	0.026	87	3 (19)	2.73	0.364
Red Junglefowl	133	17 (70)	4.26	0.258	69	9 (56)	2.17	0.346
Blue-winged Pitta	0	0	0	0	28	3 (19)	0.88	0.232
Greater Coucal	2	2 (8)	0.06	0.045	15	2 (12)	0.47	0.158
Shikra	0	0	0	0	14	1 (6)	0.44	0.151
Grey-capped Emerald Dove	17	6 (25)	0.54	0.213	11	4 (24)	0.35	0.129
White-rumped Shama	10	5 (20)	0.32	0.153	10	3 (19)	0.31	0.119
White-crested Laughingthrush	8	5 (20)	0.26	0.133	8	4 (25)	0.25	0.102
Black-capped Bulbul	0	0	0	0	6	3 (19)	0.19	0.084
Red-wattled Lapwing	0	0	0	0	6	1 (6)	0.19	0.084
Blue Rock-thrush	0	0	0	0	5	3 (19)	0.16	0.073
Rufous Limestone-babbler	0	0	0	0	4	2 (12)	0.13	0.063
Black Drongo	0	0	0	0	4	1 (6)	0.13	0.063
Streak-eared Bulbul	0	0	0	0	3	1 (6)	0.09	0.047
Sooty-headed Bulbul	0	0	0	0	2	1 (6)	0.06	0.034
Lesser Necklaced Laughingthrush	0	0	0	0	2	2 (12)	0.06	0.034
Asian Brown Flycatcher	0	0	0	0	1	1 (6)	0.03	0.02
Blue Whistling Thrush	1	1 (4)	0.03	0.026	1	1 (6)	0.03	0.02
Crested Goshawk	0	0	0	0	1	1 (6)	0.03	0.02
Oriental Honey-buzzard	14	3 (12)	0.45	0.19	0	0	0	0
Racket-tailed Treepie	1	1 (4)	0.03	0.026	0	0	0	0
Malayan Night Heron	5	2 (8)	0.16	0.094	0	0	0	0
Common Hoopoe	2	2 (8)	0.06	0.045	0	0	0	0
Sum	**194**		**6.20**	**1.21**	**277**		**8.70**	**2.14**

Notes: NOP: Number of photo; NOL: Number of locations; RAI: Relative abundance

Table 4. Comparison of the number of species, diversity index and evenness index of the mammals and ground foraging birds recorded by the camera traps between the undisturbed and disturbed limestone habitats in Saraburi province, Thailand

	Undisturbed habitat	Disturbed habitat	Combined data
Mammalian diversity			
Number of species	15	12	15
Shannon-Weiner index	2.05	1.89	2.10
Evenness index	2.85	3.77	3.18
Terrestrial aves diversity			
Number of species	11	19	23
Shannon-Weiner index	1.21	2.14	2.65
Evenness index	1.88	1.84	2.08

The results from this study show that there was no significant difference in the %RAI and the Shanon-Weiner index of wild mammals between the disturbed and undisturbed areas. This means that there is no difference in the importance of conserving the wildlife habitat, whether it be an area with limestone mining activity. However, when considering the mammalian diversity index, it was found that the undisturbed area was higher for both the Shannon-Weiner index and the Evenness index but did not significant difference, which indicates the importance of the undisturbed area for the preservation of wild mammals, especially rare wildlife that are endangered or critically endangered.

Table 5. Comparison of the activity patterns of mammals and wild birds in the limestone mountain concession area between undisturbed and disturbed areas recorded by camera traps in central of Thailand

Species	Total Number of independent photos			No. photos during daytime (%)			Activity pattern		
	Undisturbed	Disturbed	Combined	Undisturbed	Disturbed	Combined	Undisturbed	Disturbed	Combined
Mammalian species									
Northern Pig-tailed Macaque	253	155	408	232(92)	153(99)	385(94)	SD	SD	SD
Serow	128	276	404	51(40)	42 (15)	93(23)	C	SN	MN
Variable Squirrel	116	87	203	103(89)	81(93)	184(90)	SD	SD	SD
Indochinese Ground Squirrel	91	95	186	83(91)	69(73)	152(81)	SD	MD	MD
Golden Jackal	113	15	128	42(37)	5 (33)	47(36)	MN	MN	MN
Small Indian Civet	120	0	120	5(4)	0(0)	5(4)	SN	-	SN
Common Palm Civet	14	76	90	0(0)	0(0)	0(0)	SN	SN	SN
Malayan Porcupine	41	17	58	1(2)	0(0)	1(1)	SN	SN	SN
Small Asian Mongoose	13	18	31	11(85)	16(89)	27(87)	SD	SD	SD
Rat	3	23	26	0(0)	1(4)	1(3)	Not classified	Not classified	Not classified
Leopard Cat	12	8	20	5(42)	1(13)	6(30)	C	SN	MN
Northern Treeshrew	1	15	16	0(0)	15(100)	15(93)	Not classified	Not classified	Not classified
Grey-bellied Squirrel	7	0	7	7(100)	0(0)	7(100)	Not classified	Not classified	Not classified
Malayan Pangolin	2	0	2	1(50)	0(0)	1(50)	Not classified	Not classified	Not classified
Large-toothed Ferret Badger	1	1	2	0(0)	0(0)	0(0)	Not classified	Not classified	Not classified
Sum	915	786	1701	541(31)	383(22)	934(54)	MN	MN	C
Aves species									
Red Junglefowl	133	69	202	115(86)	61(88)	176(87)	SD	SD	SD
Eastern Spotted Dove	1	87	88	1(100)	83(100)	84(95)	SD	SD	SD
Grey-capped Emerald Dove	17	11	28	17(100)	11(100)	28(100)	SD	SD	SD
Blue-winged Pitta	0	28	28	0(0)	28(100)	28(100)	SD	SD	SD
White-rumped Shama	10	10	20	8(80)	10(80)	18(90)	SD	SD	SD
Greater Coucal	2	15	17	2(100)	15(100)	17(100)	SD	SD	SD
White-crested Laughingthrush	8	8	16	6(75)	8(100)	14(87)	SD	SD	SD
Oriental Honey-buzzard	14	0	14	14(14)	0(0)	14(100)	SD	SD	SD
Shikra	0	14	14	0(0)	11(79)	11(78)	Not classified	Not classified	Not classified
Black-capped Bulbul	0	6	6	0(0)	6(100)	6(100)	Not classified	Not classified	Not classified
Red-wattled Lapwing	0	6	6	0(0)	6(100)	6(100)	Not classified	Not classified	Not classified
Malayan Night Heron	5	0	5	3(60)	0(0)	3(60)	Not classified	Not classified	Not classified
Blue Rock-thrush	0	5	5	0(0)	5(0)	5(100)	Not classified	Not classified	Not classified
Limestone Wren Babbler	0	4	4	0(0)	4(100)	4(100)	Not classified	Not classified	Not classified
Black Drongo	0	4	4	0(0)	4(100)	4(100)	Not classified	Not classified	Not classified
Streak-eared Bulbul	0	3	3	0(0)	3(100)	3(100)	Not classified	Not classified	Not classified
Common Hoopoe	2	0	2	2(100)	0(0)	2(100)	Not classified	Not classified	Not classified
Blue Whistling Thrush	1	1	2	1(100)	1(100)	2(100)	Not classified	Not classified	Not classified
Sooty-headed Bulbul	0	2	2	0(0)	2(100)	2(100)	Not classified	Not classified	Not classified
Lesser Necklaced Laughingthrush	0	2	2	0(0)	2(100)	2(100)	Not classified	Not classified	Not classified
Racket-tailed Treepie	1	0	1	1(100)	0(0)	1(100)	Not classified	Not classified	Not classified
Asian Brown Flycatcher	0	1	1	0(0)	1(0)	1(100)	Not classified	Not classified	Not classified
Crested Goshawk	0	1	1	0(0)	1(100)	1(100)	Not classified	Not classified	Not classified
Sum	**194**	**277**	**471**	**170(36)**	**262(94)**	**432(91)**	**MD**	**SD**	**SD**

Notes: SN = Strongly nocturnal, MN = Mostly nocturnal, MD = Mostly diurnal, SD = Strongly diurnal

Table 6. Comparison of the activity time of mammals and wild birds recorded from camera traps in the undisturbed and disturbed areas of species with large numbers recorded and the combined data of wildlife in the limestone mountain area of the central Thailand

Species	Undisturbed area		Disturbed area		Mardia-Watson-Wheeler Tests	
	n	Hour (SD)	n	Hour (SD)	W	P
Separated by species						
Northern Pig-tailed Macaque	2,556	12:27 (03:56)	760	12:03 (02:33)	312.26**	<0.01
Serow	875	22:00 (06:39)	1,415	23:21 (03:58)	121.46**	<0.01
Red Jungle-fowl	411	10:09 (04:51)	159	09:49 (04:58)	1.29 ns	0.52
Golden Jackal	399	01:42 (09:31)	33	05:26 (04:23)	11.59**	<0.01
Malayan Porcupine	266	02:16 (02:09)	72	23:38 (02:45)	11.203**	<0.01
Variable Squirrel	233	07:47 (03:02)	226	11:23 (04:51)	94.21**	<0.01
Common Palm Civet	62	23:21 (03:19)	119	00:08 (03:27)	1.37 ns	0.50
Leopard Cat	40	23:05 (06:00)	10	23:14 (03:26)	4.13 ns	0.13
Small Indian Mongoose	33	10:59 (03:37)	22	09:19 (03:58)	3.97 ns	0.14
Combined data						
All Mammalian species	4586	11:44 (06:05)	2672	22:52 (09:06)	337.16**	<0.01
All Aves species	463	11:20 (04:37)	653	12:38 (03:37)	93.458**	<0.01

In the case of wild birds, the RAI in the disturbed area was significantly higher than in the undisturbed area, as well as the Shannon-Weiner index and the Evenness index in the disturbed area which were also higher. This is consistent with a study by Tu et al. (2020) that natural and open spaces in bird habitats play an important role in increasing the diversity and evenness of wild bird species in the area. In the disturbed area, even with some mining activities, some areas have been preserved, thereby promoting greater bird diversity in the area. Therefore, preserving some parts of the area as well as conducting restoration activities by land adjustment and reforestation after mining, preventing disturbance by leaving enough habitat area and improvement of water and mineral resources are activities that can contribute to the conservation of wildlife in the area.

In the case of the wild birds in this study, we focused only on wild birds that forage on the ground and can be recorded by camera traps, thus the number of bird species is less than the number from sightings or net trapping. For example, the wild bird diversity study in Padawan limestone area, Sarawak, Malaysia by Mansor et al. (2011) reported the number of wild bird species in the limestone mountain area from several study methods including direct observation and using mist-nets, finding at least 80 species of birds from 34 families. Therefore, further studies on wild birds using other methods should be conducted.

In this study, the Malayan Pangolin, one of the listed critically endangered species, was recorded, as well as other vulnerable species including Serow, Northern Pig-tailed Macaque and the Rufous Limestone-babbler, an endemic species that is only found in the study area. Furthermore several important species, for example, Leopard Cat, Golden Jackal, Malayan Porcupine, Large-toothed Ferret Badger, Small Indian Civet, Common Palm Civet and Small Asian Mongoose were also recorded. The camera traps in 2 locations were also able to record images of the Elongated Tortoise)*Indotestudo elongata*) which is another critically endangered species listed by the IUCN (2021).

The comparison of the overall wildlife activity pattern recorded from the camera traps in the study showed that both mammals and birds avoid human activities and are more active during the quieter hours. It was also found that the activity patterns are significantly different within the two areas. However, different wildlife species respond differently to disturbance activities. The most obvious ones are the serow and the leopard cat. This is similar to the study by Cremonesi et al. (2021) who reported the variation in the activities of medium-sized mammals between disturbed habitats and undisturbed habitats in Myanmar in the form of human activity avoidance. Similarly, the results of this study showed that in the mining activity area, Serows and Leopard Cats have variations of the activity pattern and are strongly nocturnal, whereas, in the undisturbed areas the activity patterns are more cathemeral. In the wild birds, especially Red Junglefowl, there was no difference in the activity patterns between the two areas.

In conclusion, the results of the camera trap survey conducted in the limestone mountains of Saraburi province recorded 15 species of mammals from 6 orders, 12 families and 23 species of wild birds from 15 families 7 orders, adding up to a total of 38 species from 27 families, 13 orders. The results of the study record 15 species of mammals in the undisturbed area and 11 in the disturbed area. The Malayan Pangolin, Small Indian Civet and Grey-bellied Squirrel, as well as the Elongated Tortoise, were found in the undisturbed area, while the number of wild bird species in the disturbed areas was more than in the undisturbed area. It was also found that the overall abundance and diversity of mammals in the disturbed and undisturbed areas were similar, which is not in accordance with the hypothesis. However, for the wild bird species, the relative abundance was different between the two areas, with the higher value found in the mining area which is more open, while there was no significant difference in the diversity index of the wild birds in the two areas. This shows the importance of conservation in both areas, with and without disturbance activities. For the activity patterns of the wildlife, the results show many species of wildlife

e.g., Malayan Pangolin, Serow, Northern Pig-tailed Macaque, Rufous Limestone-babbler, Elongated Tortoise, Golden Jackal, Leopard Cat, Large-toothed Ferret Badger, Small Asian Mongoose, Common Palm Civet, Small Indian Civet, Malayan Porcupine, etc. Therefore, it is important to recognize the importance of the area to preserve the natural resources that still exist. The management by conserving the natural areas in the limestone quarry activity areas as a wildlife refuge is important. Furthermore, the restoration, conditioning the area after mining, increasing water resources, food sources, public relations, education and training for youths in the form of a natural learning center for the natural restoration process as well as wildlife management in the limestone mountain area should be conducted. The size of the trapping area did not influence the number of species caught on camera. It is logistically most efficient to keep the trapping area as small as possible (Tobler et al. 2008), in this study the sampling area remains representative of the total habitat as much as possible.

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