PRELIMINARY ANALYSIS ON ABUNDANCE OF LARGE MAMMALS AT SUNGAI RELAU, TAMAN NEGARA

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Abstract

This paper presents a preliminary analysis of the relative abundance of mammals based on camera-trapping data and track counts at Sg. Relau (Merapoh), Taman Negara, Pahang. Abundance is expressed as a Relative Abundance Index (RAI_{CT}) based on 'detection' (*i.e.*, ≥1 photographs of a species/trap-night/trap-location) and total trap nights (n = 4192) for camera-trapping data. The track-count data, or RAI_{TC}, were based on 'counts' (*i.e.*, a 100-m strip of the ground where ≥1 tracks of species were recorded) on a total of 119 sample strips. The camera trapping yielded a total of 1513 photographs of 43 vertebrate species, which translated into 923 detections. The track counts produced a total of 312 counts of 16 species. The most common medium to large ungulate were wild boar, *Sus scrofa* (RAI_{CT} = 2.55, RAI_{TC} = 0.67), tapir, *Tapirus indicus* (RAI_{CT} = 4.22, RAI_{TC} = 0.35), barking deer, *Muntiacus muntjac* (RAI_{CT} = 2.55, RAI_{TC} = 0.41), and elephant, *Elephas maximus* (RAI_{CT} = 1.03, RAI_{TC} = 0.41), in that order. Both sambar deer, *Cervus unicolor* (RAI_{CT} = 0.29, RAI_{TC} = 0.13), and seladang, *Bos gaurus* (RAI_{CT} = 0.072, RAI_{TC} = 0.24), were uncommon. Among carnivores, the sun bear, *Helarctos malayanus* (RAI_{CT} = 1.27, RAI_{TC} = 0.0067) and leopard, *Panthera pardus* (RAI_{CT} = 2.48, RAI_{TC} = 0.034) were relatively common. The rarest large terrestrial mammals in the study site were Sumatran rhinoceros, *Dicerorhinus sumatrensis* (RAI_{CT} = 0, RAI_{TC} = 0), serow, *Capricornis sumatrensis* (RAI_{CT} = 0.024, RAI_{TC} = 0), wild dog, *Cuon alpinus* (RAI_{CT} = 0.07, RAI_{TC} = 0.0017) and the tiger, *Panthera tigris* (RAI_{CT} = 0.29, RAI_{TC} = 0). Recommendations in the application of camera trapping and track count to assess large mammal abundance are discussed.

Abstrak

Kertas kajian ini merumuskan mengenai penganalisa relatif kepadatan mamalia berdasarkan kepada tangkapan berkamera and pengamatan kesan tapak di Sungai Relau (Merapoh), Taman Negara, Pahang. Kepadatan di huraikan sebagai Indek Kepadatan Relatif (RAI_{CT}) berdasarkan kepada pengamatan (i.e.,=1gambar foto species/tangkapan-malam/tangkapan-tempat) dan jumlah tangkapan malam (n=4192) bagi data kamera tangkapan. Data bagi pengamatan kesan tapak, atau RAI_{TC}, adalah berdasarkan kepada pengiraan (i.e., jalur lintang berjarak 100-m dimana = l kesan species dicatitkan) berjumlah 119 sampel. Tangkapan berkamera telah menghasilkan sebanyak 1513 gambar foto, dimana hanya 923 pengamatan berpositif mampu mengenalpasti sebanyak 43 species vertabrata. Ungulata yang biasa dikenalpasti terdiri daripada babi hutan,

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Sus scrofa (RAI_{CT} =2.55, RAI_{TC}= 0.67), *tapir, Tapirus indicus* (RAI_{CT} =4.22, RAI_{TC}= 0.35), *Kijang, Muntiacus muntjac* (RAI_{CT} =2.55, RAI_{TC}= 0.41), *dan gajah, Elephant maximus* (RAI_{CT} =1.03, RAI_{CT}= 0.41). *Kedua-dua rusa, Cervus unicolor* (RAI_{CT} =0.29, RAI_{TC}= 0.13) *dan seladang, Bos gaurus* (RAI_{CT} =0.072, RAI_{TC}= 0.24) *jarang dijumpai. Bagi Karnivora pula, Beruang Matahari, Helarctos malayanus* (RAI^{CT} =1.27, RAI_{TC}= 0.0067) *dan Haramau dahan, Panthera pardus* (RAI_{CT} =2.48, RAI_{TC}= 0.034) *adalah biasa ditemui disini. Badak sumatra, Dicerorhinus sumatrensis* (RAI_{CT} =0, RAI_{TC}= 0.), *Kambing gurun, Capricornis sumatrensis* (RAI_{CT} =0.24, RAI_{TC}= 0.), *Angjing hutan, Cuon alpinus* (RAI_{CT} =0.07, RAI_{TC}= 0.0017) *dan Harimau belang, Panthera tigris* (RAI_{CT} =0.29, RAI_{TC}= 0.). *Cadangan bagi penggunaan kamera tangkapan dan pengamatan kesan tapak telah dihuraikan dengan lebih lanjut lagi.*

Introduction

Determining the abundance of large mammals is difficult because these animals naturally occur at low densities and thus large areas must be sampled in order to collect sufficient data. The sampling difficulty is aggravated in rainforest habitats where chances of visual observations are greatly reduced due to dense vegetation and the secretive nature of many animals. These biological difficulties, in addition to rugged terrain, frequent rain, and often lack of accommodations and trained personnel, has resulted in little ecological information being collected on many large mammals in Asian rainforests.

Estimation of absolute abundance requires either a total count or an estimation of statistical variances that can be only afforded by data sets of adequate sample sizes. The effort required to collect the requisite data are often much higher than available resources and time. Thus many researchers and conservation authorities have resorted to rapid survey or inventory studies, which produce results that are useful for that particular area but not for comparative purposes over space and time.

Malaysia is a biodiversity 'hotspot' (*sensu* Myers 1988; Aiken and Leigh 1985, Hurst 1990, Dinerstein and Wikramanayake 1993) and Taman Negara National Park, a 434,000-ha tract of protected primary forest, supports a rich flora and fauna. Many endangered or threaten species of Southeast Asia and some endemic species of Malaysia are found in Taman Negara. Charismatic megadiversities of Taman Negara undoubtedly draw many tourists to the park, and Taman Negara is considered as a stronghold of viable populations of many endangered species in Peninsular Malaysia (Khan, 1988 and 1990). However, due to the remoteness of the area and sampling difficulties mentioned above, there have been only a few scientific studies of large mammals in the park (Olivier 1978, Williams 1979, Stuwe, et al. 1998), and quantitative data on abundance of many large mammals in a form other than "number of tracks" are mostly unavailable to conservationists.

There is nevertheless a need for a reliable census method. Early detection of a subtle decline of some already rare species, thus endangered species, may be critical for its conservation. A reliable abundance assessment requires that information be accountable and in a form useful over space and time. Thus the objective of this study is to quantify the abundance of medium to large terrestrial mammals in Taman Negara in a comparable form.

Data on the abundance and distribution of large mammals in Sungai Relau, otherwise known as Merapoh, Taman Negara, Pahang, were collected between November 1998 and May 2000 as part of the University of Florida – Malaysia Tiger Project. As a preliminary analysis, this paper examines a method to derive a Relative Abundance Index (RAI) based on camera-trapping and track-count data. The RAI is then used to assess the relative abundance or rarity of medium to large terrestrial mammals in the study site. The RAI can also be used for future comparative studies over space and time, as long as the data are collected and treated in a similar manner.

Study Site

Taman Negara NP (4°10' - 4°56'N, 102°00' - 103°00'E) is located in the north-central peninsula where three states, Trengganu, Kelantan, and Pahang adjoin. Sg. Relau, otherwise known as Merapoh (4°41'N/102°04'E), is at the western border of the park and is the secondary entry point to the park after Kuala Tahan. It has the only paved road in the park, a 14-km long tract, which is used by climbers to get closer to Gunung Tahan. The altitude ranges from 100 m to 714 m at Gua Peningat peak. The vegetation is classified as typical lowland to hill tropical evergreen rainforest of the Indo-Malayan formation, dominated by the family Dipterocarpaceae (Whitmore 1984). A dense understory consists of many species of Euphorbiaceae, Rubiaceae, and Annonaceae (Soepadmo 1971). There are no aborigines (Orang Asli) living in this part of the park. A 200-km^2 study site extends 28 km along the Sg. Relau from Kuala Yu in south to Ulu Sg. Ketil in north and 11 km into the park from the Merapoh post to the Sg. Luis in east, which is 3 km east of Kuala Juram. It includes Gua Peningat, the largest limestone outcrop in Peninsular Malaysia, and several active salt lick sites such as Jenut Renkin, Cheruai, Atok, Atai, and Kumbang.

Materials And Methods

Camera Trapping

Camera trapping was conducted in the study site from April 1999 to May 2000 to capture terrestrial animals on film. We first used the TrailMaster (TM) active infrared camera-trap (TM1500: Goodson & Associates, Inc., 10614 Widmer, Lenexa, Kansas, 66215 USA), which is activated by an object breaking a linear beam for a programmed duration (0.2 seconds for this study). This triggers the camera to take a picture, which can occur as frequently as every 6 seconds. We used Kodak or Fuji film, 36 exposure, with an ASA of 400. The TM unit consists of three components: a transmitter, receiver, and a camera, which is connected to the receiver by an electric cable. We designed a crude, lightweight casing for the camera to protect it from rain, elephants and vandals. The casing was mounted to a tree with a bicycle cable lock. In February 1999, in order to enhance the trapping performance and to further expand the sampling area, we introduced 16 units of CamTrakker (CT), a passive infrared camera-trap (Cam Trak South, Inc., 1050 Industrial Drive, Watkinsville, GA 30677). The CT cameras are triggered by the sensor detecting heat and motion within range of a conical infrared beam. With these units, a picture could be taken every 3 minutes. The sensor and the camera were housed in a weather-resistant casing, which was mounted on a tree with the same cable lock used for the TM unit. Cameras were set along well used game trails and both models were mounted on sturdy trees 50 cm above the ground with a focal range (the distance between camera and the middle of the trail) of 3 – 5 m.

Thirty-nine camera traps were semi-permanently stationed at strategic locations in the forest and eight units were placed along the 14-km paved road,' Jeep Track'. Since the target species of the project was tigers, we took every measure to try and maximize the capture probability of the species. All camera-traps were set on active game trails or locations where tiger signs were found. In the vicinity of some 'hot spots' such as game trails leading to active salt licks, we set two camera-traps within 500 m of each other. Otherwise, the average distance between trap locations was 2-4 km. Many camera-traps were at remote sites where it took one day just to check two cameras. Not all of the 47 camera-traps were operational all the time. The number of camera-traps increased as we gradually expanded the sampling area from an initial 40 km^2 to the final 200 km^2. Some camera-traps were temporarily closed or moved to minimize damage by elephants or vandals. Others prematurely ceased to function due to mechanical errors, most often associated with high humidity. These cameras were replaced with new units after a month. Finally, due to daytime vehicle traffic on the Jeep Track, the timer of the TM camera-traps along this tract were set to operate only from 1700 – 0900 hr. We also moved some camera-traps to new locations in the vicinity of the original trap site if the results were continuously poor (< 3 wildlife photos / month for 2-3 months). If a site was perceived as void of wildlife, trapping was terminated at that particular location.

Camera traps were checked every 4 weeks in the forest and 2 weeks on the Jeep Track. Upon arrival at a camera-trap location, we replaced the old camera trap with a new unit, in which fresh batteries and a film had been installed, reset the camera trap, conducted a test shot, then left the trap site for a month or 2 weeks, depending on the location. Film and batteries were removed from cameras in the field station or base camp. Film was processed in Kuala Lumpur and all data (negatives, prints, date and time of events, trapping performance, number of trap nights) were logged and recorded monthly.

The number of photographs *per se* cannot be used to determine population size or compare abundance among sites over time. Only when it is expressed in unit effort, hence an index (e.g., number of photo / 100 trap nights or number of trap-nights / 1 photo), can the relative abundance be compared among studies. Therefore, to derive an index based on number of photographs, the total number of trap-nights (TN) must first be determined using the following formula:

$$Total\ TN = \Sigma_{i=1}\ tn_{i,} \quad (1)$$

where *i* is a trap location and *tn* is a trap-night at *i*th location; thus, total TN is a summation of trap-nights from 1[st] to the last trap location. A trap-night is a 24-hour period during which a camera-trap was functional. Thus on the Jeep Track, where camera-traps were functional between 1700 – 0900 hr, each trap accumulated only 0.67 trap-night per day.

The number of photographs may be positively correlated with two ecological phenomena: 1) abundance and/ or 2) activity level. For example, an individual tapir may finish an entire roll of film in one night at a trap location near a favorite salt-lick site. These 36 exposures of tapir reflect its high activity rather than high abundance. Since individual recognition of most species based on photographs is impossible and because camera-traps are spaced 200 m – to 4 km apart, there is no way of ensuring independent observations of individual animals for all species. Thus, the effect of activity level on the number of photographs cannot be completely separated from the true abundance. Nonetheless, to minimize the effect of the activity level and to standardize the analytical procedure among studies, we define 'detection', a unit of observation, as more than one photograph of a species per trap night per camera-trap location. Thus, for the above example of a tapir, the detection of the species at the trap location was one. When several individual animals were photographed in one frame, it was still counted as one detection. The Relative Abundance Index (RAI) for each species is calculated as:

$$RAI_{CT} = \Sigma_{i=1}\ d_i X\ 100/Total\ TN, \quad (2)$$

where *i* is a trap location and *d* is a detection of the species at *i*th location. Or from Equation (1) and (2), the RAI_{CT} may be expressed as:

$$RAI_{CT} = \Sigma_{i=1}\ d_i X\ 100/\Sigma_{i=1}\ tn_{i,} \quad (3)$$

where *i* is a trap location, and *d* and *tn* is a detection and trap night at *i*th location.

100-m Strip Track Counts

Track counts were conducted between November 1998 and May 2000 for the purposes of mapping the distribution and an assessment of relative abundance. Locations of all survey sites were determined using GPS, and the spatial information will be later incorporated into GIS for the mapping and spatial analysis. Here we describe the method using track-counts to determine the relative abundance of terrestrial species. We conducted track counts near camera-trap sites, at random locations between camera-trap sites that were in most cases on game trails we routinely traveled, and at random locations in newly surveyed areas. During the track count, we recorded the species of tracks encountered and not the number of tracks per species encountered on a 100-m strip on the ground. The track count was conducted monthly, and we recorded only relatively fresh tracks (<1 month old). The track identification was done by only experienced personnel, in most cases by the secondary author. Tracks that can be easily confused were pooled by genus (*Tragulus* for two species of mouse deer *T. javanicus* and *T. napu*) or family (Viverrids for all civets). Tracks of feline species were classified as either of tigers *Panthera tigris*, leopards *Panthera pardus*, medium cats (including clouded leopards *Neofelis nebulosa* and golden cats *Catopuma temminkii*), or small cats (including leopard cats *Prionailurus bengalensis* and marble cats *Pardofelis marmorata*). Although it was not necessary for the abundance study, all locations of the track-count sites were determined using GPS and recorded for later distribution analysis.

The unit of observation for the track counts is a 'count' that is a 100-m strip of the ground where $\geq$1 tracks of a species were observed. A strip can contain tracks of more than one species; therefore, a total 'count' of all species can be greater than a total number of strips sampled. However, a total count of one species cannot be greater than the total number of strips sampled. The Relative Abundance Index (RAI) for each species is calculated as:

$$RAI_{TC} = count \, / \, total\ number\ of\ strips. \tag{4}$$

Results

In a total of 4192 trap-nights between April 1999 and May 2000, we collected 1519 wildlife photographs, including 6, 4, 168, and 1341 photographs of invertebrates, reptiles, birds, and mammals, respectively. A total of 43 vertebrate species, consisting of 2 reptilian, 9 avian, and 32 mammalian species, have been captured on film (Table 1). Majority of the species were either totally protected or protected species under the Protection of Wildlife Act, 1972, Malaysia. The cameras captured the first record of the storm stork, *Ciconia stormi*, and the first positive evidence of the wild dog, *Cuon alpinus*, from the park as well as incontestable documentation of other uncommon mammals. The species list included all the medium to large terrestrial mammals that are reportedly found in Peninsular Malaysia except for the Sumatran rhinoceros, *Dicerorhinus sumatrensis*. We located tracks of a Sumatran rhinoceros 4 km west of the southern end of Gua Peningat (4°355'N/ 102°065'E) during our last track survey in May 2000, but the tracks were not near any of our camera-traps. Also during our survey along Sg. Tanum, east of Gua Peningat, we found tracks of a cat on the sandy riverbank (4°370'N/ 102°065'E) and, based on the maximum track width (between outer digits) of 40 mm and the protruding claws, it could possibly be a fishing cat, *Prionailurus vivverinus*.

The cumulative number of species captured photographically during the sampling period rose continuously (Figure 1), and it is possible that we would have captured more species of small to medium-sized mammals (*e.g.*, civets, mongoose, squirrels, and rats) if the sampling had continued.

The numbers of photographs were then translated into detections, and the Relative Abundance Index (RAI_{CT}) was calculated for each species (Table 2). On average, 22 detections were made in every 100 trap-nights (Total RAI_{CT} = 22.07). Since the Jeep Track was not a representative habitat type in Taman Negara, photographs collected from the Jeep Track were separated from those obtained in the forest, and the mammalian communities camera-trapped at the two sites were compared. Data on humans were excluded from this analysis. The cumulative number of camera-trapped species (species richness) was lower on the Jeep Track (n = 19) than in the forest (n = 26). The Shannon-Wiener Diversity Index (H', base 10 logs: Krebs 1989) was also slightly lower on the Jeep Track (H'_{JT} = 0.991 decits/individual) than in the forest (H'_{FT} = 1.004 decits/individual), but the difference was not statistically significant [t = -0.39, v (approximated degrees of freedom) = 676, $p \geq 0.05$].

Although the overall diversities of camera-trapped mammalian species were similar in the two communities, the representative species were strikingly different. The six most commonly detected species along the Jeep Track were the leopard cat, *Prionailurus bengalensis* (RAI_{CT} = 5.90), leopard, *Panthera pardus* (RAI_{CT} = 5.40), Malay civet, *Viverra tangalunga* (RAI_{CT} = 4.14), golden cat, *Catopuma temminckii* (RAI_{CT} = 1.88), common porcupine, *Hystrix brachyura* (RAI_{CT} = 1.88), and tapir, *Tapirus indicus* (RAI_{CT} = 1.63), in decreasing order of commonness. However, in the forest the most commonly detected species was the tapir (RAI = 4.83), followed by barking deer, *Muntiacus muntjac* (RAI_{CT} = 2.89), wild boar, *Sus scrofa* (RAI_{CT} = 2.80), leopard (RAI_{CT} = 1.80), sun bear, *Helarctos malayanus* (RAI_{CT} = 1.47), and elephant, *Elephas maximus* (RAI_{CT} = 1.21). A graphical comparison of the difference in species assemblages from the two communities is shown in Figure 2. Feline species were more often trapped on the Jeep Track, and ungulates were more often trapped in the forest. The leopard cat was never trapped in the forest site. Both the tiger, *Panthera tigris*, and clouded leopard, *Neofelis nebulosa*, were trapped about ten times more frequently on the Jeep Track than in the forest (Table 2). All photographs (n = 113) of the leopard from the road and forest sites were of melanistic animals.

A total of 312 counts of tracks was made on 119 100-m strips on the ground from November 1998 to May 2000. On average, 2.6 species of tracks were observed on every 100-m strip (Total RAI_{TC} = 2.62). Four strips (3.4%) contained no tracks of animals. Tracks of the wild boar were most frequently encountered (RAI_{TC} = 0.67), followed by elephant (RAI_{TC} = 0.41), barking deer (RAI_{TC} = 0.41), and the tapir (RAI_{TC} = 0.35). The most abundant species as measured by track counts coincided with the camera-trapping data from the forest site except for the elephant, which was the 6th most commonly detected animal by camera-traps (Table 3).

A comparison of the percentage of total counts and camera-trapping results (Table 3) were used to depict potential bias of the two sampling techniques in detecting terrestrial animals (Figure 3). For this analysis, we excluded the wild dog, tiger, and the small cats data because of small sample sizes [total n (counts + detections) < 5], and human data, tracks of which we neglected at the beginning of the track-count sampling. Also, only the camera-trapping data from the forest trapping sites were included for the comparison since track counts were not conducted on the paved Jeep Track. The elephant, sambar deer, and seladang were underrepresented, thus negatively biased (< 33.33%) in camera-trapping data, and the argus pheasant *Argusianus argus*, sun bear, civets, leopard were underrepresented (< 33.33%) in the track-count data. Other species were relatively equally represented (33.33% – 66.67%) by both sampling techniques.

The overall relative abundance of terrestrial animals may be possibly assessed by combining the results of both sampling methods. One way of achieving this is to add RAI_{CT} and RAI_{TC} to derive the cumulative RAI. Without knowing the absolute abundance of focal species, there is no way of calibrating the effectiveness of the two sampling methods in detecting terrestrial animals. The simple summation of RAI_{CT} and RAI_{TC} would likely result in too much weight being placed on the camera-trapping data since the total RAI_{CT} (22.07) was one magnitude higher than the total RAI_{TC} (2.62). Therefore, RAI_{CT} was first divided by 10, then added to the RAI_{TC} to make the inference on the overall relative abundance (Figure 4). The numerical values derived by this calculation have no biologically significant meanings other than used for an illustrative purpose. The most common medium to large ungulate were wild boar (RAI_{CT} = 2.55, RAI_{TC} = 0.67), tapir (RAI_{CT} = 4.22, RAI_{TC} = 0.35), barking deer (RAI_{CT} = 2.55, RAI_{TC} = 0.41), and elephant (RAI_{CT} = 1.03, RAI_{TC} = 0.41), in that order. Both sambar deer (RAI_{CT} = 0.29, RAI_{TC} = 0.13), and seladang (RAI_{CT} = 0.072, RAI_{TC} = 0.24), were uncommon. Among carnivores, the sun bear (RAI_{CT} = 1.27, RAI_{TC} = 0.0067) and leopard (RAI_{CT} = 2.48, RAI_{TC} = 0.034) were relatively common. Excluding semi-arboreal species such as the binturong *Arctictis binturong* and clouded leopard, the rarest large terrestrial mammals in the study site were Sumatran rhinoceros (RAI_{CT} = 0, RAI_{TC} = 0), serow (RAI_{CT} = 0.024, RAI_{TC} = 0), wild dog (RAI_{CT} = 0.07, RAI_{TC} = 0.0017) and the tiger (RAI_{CT} = 0.29, RAI_{TC} = 0). These figures include data from the Jeep Track.

Discussion

Efforts required to census or estimate absolute abundance of rainforest mammals may be too costly or time-consuming to be applicable in many cases. Yet without an abundance assessment, management and conservation planning are misguided and ill effective. This paper demonstrated the method to derive relative abundance indices based on camera-trapping and track-count data that can be used to compare the abundance over time or among different sites.

Although camera trapping is probably the most promising method to study distribution and abundance of medium to large terrestrial mammals in rainforest habitats, the technique is not free of bias and problems. The ability to sample multiple taxa was somewhat limited with the active infrared (TM) system. The height of the sensor beam was set at 50 cm above ground to ensure the capture of tigers, which probably resulted in missing smaller mammals. This is not a problem with the non-discriminatory passive infrared (CT) system. Indeed, the majority of photographs of smaller mammals such as the pangolin *Manis javanica* (67%, $n = 3$), brush-tailed porcupine *Atherurus macrourus* (100%, $n = 5$), and mouse deer *Tragulus* spp. (93%, $n = 28$) were obtained with the CT system, albeit these units were only deployed for a limited duration. The high detection rate of mouse deer with the CT system is worthy of further consideration. Twenty-six photographs of mouse deer were obtained with the passive infrared cameras during the last 3 months of trapping. Among terrestrial mammals, mouse deer was most frequently encountered on trail while trekking in the forest (personal observation, UF-Malaysia Tiger Project). Furthermore, 42 km of transects we have walked to visually detect ungulates produced data of only mouse deer ($n = 2$) and no other species (Unpublished data, UF-Malaysia Tiger Project). Therefore, we believe that the mouse deer is quite common in the area, at least much more so than cumulative relative abundance based on camera-trapping and track-count data (Figure 4). Due to its small size, they were probably missed by both sampling techniques.

Large mammals such as elephants, sambar deer, and seladang were underrepresented in the camera-trapping data compared to the track-count data. This is partially due to 1) tracks of such large animals are almost never missed, and 2) the slender limbs of the sambar and seladang might not have triggered the TM camera traps, which was set at 50 cm above ground and had to be broken by the body of an animal instead of limbs. In the case of elephants, the reason for the underrepresentation may relate to the way the detection was calculated. When the number of the total photographs was converted to detection, elephant data were reduced by 74% (167 photographs to 43 detections). A herd of elephants passing by cameras can finish an entire roll of film over one trap-night, which is counted as one detection. This is different from an individual tapir going back and forth in front of a camera trap near a salt lick over one trap-night, which is also counted as one detection. Also, unlike another social species, wild boar, elephants being curious animals tended to stay longer at trap locations to play and investigate the camera traps. By finishing the roll of film, they eliminated further possibilities of being camera-trapped on subsequent days, which would have meant more detections. The treatment of social species in abundance assessment based on camera-trapping data is further discussed later. Lastly, there probably would have been more photographs of elephants if the animals did not damage the camera-traps and thus reduce the possible data.

The selective feature of the TM system is advantageous to researchers, who wish to eliminate the chance of non-focal species triggering the cameras, which consequently reduces the detection frequencies of the focal species. Many technical problems associated with both types of camera traps were related to the high humidity of the local condition. Many rolls of film were stuck inside the cameras, battery power was drained faster, and metal parts (e.g., electrical circuits and conducting points) became rusted, to name a few problems. It is advisable to use camera traps equipped with waterproof cameras and check and change the film as often as possible. The high cost of purchase and maintenance of the camera equipment can be problematic when the camera traps are damaged by animals or stolen. Over the 13 months of sampling, the study lost 2 cameras, 3 sets of the TM sensors, and 1 CT camera-trap to elephants, and 4 cameras, 1 set of the TM sensor and 2 CT camera-traps to vandals.

There was only one incidence in which animals severed the steel wire locks, but the protective casings of for TM camera were no match for playful elephants. Camera traps are better camouflaged with vegetation and set in hidden spots rather than immediately adjacent to game trails where they are easily detected. Regular elephant trails should be avoided if damages are repetitive. None of the protective measures was effective in stopping determined vandals. There was no case in which vandals cut a tree to remove a camera-trap. They either cut the cable lock with a parang or ax for CT units or open the camera casing at the hinge for TM units. To some extent the loss to vandals may be inevitable. Their very presence in the protected area calls for a greater concern for protection of the study animals rather than the study equipment.

The abundance assessment based on track counts is highly subjective. Besides the true abundance, the encounter rate may be subjected to (1) the experience of the observers, (2) size of animals, (3) substrate on which tracks are printed, and (4) the recent weather. The latter three factors relate to the quality of prints, which in turn affects the ability of the tracker to find them. Tracks of smaller animals such as porcupines, civets, mouse deer, and ground birds on or below thick leaf litter can be easily missed by inexperienced trackers. Also frequent rain would wash away tracks of smaller animals first. Our data indicate that the argus pheasant and civets were underrepresented in the track-count data (Figure 3). Since the affecting factors (2), (3), and (4) are beyond our control, we have tried to keep factor (1) constant by only having the secondary author observe the tracks the majority of time. We recommend that track counts be conducted by the same experienced personnel consistently throughout a study to minimize the negative bias towards missing smaller animals and to keep any possible bias consistent.

Reasons for the underrepresentation of the sun bear and leopard in the track-count data (Figure 3) are unclear. The sun bear appears to like higher ground (personal observation, UF-Malaysia Tiger Project). If they are more abundant in hills where thick leaf litter accumulates, the likelihood of missing the tracks of these species is high because pads of cats and bears, in contrast to the sharp hooves of ungulates, do not register well on leaves. Both sun bears and leopards appeared to be widely distributed (camera trapped at 23 and 21 trap locations, respectively: Table 1). A further investigation into the altitudinal effects in their distributions may reveal the factor contributing to the negative bias.

The difference in representative species camera-trapped on the Jeep Track and in the forest suggested a selective usage of the road by feline species and civets. RAI_{CT} of all feline species except the marbled cat (n =1) were higher on the Jeep Track, in most cases by an order of a magnitude. Consequently, all ungulates avoided using the road as RAI_{CT} of all ungulate species were higher in the forest except for the serow (n=1). Instead of strolling down the road like the cats, the ungulates probably just crossed the road, preferring to stay in the cover where they were safer from predation. Since no large mammals could live on the road, RAI_{CT} on the road represent more activity levels than abundance. Nonetheless, the data from the road could be used to determine presence/absence, and thus were included to assess the overall abundance or rarity.

Based on both camera-trapping and track-count data, the four most common species were the wild boar, tapir, barking deer, and elephant in that order of commonness. Undoubtedly many detections were registered with camera traps near salt licks, however, that all four species were camera-trapped at many locations (Table 1) suggest they are widely distribution throughout the study site.

Since individual animals were not counted in the photographs or during track counts, the true abundance of social species such as the elephant and wild boar are likely to be higher than inferred in this study. Indeed a large number of elephant photographs were of multiple individuals. Counting individual animals in photograph to deduce the group size is misleading because with the focal distance of 3-5 m, a frame often misses an entire herd of large mammals (*c.f.*, elephants versus porcupines). Counting individual animals of a herd in a series of photographs is also problematic because the CT cameras could only take photographs every 3 minutes, whereas the TM units could take a picture every 6 seconds. The average group sizes need to be determined by direct observations or possibly by existing literature from similar environments. When this information from the local forest is known, the RAI can be multiplied by the average group size for a better inference of a relative abundance. In the same way, relative biomass can be inferred by multiplying the RAI by the average biomass of a group. Meanwhile, in this study we conclude that the abundance of elephants and wild boars were underestimated.

We encourage further investigations and discussions on the derivation of the total RAI using data collected by the two sampling techniques. Weighting of each sampling technique based on detectabilities of focal species requires prior knowledge of absolute abundance of the species. In the absence of such data, we believe that the method we applied, a summation of RAI_{TC} and 10% of RAI_{CT}, was reasonable.

Merapoh harbors a rich assemblage of large mammals. The abundance of uncommon ungulates such as sambar and seladang can be enhanced by an active habitat management and better protection, which will consequently increase the resources for top predators. The rare species, the Sumatran rhinoceros, serow, wild dog, and the tiger, require further attention and considerations for research of the status and threats, on which conservation strategies can be based. The University of Florida – Malaysia Tiger Project will be sampling two more sites in Taman Negara. In the end we will have a much better pictures of the status of the large mammals from this large protected primary forest in Peninsular Malaysia.

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Table 1. Summary of vertebrate species camera-trapped from April 1999 to May 2000 in Merapoh, Taman Negara, Malaysia.

Reptilian/Avian Species

Common Name	Scientific Name	Status	Total No. of Photos	Total No. of Trap Sites
Harlequin monitor	*Varanus rudicollis*	TP	1	1
Water monitor	*Varanus salvator*	P	3	2
Storm's stork	*Ciconia stormi*	TP	3	2
Crested serpent-eagle	*Spilornis cheela*	TP	2	2
Crested wood-partridge	*Rollulus rouloul*	TP	1	1
Great argus pheasant	*Argusianus argus*	TP	111[a]	11
Malay peacock pheasant	*Polyplectron malacense*	TP	33[a]	2
Crested fireback	*Lophura ignita*	TP	11	5
Crestless fireback	*Lophura erythropthalma*	TP	3	3
White-crowned hornbill	*Berenicornis comatus*	TP	1	1
Garnet pitta	*Pitta granatina*	TP	3	1

Total – 11 species, 172 photographs

Mammalian Species

Common Name	Scientific Name	Status*	Total No. of Photo	Total No. of Trap Site
Bat	Unknown[b]	N/A	3	3
Pig-tailed macaque	*Macaca nemestrina*	P	11	5
Long-tailed macaque	*Macaca fascicularis*	P	1	1
Pangolin	*Manis javanica*	TP	3	3
Ground squirrel	*Sciurid spp.*[b]	NP	3	2
Shrew-faced squirrel	*Rhinosciurus laticaudatus*	NP	1	1
Spiny rat	*Maxomys spp.*	NP	2	2
Common porcupine	*Hystrix brachyura*	P	55	11
Brushed-tailed porcupine	*Atherurus macrourus*	P	5	1
Wild dog (dhole)	*Cuon alpinus*	TP	6	3
Sun bear	*Helarctos malayanus*	TP	95	23
Yellow-throated marten	*Martes flavigula*	TP	5	4
Malay civet	*Viverra tangalunga*	P	61	10
Common palm civet	*Paraduxurus hermaphroditus*	P	1	1
Large indian civet	*Viverra zibetha*	TP	2	1
Binturong	*Arctictis binturong*	TP	1	1
Banded palm civet	*Hemigalus derbyanus*	NP	1	1
Tiger	*Panthera tigris*	TP	22	6
Leopard	*Panthera pardus*	TP	113	21
Clouded leopard	*Neofelis nebulosa*	TP	5	3
Golden cat	*Catopuma temminckii*	TP	21	8
Marbled cat	*Pardofelis marmorata*	TP	1	1
Leopard cat	*Prionailurus bengalensis*	TP	59	4
Elephant	*Elephas maximus*	P	167	19
Tapir	*Tapirus indicus*	TP	324	29
Wild boar	*Sus scrofa*	P	133	31
Mouse deer	*Tragulus spp.*[c]	P	28	7
Sambar deer	*Cervus unicolor*	P	20	5
Barking deer	*Muntiacus muntjac*	P	137	30
Seladang	*Bos gaurus*	TP	5	3
Serow	*Capricornis sumatrensis*	TP	1	1
Human	*Homo sapiens*	N/A	49	10

Total – 32 species, 1341 photographs, Grand Total – 43 species, 1513 photographs

* Protected status under the Protection of Wildlife Act, 1972, Malaysia: TP – totally protected, P – protected, NP – not protected, and N/A – not applicable. The tiger was listed as TP in 1976.

[a] Mostly repeated shots of individuals at dancing grounds.

[b] Animals were too small to be identified to the species level.

[c] Two species of the mouse deer, *Tragulus napu* and *T. javanicus*, were pooled as they were sometimes indistinguishable on photographs.

Table 2. Detection* and Relative Abundance Index (RAI_{CT}) of vertebrate species camera-trapped from April 1999 to May 2000 in Merapoh, Taman Negara, Malaysia. The Jeep Track had a total of 8 camera-trap locations and 797 total trap-nights, and the forest trapping area had a total of 39 camera-trap locations and 3395 total trap-nights, respectively. RAI_{CT} in bold prints represent 6 most frequently detected species from each trapping area.**

Common Name	Scientific Name	Jeep Track		Forest		Total	
		Detection	RAI_{CT}	Detection	RAI_{CT}	Detection	RAI_{CT}
Reptilian/Avian Species							
Harlequin monitor	*Varanus rudicollis*	0	0.00	1	0.03	1	0.02
Water monitor	*Varanus salvator*	0	0.00	2	0.06	2	0.05
Storm's stork	*Ciconia stormi*	0	0.00	3	0.09	3	0.07
Crested serpent-eagle	*Spilornis cheela*	2	0.25	0	0.00	2	0.05
Crested wood-partridge	*Rollulus rouloul*	0	0.00	1	0.03	1	0.02
Great argus pheasant	*Argusianus argus*	1	0.13	34	1.00	35	0.83
Malay peacock pheasant	*Polyplectron malacense*	1	0.13	1	0.03	2	0.05
Crested fireback	*Lophura ignita*	0	0.00	6	0.18	6	0.14
Crestless fireback	*Lophura erythropthalma*	0	0.00	3	0.09	3	0.07
White-crowned hornbill	*Berenicornis comatus*	0	0.00	1	0.03	1	0.02
Garnet pitta	*Pitta granatina*	0	0.00	1	0.03	1	0.02
Mammalian Species							
Bat	Unknown[b]	0	0.00	3	0.09	3	0.07
Pig-tailed macaque	*Macaca nemestrina*	0	0.00	8	0.24	8	0.19
Long-tailed macaque	*Macaca fascicularis*	1	0.13	0	0.00	1	0.02
Pangolin	*Manis javanica*	0	0.00	3	0.09	3	0.07
Ground squirrel	*Sciurid spp.*[b]	2	0.25	1	0.03	3	0.07
Shrew-faced squirrel	*Rhinosciurus laticaudatus*	0	0.00	1	0.03	1	0.02
Spiny rat	*Maxomys spp.*	0	0.00	2	0.06	2	0.05
Common porcupine	*Hystrix brachyura*	15	1.88	26	0.77	41	0.98
Brushed-tailed porcupine	*Atherurus macrourus*	0	0.00	5	0.15	5	0.12
Wild dog (dhole)	*Cuon alpinus*	1	0.13	2	0.06	3	0.07

Table 2: Continued

Common Name	Scientific Name	Jeep Track		Forest		Total	
		Detection	RAI_{CT}	Detection	RAI_{CT}	Detection	RAI_{CT}
Sun bear	*Helarctos malayanus*	3	0.38	50	1.47	53	1.27
Yellow-throated marten	*Martes flavigula*	2	0.25	3	0.09	5	0.12
Malay civet	*Viverra tangalunga*	33	4.14	15	0.44	48	1.15
Common palm civet	*Paraduxurus hermaphroditus*	1	0.13	0	0.00	1	0.02
Large indian civet	*Viverra zibetha*	1	0.13	0	0.00	1	0.02
Binturong	*Arctictis binturong*	0	0.00	1	0.03	1	0.02
Banded palm civet	*Hemigalus derbyanus*	0	0.00	1	0.03	1	0.02
Tiger	*Panthera tigris*	8	1.00	4	0.12	12	0.29
Leopard	*Panthera pardus*	43	**5.40**	61	**1.80**	104	**2.48**
Clouded leopard	*Neofelis nebulosa*	2	0.25	1	0.03	3	0.07
Golden cat	*Catopuma temminckii*	15	**1.88**	4	0.12	19	0.45
Marbled cat	*Pardofelis marmorata*	0	0.00	1	0.03	1	0.02
Leopard cat	*Prionailurus bengalensis*	47	**5.90**	0	0.00	47	1.12
Elephant	*Elephas maximus*	2	0.25	41	**1.21**	43	1.03
Tapir	*Tapirus indicus*	13	**1.63**	164	**4.83**	177	**4.22**
Wild boar	*Sus scrofa*	12	**1.51**	95	**2.80**	107	**2.55**
Mouse deer	*Tragulus spp.*[c]	0	0.00	25	0.74	25	0.60
Sambar deer	*Cervus unicolor*	0	0.00	12	0.35	12	0.29
Barking deer	*Muntiacus muntjac*	9	1.13	98	**2.89**	107	**2.55**
Seladang	*Bos gaurus*	0	0.00	3	0.09	3	0.07
Serow	*Capricornis sumatrensis*	1	0.13	0	0.00	1	0.02
Human	*Homo sapiens*	11	1.38	14	0.41	25	0.60
Total		226	28.36	699	20.59	925	22.07

Detection is a more than one photograph of a species per trap night per camera-trap location.

** $RAI_{CT} = S_{i=1}\, d_i X\, 100/S_{i=1}\, tn_i$, **where *i* is a trap location, *d* is a detection of the species and *tn* is a trap-night at *i*th trap location**

Table 3. Comparison of the track-count and camera-trapping results from Merapoh, Taman Negara, Malaysia. The unit of observation for the track count, 'count' is a number of 100-m strip where tracks of vertebrate species are recorded, and that of camera trapping is a 'detection' where a species can be counted only once/trap-night/trap location regardless of a number of photographs taken during the same trap-night. Since track count was not conducted on the paved Jeep Track, camera-trapping data from the Jeep Track were excluded from this analysis

	Track Count			Camera Trapping		
Common Name	**Counts**	**% of total counts**	**RAI_{TC} ***	**Detection**	**% of total detection**	**RAI_{CT}****
Great argus pheasant	1	0.32	0.0084	34	5.22	1.00
Common porcupine	8	2.56	0.067	26	3.99	0.77
Wild dog	2	0.64	0.0017	2	0.31	0.059
Sun bear	8	2.56	0.0067	50	7.68	1.47
Civets	1	0.32	0.0084	15	2.46	0.47
Tiger	0	0.00	0.00	4	0.61	0.12
Leopard	4	1.28	0.034	61	9.37	1.80
Medium cats[a]	2	0.64	0.017	5	0.77	0.15
Small cats[b]	2	0.64	0.017	0	0.15	0.03
Elephant	49	15.71	0.41	41	6.30	1.21
Tapir	42	13.46	0.35	164	25.19	4.83
Wild boar	80	25.64	0.67	95	14.59	2.80
Mouse deer	17	5.45	0.14	25	3.84	0.74
Sambar deer	16	5.13	0.13	12	1.84	0.35
Barking deer	49	15.71	0.41	98	15.05	2.89
Seladang	28	8.97	0.24	3	0.46	0.088
Human	3	0.96	0.025	14	2.15	0.41
Total	**312**	**100**	**2.62**	**649**	**100**	**19.18**

* RAI_{TC} = *counts / total number of strips.*

** $RAI_{CT} = \Sigma_{i=1} d_i X\ 100/\Sigma_{i=1} tn_i$, where *i* is a trap location, *d* is a detection of the species and *tn* is a trap-night at *i*th trap location.

a Medium cats include clouded leopards and golden cats.

b Small cats include marbled cats and leopard cats.

Figure 1. Cumulative number of vertebrate species photographically captured with camera traps as a function of 24-hr trap nights from April 1999 to May 2000 in Merapoh, Taman Negara, Malaysia.

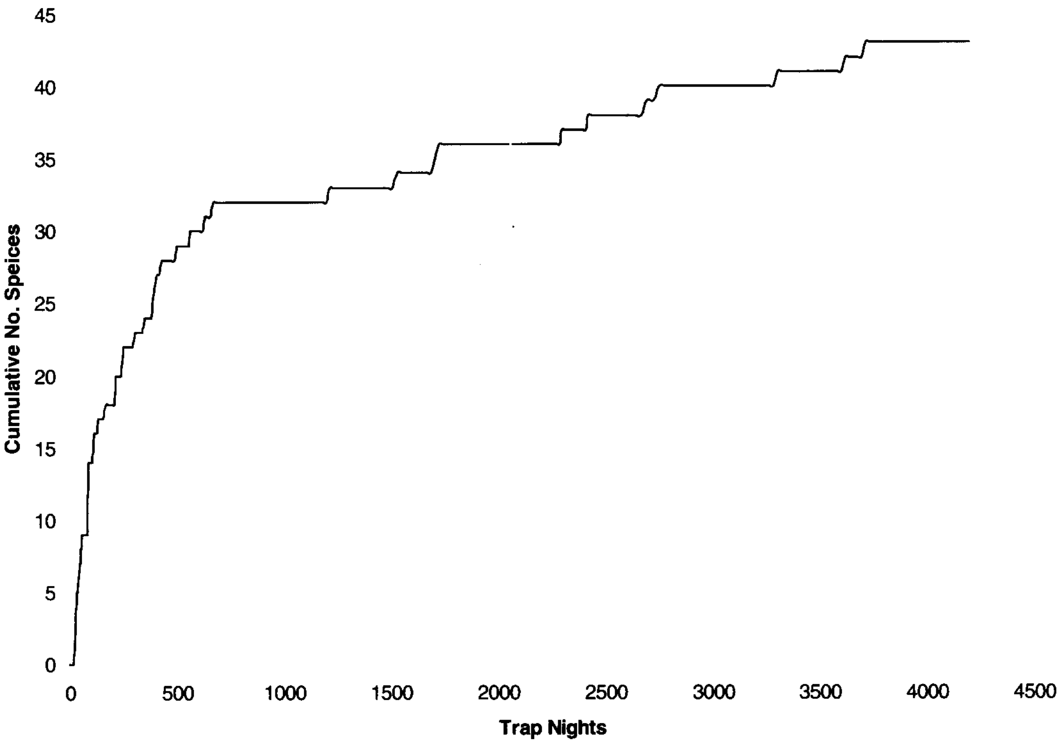

Figure 2. Comparison of Relative Abundance Indices of the ten most commonly camera-trapped species from two trapping areas in Merapoh, Taman Negara, Malaysia.

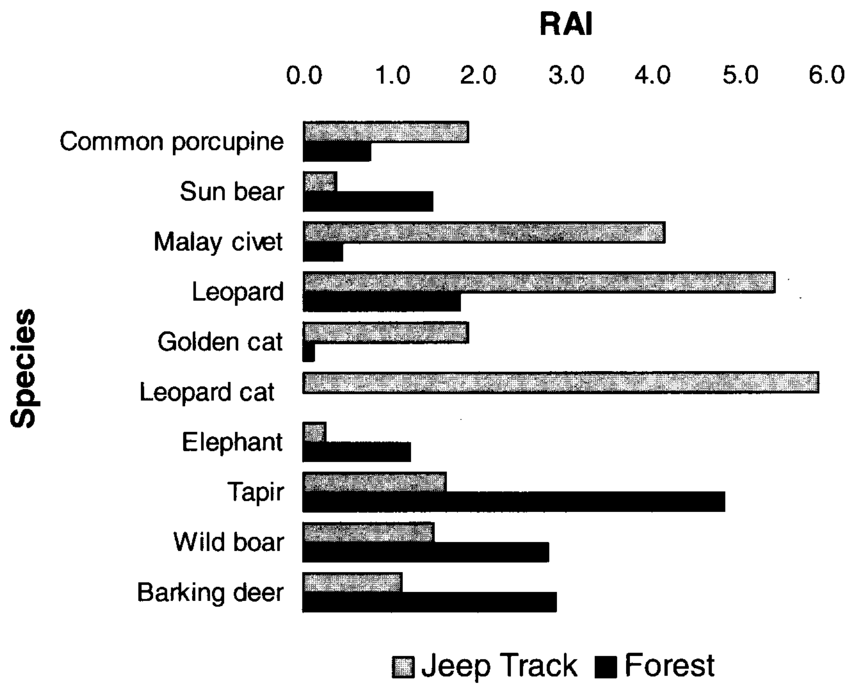

Figure 3. Potential bias of the camera-trapping and track-count sampling techniques in detecting medium to large terrestrial animals, which resulted in underrepresentation of some species in either technique. The medium cats include clouded leopards and golden cats.

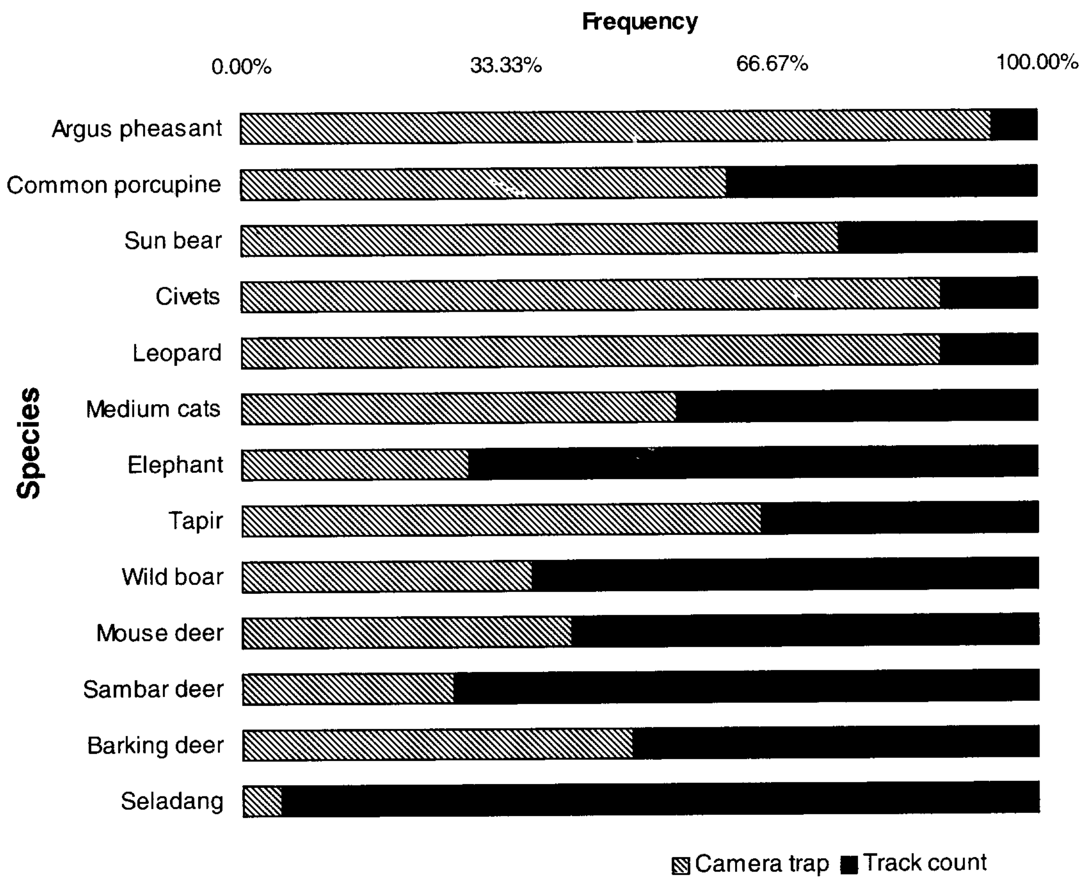

Figure 4. Cumulative relative abundance of medium to large terrestrial animals based on camera-trapping and track-count data from Merapoh, Taman Negara, Malaysia. The Medium cats include clouded leopards and golden cats and the small cats include marbled cats and leopard cats.