Diversity and Distribution of Murid Rodents in Tarutao National Park – a Biogeographic Perspective

ความหลากหลายและการแพร่กระจายของหนูในอุทยานแห่งชาติตะรุเตา – มุมมองทางชีวภูมิศาสตร์

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ABSTRACT

The species-area and species-isolation relationships as well as nestedness pattern were studied for murid rodents on five Islands in Tarutao National Park. Live murid rodents were captured in the field using 100 live cage traps baited with either corn or banana from February – March, 2012 and in January of 2013. The traps were set in line transects. Four species of murid rodents were captured in this study – *Rattus tanezumi, Maxomys surifer, Leopoldamys sabanus* and *Niviventer cremoriventer*. Species richness was found to be highly correlated with Island area (r^2 = 0.882) than the isolation of the Islands from the mainland (r^2 = 0.474). The nestedness patterns of the murid rodents were found to be more organized than would be expected by chance. This means that the murid fauna in this National Park have been affected past by extinctions but are now well adapted to the Islands and there have been no subsequent recolonisations.

บทคัดย่อ

การศึกษาความสัมพันธ์ระหว่างจำนวนชนิดและขนาดพื้นที่ และความสัมพันธ์ระหว่างจำนวนชนิดและระยะห่างของเกาะจากแผ่นดินใหญ่รวมถึงรูปแบบ nestedness ของหนู ในบริเวณห้าเกาะของเขตอุทยานแห่งชาติตะรุเตา ทำการศึกษาโดยวางกรงดักหนูในธรรมชาติโดยใช้กล้วยและข้าวโพดเป็นเหยื่อล่อจำนวน 100 กรงตามเส้นสำรวจ ระหว่างเดือนกุมภาพันธ์ ถึง เดือนมีนาคม พศ. 2555 และ เดือนมกราคม พศ. 2556 พบหนู 4 ชนิด คือ *Rattus tanezumi, Maxomys surifer, Leopoldamys sabanus* และ *Niviventer cremoriventer* ความหลากชนิดของหนูมีความสัมพันธ์กับขนาดของเกาะ (r^2 = 0.882) มากกว่าความสัมพันธ์ระหว่างความหลากชนิดกับระยะห่างของเกาะจากแผ่นดินใหญ่ (r^2 = 0.474) และพบว่าหนูในแต่ละเกาะมีรูปแบบ nestedness ที่เป็นระบบมากกว่าที่จะเกิดโดยบังเอิญ ชี้ว่าสังคมหนูพื้นที่นี้ถูกกำหนดโดยการสูญพันธุ์ในอดีต และไม่ปรากฏการอพยพแทนที่เกิดขึ้นในเวลาต่อมา

Key words: Species richness, Murid rodents and Tarutao National Park,

คำสำคัญ: จำนวนชนิด สัตว์ฟันแทะกลุ่มหนู อุทยานแห่งชาติตะรุเตา

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Introduction

The Islands in Tarutao National Park were once part of the mainland. Although it is not known how many times that these Islands have been isolated from the mainland in the past, the most recent isolation is approximately 8,500 years ago (Voris, 2000, Sathiamurthy and Voris, 2006, Wongbusarakum, 2007). Therefore the current murid rodents on these Islands can either have originated before the latest separation or have dispersed to these Islands after separation from the mainland (with the mainland acting as the source population).

According to the equilibrium model of Island biogeography by MacArthur and Wilson (Lomolino et al., 2006) these Islands initially would have unbalanced faunas, which after time relaxed to equilibrium. If this is the case, then it is safe to assume that these Islands were formed as a result of fragmentation from a continuous mainland habitat, which supported a common species pool prior to the rise in sea water levels and thus the murid rodents on these Islands would be composed of non-random subpopulations of the total available species pool on the mainland (Cutler, 1991).

Whereas some studies in plants (Congdon, 1982, Chantanaorrapint, 2010), social welfare of the local people (Wongbusarakum, 2007), a number of studies on ants (Watanasit et al., 2003, Watanasit and Jantarit, 2006, Abdullah and Watanasit, 2011) and recently in bats and birds (by researchers from Prince of Songkhla University but not yet published) have been basically conducted in Tarutao National Park, there is no comprehensive and exhaustive study on murid rodents. Murid rodents are important as seed dispersers, in zoonoses and other ecological functions.

The species-area relationship is one of community ecology's laws (Schoener, 1886)and one of the most general, best documented patterns in nature (Lomolino et al., 2006). This is a relationship in which the species richness tends to increase with increasing area. Since the areas of the five Islands from Tarutao National Park included in this study varied in size we assessed the strength of the Island area has on the species richness of murid rodents. The species-area relationship (also the species-isolation relationship and nestedness pattern) is believed to be driven by immigration and extinction leading to the population reaching relaxation in distribution.

The species-isolation relationship is also one of the well studied patterns in nature. According to Lomolino et al. (2006) "since the early 1800s, it has been well known that single, isolated Islands far out in the ocean support fewer species than Islands that are part of a major archipelagoes or Islands that are located nearer to continents. Therefore, for a variety of taxa and ecosystems, species richness should decline as a negative exponential or sigmoidal function of isolation." Despite having the knowledge that the isolation of four Islands included in this study are not very different we still tested this relationship.

Another trend that has been observed in a number of insular taxa is the nestedness pattern. "The nested subset hypothesis was formulated to describe and explain patterns in the community structure of insular mammals which are in the state of 'relaxation'. The hypothesis states that the species comprising a less species rich fauna should constitute a proper subset of the species in richer faunas, and that an archipelago of such faunas arranged by species richness should present a nested series" (Patterson and Atmar, 1986) This means that a less rich fauna will represent a subset of the more species rich faunas and if a species is absent in the species-rich fauna then it should also be absent in the less species-rich fauna if the distribution represents a perfect nested subsets provided they have the same source populations (mostly considered to be the mainland or nearest major Island).

Suffice to say that past records of murid rodents in Tarutao National Park have exclusively been to identify the murid rodents based on collections of museum specimens (Miller, 1900, Thomas and Wroughton, 1909, Chasen, 1940). Therefore, little is known about the biogeographic distributions of the murid rodents around the small Islands in Tarutao Nation Park and in South East Asia in general. This is evident from the study of Meijaard (2003) who in his analyses excluded the specimens from Tarutao National Park on the basis that there was little information of the murid rodents from this site.

The aim of this study was to apply the biogeographic theories of the species-area, species-isolation and nestedness distribution of the murid species in Tarutao National Park. This will help to understand the diversity and distribution pattern of the murid rodents on the Islands in this National Park.

Materials and methods

Study areas

Tarutao National Park is located in the Andaman Sea off the west coast of peninsular Thailand in Satun Province between 6° 30′ N and 6° 44′ N latitude and 99° 44′ E and 99° 9′ E longitude (Congdon, 1982). It was gazetted as a National Park in 1974, covers an area of 1,490 km^2 and is described as a coastal and marine ecosystem, IUCN category II (UNDP, undated). In 1984 Tarutao National was declared as an ASEAN Heritage National Park (ASEAN, 1984). Tarutao National Park encompasses 51 Islands covered with well-preserved virgin rainforest which have a rich fauna. Most of these Islands are considered important sites for birds (Pookpakdi, 2000).

This study was conducted on five Islands in Tarutao National Park namely; Tarutao, Adang, Rawi, Butong and Yang (or Ka Ta) Islands (Figure 1). The size of these Islands ranges from <1 km^2 (Yang Island) to as large as 151 km^2 (Tarutao Island). The various dimensions of the Islands included in this study are summarized in Table 1.

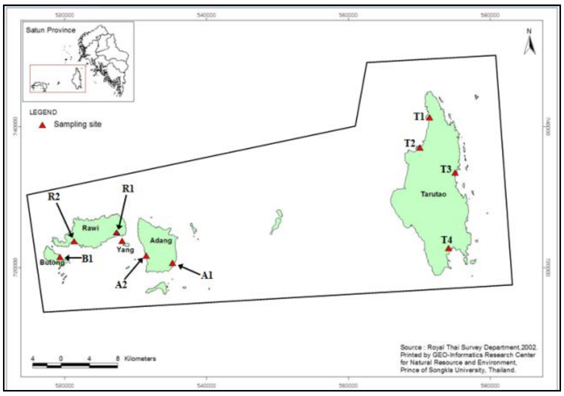

Figure 1: Map of Tarutao National Park. The labels T1, T2, T3 and T4 show the sampling sites on Tarutao Island, A1 and A2 are the sampling sites on Adang, R1 and R2 were the sampling sites on Rawi Island, B1 was the only site sampled on Butong and the whole of Yang was sampled.

Table 1: The Islands in Tarutao National Park included showing the length, width, highest point and area the relative distance from the mainland and the dimensions Yang estimated from Google Earth

Island	Area (km^2)	Relative distance from mainland (km)
Tarutao	151	26
Adang	29.8	~71
Rawi	28	~ 82
Butong	4	~ 90
Yang	<1	~76

Trapping in the field

Live murid rodents on five Islands were sampled using live cage traps baited with either corn or banana from 11-16th February and 15-20th March 2012 on Adang, Rawi, Butong and Yang Islands and from 5-15th January of 2013 on Tarutao Island. At each site 25 traps were set at approximately 40-50m intervals (except for Tarutao Island were the traps were spaced for approximately 70-100m intervals considering the size of this Island compared to other Islands). Further at each site the traps were divided into two sets to try and maximize the area covered (one set had 12 traps and the other 13 traps). The traps were randomly set starting from near the coast (beach) and moving towards the interior of the forest and the distance between the two sets of traps at each site ranged from 200-300 meters to try and increase the area covered.

The traps were most often baited with banana or corn because these are well known as the baits for trapping rats and also because these were readily available in local markets. The purpose of "the baits are not only to lure rats to the traps, but also to sustain them once they have been caught. The traps were usually visited once a day in the early morning, however, where possible traps were checked twice a day to reduce the stress of capture (Sutherland, 2006). The specimens were identified in the field following the guide book by Francis (2008) and the taxonomy is after Musser and Carleton (2005).

On Adang, Rawi, Butong and Yang the traps were left at each site for at least three nights and checked once per day in early morning and the bait was replaced/changed at the time of checking. The traps were then moved to new places but within the same site to cover as much microhabitat and area as possible meaning a total of 150 (6 days x 25 traps) trapping nights per site. On Tarutao Island we spent three trapping nights with all the 100 traps at one sampling site per time. We then moved to another sampling site and covered four sampling sites on this Island in total as follows; (1) on the north end we trapped at Phante Malacca and the places near to Phante Malacca; (2) on the west side we sampled at Ao Molae, Ao Sone and along the trail leading to Ludu waterfall; (3) on the eastern end we sampled at Talow Wow and along the trail leading to Taloh Udang; and (4) our last site was at the south end and here we sampled around Taloh Udang and along the trail leading to Taloh Wow. This means on Tarutao Island at each site we had a total of 300 (3 days x 100 traps) trapping nights per station. Each point where the trap was set was marked using a GPS.

The captured individuals were recorded, measured, sexed, and age determined, and then released at the same point of capture in the field.

The species richness and relative abundance for each Island was simply established depending on the total number of individuals captured. The distribution of each species was mapped to represent the diversity of the species in the National Park.

Results

Species richness

A total of four species of murid rodents were found in this National Park. Greatest species richness was found on Tarutao Island (4 species), followed by Rawi Island (3 species), Adang Island (2 species) and least on Butong and Yang Islands (1 species each) (Table 2). The most common species was *Rattus tanezumi* which was widespread across all the five Islands, followed by *Maxomys surifer* which was recorded on three Islands (Tarutao, Adang and Rawi) while *Niviventer cremoriventer* was recorded on Tarutao and Rawi Islands, finally *Leopoldamys sabanus* was restricted to Tarutao Island only.

Table 2. The number of murid rodent species captured, the total numbers of individuals and trapping effort (in terms of trap nights) on each Island during the study period.

	Tarutao	Adang	Rawi	Butong	Yang
# of species	4	3	3	1	1
Total # of individuals trapped	97	27	17	3	11
Total trap nights	1000	600	600	162	126

In terms of the abundance, a total of 155 individuals of the 4 murid rodent species were captured. *M. surifer* was the most abundant species and represented 48.4% of the entire murid rodent individuals captured, followed by *R. tanezumi* (41.3%). *L. sabanus* (7.7%) and *N. cremoriventer* (2.6%) were considerably less abundant.

There was no particular pattern in the distribution of the species composition of murid rodents captured from one site to another on all the Islands (Figure 2).

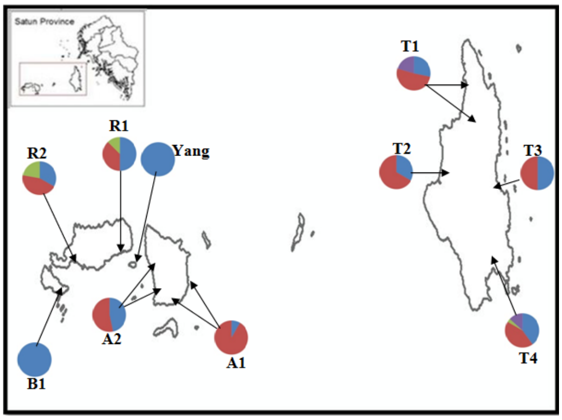

Figure2. Map of species richness, relative abundance (represented by the proportions in the pie chart) and distribution. The colors represent *R. tanezumi* (blue), *M. surifer* (red), *N. cremoriventer* (green) and *L. sabanus* (purple).

Effect of area and isolation on the diversity of species and their nestedness pattern

Our results found that the diversity of species on each Island was greatly influenced by the area and to a lesser extent by the isolation of that Island from the mainland. This is based on the r^2 values, 0.882 for species-area relationship and 0.474 for the species-isolation relationship (Figures 3 and 4 respectively). Tarutao Island which is the largest Island (151 km^2) and is the closest to the mainland (26 km) had the highest number of species and the highest densities. The other four Islands are almost equidistant in terms of isolation from the mainland (approximately 70 km from the mainland and 45 km from Tarutao Island). Adang and Rawi Islands are almost equal in area (with 29.8 km^2 and 28 km^2 respectively) and were found to have 2 and 3 species respectively. However, if we include the records of Miller (1900), who reported *N. cremoriventer* on Adang Island but we didn’t capture in the present survey, we can say that both Adang and Rawi Islands have three species each. Butong is much smaller (4 km^2) than Adang and Rawi and had only one species. The smallest Island Yang (<1 km^2) also has only one species.

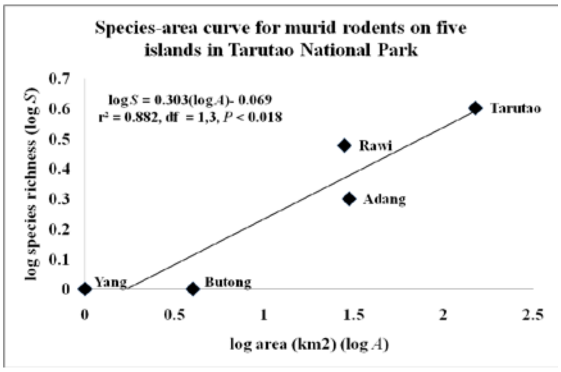

Figure 3. Species-area curve of murid rodents based on the individuals captured. The graph follows the Arrhenius equation, $\log_{10} S = c + z \log_{10} A$.

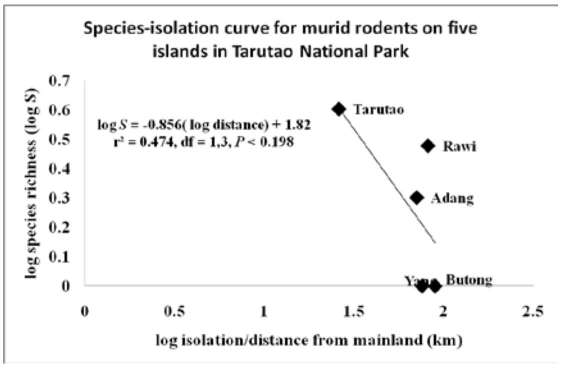

Figure 4. Species-isolation curve of murid rodents based on the individuals captured. The graph follows the Arrhenius equation, $\log_{10} S = c + z \log_{10} D$.

Despite the relatively small number of Islands and rodent species included in this study, our results showed quite a good structure in terms of distribution of the species on the Islands in Tarutao National Park as shown in Table 3. Our results show that the distribution is thus not by chance or randomly but well structured as would be predicted of a nested distribution. From Table 3 below it can be seen that the species composition on each Island reflects the effect of area and isolation of that Island from the mainland. The results show what would be expected of a fauna in a relaxed state or at equilibrium as would be predicted of a perfectly nested fauna.

Table 3. The presence-absence matrix of murid rodent species on each Island (based on all records to date). *S* is the total number of species recorded on each Island. Species are ordered in such a way that the most widespread is listed first and the least common last.

Species	Tarutao	Adang	Rawi	Butong	Yang
R. tanezumi	✓	✓	✓	✓	✓
M. surifer	✓	✓	✓	X	X
N. cremoriventer	✓	✓	✓	X	X
L. sabanus	✓	X	X	X	X
S	4	3	3	1	1

Discussion

Despite the first collections of murid rodents in Tarutao National Park having been reported during early 1900s (Miller 1900, Thomas and Wroughton, 1909, Chasen, 1940), the species that we found on the Islands are still the same as those recorded previously. This means that the species composition over approximately a period of 100 years has been the same and thus we can assume that the habitats on the Islands in Tarutao National Park have not been disturbed or if they have been disturbed, it can be assumed that maybe murid rodents are tolerant to different habitat changes. The only slight difference between the earlier records and the current study is that we recorded *N. cremoriventer* on Tarutao and Rawi Islands while in the previous collections this species was only recorded on Tarutao and Adang Islands. This difference can be accounted for because the numbers of individuals of this species captured were very low (with only one individual on Tarutao and three individuals on Rawi). Therefore, it is possible that there is also a small population of *N. cremoriventer* on Adang but we did not capture any individual during our study.

The results showed that *M. surifer* despite being found only on three out the five Islands sampled (Table 3) was the most abundant in terms of the number of individuals captured. This would be explained in terms of Island rodents having a tendency to support high densities when in suitable habitats according to the Island syndrome in rodents (Adler and Levins, 1994). This is supported by the fact that the forest type in Tarutao National Park appears to be especially suitable for *M. surifer*, which is reported as being a rain-forest dependant rat (Gorog, et al., 2004). *R. tanezumi* was the second most abundant rodent in terms of the individuals captured. This is due to the fact that it was widespread across all the five Islands and is highly adaptable to various habitats, including disturbed and undisturbed habitats and also in human settlements (Corbet and Hill, 1992, Francis, 2008). Another reason could be that *R. tanezumi* is a better colonizer and/or competitor than other species recorded on these Islands. *R. tanezumi,* being a sister species of *R. rattus* (Lunde and Son, 2001, Musser and Carleton, 2005) is expected to have the same behavior as *R. rattus* of territorial defense; be a generalist in diet (taking almost whatever food is available); displace smaller species such as *R. exulans* from their environmental niches; and once it establishes itself to show great resilience to natural disasters such as short time flooding of an Island by storm surges (Spennemann, 1997).

On the other hand, *L. sabanus* is probably restricted to Tarutao Island because this is the biggest Island and only this Island provides enough resources and home range for this species.

The low density of *N. cremoriventer* could be explained in terms of its size. It is the smallest of all the species recorded and is probably unable to compete with the larger taxa. However, it has found a niche in forest edges which are a bit disturbed by humans and not in sympatric with other species.

Another point of interest was that despite Yang being smaller in area than Butong more individuals were captured on this Island than the latter despite there being more trap nights on Butong Island (27 traps x 6 nights = 162 trap nights) than Yang Island (21 traps x 6 nights = 126 trap nights). The higher density of *R. tanezumi* individuals on Yang as compared to Butong can be explained more in terms of resource availability and to a lesser extent in terms of the proximity of these two Islands to other small Islands. Butong as can be seen on the map (Figure 1) is located on the periphery of the other Islands. In addition, Butong Island has fewer fresh water sources as compared to Yang Island. This latter Island, which lies somewhat between Adang and Rawi, and has more fresh water sources and also a rubbish pit where tourists dump their refuse, including food. Therefore the food resources are artificially boosting to the advantage of the rodents densities on Yang Island. This may lead to increased carrying capacity and an increased reproduction rate on Yang than Butong Island.

Even though we conducted the study on only 5 Islands, the species–area curve had a high r^2 value (Figure 3). This indicates that the area of the Island has a great effect on the number of species on that Island. It is particularly striking because these Islands have a range of different sizes. It is also important to note that one exception to the species-area relationship called the 'small Island effect' (McArthur and Wilson, 1967) was found. The small Island effect is tendency of species richness varying independently of the Island area for smaller Islands (or biotas) (Niering, 1963). This varies in a manner consistent with the resource requirement, immigration abilities, and degree of isolation of these biotas (Lomolino and Weiser, 2001).

On the other hand the isolation of the Islands seemed not to have a greater effect ($r^2 = 0.474$) (Figure 4). This result was not surprising because with the exception of Tarutao Island which had a different distance from the mainland, the other Islands are very close to each other and hence they somewhat clumped together on the graph. It is worthy to note here that this does not mean isolation of the Island does not have an effect on the species richness but that the Islands included in this study were too close to each other and hence this relationship could not be clearly assessed. Thus if someone wants to test this relationship, he/she should ensure that the Islands have varying distances from the mainland or the nearest big Island.

From the pattern shown in the distribution of murid rodents in this National Park, it can reasonably be assumed that the species first colonized Tarutao Island from the mainland, which in turn acted as the source population for secondary colonization or dispersal to the other smaller Islands which are further from the mainland. Another plausible explanation of the observed pattern could be that originally when the Islands were still connected to each other they had the same species but after isolation, on the small Islands there could be competition among the species leading to extinction of the less competitive. Our results showed a perfectly nested distribution of the murid rodents on the Islands in the National Park associated with the size and isolation which is a characteristic of extinction dominated faunas, which have had no subsequent recolonisations (as described by Atmar and Patterson,1993). However it is hard to confidently point out which species are native or subsequently introduced by either humans or natural phenomena to the National Park because there is no fossil records of the original fauna in this National Park, therefore, this distribution can only be associated to isolation/area of the Islands and possible extinction of the species.

Despite this being a relatively simple test of the biogeographic theories discussed here, it was evident that various factors could be behind the current distribution patterns of murid rodents on the Islands in Tarutao National Park ranging from the which faunas are actually the source populations for these species, what might be happening to the species post-isolation from the mainland more than 8,500 years ago, to extinctions which could result from human caused habitat degradation. However, as pointed out earlier, because lack of supplementary information, it still remains unclear which mechanisms is responsible for the current species composition on the individual Islands (Krystufek and Kletecki, 2007).

Conclusion

In conclusion, it can be said that despite this being the first extensive and exhaustive research of murid rodents to be conducted in Tarutao National Park, in terms of the number of Islands surveyed and the number of individuals captured, more research is required especially at the sites where we were unable to access. This would lead to a more complete list of the species richness of murid rodents in Tarutao National Park. However, it can also be predicted in simple terms that the species lists for the Islands are not likely to change much because despite sampling multiple sites in our study, as shown on the map, the species composition was essentially uniform within different sites on each Island.

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