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Species diversity, abundance, and movement of small mammals in the dry evergreen forest at Khao Yai National Park, Thailand

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Abstract. *Chanachai Y, Nathalang A, Duengkae P, Sukmasuang R. 2022. Species diversity, abundance, and movement of small mammals in the dry evergreen forest at Khao Yai National Park, Thailand. Biodiversitas 23: 5892-5901.* Small mammals play an integral role in the forest ecosystem. This research was conducted on The Mo Singto Forest Dynamics Plot, Khao Yai National Park. Trapping of small mammals was carried out in June-September 2019 and from January-April 2020 based on a total of 64 Tomahawk for small mammal live traps were systematically placed in an 8×8 grid of 20 m intervals, ripe bananas and palm oil as bait was used. Trap cages were opened for 3 consecutive months per season in each study period covering a total study period of 1 year. The result showed that a total of 4015 individuals from 9 species, 9 genera, 4 families and 3 orders were captured with a sampling effort of 32,555 trap nights. The most common species were Red Spiny Rat (*Maxomys surifer*), followed by Northern Tree Shrew (*Tupaia belangeri*), Long-tailed Giant Rat (*Leopoldamys sabanus*), Indochinese Ground Squirrel (*Menetes berdmorei*), Asian House Rat (*Rattus tanezumi*), Indomalayan Niviventer (*Niviventer fulvescens*), Savile's Bandicoot Rat (*Bandicota savilei*), (*Tamiops mcclellandii*), and Short-tailed Gymnure (Hylomys *suillus*) respectively. Considering the number of small mammals caught, *Maxomys surifer* was the most abundant, accounting for 61.69% of all mammals caught. The sex ratio was found to somewhat favor females in both seasons. This study indicated that the small mammal diversity was high in the primary dry evergreen forest. These results have important implications not only for conservation but are also useful for further investigation if there is any disturbance or change in the area or any potential disasters that may occur in the future.

Keywords: Dong Phaya Yen-Khao Yai Forest Complex, forest dynamics plot, population characteristics, small rodent

INTRODUCTION

Small mammals play an integral role in forest ecosystems as prey, benefitting mammalian and avian predators in forested areas (Kang et al. 2013). They are also important in seed and spore dispersal, pollination, seed predation, energy and nutrient cycling, and the modification of plant succession and species composition (Witmer and Shiels 2018). Approximately 42% of all mammalian species in the world are rodents, amounting to about 2277 species (Witmer and Shiels 2018). Thus, small rodents have a very high potential role in the ecosystem (Fischer et al. 2017). Small rodents are also essential to humans for animal experiments (Vandamme 2014). However, rodents also have negative effects on humans. Rodents present a major problem for food security in Asia (Singleton et al. 2021). Rodents are known to be reservoir hosts for at least 60 zoonotic diseases and are known to play an important role in their transmission and spread in different ways (Dahmana et al. 2020). In the aspect of species diversity, rodent species refers to the range and abundance of species in an area and is also a reliable indicator of ecosystem health (Simelane et al. 2018). Reduced community evenness can indicate species and diversity declines, resulting in the homogenization of formerly diverse landscapes and the extinction of local species (Magurran 2007). The presence of invasive rodent species in a landscape can also indicate land disturbance, displacement of indigenous species, and, most likely, declines in biodiversity (Ramahlo et al. 2022). Along with the presence and number of species, it is essential to record the diversity of a region over time, as this further demonstrates how impactful anthropogenic activities are upon natural environments (Christie et al. 2019). The investigation of the presence of land-use-based species can inform about the impact of various alterations to landscapes and determine which human activities are most impactful upon the ecosystem and resident species (Aronson et al. 2016). Estimating population size and understanding its variation is a fundamental yet complicated aim of many ecological studies (Tenan et al. 2013).

Moreover, animal movement patterns and distances vary depending on individual needs. For instance, climatic seasons will affect food resources (Naxara et al. 2009), and during food shortage periods, animals might have to move longer distances to find food (Loretto and Vieira 2005) and the same happens for animals with larger body sizes that need more food resources (Lima et al. 2016). The results not only provide evidence for future comparisons but also increase knowledge of species diversity and the abundance of these wild animals, including the species' movement. This knowledge is useful for understanding the interactions in both temporal and spatial aspects of the various species with their environment, mainly based on variations in the forest dynamics in this ecosystem. This can provide guidance for further management.

The monitoring of small mammals in Khao Yai National Park (KYNP), where the ecosystems are still intact, is rarely conducted. It is necessary to study the composition of the population structure as well as the interactions of the wildlife in terms of population structure, sex ratio, movement in relation to the season, as well as different habitat conditions according to the replacement of natural ecosystems. In addition to creating an understanding of the interactions of this wildlife, the study can also be used as a base for tracking wildlife that is sensitive to environmental changes. These include climate change, disturbances from human activities, the invasion of exotic wildlife, and the spread of disease and insects. The findings may also be used in terms of ecosystem management to maintain carnivorous wildlife populations of both terrestrial animals as well as almost all species of carnivorous birds that are under threat and should be closely monitored.

KYNP is the first national park in Thailand and was declared a natural World Heritage site by UNESCO in 2005 (UNESCO 2022). Furthermore, it is also an important protected area that exhibits various habitats for a diverse collection of flora and fauna. However, the impact on the area from direct human activities, and especially tourism activities, is ongoing. The impact of infrastructure development around the area, agricultural area expansion allowing pets to enter the area, as well as the impacts of global climate change are still threatening factors in the region.

The Mo Singto (MST) Forest Dynamics Plot, which is distinguishable from most other plots in the Forest Global Earth Observatory (ForestGEO) network, is located near the head office of the park for long-term ecological research by studying the natural dynamics related to the various environments. The study of small mammals in the MST Forest Dynamics Plot was previously conducted by Suzuki et al. (2007) with camera traps. Seven species of small mammals were found when studying fruit visitation patterns. The study found that four Muridae species, Island rat (*Rattus remotus*), Chestnut White-bellied Rat (*Niviventer fulvescens*), Long-tailed Giant Rat (*Leopoldamys sabanus*), and Red Spiny Rat (*Maxomys surifer*), all of which were nocturnal, were almost completely temporally segregated from the Tree Shrew, *Tupaia belangeri*, and the two squirrels, Finlayson's Squirrel (*Callosciurus finlaysonii*) and Berdmore's Ground Squirrel (*Menetes berdmorei*), which were diurnal or crepuscular. Studies on small mammals remain an urgent matter. Therefore, the expected results of diversity, abundance, population characteristics, and some movement studies of the small mammal community in the MST Forest Dynamics Plot will be a baseline study that can increase the ecological knowledge of these small mammals. Such studies are uncommon in Thailand, so this work can be used for more understanding and as an important tool for habitat management especially the disturbances caused by human activities.

The objectives of this study were (1) to investigate the species composition and population characteristics of small terrestrial mammals and (2) to investigate the movements of the small mammals in the dry seasonal evergreen forest areas. The knowledge gained from this study is expected to be of use for forest management and restoration and as a tool for the conservation of other species, especially medium and small carnivore species of similar areas.

MATERIALS AND METHODS

Study area

The research was conducted on the MST Forest Dynamics Plot in Khao Yai National Park (KYNP), Thailand (Figure 1). KYNP was established since 1962, covering 2168 km^2 and exhibiting a diverse collection of flora and fauna. This national park was a part of the Dong Phayayen-Khao Yai Forest Complex. The MST Forest Dynamics is 30.48 ha in area and is part of the Center of Tropical Forest Science (CTFS). Forest GEO worldwide network of large forest plots coordinated by the CTFS, Smithsonian Tropical Research Institute, Washington, DC (Anderson-Teixeira et al. 2015). The climate is monsoon with heavy rainfall in the rainy season from May to October and a dry season from November to April. Average annual rainfall has been approximately 2200 mm (Brockelman et al. 2017). However, based on 10 years of meteorology data around the head office in the park (2009-2018), the area receives 1897 mm of annual rainfall with an average temperature of 21°C. The northeastern region of the park falls within a rain shadow area and has an annual rainfall of 1300 mm (National Parks Research and Innovation Development Center 2018).

Data collection

Due to the differences in plant community composition even in the same dry evergreen forest type as well as forest areas that are in the process of being rehabilitated naturally condition or secondary forests. Therefore, 3 plots of the study area were determined in 2 different places of the dry evergreen forests and 1 in the rehabilitated area or secondary forest around the permanent plot. Thus, three small mammal trapping grids were established on the forest floor covering primary dry evergreen forest (grid 1 and grid 3) and secondary forest (grid 2). Trapping was conducted in 2 sessions, including session 1 (the rainy season) covering June-September 2019 and session 2 (the dry season) from January-April 2020, with the same number of trap nights in every small mammal trapping grid.

Three small mammals, 3 trapping grids, grids 1 and 3 in the primary dry evergreen forest with the most similar geography characteristics can be done to reduce the variation of geographic variables. Whereas grid 2 placed in the secondary forest, was established on the forest floor, 200 meters distant, so that each grid covered an area of 25600 m^2. Thus 76800 m^2 was the total study area. The cage was placed on the forest floor, the base of the tree, Grid 1 and 3, the primary forest plot, the cage ground was flat and down the hill, Grid 3 was the highest, Grid 2 was the second-generation forest where the trees are not dense. There is less wood on the ground floor. The hill is not as high as Grids 1 and 3.

A total of 64 Tomahawk live traps (5.5×6.5×16 cm) were systematically placed in an 8×8 grid at 20 m intervals, and ripe bananas and palm oil as bait were used (Ardente et al. 2017; Francis 2019). Trap cages were opened for 3 consecutive months per season, or 1 session, in each study period covering a total study period of 1 year, amounting to 32,555 trap-nights in total.

All traps were checked once a day in the morning (8.00-12.00 hours). All captured animals were measured for their important characteristics as follows: head and body length (HB), tail length (T), hind foot length (HF), and ear length (E), using a plastic digital vernier caliper while weighing was performed with a Newton spring weight balance. Each live-captured animal was marked with an ear tag and toe clipping. The reproductive condition of individuals was classified into two categories, juvenile and adult (Fuentes-Montemayor et al. 2009). The tagged animals were released back into the wild.

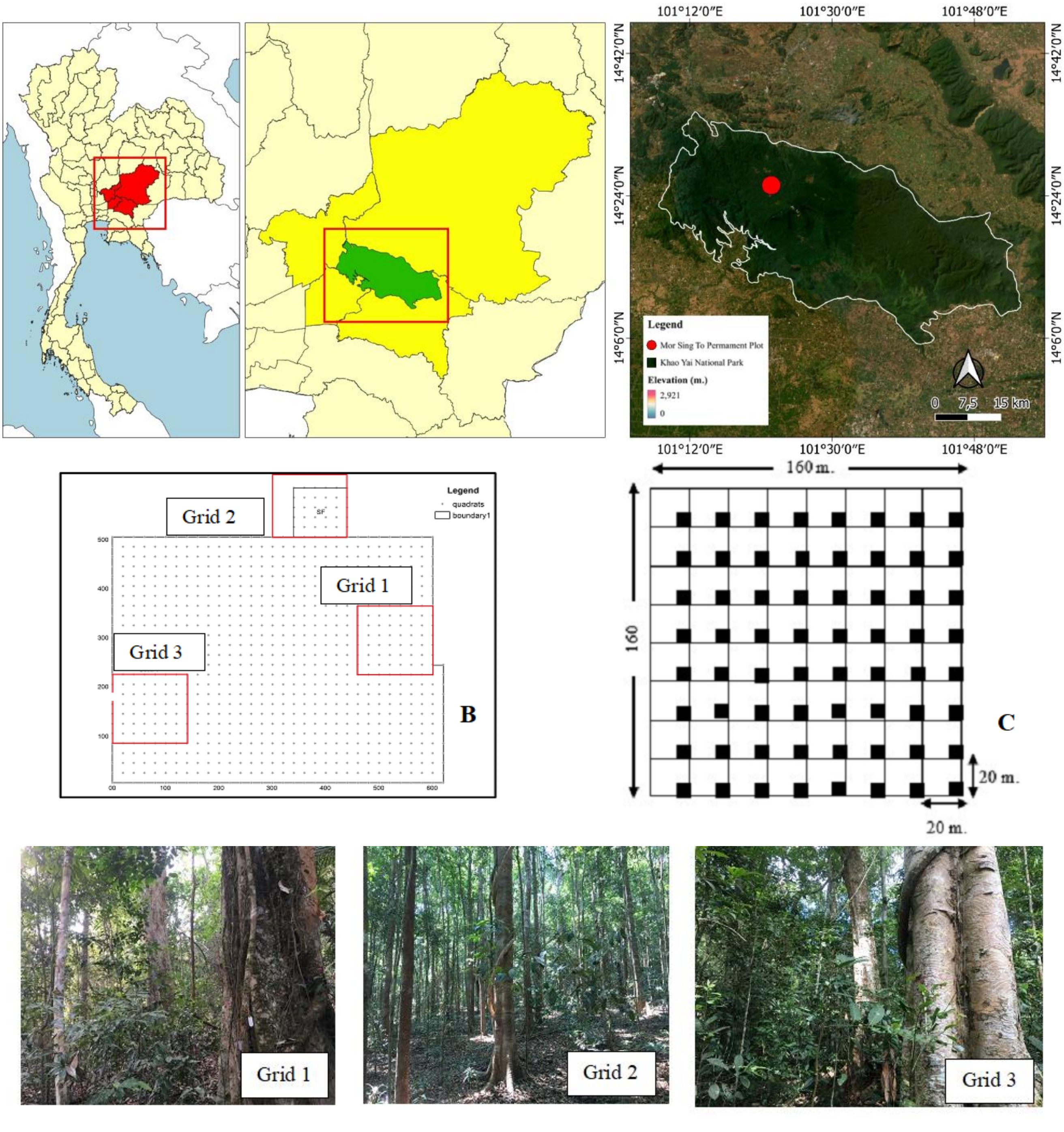

Figure 1. Location of the Khao Yai National Park and the Mor Sing to Permanent Plot (A), the position of the three grids in the permanent plot (B) and small mammal trap cage system (C) and forest environment in the area of each grid

The species of captured animals were identified based on Francis (2019). In cases where species cannot be identified, photographs are taken to compare with specimens of small mammals contained within the Natural History Museum of Thailand. In this regard, every sample collection will be done with care and consideration for the safety of the animals as much as possible so as not to affect resources. The operation will be under the control of the supervision of competent officials and will strictly coordinate before entering the area to ensure proper sampling without damaging other resources.

Data analysis

The total number of individuals captured in each grid was used as an index of abundance since small mammals were captured too infrequently for the use of mark-recapture analysis (Simelane et al. 2018).

The comparison number of all small mammal species captured during the dry season and those of the rainy season was tested using Wilcoxon rank-sum test (Pratt 2010). Significant difference was determined at P<0.05.

Species richness was taken as the total number of small mammal species recorded, whereas species diversity was calculated using the Shannon Diversity Index (H′) (Krebs 1989). Trap success was calculated as the number of small mammals captured per 100 trap nights, where one trap night describes a single trap set for a 24-h period (Simelane et al. 2018).

$$\%\ \text{Trap success} = \frac{\text{Number of trapped animals} \times 100}{\text{Number of trap} - \text{nights}}$$

The Shannon-Weiner Index (H) was used to compute species diversity in the habitats. Density was estimated as the number of individuals per hectare. However, the names of the traps in both spreadsheets must fit with each other.

$$\text{H} = -\sum_{i=1}^{s} P_i \ln P_i$$

In the Shannon Index, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), ln is the natural log, Σ is the sum of the calculations, and s is the number of species. This diversity measure comes from information theory and measures the order (or disorder) observed within a particular system. In ecological studies, this order is characterized by the number of individuals observed for each species in the sample plot.

Simpson's Index (D) indicates the probability that two randomly selected individuals in the community belong to the same category (e.g., species). The Simpson Index is a dominance index because it gives more weight to common or dominant species. In this case, a few rare species with only a few representatives will not affect the diversity. In the Simpson index, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), Σ is still the sum of the calculations, and so is the number of species.

$$\text{D} = \frac{1}{\sum_{i=1}^{s} P_i^2}$$

Evenness (E) is a measure of how similar the abundances of different species are in the community.

$$\text{Species Evenness (E)} = \frac{i}{\text{Ln}((S-1)/Ln(n))}$$

Where,
s: Number of Species Recorded
n: Total Number of Individuals in the Sample
i: Shannon's Diversity Index

The Trap Deployment File (TDF) contains a list of trap information (Sutherland et al. 2019), such as the name of each trap followed by the identification system, the number of traps, and trap locations within a grid consisting of the X and Y coordinates. The Encounter Data File (EDF) consisted of the individual encounter history data. This spreadsheet revealed the captured information such as date, time, individual ID (ID), detector, sex, session, and occasion. The detection probability is the number of individuals detected to estimate population size or estimate density (Sutherland et al. 2019). All analyses were done with the program R (R Core Team 2020) using the package oSCR (Sutherland et al. 2019). The data of the terrestrial small mammal density and seasonal movement were obtained with spatial capture-recapture analysis in R. Single-session models (R Core Team 2019) used the package oSCR (Sutherland et al. 2019).

The sex ratio and age structure of all captured individuals were calculated (McKnight and Ligon 2017). Adults were identified by weight, body length, and reproductive condition; for example, noticeable testes or nipple status (such as swollen, lactating) or the evidence of pregnancy. However, not all animals could be sexed because some captured individuals had probably escaped before the process of ear tagging and sex determination finished and were not recaptured again.

RESULTS AND DISCUSSION

Monthly variables

The study found that the number of small mammals caught each month varied. The month in which most were caught was August with 830, followed by February with 791, and September with 624. The month with the lowest frequency was June based on the same number of trap night for every month. It is worth noting that small mammals were caught in large numbers from August to February (mean 660.75 individuals), but the numbers dwindled during the months of March-July (mean 286.33 individuals), which is a difference of about 2.3 times. The number of small mammals caught in each species and each month is shown in Table 2.

Variation in each study site

In the case of different study sites, the results showed that the % trap success in the study area in the dry evergreen forest in Grid 1 and the secondary forest that was recovering in Grid 2 showed a significant difference when using the Wilcoxon Signed-Rank Test with z: -2.6371, P: 0.0083. It was also found that the % trap success between the dry evergreen forest in Grid 3 was significantly different from the rate found in the Grid 2 study area (z: -2.97, P<0.05). Meanwhile, the dry evergreen forest areas in Grid 1 and Grid 3 had % trap success values which were significantly different (z: -2.9701, P: 0.005). Grid 1 is the primary forest; Grid 2 is secondary forest. Grid 1 is denser with rattan as well the predominant plants such as Hog Plum (*Choerospondias axillaris*) and Cinnamon (*Cinnamomum subavenium*), while Grid 2 has Needlewood Trees (*Schima wallichii*) as the predominant plant, with many young plants in the plot. The ground condition is lower than Grid 1.

Considering diversity, the Shannon-Weiner Index found an overall mean of 1.33. The highest value occurred during the rainy season (1.71). Magige (2016) reported the diversity index. The Shannon-Weiner Index in the Serengeti National Park was found to be in the cultivated areas at 0.84, but in the national park only 0.57. This study found that in areas that have disturbed forest characteristics, whether they are rehabilitated forests (Grid 2) or reforested rainforests, the biodiversity index was similar at 1.21, while in the dry evergreen forest the highest value was 1.41. The result of calculating the evenness index was found to be similar to the Diversity Index with the highest values found in Grid 3. Evenness is a standard index in community ecology, and it quantifies how evenly the abundances of different species are distributed.

Table 1. Summary of small mammals captured in the MST Forest Dynamics Plot, Khao Yai National Park (KYNP), Thailand

Order/Family/Species	Common name	Season				Total	% TS
		Rainy	% TSR [1]	Dry	% TSD [2]		
Order Rodentia		1695	5.21	1674	5.14	3369	10.35
Family Muridae		1541	4.73	1559	4.79	3100	9.52
Maxomys surifer	Red spiny rat	1289	3.96	1130	3.47	2419	7.43
Leopoldamys sabanus	Long-tailed giant rat	28	0.09	256	0.79	284	0.87
Rattus tanezumi	Asian house rat	103	0.32	87	0.27	190	0.58
Niviventer fulvescens	Indomalayan Niviventer	108	0.33	5	0.02	113	0.35
Bandicota savilei	Savile's Bandicoot Rat	13	0.04	81	0.25	94	0.29
Family Sciuridae		154	0.47	115	0.35	269	0.83
Menetes berdmorei	Indochinese Ground Squirrel	151	0.46	113	0.35	264	0.81
Tamiops mcclellandii	Himalayan striped squirrel	3	0.01	2	0.01	5	0.02
Order Scandentia		285	0.88	360	1.11	645	1.98
Family Tupaiidae		285	0.88	360	1.11	645	1.98
Tupaia belangeri	Northern Treeshrew	285	0.88	360	1.11	645	1.98
Order Eulipotyphla		0	0.00	1	0.00	1	0.00
Family Erinaceidae		0	0.00	1	0.00	1	0.00
Hylomys suillus	Short-tailed gymnure	0	0.00	1	0.00	1	0.00
	Total	1980	6.08	2035	6.25	4015	12.33
	Trap night						32555
	Number of trap sites	179	179	179	179	179	
	Occasions	543	543	543	543	543	
	Shannon-Weiner index (H)	1.70		1.34		1.31	
	Simpson's index (D)	0.45		0.36		0.40	
	Evenness (E)	0.56		0.61		0.60	

Notes: [1]) TSR: Trap success in the rainy season; [2]) TSD: Trap success in the dry season

Table 2. Numbers of small mammal species captured in each month during the study period between June 2019 and July 2022 in the MST permanent plot, Khao Yai National Park, Thailand

Species	2019 (the rainy season)					2020 (the dry season)				
	Jun	Jul	Aug	Sep	Total	Jan	Feb	Mar	Apr	Total
Leopoldamys sabanus	1	20	5	2	28	63	131	38	24	256
Maxomys surifer	46	260	537	446	1289	217	416	241	256	1130
Menetes berdmorei	1	35	71	44	151	31	68	9	5	113
Niviventer fulvescens	2	37	46	23	108	0	0	0	5	5
Rattus tanezumi	3	25	57	18	103	9	33	32	13	87
Tupaia belangeri	14	82	102	87	285	72	111	66	111	360
Bandicota savilei	0	0	10	3	13	6	32	33	10	81
Tamiops mcclellandii	0	0	2	1	3	0	0	1	1	2
Hylomys suillus	0	0	0	0	0	0	0	0	1	1
Total	67	459	830	624	1980	398	791	420	426	2035

Table 3. Summary of small mammals captured in the MST Forest Dynamics Plot, Khao Yai National Park, Thailand, separated by habitat

Species	Primary forest 1		Secondary forest 2		Primary forest 3		Total	
	n	%Trap success	n	%Trap success	n	%Trap success	n	%Trap success
Order Rodentia	**1244**	**10.39**	**684**	**5.72**	**1280**	**14.85**	**3208**	**9.85**
Family Muridae	**1149**	**9.60**	**660**	**5.51**	**1151**	**13.35**	**2960**	**9.09**
Maxomys surifer	902	7.54	471	3.94	833	9.66	2206	6.78
Leopoldamys sabanus	153	1.28	61	0.51	61	0.71	275	0.84
Rattus tanezumi	34	0.28	45	0.38	123	1.43	202	0.62
Niviventer fulvescens	50	0.42	81	0.68	53	0.61	184	0.57
Bandicota savilei	10	0.08	2	0.02	81	0.94	93	0.29
Family Sciuridae	**95**	**0.79**	**24**	**0.20**	**129**	**1.50**	**248**	**0.76**
Menetes berdmorei	95	0.79	19	0.16	129	1.50	243	0.75
Tamiops mcclellandii	0	0.00	5	0.04	0	0.00	5	0.02
Order Scandentia	**152**	**1.27**	**38**	**0.32**	**180**	**2.09**	**370**	**1.14**
Family Tupaiidae	**152**	**1.27**	**38**	**0.32**	**180**	**2.09**	**370**	**1.14**
Tupaia belangeri	152	1.27	38	0.32	180	2.09	370	1.14
Order Eulipotyphla	**1**	**0.01**	**0**	**0.00**	**0**	**0.00**	**1**	**0.00**
Family Erinaceidae	**1**	**0.01**	**0**	**0.00**	**0**	**0.00**	**1**	**0.00**
Hylomys suillus	1	**0.01**	**0**	**0.00**	**0**	**0.00**	**1**	**0.00**
Total	1397	11.70	722	6.07	1460	17.00	3579	11.01
Trap night	11968		11968		8619		32555	
Number of trap sites	64		51		64		179	
Occasions	187		169		187		543	
Shannon-Weiner index (H)	1.20		1.21		1.41		1.33	
Simpson's index (D)	0.44		0.45		0.36		0.41	
Evenness (E)	0.57		0.58		0.72		0.61	

Some physiological characteristics of small mammal species

Based on 3685 of all the small mammals captured that could be measured, it was found that the body sizes of the animals found when sorted by species from average largest to average smallest body weight were *Leopoldamys sabanus*, *Menetes berdmorei*, *Tupaia belangeri*, *Maxomys surifer*, *Rattus tanezumi*, *Bandicota savilei*, *Niviventer fulvescens*, *Hylomys suillus* and *Tamiops mcclellandii* with the average bodyweight (grams ± SE) of 293.30 ± 4.11, 178.29 ± 1.81, 142.71 ± 1.59, 136.74 ± 0.76, 130.15 ± 3.11, 129.78 ± 4.73, 78.87 ± 1.73, 70.00 ± 0.00, and 63.00 ± 1.22 respectively. The averages of some of the physiological characteristics of the small mammal species are shown in Table 4.

Population density

The results showed that the average density of females (7.51 individuals ha^{-1}) of the small mammals in all species was found to be slightly greater than that of males (7.06 individuals ha^{-1}). It was also found that during the rainy season, the density based on this study of the small mammals of all species was greater than during the dry season. May be because they were more likely to be caught in traps.

The results showed that the estimated population density of *Maxomys surifer* (mean ± SE) in males was approximately 27.05 individuals ha^{-1} while females were 22.84 individuals ha^{-1}. Population density estimations of male *Leopoldamys sabanus* accounted for 2.52 individuals ha^{-1} while for females the value was 4.20 individuals ha^{-1}. *Rattus tanezumi* showed an average density for males of 4.14 individuals ha^{-1} while female rats amounted to 4.10 individuals ha^{-1}. *Niviventer fulvescens* showed an average population density for females of 5.93 individuals ha^{-1} and 2.59 individuals ha^{-1} in males. The population density of *Bandicota savilei* was an average of 1.50 individuals ha^{-1} for females and estimated to be 0.59 individuals ha^{-1} in males *Menetes berdmorei* showed an average population density of females at 5.84 individuals ha^{-1} and population density for males of 5.70 individuals ha^{-1}. The population density of *Tupaia belangeri* was 8.17 individuals ha^{-1} for females and 6.82 individuals ha^{-1} for males. The details are shown in Table 2.

The results showed population density per hectare depends on the different seasons and sex. *Tamiops mcclellandii* and *Hylomys suillus* were the only two species that contained the lowest numbers of individuals and it was not possible to investigate the density due to the inadequate number of captured individuals. *Maxomys surifer* was the most abundant species captured at the study site followed by *Tupaia belangeri* and *Tamiops mcclellandii*, respectively. However, *Bandicota savilei* showed the lowest population density due to the lack of captured individuals and insufficient marked-recaptured data, leading to the underestimated density in the study site, followed by *Rattus tanezumi*, *Niviventer fulvescens*, and *Leopoldamys sabanus* (Table 1).

Sex ratio and age class

The summary of sex ratio and age structure revealed the population characteristics of captured small mammals

(Table 6). The proportion of sex ratio between males and females was quite similar in both seasons. However, the insufficient number of captured individuals of some species led to the inability to calculate the proportion for the sex ratio, such as *Niviventer fulvescens* in the rainy season and *Bandicota savilei* in the dry season.

The comparison of age structure in different seasons revealed a higher percentage of adults than juveniles in both seasons, however, *Tupaia belangeri* was the only species that showed a larger proportion of juveniles than adults in the rainy season. In the case of the whole species, the adult sex ratio was quite similar between males and females (1587:1570 respectively). Nevertheless, in juveniles, it was found that the number of juvenile males was lower than the number of juvenile females (265:423 respectively). The results showed variation between the number of adult males and adult females, especially in *Tupaia belangeri*, *Niviventer fulvescens, Bandicota savilei*, and *Menetes berdmorei* as details are shown in Table 6.

Movement

Based on the oSCR estimator model, considering the average distances of all species combined, it was found that during the rainy season the average distance traveled (73.76 m) was greater than in the dry season (62.37 m). The species with the most movement on average were: *Tupaia belangeri* (73.14 m), followed by *Bandicota savilei* (71.46 m), *Niviventer fulvescens* (71.42 m), *Menetes berdmorei* (67.21 m), *Maxomys surifer* (64.11 m), *Leopoldamys sabanus* (57.73 m), and *Rattus tanezumi* (45.65 m), respectively.

Determined by season, it was found that the average distance movement of small mammals was different by species and season. In the rainy season, *Tupaia belangeri* showed the longest average distance movement at 78.47 ± 3.15 m followed by *Menetes berdmorei* (64.55 ± 2.68 m), *Niviventer fulvescens* (63.84 ± 3.88 m), *Maxomys surifer* (63.28 ± 1.16 m), *Leopoldamys sabanus* (57.90 ± 6.05 m), *Rattus tanezumi* (53.44 ± 2.28 m), and *Bandicota savilei* (50.12 ± 11.29 m). Meanwhile, during the dry season, *Bandicota savilei* had the longest average distance movement at approximately 92.33 ± 9.21 m, followed by *Menetes berdmorei* (69.88 ± 4.25 m), *Tupaia belangeri* (67.82 ± 4.42 m), *Maxomys surifer* (64.94 ± 1.47m), *Leopoldamys sabanus* (57.57 ± 1.88 m), *Niviventer fulvescens* (47.32 ± 26.41m), and *Rattus tanezumi*, which showed the shortest average distance movement estimated at 36.75 ± 1.87 m for this season. The data can be seen in Figure 2.

Table 4. Species list, average and standard deviation (mean ± SD) of weight and body length measurements of small mammal species in the dry evergreen forest, Khao Yai National Park, Thailand

Common name	N	Average weight (g) ± SE	Head and body (mm) ± SE	Tail (mm) ± SE	Hind foot (mm) ± SE	Ear (mm) ± SE
Maxomys surifer	2267	136.74 ± 0.76	17.63 ± 0.37	19.98 ± 0.46	3.51± 0.01	0.23 ± 0.02
Tupaia belangeri	418	142.71 ± 1.59	15.05 ± 0.07	17.19 ± 0.10	3.78 ± 0.01	1.38 ± 0.01
Leopoldamys sabanus	273	293.30 ± 4.11	19.15 ± 0.09	31.90 ± 0.33	4.36 ± 0.02	2.62 ± 0.01
Menetes berdmorei	243	178.29 ± 1.81	16.19 ± 0.09	12.88 ± 0.12	3.56 ± 0.01	1.56 ± 0.01
Rattus tanezumi	201	130.15 ± 3.11	20.36 ± 1.46	25.74 ± 1.59	2.99 ± 0.02	1.86 ± 0.02
Niviventer fulvescens	187	78.87 ± 1.73	12.58 ± 0.12	16.12 ± 0.20	2.51 ± 0.01	1.61 ± 0.01
Bandicota savilei	90	129.78 ± 4.73	15.02 ± 0.23	20.02 ± 0.26	3.04 ± 0.02	1.71 ± 0.01
Tamiops mcclellandii	5	63.00 ± 1.22	9.94 ± 0.26	10.12 ± 0.29	2.70 ±0.06	1.20 ± 0.01
Hylomys suillus	1	70.00 ± 0.00	12.90 ± 0.00	1.90 ± 0.00	2.37 ± 0.00	1.61 ± 0.00
Total	3685					

Table 5. Population density of seven small mammals in the MST Forest Dynamics Plot, KYNP

Species	Male (individuals ha^{-1})			Female (individuals ha^{-1})		
	Rainy	dry	average	Rainy	dry	average
Maxomys surifer	32.25 ± 3.32	21.85 ± 2.56	27.05	27.22 ± 2.99	18.45 ± 2.28	22.84
Tupaia belangeri	8.46 ± 1.65	5.19 ± 1.34	6.82	10.12 ± 1.89	6.21 ± 1.57	8.17
Niviventer fulvescens	2.59 ± 1.21	2.59 ± 3.18	2.59	5.92 ± 1.70	5.93 ± 6.75	5.93
Menetes berdmorei	6.99 ± 1.60	4.41 ± 1.19	5.7	7.16 ± 1.63	4.51 ± 1.21	5.84
Leopoldamys sabanus	1.09 ± 0.57	3.96 ± 1.25	2.52	1.81 ± 0.89	6.58 ± 1.71	4.2
Rattus tanezumi	3.53 ± 1.18	4.75 ± 1.68	4.14	3.50 ± 1.17	4.70 ± 1.66	4.1
Bandicota savilei	0.45 ± 0.39	0.73 ± 0.38	0.59	1.15 ± 0.92	1.86 ± 0.73	1.5
Average	7.91	6.21	7.06	8.13	6.89	7.51

Table 6. Sex and age structure of the small mammals trapped in the MST Forest Dynamics Plot, KYNP

Species	Male		Female		Total
	Adult	Juvenile	Adult	Juvenile	
Maxomys surifer	1058	199	920	300	2477
Tupaia belangeri	26	0	251	66	343
Leopoldamys sabanus	137	4	140	0	281
Menetes berdmorei	87	43	116	8	254
Rattus tanezumi	108	5	79	12	204
Niviventer fulvescens	111	5	43	31	190
Bandicota savilei	59	9	19	3	90
Tamiops mcclellandii	0	0	2	3	5
Hylomys suillus	1	0	0	0	1
Total	1587	265	1570	423	3845

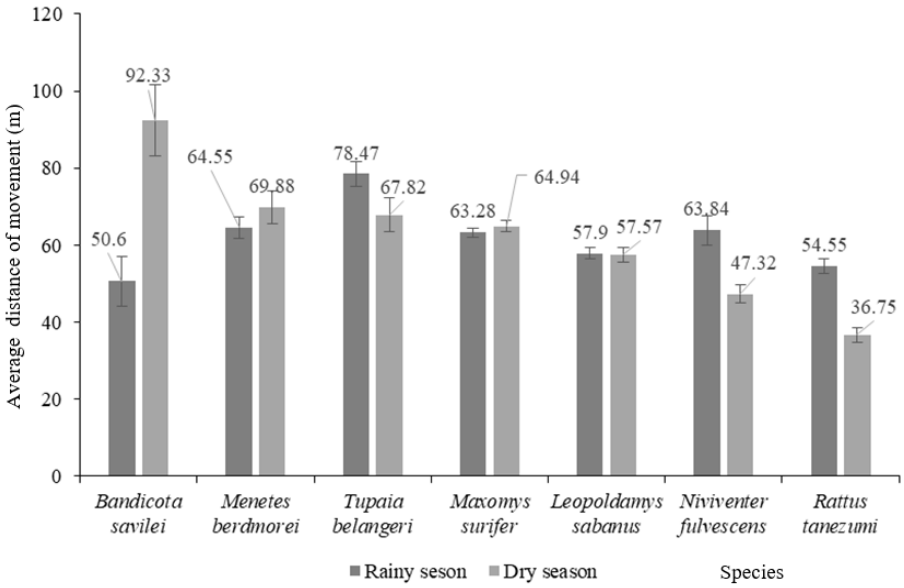

Figure 2. Average distance of movement (m) of the seven small mammals in the MST Forest Dynamics Plot, KYNP, using the oSCR estimator

Discussion

The results of this study identified seven species of the order Rodentia, one species of the order Scandentia, and one species of the order Eulipotyphla, for 9 species in total. A past study in this area by Suzuki (2007) using camera trap techniques found 6 species of the order Rodentia, four species of animals in the family Muridae and two species of family Sciuridae. In the case of the Variable squirrel (*Callosciurus finlaysonii*) and Grey-bellied squirrel (*Callosciurus caniceps*) that were found occasionally in the area outside of the study plot, these animals were not captured during the study period and this may be due to that species requiring a different habitat. Other factors would be that cages were placed at ground level and there was an abundance of carnivores in the area (Khoewsree et al. 2020, 2022). Determination of the order and the family levels revealed that all numbers of the order and family levels were more likely to be found in the dry evergreen forest than in disturbed areas. Only *Tamiops mcclellandii* in the family Sciuridae and order Rodentia was mostly found in the secondary forest rather than the dry evergreen forest, confirming the primitive habitat use of each small mammal species.

Trapping methods can strongly influence the sampling of mammal communities (Vieira et al. 2014) which affects the capture of those small mammals (Astúa et al. 2006) and the probability of capturing relative to trap locations (Freeman et al. 2022). This study desired to reduce the variance in probability capture to be similar across all grids, so cage traps were placed at ground level in each grid. Considering the number of the small mammals caught, *Maxomys surifer* was the most frequent, accounting for 61.69% of all mammals caught. This corresponds to the highest observed densities of this species, at 27.05 animals ha^{-1} and 22.84 animals ha^{-1} in males and females, respectively, underlining its highly significant role in this ecosystem, followed by *Tupaia belangeri*, with 645 individuals (Table 1), or 16.06%, and *Menetes berdmorei*, with 264 individuals, or 6.57%, respectively. It was reported by de Lima et al. (2021) that males moved greater distances than females and reproductive individuals moved greater distances than non-reproductive individuals, although there was some variation. Wróbel and Bogdziewicz (2015) reported that weather conditions strongly affect animal activity. Temperature had a negative effect on the activity of both species and rainfall had a positive influence. This is consistent with the results of this study which found that movement during the rainy season is greater than during the dry season. In the case of adult sex ratio, it was found that the ratio between males and females was quite similar (1587:1570 or 1:0.99), in concurrence with several earlier studies that showed the proportion of males to females such as Bantihun and Bekele (2015) in Arditsy Forest, Awi Zone, Ethiopia. This study also showed differences in the number of juvenile females, with the numbers approximately 2 times greater than those of males (265:423 or 1:1.60). This indicated the predominance of juvenile females in small mammal populations. The sex ratio was male-biased, both in the wet and dry seasons. This contradicts the prediction that females should be more abundant than males both in the rainy season and the dry season. The male-biased sex ratio is probably due to the tendency of males to travel longer distances than females, resulting in a higher probability of getting trapped (Shilereyo et al. 2022).

In conclusion, the result showed that a total of 4015 individuals from 9 species, 9 genera, 4 families, and 3 orders were captured with a sampling effort of 32,555 trap nights. The most common species were *Maxomys surifer*, followed by *Tupaia belangeri*, *Leopoldamys sabanus*, *Menetes berdmorei*, *Rattus tanezumi*, *Niviventer fulvescens*, *Bandicota savilei*, *Tamiops mcclellandii*, and *Hylomys suillus* respectively.

Determination of the order and the family levels showed that all numbers of the order and family levels were more likely to be found in the dry evergreen forest than in the secondary forest area. Only *Tamiops mcclellandii* in the family Sciuridae was predominantly found in the secondary forest rather than the dry evergreen forest. This study found that during the rainy season, the density of the small mammals of all species was greater than during the dry season. Considering the number of small mammals caught, *Maxomys surifer* was the most frequently encountered, accounting for 61.69% of all mammals caught. This corresponds to the highest observed densities of this species.

The proportion of sex ratio was found somewhat higher in females in both seasons. Nevertheless, in the case of the number of juveniles, it was found that the number of juvenile males was approximately 1.60 times lower than the number of juvenile females. Further study of long-term species diversity and population characteristics in the area should be conducted. This study is the first report to study the small mammal community in KYNP using continuous live trapping. These surveys indicate that the small mammal diversity was high in the primary dry evergreen forest or even in the secondary forest. These results have important implications not only for conservation but are also useful for further investigation if there is any disturbance or change in the area or any potential disasters that may occur in the future (Gentile et al. 2018). However, to confirm the visible trends, further data should be collected intensively, with less biased sampling techniques. With the forests changing on a daily basis due to climate change, it is imperative that current relationships between small mammals and their surroundings are understood to help predict future changes that should be monitored continuously.

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