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รายงานฉบับสมบูรณ์

โครงการวิทยานิพนธ์เรื่อง อิทธิพลของโครงสร้างป่าและความชุกชุมของอาหาร (ผลไม้และสัตว์เลี้ยงลูกด้วยนมขนาดเล็ก) ที่มีต่อสังคมสัตว์ผู้ล่าขนาดเล็ก (Mammalia: Carnivora) ในเขตรักษาพันธุ์สัตว์ป่าทุ่งใหญ่นเรศวรด้านตะวันตก (รหัสโครงการ BRT T_351001)

(Effects of forest structure and food availability on the small carnivore community in Thung Yai Naresuan Wildlife Sanctuary, western Thailand)

รายงานในช่วงตั้งแต่วันที่ 1 ตุลาคม 2550 – 31 ตุลาคม 2551

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1) PROJECT OBJECTIVES

This study consists of three objectives;

1.1 Examine the patterns of occurrence and relative abundance as a surrogate of animal abundance of small carnivore species in 2 major forest types of Thung Yai Naresuan Wildlife Sanctuary, western Thailand.

1.2 Assess the availability of food resources (fruiting trees and small mammals) in each forest types.

1.3 Model the probability of site occupancy of small carnivores in relation to habitat and landscape features.

2) METHODS

Study Area

Thung Yai Naresuan Wildlife Sanctuary (TYN) is 3,622 km^2 in area, (15° 00'-15° 23' N, 98° 30'-99° 05' E) adjacent to Myanmar. Together with the adjacent Huai Kha Kaeng (HKK), constitutes Thailand's first Natural World Heritage Site, and forms the core of the largest contiguous protected, forest complex in mainland SE Asia, known as the Western

Forest Complex. The sanctuary is characterized by rugged mountainous terrain with elevations up to 1,800 m. The main forest types in TYN are mixed deciduous, MDF (45 – 47%), seasonal dry evergreen (also referred to as semi-evergreen forest, SEF; 28 – 31%), and montane evergreen, MEF (15%). Secondary forest covers 4% of the sanctuary, and the remaining 5% consists of savanna, grassland and dry dipterocarp forest, DDF (Anon. 1997; Kutintara & Bhumpakphan 1989; Nakhasathien & Stewart-Cox 1990). There are three distinct seasons: a cool dry season between November and February, a hot dry season from March through May, and a rainy season between May and October. Ten-year mean annual rainfall in the western TYN, was 2,337 mm between 1986 and 1996 (van de Bult 2003). Less than 100 mm of rain per month falls for five months of the year (based on data from 1997 and 2005), and rainfall is concentrated between July and September. Mean annual temperature is 28° C (The Thai Meteorological Department 2005).

SEF and MDF occur between 400 and 1000 m elevation, as alternating patches in a mosaic determined largely by gradients of soil moisture. SEF is tall, with a closed canopy at 25-40 m formed predominantly by evergreen tree species (Maxwell 1995). This forest type is thought to be the most species- rich forest type within the western forest complex of Thailand (van de Bult 2003). Woody climbers are common, and ground cover is often dense with herbs, seedlings, and saplings. The midstory (7-25 m) is usually dense with smaller trees. This characteristic leads to greater multi-layered complexity of vegetation structure relative to MDF and DDF (van de Bult 2003).

MDF, in contrast, is dominated by deciduous tree species, especially from the families Leguminosae, Combretaceae, Dilleniaceae, and Lythraceae (van de Bult 2003). Although the canopy can reach 30 m, tree density is lower and the mid-storey more open than in SEF. Woody climbers are uncommon, and the ground cover is usually dense with herbs and grasses. Bamboo is locally abundant in this forest type and sometimes dominates the understory.

DDF occurring in this area is dominated by dipterocarp species; *Shorea siamensis*, *S. obtusa*, *Dipterocarpus tuberculatus*, *D. obtusifolius*. Also Leguminosae species are well represented in this forest type, for instance, *Xylia xylocarpa*, *Dalbergia cultrata* and *D. cana*. The canopy is very open, mainly deciduous and mostly a one-layered tree stand reaching 10-20 m with very few emergent trees that can reach 30 m and the lower story is almost absent (van de Bult 2003).

Gallery SEF can be found commonly along streams forming 20-50 meter wide strips running through extensive grassy MDF (Nakhasathien & Stewart-Cox 1990; Steinmetz & Simcharoen 2006). Larger patches of secondary, SEF and less disturbed, SEF and MEF are confined to higher elevations.

The forest type at **Sesawo** and **Maegatha**, the proposed study sites, as representative for MDF/Savanna forests, are open, mixed *Shorea siamensis – Quercus kerrii* forest that sustains annual fires and therefore has a high component of grasses (hereafter, savannah). It is also classified as dipterocarp-oak forest (Maxwell & Elliott 2001). The open savannah has an open canopy, only scattered large trees and an apparently high density of small trees. Forest fires caused by human activity occur annually. The tree-dominated forest had a moderately closed canopy, simple stratification, and less grass but more perennial understory shrubs and tree seedlings than the open savannah. Fire damage was apparent but it was clear that the ground fire intensity was much lower in the tree-dominated habitat than the open savannah habitat. Whereas forest types at **Tikong** and **Tinuay** (Headquarter), representatives of SEF study sites, resemble SEF described earlier.

Camera trap survey

From November 2007 to August 2008 60 camera-trap units (Deer Cam [] and Stealth Cam [Stealth Cam, LLC, TX, USA]) were placed in 2 semi-evergreen (SEF) and 2 mixed deciduous/savanna forest (MDF/Savanna), at a density of 1 camera-trap station/1 km^2 in a grid system (i.e. cameras were installed in adjacent cells of 1 km^2). The 2 forests are > 40 km apart to promote independency assumption (Appendix A – A map of TY with camera trap locations). Camera units were placed at locations based on those areas where animals usually travel and leave sign of recent activity - by small streams, existing animal trails, along riparian vegetation running through grassland - and coordinates were taken using GPS. These non-random camera placements and spacing between cameras are designed to increase the probability of photographing the focal species. Cameras were mounted on trees or poles with the infrared beam set at a height of ca. 30 cm. Each unit was programmed to delay sequential photographs by 1 minute and operate 24 hours per day until the film was fully exposed. Cameras were left in the field for ca. 30 days before subsequent visits were made for film and battery retrieval and replacement. All units were installed in each study site for *ca.* 4 months and then moved to new locations resulting in two temporal/spatial replicates within each forest type. Average elevation of camera placements was 854 ±87 m (range 700 – 1147m) in both forest types. Fifty eight per cent of camera trap stations (n=32) were between 1 – 100 m to streams and thirteen per cent (n=7) were in the proximity > 1,000 m from streams.

Measuring of habitat and landscape features

To test whether landscape and habitat characteristics influence the pattern of occupancy of small carnivores, I used ArcView 3.2 software (ESRI Inc., Redlands, CA, USA) to derive the estimates of these landscape variables that are distance to nearest contrast habitat, distance to stream, and camera elevation. While habitat variables data consisting of fruiting tree density, percentage of fruit abundance, small mammal relative abundance, presence/absence of large predators data were collected during field surveys (more detail below). These variables were used as explanatory variables in occupancy models.

Small mammal relative abundance

Forty mesh live traps (dimensions; 38 x 10 x 12 cm) were used to assess small mammal relative abundance in each forest type. Traps were placed at 20m intervals along 4, 200 m trap-lines for 5 consecutive days. Traps were baited with ripe banana or fried coconut pieces covered by peanut butter. Traps were placed under shade to reduce heat to captured animal. Operating traps were checked daily between 0700 – 1200 hr. Captured animals were weighed and marked by painting where hairs were clipped and released at the point of capture.

Fruiting trees density

Fruiting tree density (trees per hectare) were determined using transects with variable width and circular plots. Three transects 200 x 10 m were placed randomly within the first SEF site with a minimum distance of 200 m spacing. In the first MDF site 4 200 x 20 m transects were sampled. The second sites of both forests were sampled using circular plots circled around camera placements with 20 m and 10 m radii for MDF and SEF, respectively. Only trees, shrubs, and climbers bearing fruit located within area sampled were measured diameter at breast height (DBH). For woody climbers I followed the protocol described in Gerwing et al. (2006). Due to the difficulty to determine the abundance of lianas' fruits using visual estimate and the imprecision of extrapolating fruit abundance from crown volume estimates (Chapman et al. 1992), therefore, the production of lianas' fruits were recorded if there are fruits presence. Fruit maturity (young and mature) was determined regardless of fruit conditions (ripe or unripe). Fruiting tree species were determined based on previous studies on small carnivores' diet (e.g., Grassman 1997; Grassman 1998; Kitamura et al. 2002; Rabinowitz 1991; Rabinowitz & Walker 1991).

Data analysis

Estimation of species richness

Program CAPTURE (Rexstad & Burnham 1991) was used to estimate species richness of small carnivores in relation to forest type as well as overall using detection/non-detection data by treating camera trap stations as sampling units (Williams et al. 2002). Closure assumptions and goodness of fit of the models were tested for each estimate.

Criteria for independence of animal photographs

Each photograph of a small carnivore included date and time printed on film was examined and identified to species. Photographs which we could not assign to species were omitted accounting for 3%. Determination of independence of photographs was based on the following criteria; (1) consecutive photographs of different individuals of the same or different species, (2) consecutive photographs of individuals of the same species taken more than 0.5 hours apart, and (3) nonconsecutive photos of individuals of the same species (O'Brien et al. 2003).

Habitat use

Habitat use by small carnivores was assessed using relative abundance index. Two widely used relative abundance indices (RAI) derived from indexing the numbers of independent photographs of a species are used to compare differences in relative abundance among species traits between forest types. The average numbers of days required to acquire the first photograph of a species (RAI1) is a measure of survey effort and is expected to decrease when animal's density increases (Carbone et al. 2001). The number of photographs acquired per day (RAI2) is expected to increase when an animal's density increases (O'Brien et al. 2003). RAI2, also called "capture rate", was indexed as number of photographs of a given species recorded per 100 trap days.

In order to avoid misleading inferences about species relative abundance in relation to forest types, it is safe to assume that species relative abundance may be caused by their readiness of being detected by survey method due to differences in behavioral responses rather than their abundance (e.g., Duckworth & Nettelbeck 2007), thus, underrepresented the patterns of species relative abundance observed. Small carnivore species were assigned according to their ecological/functional traits, terrestrial and semi – to arboreal. Hypotheses and predictions were tested as follows; (1) among species of the same functional trait between forest types, (2) within the same species between forest types, and (3) among species of the same functional trait within the same forest type. Log transformations of the data did not help normality assumptions (Shapiro–Wilk test; $W = 0.7518$, $P < 0.0001$), therefore, we used non-parametric tests (Wilcoxon, and Kruskal – Wallis). However, for species with sufficient detections (see Results), log-transformations were used to normalize data to test with parametric statistics. Significance level was set at $\alpha = 0.05$. All tests were performed using JMP 5.0.1 (SAS Institute 2007) unless otherwise stated.

***Habitat attributes** (food availability)*

Small mammal relative abundance

Small mammal relative abundance in each study site was estimated using live trapping data indexing as numbers of animals caught per 100 trap nights. Trapping efforts for each study site was 200 trap nights comprising 800 trap nights in total. Differences in small mammal relative abundance between forest types and study sites were assessed to see if 5 small carnivores had higher probability of occupancy where small mammals were also significantly higher in relative abundance. These estimates were used as predictor variables in modeling small carnivore site occupancy probability.

Fruiting tree density and percent fruit abundance

The total area sampled for each forest type were 1.6 ha (MDF1), 2.0 ha (MDF2), 0.6 ha (SEF1), and 0.5 ha (SEF2). Due to SEF has higher tree density than MDF, therefore, more area in MDF was sampled to compensate for this different. Fruiting tree densities were compared between sites to examine differences between values of fruiting tree densities at camera trap station where species was detected and not detected. The densities of fruiting tree for each study site were used to predict the probability of site occupancy of small carnivores, subsequently.

Landscape attributes

I assess values of landscape and habitat variables (mentioned above) using nonparametric Mann – Whitney *U* tests for continuous data and Chi – square test for categorical data between site (camera trap station) where species were detected and not detected. I highly recognize that this information cannot be used or even mixed in interpreting results derived from occupancy modeling since they adopt different approaches (Burnham & Anderson 2004). Therefore, I provide this information (Appendix B) solely for future research on small carnivores when researchers asking similar questions.

Estimations of site occupancy and detection probabilities

Detection/non-detection data of 5 most common small carnivores detected by camera traps, namely, Large Indian Civet, Common Palm Civet, Masked Palm Civet, Crab-eating Mongoose and Leopard Cat, were grouped by 2-week periods resulting in 9 survey occasions for occupancy modeling. This sampling period was assumed to be closed to possible changes in species turnover, local extinction and colonization to satisfy the closure assumptions of the single season occupancy model (MacKenzie & Royle 2005). To confirm whether the assumption is met closure tests were performed for each individual species using program CAPTURE.

I considered bivariate relationships with Spearman rank correlation for predictor variables (both landscape and habitat scales) to control for multi – collinearity and removed variables of lesser ecological relevance if correlation coefficient (Spearman's rho, r) > 0.70 (Luck 2002). Due to fruiting tree density and average percent fruit abundance showed strong correlation ($r = 0.718$, $P < 0.001$), therefore, I removed average fruit abundance as of lesser ecological relevance from further analyses.

Variables having continuous characteristic were standardized (Z – transformation) before being modeled as covariates in determining the probability of site occupancy of 5 small carnivore species. Detection probabilities were assumed constant over the survey period.

A set of a priori 10 models were constructed for each species to describe the variation in occupancy probabilities; (a) *landscape variables* (LANDSCAPE); distance to nearest contrast habitat (DIST_HAB), distance to nearest stream (DIST_STRM), elevation (ELEV), and the presence/absence of large predators (PREDATORS), (b) *habitat variables* (HABITAT); fruiting tree density (FTD), small mammal relative abundance (RODENTS_RAI), and forest types (FTYPE), (c) each variable modeled separately, and (d) null model where probability of occupancy (ψ) and detection probability (p) were modeled independently from variables' effects (i.e., constant). All models with covariates assume constant detection probability.

I use model selection criteria that enable multiple models to be compared simultaneously to rank competing models in a model set of each small carnivore species and to weigh relative support for each model (Johnson & Omland 2004). I select the most parsimonious model as suggested by the difference in second-order Akaike's Information Criterion (AIC_c) adjusted for small sample size (Δ_i) (Anderson et al. 2001). Model probability (Akaike weight, w_i) is used to determine the best fit model to camera trapping data by assuming that one of the model in the model set must have been the best model (Burnham & Anderson 2004).

The main objective of this analysis is to determine variable(s) that contribute most to small carnivores' probabilities of occupancy. I use model-averaged estimates of variable coefficients based on multi-model inference to account for model selection uncertainty since we expect that no single model is overcoming supported by the data (w_i > 0.9) (Burnham & Anderson 2004; Johnson & Omland 2004). I calculate these variable(s) by multiplying variable coefficient ($\hat{\beta}$) by model probability (w_i) and summing the value across all models in the model set including the variable (Burnham & Anderson 2004; Johnson & Omland 2004).

Unconditional sampling variance (the estimate of coefficient variance across the entire model set that is not conditional on a particular model) for the model coefficient in the most parsimonious model was calculated using standard error and model probability (w_i) from models in the model set including the coefficient variable. Confidence intervals for the unconditional sampling variance are also estimated using model-averaged variable coefficients and standard errors (Burnham & Anderson 2004; Johnson & Omland 2004).

All models and parameters of interest (occupancy, detection probability and coefficient of estimated predictors) were estimated using PRESENCE (http://www.mbr-pwrc.usgs.gov/software/presence.html. 2006).

3) RESULTS

Due to failure and loss of camera units, the total number of camera-trap stations used in the analyses were 55 stations; SEF (n=26), MDF/Savanna (n=29). The total number of photographs taken during the survey period between November 2007 and August 2008 was 1,191 photographs (Table 1); 730 photographs (61%) from MDF/Savanna and 461 photographs (39%) from SEF. Approximately 3 per cent (30 out of 1,191) of total photographs were either too far or too close to the recorded animal and could not be identified to species. Among those usable, 205 photographs (17%) were small carnivores consisting of 11 species with 153 photographs considered independent (75%) excluding Small-clawed Otter *Aonyx cinerea* and Golden Jackal *Canis aureus* where photographs taken during preliminary surveys and the otter is considered an aquatic species hence detection from camera trap survey may underestimate species abundance and was not used in subsequent analyses. Among those independent photographs 113 photographs (74%) of small carnivores were taken from MDF/Savanna whereas only 40 photographs (26%) were from SEF. Average number of non-independent photographs taken per day for all species was 3.52 photographs, excluding humans and 0.74 photographs for small carnivores (0.55

photographs per day for those considered independent). Total camera trapping effort was 4,569 trap days (TD): 2,362 trap days were from SEF and 2,207 trap days were from MDF/Savanna forest. Of 55 active camera-trap stations, 22 stations (40%) had no small carnivore photographs; 12 stations (*ca.* 20%) from SEF and 10 stations (*ca.* 20%) from MDF/Savanna. The overall rate of detection for small carnivores was 3.91 photographs/100 TD (Table 2).

Similarity between forest types

Although both forest types shared 8 out of 11 species observed, the coefficient of similarity derived from using Sorensen Quantitative Index (Magurran 1988) revealed that the groups of small carnivore species observed between SEF and MDF/Savanna were distinct in composition (Sorenson index = 0.39). This was partly explained by differences in species abundance (i.e., absolute numbers of species photograph) between forest types (χ^2 = 4.3630, df = 1, P = 0.037).

Species Richness

Closure tests revealed that combined data from MDF/Savanna and SEF for the overall species richness estimate failed to meet closure assumptions (z = -2.557, P = 0.005). However, the test is just "reacting" to the behavioral change in capture probabilities (e.g., trap shyness) which *looks* like recruitment (i.e., new species move into study sites) but in fact the population is closed (White et al. 1982: 97). Thus, the assumption of closed population is actually satisfied. Provided that trapping period for each habitat lasting approximately four months would not long enough to permit the demographic changes in studied population (Lekagul & McNeely 1977). In addition, only photographs of fully grown animals – subjectively determined – were used in analyses; therefore, it is safe to say that no data from young or 'new' animal was used that could cause violation of closed population. Goodness of fit test also failed to accept model M_h as the best fit model (χ^2 = 93.099, d.f. = 52, P < 0.001). However, this model was still chosen the first over other available models (model selection criteria = 1.00). Closure assumptions were satisfied for data from both MDF/Savanna and SEF when modeled separately (z = 0.129, P = 0.551 and z = -0.393, P = 0.347, respectively). However, goodness of fit test revealed a poor fit of model M_h to the given data (MDF/Savanna: $\chi^2 = 45.377$, d.f. = 27, $P = 0.015$ and SEF: $\chi^2 = 37.600$, d.f. = 24, $P = 0.038$), still the model was selected for MDF/Savanna but not for SEF. Here I followed the recommendations of Boulinier *et al.* (1998) by choosing model M_h which assumes variation in species detection probability regardless of model selection criteria in the estimation of species richness of small carnivores.

Small carnivore species richness estimated using program CAPTURE under model M_h showed high precision for the overall estimate (i.e., two forests combined). Species richness of small mammalian carnivore community found in both MDF/Savanna and SEF of TYN between November 2007 and August 2008 was estimated between 12 – 22 species (Table 3). Slightly higher species richness was estimated for MDF/Savanna ranging from 12 – 30 species. However, the estimate was less informative for SEF possibly due to many camera stations (10 out of 26 stations) having no detections of small carnivores resulting in very low detection probabilities and, consequently, low precision of species richness estimates.

Species Distribution

Overall, Large Indian Civet had the widest distribution, being recorded at 45% of camera locations pooled across forest types. This species was followed by Leopard Cat, Masked Palm Civet and Crab-eating Mongoose, recorded at 16%, 15% and 11% of locations, respectively. This same ranking was also observed in MDF/Savanna. In SEF, Large Indian Civet also had the widest distribution (42% of locations), but, unlike MDF/Savanna, was followed by Common Palm Civet (15% of locations) (Figure 1).

Hog Badger, Large-toothed Ferret-badger, Banded Linsang, Common Palm Civet and Golden Cat were observed at only single locations in MDF/Savanna. Yellow-throated Marten, Hog Badger and Large-toothed Ferret-badger were only recorded in MDF/Savanna.

Habitat use

Small carnivores observed in MDF/Savanna had higher relative abundance than those in SEF ($\chi^2 = 5.5119$, d.f. = 1, $P = 0.019$). Only 5 species were recorded with sufficient numbers in both forest types to compare their relative abundance. There was no statistical difference in relative abundance between forest type for Large Indian Civet ($\chi^2 = 0.3807$, d.f. = 1, $P = 0.537$), Common Palm Civet ($\chi^2 = 2.4177$, d.f. = 1, $P = 0.120$), Masked Palm Civet ($\chi^2 = 2.1229$, d.f. = 1, $P = 0.145$), and Crab-eating Mongoose ($\chi^2 = 2.7253$, d.f. = 1, $P = 0.099$). But the exception was for Leopard Cat whose significantly higher relative abundance was observed in MDF/Savanna ($\chi^2 = 5.6082$, d.f. = 1, $P = 0.018$) (Table 2, Figure 2).

Relative abundance between small carnivore groups with different ecological traits was not significantly different between forest types ($\chi^2 = 0.0335$, d.f. = 1, $P = 0.855$). (Terrestrial: *Dhole, Hog Badger, Large Indian Civet, Crab-eating Mongoose, Leopard Cat and Golden Cat* versus Semi – to Arboreal: *Yellow-throated Marten, Large-toothed Ferret-badger, Banded Linsang, Common Palm Civet and Masked Palm Civet*; There were no difference in relative abundance between the two ecological groups within forest type (MDF/Savanna; $\chi^2 = 0.5358$, d.f. = 1, $P = 0.464$ and SEF; $\chi^2 = 0.0801$, d.f. = 1, $P = 0.777$). However, terrestrial species in MDF/Savanna had significantly higher relative abundance than those in SEF ($\chi^2 = 4.4104$, d.f. = 1, $P < 0.05$), whereas semi – to arboreal species did not differ between forest types ($\chi^2 = 1.5902$, d.f. = 1, $P = 0.207$).

I further compared, for five species with sufficient detections, overall relative abundance (forests combined) between terrestrial and semi – to arboreal species. Data met assumptions of normality (Shapiro – Wilk; W = 0.8896, $P = 0.1598$) and homogeneity of variance (Levene Test; $F_{1,8} = 1.0358$, $P = 0.3386$) after logarithmic transformation. However, I did not detect a difference in relative abundance between terrestrial species (*Large Indian Civet, Crab-eating Mongoose and Leopard Cat*) and semi – to arboreal species (*Common Palm Civet and Masked Palm Civet*) ($t = -0.572$, $P = 0.583$).

Habitat attributes (food availability)

Overall, fruiting tree density is significantly higher in SEF than MDF/Savanna during survey (Figure 3, Appendix B), while, MDF/Savanna 1 and SEF1 contain similar density of trees bearing fruits. However, for small mammals, higher relative abundance was observed in MDF/Savanna (Figure 4; Appendix B). There were no differences in terms of distance from camera trap stations to nearest contrast habitats and to stream in both forest types (Appendix B). Camera traps installed in SEF were of higher in elevation than those in MDF/Savanna (Appendix B).

Estimations of site occupancy and detection probability

Closure tests

Program CAPTURE suggests strong evidence of behavioral response after initial capture for Large Indian Civet, and Leopard Cat (χ^2 = 17.205, d.f. = 1, P = 0.00004, and χ^2 = 4.042, d.f. = 1, P = 0.044, respectively), thus, resulting in the rejections of the null hypothesis of population closure (z = -3.027, P = 0.001, and z = -1.673, P = 0.047, respectively). However, this may be the "reacting" to the behavioral change in capture probabilities which "looks" like recruitment but in fact the population is closed (White et al. 1982: 97). Provided that trapping period for each habitat lasting approximately four months would not long enough to permit the demographic changes in studied population (Lekagul & McNeely 1977). Moreover, I included only those photographs of adult animals into analyses. Hence, the violation of closure assumption of the species mentioned above can be relaxed.

Site occupancy probabilities

Occupancy probabilities estimates for 5 small carnivores vary considerably among species with different predictor variables modeled as covariates. I report results for those predictor variables included in the models that fall within the confident set ($w_i \geq$ 10% of the weight of the best model) (Burnham & Anderson 2004).

Model that contains presence/absence of large predators is the most parsimonious for **Large Indian Civet** (Δ_i = 0) (Table 4). This variable contributes to the probability of occupancy of Large Indian Civet in much higher proportion over others given the data and candidate models (Figure 5a). Occupancy estimates of Large Indian Civet are positively related to the presence and absence of large predators (0.86 and 0.47, respectively) (Figure

6), however, the occupancy and parameter's coefficient estimates derived from model averaged suggest no effect (i.e. 95% CI encompass zero) (Table 5).

The probability of site occupancy of **Common Palm Civet** is independent from variables tested as predictors (Δ_i > 2.0 for others models with covariates) (Table 4). Where neither forest type, fruiting tree density, small mammal relative abundance, elevation, the presence/absence of large predators, any distance to nearest contrast habitat nor stream have a clear effect on site occupancy estimation for the species (Table 5 and Figure 5b). Site occupancy estimate of Common Palm Civet is less precise (0.19, 95% CI: 0.05 – 0.51) (Figure 6).

Model selection uncertainty is highest for **Masked Palm Civet** (4 of 9 models Δ_i < 2.0), thus, care should be taken when interpreting model set of this species. Model that contains habitat variables is the 2nd best model after null model (Table 4). Three variables contained in 'habitat variables' contribute relatively similar to the probability of occupancy of Masked Palm Civet (Figure 5c). There was little evidence that the probability of occupancy of Masked Palm Civet negatively relates to small mammal prey relative abundance and the presence of semi-evergreen forest whereas positively relates to fruiting tree density and the presence of mixed deciduous forest since confident intervals of all model-averaged parameter estimates encompassing zero (Table 5). Site occupancy probability of Masked Palm Civet is estimated at 0.24 (0.10 – 0.47) under the null model (Figure 6).

Model that contains forest type is the most parsimonious model for **Crab-eating Mongoose** (Table 4). Forest type is the single variable contributes most in site occupancy estimates of Crab-eating Mongoose over other variables (≥ 3.6 times) with the exception of distance to nearest contrast habitat (Figure 5d). The estimated site occupancy for Crab-eating Mongoose is 0.13 (0.06 – 0.27) under the null model (Figure 6). While the probability of site occupancy estimates with forest type as a covariate suggest no clear habitat preference ($\hat{\psi}_{\text{MDF/Savanna}}$ = 0.21, 95% CI: 0.01 – 0.44; $\hat{\psi}_{\text{SEF}}$ = 0.05, 0.01 – 0.27).

Leopard Cat is another species where model selection criterion shows high uncertainty (Table 4). Forest type and predators that included in the suite of 'parsimonious' candidate models contribute similarly in determining the probability of occupancy of the species whereas distance to nearest contrast habitat contributes in lesser proportion (1.7 and 1.6 times, respectively) after the first two variables (Figure 5e). Probably due to extremely low detection probability ($\hat{p} = 0.05 \pm 0.01$ S.E.), site occupancy probability estimates of Leopard Cat as a function of forest type and the presence/absence of large predators are less informative (Table 5 and Figure 6).

4) PROJECT'S OUTPUTS

Activity	Expected outputs	Project's outputs	Constraints
1) Camera trapping	▪ Camera trapped in 2 major forest types ▪ Each forest types received 2 replications	Two forest types (semi-evergreen – SEF and mixed deciduous/savanna – MDF/Savanna) received camera-trapping efforts; SEF 2,362 trap days and MDF/Savanna 2,207 trap days	Cameras were checked for films and batteries only once a month due to logistic and man power constraints probably causing small numbers of animals' photographs.
2) Estimating food abundance (small mammal and fruit)	▪ Small mammal live-trapping ▪ Vegetation sampling	▪ Relative abundances of small mammal in 4 study areas were estimated ▪ Fruiting trees density were estimated	Due to no recapture of small mammals in SEF site 2 the estimate of abundance could not be performed, thus, relative abundance were indexed as number of animals caught per 100 trap nights instead as surrogates of animals abundance.
3) Data analysis	▪ Estimates of small carnivore species richness, relative abundance and occupancy ▪ Small mammal relative abundance ▪ Fruiting tree density	▪ Small carnivore species richness, relative abundance and probability of site occupancy in relation to variables measured at both habitat and landscape scales ▪ Small mammal abundance ▪ Fruiting trees density ▪ Final report	After surveys completed, some species still have very few detections resulting in weak inferences about probability of site occupancy in relation to environmental variables. This may partly be explained by either they are rare or very elusive.

5) DISCUSSION

Patterns of species richness and species relative abundance

This study showed that Large Indian Civet was the commonest small carnivore species among 11 species observed in TYN. This result was also documented by previous studies in the same area (Conforti 1996) and elsewhere (Anon. 2005; Lynam et al. 2001; Sukmasuang 2001; Zaw et al. 2008). However, the relative abundance of this species is well below that of Conforti (1996) and Sukmasuang (2001) whose studies took place in adjacent HKK in similar habitat types (22.4 and 9.38/ 100 TD, respectively). Large Indian Civet did not show preferences for particular habitat types in TYN which was consistent with what observed elsewhere where species utilized a wide range of habitats and elevations (Conforti 1996; Duckworth 1997; Lynam et al. 2001; Sukmasuang 2001).

Estimation of species richness indicated no difference being observed between MDF/Savanna and SEF. However, considering species richness alone may mislead conclusions unless accounting for species detection probability which varies among species due to their behavior. For instance, Small-toothed Palm Civet was never detected at both sites by camera traps, however, the species was encountered in trees often in both forests during spotlighting surveys. It indicated that the species resided within both habitats but their strong arboreal behavior (Duckworth & Nettelbeck 2007; Rabinowitz 1991) caused biased estimates of their relative abundance derived from camera traps (Duckworth & Nettelbeck 2007). This is an important point of concern that relative abundance index derived from camera traps does not necessary reflect the 'true' abundance (both relative and absolute) of animals unless detection probability is accounted for. Provided the relationship between relative abundance and absolute animal abundance is unknown, care must be taken when interpreting the results particularly for arboreal to semi – arboreal species such as this civet. This explanation could be applied for other semi-arboreal small carnivores, e.g., Binturong, Masked Palm Civet and Common Palm Civet, as well. Relative abundances of these species were likely underestimated in TYN mainly due to animals' strong arboreal behavior, as also suggested in other studies (Anon. 2005; Conforti 1996; Lynam et al. 2006; Zaw et al. 2008). .

Among semi-arboreal viverrids Masked Palm Civet was photo-trapped at higher rates than Common Palm Civet, particularly in MDF/Savanna. This result coincided with a study in northern Myanmar that showed the former species to be more abundant (Rao et al. 2005) (but see Anon. 2005; Conforti 1996; Sukmasuang 2001; Zaw et al. 2008). Although higher relative abundance of Masked Palm Civet in MDF/Savanna was not significant, the number of photographs obtained from this forest (n = 15) suggested that the species traveled on the ground more often in this forest, probably due to discontinuity of the canopy which compels them to travel terrestrially relatively often, making them more prone to being photo-trapped. In contrast, evergreen forest has more complex forest structure and largely continuous canopy (van de Bult 2003), hence, Masked palm civets would be able to travel more in trees without descending.

Recent findings showed that Masked Palm Civet track resources based on availability rather than preference. In China, when fruit availability dropped, this civet species consumed small mammals in higher proportion and when fruits became more abundant they shifted their diets to include fruits in a much higher proportion (Zhou et al. 2008). This shift in diet of Masked Palm Civets observed in southern China may help explain the patterns observed in TYN in this study. During the survey period, fruiting trees were relatively scarce in both habitats but abundance of small mammals was higher in MDF/Savanna sites (23 ±7 *SE* animals, and 52 ±10 animals) and the SEF site 1 (32 ±8 animals; unpublished data). Abundance estimates for SEF site 2 could not be performed due to zero recaptures, and I believe that this site had the lowest rodent abundance. Thus, the relative higher abundance of rodent prey in MDF/Savanna during this study, combined with low fruit availability overall, may explain the pattern of higher relative abundance of Masked Palm Civet in this forest type.

Banded Linsangs were documented in both SEF and MDF/Savanna. Single photographs from each location were taken, always at night. Both photographs were of a single animal. The species went undetected during Conforti's (1996) study in the same area and elsewhere where the species is thought to occur (e.g., Ngoprasert 2004; Sukmasuang 2001). This species may not be as uncommon in TYN as previously thought since they were occasionally observed by local fishermen and rangers especially along streams (TYN rangers pers. comm.) although confusion in species identification may exist (Zaw et al. 2008). Banded Linsang is thought to occur in association with evergreen forest (Steinmetz

& Simcharoen 2006: Boontua 2004, Kanchanasaka et al. 1998 and Kekule 2004, cited in Steinmetz and Simcharoen 2006, Steinmetz et al. unpublished data) and perhaps with the presence of streams (Steinmetz et al. unpublished data). Surveys in adjacent Myanmar also revealed the occurrence of Banded Linsang in evergreen forest (Zaw et al. 2008). The low relative abundance of this species in this study (0.03 – 0.07/ 100 trap days) was likely due to its strong arboreal behavior (Van Rompaey 1993).

Yellow-throated Marten was not photographed in SEF, however, I observed the species there (during the day) several times. This suggests a caveat of camera-trapping surveys for partially to mostly arboreal species, whereby such species is likely to be underrepresented in relative abundance indices from photographs (e.g., Zaw et al. 2008). Yellow-throated Marten is primarily diurnal (Grassman et al. 2005a; Lekagul & McNeely 1977) even though increasing nocturnal activities were observed during a waxing moon (Grassman et al. 2005a; and this study, but see also Lekagul and McNeely, 1977). Yellow-throated Marten appear to utilize habitats proportionally to availability (Grassman et al. 2005a).

Leopard Cat and Golden Cat were photographed only once in SEF differing from what was observed in MDF/Savanna. These two cats are largely terrestrial (Lekagul & McNeely 1977) and use habitat in proportion to availability (Grassman et al. 2005b, 2005c). The observed higher relative abundance of Leopard Cat in MDF/Savanna may be explained by the higher abundance of small mammals in this forest type, since small rodents are the main food of this cat (Grassman et al. 2005b, 2005c; Rajaratnam et al. 2007; Walker & Rabinowitz 1992).

Detections of Dhole were too few to draw any conclusion about animal habitat use. Dhole was among the rarest species in this study along with Hog Badger which, the latter, had only a single detection from MDF/Savanna. The rarity of Dhole from this study was consistent with other studies in Thailand (Anon. 2005; Lynam et al. 2006; Sukmasuang 2001) with the exception of studies in Northern Myanmar (Rao et al. 2005) and in TY/HKK by Conforti (1996) both of which observed very high relative abundance of Dhole (3.39 and 2.1/100 TD, respectively). However, it is worth noting that, although I categorized Dhole as a small carnivore in this study due to its body weight (≤ 15 kg), this species preys upon larger animals, particularly ungulates (e.g., Karanth & Sunquist 1995; Venkataraman et al. 1995). Therefore, the abundance of small mammals is probably of low importance in determining the presence of Dhole. The scarcity of Dhole's photographs may partly be explained by competition avoidance from larger predator – Tigers. At least 5 adult Tigers were photo-trapped in this study (W. Chutipong, unpublished data). This may help explaining why Dhole was so scarce in the study area where Tigers predominate. Studies in large predator community where Tiger, Leopard and Dhole coexist suggested that the mechanisms facilitating spatio-temporal coexistence among these specialized flesh-eating predators are the abundance of ungulate prey species and availability in different size classes (Andheria et al. 2007; Karanth & Sunquist 1995). However, provided the availability and diversity of ungulates that could potentially considered as prey (Gaur – mostly herd, Sambar, Serow, Wild Pig, 2 Muntjac species and Lesser Mouse Deer) in both forest types in TYN during study period (553 non-independent photographs of all species combined), the *availability* may well below the threshold where it can facilitate spatial co-existence between Dhole and Tigers in study area.

Species have yet to be detected by camera traps

There are 8 additional small carnivore species thought to occur in the study area but yet to be detected in this camera trap survey (Table 6). An individual Golden Jackal was photo-trapped during the preliminary survey in SEF, however, the species was never detected again afterward. Among these unseen-by-camera-trap species, two were observed during night surveys, namely, Small-toothed Palm Civet and Small Indian Civet. All Small-toothed Palm Civet observations made during night walks in both forest types (MDF/Savanna: 7 observation/ 17 searching hours; SEF: 7 observations/ 20 searching hours; W. Chutipong, unpublished data). The animals were usually observed in trees, reflecting their strictly arboreal habits and emphasizing that this species is unlikely to be detected by camera traps. The species was the most commonly encountered nocturnal palm civet during night surveys in evergreen forest of Lao PDR (Duckworth 1997). Tracks of Binturong were also observed occasionally in TYN, confirming the presence of this species within the study sites. Thus, the lack of records of some of these species by camera trapping surveys does not necessary imply that the animal is rare in the study site, rather, simply mainly arboreal (Walston & Duckworth 2003).

The lack of photographs of Small Asian Mongoose in SEF is not unexpected. Since the species rarely occurs in this habitat (Duckworth 1997). However, the species was also undetected in MDF/Savanna, a habitat which appears to be more suitable based on what is known of its habitat preferences (Lekagul & McNeely 1977). Thus, it might indeed be scarce in general in TYN, as also observed in similar habitat of Hukaung Vallay, Northern Burma (Zaw et al. 2008).

However, other explanations are required to explain the distribution of the Small Indian Civet. This species was observed only once on a road during spot-lighting surveys, but their tracks were always found along the road that passes through the study area. It seems that Small Indian Civet forages mostly near roads, forest edges, and degraded habitats (Duckworth 1997) where structure is open, but does not enter deep into thick evergreen or mixed deciduous – grassland vegetation where most of the camera traps were stationed. Camera trapping in Myanmar with the concentration of trapping effort in evergreen forest also resulted in small numbers of photographs of the species (Zaw et al. 2008).

The lack of records for some terrestrial small carnivores, mainly felids, is of particular interest and may have biological implications about the scarcity of the species. The set up of camera traps in this study were designed to maximize the detection of small carnivores traveling on the ground (i.e. camera units were installed 30 to 40 cm above ground nearby small streams and active animal trails). However, since there were no records of 3 felids, namely Jungle Cat, Fishing Cat and Marbled Cat additional explanations are required. These small – to – medium cats are considered rare elsewhere. For example, Marbled Cats a forest – dependent cats are mainly associated with moist and mixed deciduous-evergreen tropical forest (Nowell & Jackson 1996). The cats are rarest among other cats (Golden Cat and Leopard Cat) found in partially logged tropical evergreen forests of peninsular Malaysia (Mohd. Azlan 2006; Mohd. Azlan & Sharma 2006) and in the largest contiguous mosaic forested area of western Thailand (Conforti 1996; Ngoprasert 2004; Sukmasuang 2001) and evergreen forests of northeast Thailand (Anon. 2005; Grassman et al. 2005b) where there seem to be the animals preference habitat.

Jungle Cats, a widely distributed cats which considered common in south Asian countries but rare in east and southeast Asia countries (IUCN 2008), are absent from many studies in the countries of its distribution range, for example, Myanmar (Rao et al. 2005), Indochina (Duckworth et al. 2005) and Thailand (Anon. 2005; Conforti 1996; Lynam et al. 2006; Ngoprasert 2004). The population status of the cat is assessed as decreasing (IUCN 2008) mainly due to hunting pressure e.g., trapping and snaring (Duckworth et al. 2005). However, this is unlikely the case for Thung Yai where hunting specifically for the rare cat is minimal based on information from rangers such as encounter rate with poachers and trapping evidence and extensive experience of principal investigator in the area (> 10 years). Therefore, some other explanation is needed for the 'absence' of Jungle Cats in Thung Yai given that survey took place in areas with extensive grassy deciduous dipterocarp forest and scattered surface water which are the species predominant known habitat in Indochina (Duckworth et al. 2005).

Fishing cats are widely distributed but concentrated mainly in wetland habitats (IUCN 2008). This seems to be the most reasonable explanation why the cats are 'absent' from this study in Thung Yai since the area does not contain such habitat. The cats are never detected by prior camera trap studies in nearly the entire Thailand (Boontua 2004; Conforti 1996; Lynam et al. 2006; Ngoprasert 2004; Sukmasuang 2001), however, a seemingly healthy and long established population of Fishing Cats were recently uncovered in an extensive wetland habitats of Prachuab Kirikhan province, southwestern Thailand (P. B. Cutter *pers. comm.*). There are evidences of severe decline for the Fishing Cats population over much of its range primarily due to habitat degradation, conversion and hunting (IUCN 2008).

Other possible explanation for the absence of the unseen-by-camera-trap species could be interspecific competition. For instance, Large Indian Civet was among the most abundant species in the study area at both forest types, whereas Large-spotted Civet, of similar body size was not photographed at either site. The absence of the latter may be due to the high relative abundance of the former species. Within the range of the two species, camera trap surveys revealed higher relative abundance of Large Indian Civet than Large-spotted Civet (Austin 1999) with the absence of the latter in many sites (e.g., Conforti 1996; but see Lynam et al. 2005; Sukmasuang 2001; Zaw et al. 2008). At only 1 site in the region, in Lao PDR, has Large-spotted Civet been camera-trapped at higher relative abundance than Large Indian Civet (2.5 versus 0.5 photograph/100 TD) (Austin 1999). Furthermore, Large-spotted Civet was considered a lowland species where photographs from camera traps survey from this region were from below 300 meters in elevation (Lynam et al. 2005). All camera trap stations in this study were set in higher elevation (*ca.* 900 m), and with high relative abundance of Large Indian Civet thus it might explain why the species were not detected by this study.

Interspecific competition may lead to spatial avoidance and limited distributions among predators (Linnell & Strand 2000 in review). Given the presence of larger carnivores (Tiger, Leopard, Clouded Leopard and Dhole) within the study sites the pattern of occurrence of small carnivores observed by this study may reflect the avoidance in space use among members of this guild due to intra-guild predation pressure. Rabinowitz and Walker (1991) reported finding Large Indian Civet remains (e.g., hairs) in scats of large cats in HKK. Grassman (1999) also reported that intra-guild predations by Leopards on Hog Badgers were common in western of Thailand. Common Palm Civets were preyed on by large cats where they were sympatric in Nepal (Joshi et al. 1995). Thus the absence of terrestrial species such as Small Indian Civet may be partly explained by interspecific competition; this hypothesis remains to be tested.

Why these small carnivores are more likely to be independent from variables used to predict their probabilities of site occupancy?

Models with high uncertainty suggest that none of the models within the model set are exceptionally better in predicting the probabilities of occupancy of species than the others. This can be seen clearly for all 5 small carnivores modeled here. Therefore, interpretation of the results from model selection must be cautious for the model sets given models averaging (Table 5) which account for this uncertainty being estimated (Burnham & Anderson 2004).

Null models are the most parsimonious models for Common Palm Civet, Masked Palm Civet and Crab-eating Mongoose. This suggests that the independent variables used here were largely unable to predict these species' probabilities of occupancy provided that fruits are considered a major food source especially for those civets living in trees, for example, Masked Palm Civets and Common Palm Civets (e.g., Grassman 1998; Kitamura et al. 2002; Rabinowitz 1991; Rabinowitz & Walker 1991). In HKK, 18 species of fruits were reported being consumed by civets even though those tree species accounted for only 20% of trees found in the study area (Rabinowitz 1991). Although availability of fruit, measured in term of density of fruiting tree for this study, within a habitat is thought to be an important factor in determining the probability of occupancy of frugivorous species of small carnivores (Grassman 1998; Rabinowitz 1991), the findings do not suggest so. This may partly be explained by the evidence from China that Masked Palm Civets had shifted their diet according to the apparent availability of resource. Zhou et al. (2008) reported that Masked Palm Civet tracked resources based on their apparent availability rather than preference. When there was a drop in fruit availability the animal consumed small mammals in higher proportion and when fruits became more abundant the animals shifted their diets to include fruits in much higher proportion. During the study the observed fruiting tree densities were higher in evergreen forests whereas small mammal relative abundances were higher in mixed deciduous forests (Figure 1 and 2), as a result, the species did not show a particular habitat preference when forest types were included into models.

Cats are thought to highly dependent on abundance of small mammals. Mukherjhee et al. (2004) reported that rodents are more important in term of energy requirement for felids which might be the case for Leopard Cat – the solely cat species being modeled here. Leopard Cats were observed to highly dependent on rodent abundance in oil palm plantation landscape of Malaysia Borneo (Rajaratnam et al. 2007). However, this study cannot detect such strong dependency of Leopard Cat on rodents given that relative abundance of rats is higher in MDF where the cats were mostly detected. This may partly be due to low detection rate of the cat ($\hat{p} = 0.05 \pm 0.01$ S.E.).

Moreover, 4 of 5 species modeled here have been detected at less than 20% of all camera trap stations with the only exception of Large Indian Civet. Additionally, number of times the species being re-photographed were relatively low. This combination may have caused low precision of the probabilities of occupancy estimates of most species in this study.

For species with predictor variables included in the best model, the estimates of site occupancy were highly imprecise (the confidence intervals around the estimated coefficients encompass '0' indicating only weak inferences can be drawn from the parameters). For example, the positive relationship of Large Indian Civets occupancy with the presence/absence of large predators may suggest that Large Indian Civets are more likely to occupy areas where large predators are also 'present', however, more testing is needed to validate this prediction despite intraguild predation and avoidance behaviors were observed between large cats and Large Indian Civets where they co-occur (Rabinowitz & Walker 1991; Simchareon et al. 1999).

6) CONCLUSION

In conclusion, predictor variables used in modeling the probabilities of site occupancy of 5 small carnivore species including forest types, food availability, and landscape variables in this study largely lack of predictability. Therefore, what I have hypothesized that the patterns of occupancy of small carnivores in TYN should differ in relation to difference in forest types, differences in level of food availability and others physical components of the habitats is left largely untested. Although I currently don't have an answer for this question, I am exploring methods of increasing detection rates of the target species such as baiting, moving camera traps more frequently, employing more cameras, etc, which might improve the precision of the occupancy estimates. I will also be exploring methods of sampling small carnivore food resources that may more accurately estimate their abundance & dispersion at a scale which affects small carnivore occupancy.

Although, the efficiency of remote-triggered cameras are particularly useful for the study of rare and elusive terrestrial mammalian carnivores (e.g., Carbone et al. 2001), this study suggests a caveat regarding camera-trapping to estimate relative abundances and to monitor arboreal or semi-arboreal species, as suggested elsewhere (Srbek-Araujo & Chiarello 2005). However, it also revealed that, for arboreal species, employing other survey methods, e.g., active spotlighting (Walston & Duckworth 2003) is more effective in detecting species presence.

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Table 1 All photographs (non-independent) and average number of photographs per day of 7 classified groups derived from the camera trap survey in Thung Yai Naresuan Wildlife Sanctuary, western Thailand, between November 2007 and August 2008 (n = 277 days)

Species group	no. photos	photos/day
Small Carnivores [a]	205	0.74
Ungulates [b]	605	2.18
Large Carnivores [c]	37	0.13
Rodents, Primates and Pangolin	242	0.87
Birds and Reptiles	61	0.22
Human	11	0.04
Unknown	30	0.11
TOTAL	**1191**	**4.3**

[a] Small Carnivores, with the exception of those mentioned earlier and in Table 2, include Golden Jackal and Small-clawed Otter

[b] Ungulates consist of Lesser Mouse Deer, Red Muntjac, Fea's Muntjac, Wild Pig, Southern Serow, Sambar Deer, Gaur, Asian Tapir and Elephant

[c] Large Carnivores include Clouded Leopard, Leopard, Tiger, Malayan Sun Bear and Asiatic Black Bear

Table 2 The average number of days required for the first photograph of the species (RAI 1) and capture rate among species across forest types (RAI 2 (SE)) measured as number of independent photograph of species/100 TD between November 2007 and August 2008. Data were combined across sites within the same forest type. Significant differences (α = 0.05) in species relative abundance between forest types indicated where tests were performed. Italic *n* refers to numbers of independent photographs.

Species	RAI 1 (SE)		RAI 2 (SE)		
	SEF	**MDF/Savanna**	**SEF**	**MDF/Savanna**	**Overall**
Dhole *Cuon alpinus*	52*	32 (7)	($n = 1$) 0.03 (0.03)	($n = 2$) 0.10 (0.08)	0.07 (0.04)
Yellow-throated Marten *Martes flavigula*	no detection	66 (16)	no detection	($n = 5$) 0.16 (0.11)	0.09 (0.06)
Hog Badger *Arctonyx collaris*	no detection	165*	no detection	($n = 1$) 0.05 (0.05)	0.03 (0.03)
Large-toothed Ferret-badger *Melogale personata*	no detection	14*	no detection	($n = 9$) 0.33 (0.33)	0.17 (0.17)
Large Indian Civet *Viverra zibetha*	22 (7)	21 (5)	($n = 21$) 1.78 (0.80)	($n = 45$) 2.30 (0.70)	*n.s.* 2.06 (0.53)
Banded linsang *Prionodon linsang*	14*	145*	($n = 1$) 0.03 (0.03)	($n = 1$) 0.07 (0.07)	0.05 (0.04)
Common Palm Civet *Paradoxurus hermaphroditus*	38 (27)	84*	($n = 11$) 0.47 (0.31)	($n = 1$) 0.03 (0.03)	*n.s.* 0.24 (0.15)
Masked Palm Civet *Paguma larvata*	40 (32)	62 (10)	($n = 3$) 0.12 (0.09)	($n = 15$) 0.66 (0.30)	*n.s.* 0.41 (0.16)
Crab-eating Mongoose *Herpestes urva*	11*	38 (13)	($n = 1$) 0.03 (0.03)	($n = 22$) 0.83 (0.48)	*n.s.* 0.45 (0.26)
Leopard Cat *Prionailurus bengalensis*	59*	57 (10)	($n = 1$) 0.04 (0.04)	($n = 10$) 0.50 (0.19)	$p < 0.05$ 0.28 (0.11)
Golden Cat *Catopuma temminckii*	116*	23*	($n = 1$) 0.03 (0.03)	($n = 2$) 0.10 (0.10)	0.07 (0.06)
Overall			($n = 40$) **2.54** (1.37)	($n = 113$) **5.14** (2.44)	$p < 0.05$ **3.91** (1.60)

* Asterisk indicated species detected by only 1 camera trap station, therefore, no standard error was estimated.

Table 3 The estimates of species richness, detection probability and associated standard errors (SE) of small carnivore communities in Thung Yai Naresuan Wildlife Sanctuary, western Thailand, using program CAPTURE. Model M_h accounts for variation in capture probabilities among individual species. Model M_b accounts for variation in capture probabilities due to behavioral response of individual species after the first capture.

Forest type	Model Selection Criteria	Species richness (± SE)	95% CI	Detection probability
MDF/Savanna	M_h (1.00)	14 ± 3.50	12 – 30	0.10 (average)
SEF	M_h (0.72)	36 ± 13.70	20 – 77	0.02 (average)
	M_b (1.00)	8 ± 0.02	8 – 8	0.33
Overall	M_h (1.00)	13 ± 2.14	12 – 22	0.08 (average)

Table 4 Occupancy and detection probability model, -2 log likelihood (-2LL), number of parameter estimated (*K*), second-order Akaike's Information Criterion (AIC_c) differences (Δ_i), and model weight (w_i), for modeling of small carnivores (Large Indian Civet, Common Palm Civet, Masked Palm Civet, Crab-eating Mongoose and Leopard Cat) probability of occupancy and detection probability from camera trapping data Thung Yai, western Thailand 2007 and 2008. Refers to *Methods* section for variables' codes

Model	*K*	-2LL	AIC_c	Δ_i	w_i
Large Indian Civet					
ψ(PREDATORS), p(.)	3	251.87	264.36	0.000	0.373
ψ(.), p(.)	2	256.77	265.01	0.650	0.270
ψ(DIST_STRM), p(.)	3	253.96	266.45	2.090	0.131
ψ(FTYPE), p(.)	3	255.22	267.71	3.350	0.070
ψ(FTD), p(.)	3	256.07	268.56	4.200	0.046
ψ(ELEV), p(.)	3	256.40	268.89	4.530	0.039
ψ(DIST_HAB), p(.)	3	256.64	269.13	4.770	0.034
ψ(RODENTS_RAI), p(.)	3	256.74	269.23	4.870	0.033
ψ(LANDSCAPE), p(.)	6	247.74	273.57	9.206	0.004
Common Palm Civet					
ψ(.), p(.)	2	63.45	71.69	0.000	0.400
ψ(FTYPE), p(.)	3	61.32	73.81	2.120	0.139
ψ(FTD), p(.)	3	62.08	74.57	2.880	0.095
ψ(ELEV), p(.)	3	62.12	74.61	2.920	0.093
ψ(DIST_HAB), p(.)	3	62.48	74.97	3.280	0.078
ψ(RODENTS_RAI), p(.)	3	62.56	75.05	3.360	0.075
ψ(PREDATORS), p(.)	3	62.95	75.44	3.750	0.061
ψ(DIST_STRM), p(.)	3	63.07	75.56	3.870	0.058
Masked Palm Civet					
ψ(.), p(.)	2	100.45	108.69	0.000	0.305
ψ(HABITAT), p(.)	5	88.34	109.62	0.927	0.192
ψ(ELEV), p(.)	3	97.49	109.98	1.290	0.160
ψ(FTYPE), p(.)	3	98.03	110.52	1.830	0.122
ψ(FTD), p(.)	3	99.71	112.20	3.510	0.053
ψ(PREDATORS), p(.)	3	99.88	112.37	3.680	0.048
ψ(RODENTS_RAI), p(.)	3	100.18	112.67	3.980	0.042
ψ(DIST_STRM), p(.)	3	100.24	112.73	4.040	0.040
ψ(DIST_HAB), p(.)	3	100.38	112.87	4.180	0.038

Model	K	-2LL	AIC_c	Δ_i	w_i
Crab-eating Mongoose					
ψ(.), p(.)	2	89.18	97.42	0.000	0.406
ψ(FTYPE), p(.)	3	86.28	98.77	1.350	0.207
ψ(DIST_HAB), p(.)	3	87.24	99.73	2.310	0.128
ψ(PREDATORS), p(.)	3	88.87	101.36	3.940	0.057
ψ(RODENTS_RAI), p(.)	3	89.12	101.61	4.190	0.050
ψ(ELEV), p(.)	3	89.13	101.62	4.200	0.050
ψ(DIST_STRM), p(.)	3	89.17	101.66	4.240	0.049
ψ(FTD), p(.)	3	89.18	101.67	4.250	0.048
ψ(HABITAT), p(.)	5	84.39	105.67	8.247	0.007
Leopard Cat					
ψ(FTYPE), p(.)	3	86.96	99.45	0.000	0.340
ψ(PREDATORS), p(.)	3	87.04	99.53	0.080	0.326
ψ(DIST_HAB), p(.)	3	88.54	101.03	1.580	0.154
ψ(.), p(.)	2	94.71	102.95	3.500	0.059
ψ(LANDSCAPE), p(.)	6	77.72	103.55	4.096	0.044
ψ(FTD), p(.)	3	91.91	104.40	4.950	0.029
ψ(HABITAT), p(.)	5	83.30	104.58	5.127	0.026
ψ(ELEV), p(.)	3	94.50	106.99	7.540	0.008
ψ(DIST_STRM), p(.)	3	94.54	107.03	7.580	0.008
ψ(RODENTS_RAI), p(.)	3	94.68	107.17	7.720	0.007

Table 5 Model averaged estimates for parameters ($\hat{\beta}$) used in modeling the probabilities of site occupancy of 5 small carnivores (Large Indian Civet, Common Palm Civet, Masked Palm Civet, Crab-eating Mongoose and Leopard Cat) at Thung Yai, western Thailand 2007 and 2008. Unconditional standard error (Uncond. S.E.) and unconditional 95% confident interval (Uncond. 95% CI) are also provided. Refers to *Methods* section for variables' codes

LARGE INDIAN CIVET			**Uncond. 95% CI**	
Parameter estimates	$\hat{\beta}$	**Uncond. S.E.**	**Upper**	**Lower**
Intercept	0.189	0.484	1.138	-0.760
PREDATORS	1.957	1.156	4.223	-0.309
DIST_STRM	-0.552	0.401	0.234	-1.338
FTYPE	-0.878	0.600	0.298	-2.055
FTD	-0.305	0.412	0.504	-1.113
ELEV	-0.209	0.387	0.549	-0.968
COMMON PALM CIVET				
Intercept	-2.959	3.358	3.622	-9.540
FTYPE	1.662	1.245	4.102	-0.777
FTD	0.644	0.573	1.766	-0.478
ELEV	0.653	0.667	1.961	-0.654
DIST_HAB	-0.616	0.697	0.749	-1.982
RODENTS_RAI	-0.607	0.693	0.751	-1.964
PREDATORS	0.804	1.126	3.010	-1.403
DIST_STRM	0.280	0.444	1.150	-0.589
MASKED PALM CIVET				
Intercept	-2.356	2.191	1.939	-6.650
HABITAT	-22.59	21.87	20.27	-65.45
ELEV	1.051	1.104	3.215	-1.114
FTYPE	-1.421	0.969	0.478	-3.321
FTD	0.395	0.463	1.302	-0.512
PREDATORS	0.704	0.925	2.516	-1.109
RODENTS_RAI	-0.269	0.527	0.765	-1.302
DIST_STRM	0.178	0.379	0.920	-0.564
DIST_HAB	-0.116	0.440	0.746	-0.979

CRAB – EATING MONGOOSE			Uncond. 95% CI	
Parameter estimates	$\hat{\beta}$	**Uncond. S.E.**	**Upper**	**Lower**
Intercept	-1.768	0.539	-0.712	-2.825
FTYPE	-1.723	1.141	0.514	-3.961
DIST_HAB	-0.787	0.657	0.501	-2.075
PREDATORS	-0.613	1.152	1.646	-2.871
RODENTS_RAI	0.120	0.465	1.032	-0.792
ELEV	-0.100	0.455	0.792	-0.992
DIST_STRM	0.054	0.419	0.875	-0.767
FTD	0.018	0.451	0.902	-0.865
LEOPARD CAT				
Intercept	132.092	3192.057	6388.524	-6124.340
FTYPE	-4.169	4.332	4.321	-12.659
PREDATORS	22.364	175.304	365.960	-321.231
DIST_HAB	-1920.449	30115.362	57105.661	-60946.559
LANDSCAPE	-596.708	56067.917	109296.410	-110489.826

Table 6 The presence and absence of small carnivores in 2 forest types of Thung Yai recorded during November 2007 and August 2008. The confirmation of the presence of species in study area came from 4 different detection methods; *photo* (camera trap photographs), *sign* (tracks and signs found during excursion in the area), *night observ.* (direct observation made during night survey), and *day observ.* (direct observation made during daytime fieldwork).

Species	Detection methods	
	SEF	MDF/Savanna
Golden Jackal[1]	*photo, sign*	-
Dhole	*photo; sign*	*photo; sign*
Otter spp.	-	*photo*
Yellow-throated Marten	*sign; day observ.*	*photo; sign; day observ.*
Hog Badger	*sign*	*photo; sign*
Large-toothed Ferret-badger	-	*Photo*
Large Indian Civet	*photo; sign; night observ.; day observ.*	*photo; sign; night observ.; day observ.*
Large-spotted Civet[2]	-	*day observ.*
Small Indian Civet	-	*sign; night observ.*
Banded Linsang	*photo; night observ.*	*photo*
Common Palm Civet	*photo; sign; night observ.*	*photo; sign; night observ.*
Masked Palm Civet	*photo; sign; night observ.*	*photo; sign; night observ.*
Binturong	*sign*	-
Small-toothed Palm Civet	*night observ.*	*night observ.*
Small Asian Mongoose	-	-
Crab-eating Mongoose	*photo*	*photo; day observ.*
Jungle Cat	-	-
Leopard Cat	*photo; sign*	*photo; sign*
Fishing Cat	-	-
Golden Cat	*photo*	*photo*
Marbled Cat	-	-

[1] Golden Jackal was photo-trapped once during preliminary survey in SEF, however, the animal has never been detected by camera trap anymore afterward.

[2] Large Spotted Civet was seen during a daytime in adjacent forested area approximately 40 kilometers from Thung Yai Naresuan Wildlife Sanctuary – west.

Figure 1 Distribution of small carnivore (% camera traps detected) in relation to forest types, MDF/Savanna and SEF in Thung Yai Naresuan Wildlife Sanctuary between November 2007 and August 2008

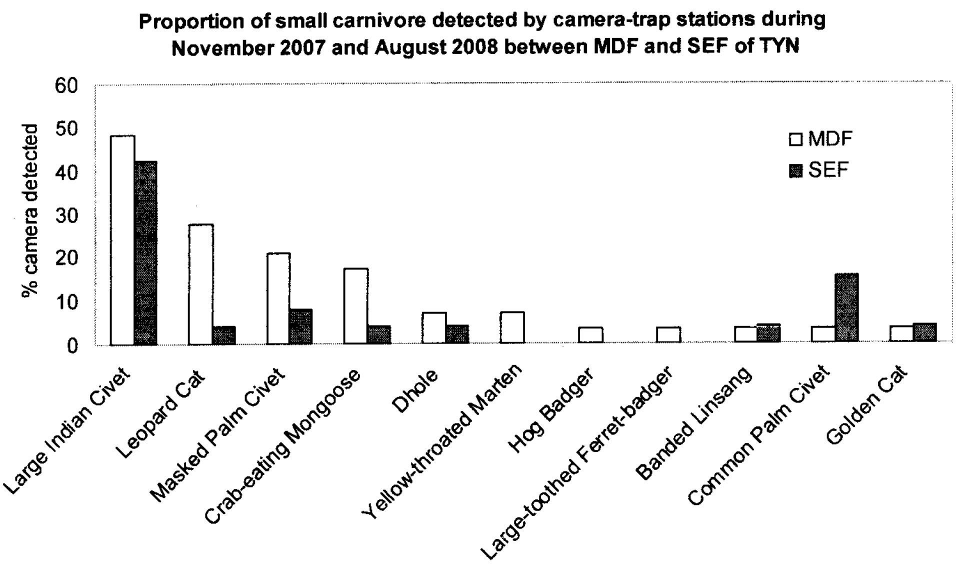


Figure 2 Relative abundance of small carnivores (photo/100 TD) in relation to forest types, SEF and MDF/Savanna, in Thung Yai Naresuan Wildlife Sanctuary during camera trapping surveys between November 2007 and August 2008.

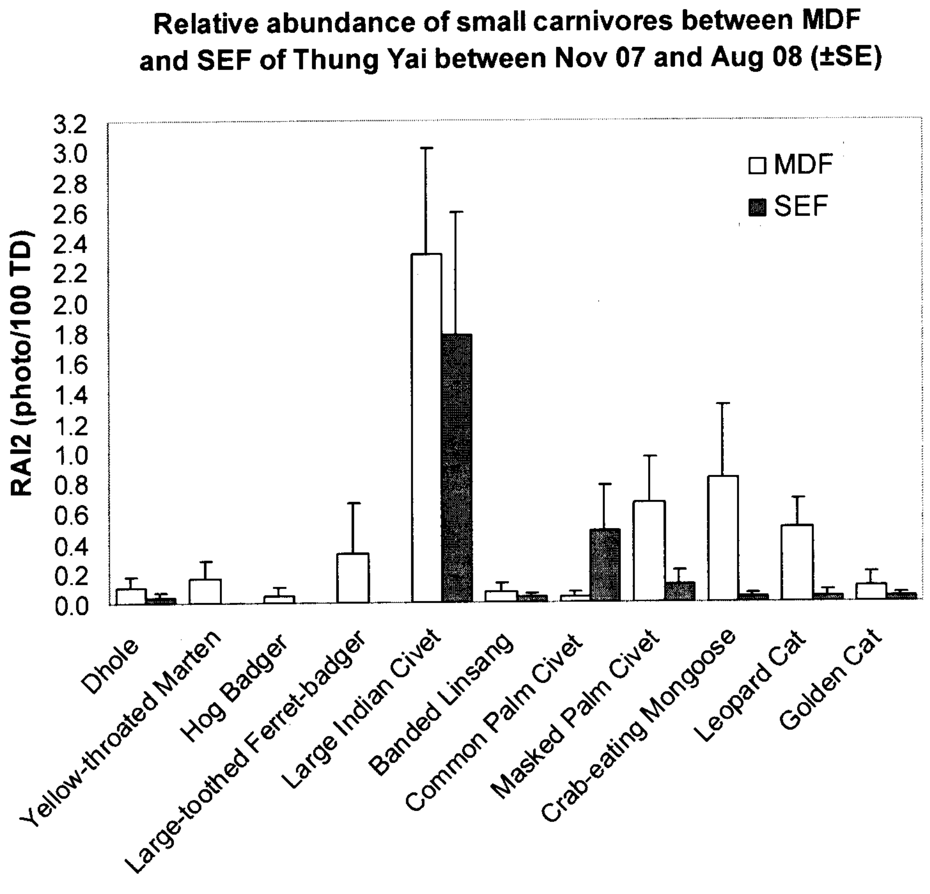


Figure 3 Small mammal relative abundance measured as number of animals captured per 100 trap nights (TN) in 4 study sites representing 2 major forest types (MDF/Savanna – Mixed deciduous/Savanna and SEF – Semi – evergreen forests) of Thung Yai Naresuan Wildlife Sanctuary, western Thailand, during 2007 and 2008

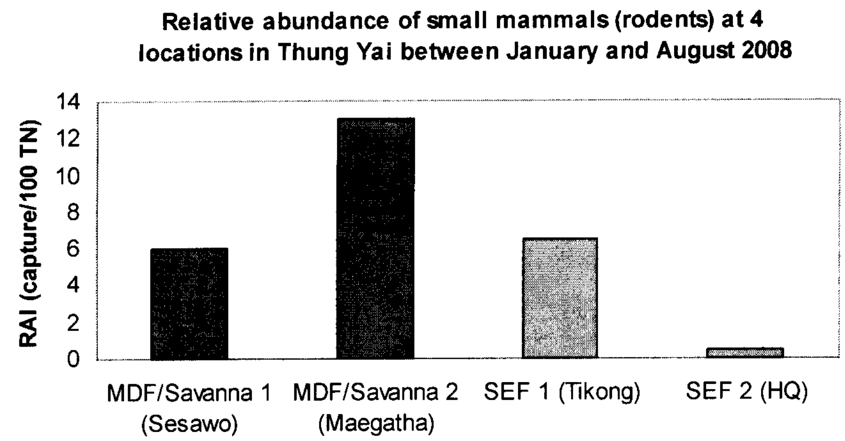


Figure 4 Fruiting tree densities (tree/hectare) in 4 study sites representing 2 major forest types (MDF/Savanna – Mixed deciduous/Savanna and SEF – Semi – evergreen forests) of Thung Yai Naresuan Wildlife Sanctuary, western Thailand during 2007 and 2008

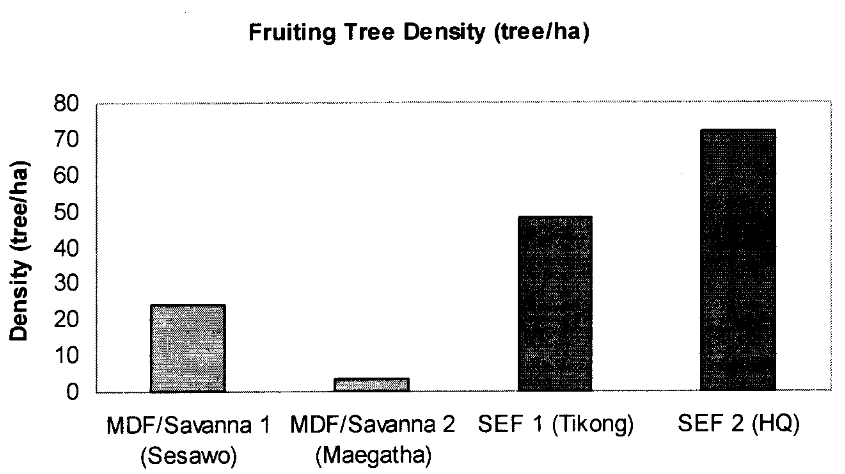


Figure 5 Relative variable importance values (variable importance in the context of model set, calculated by summing the Akaike weights [w_i] over all models fall within the confident set including the given variables) for each variable used in 5 small carnivore species (Large Indian Civet, Common Palm Civet, Masked Palm Civet, Crab-eating Mongoose and Leopard Cat) occupancy modeling at Thung Yai, western Thailand 2007 and 2008. Refers to *Methods* section for variables' codes

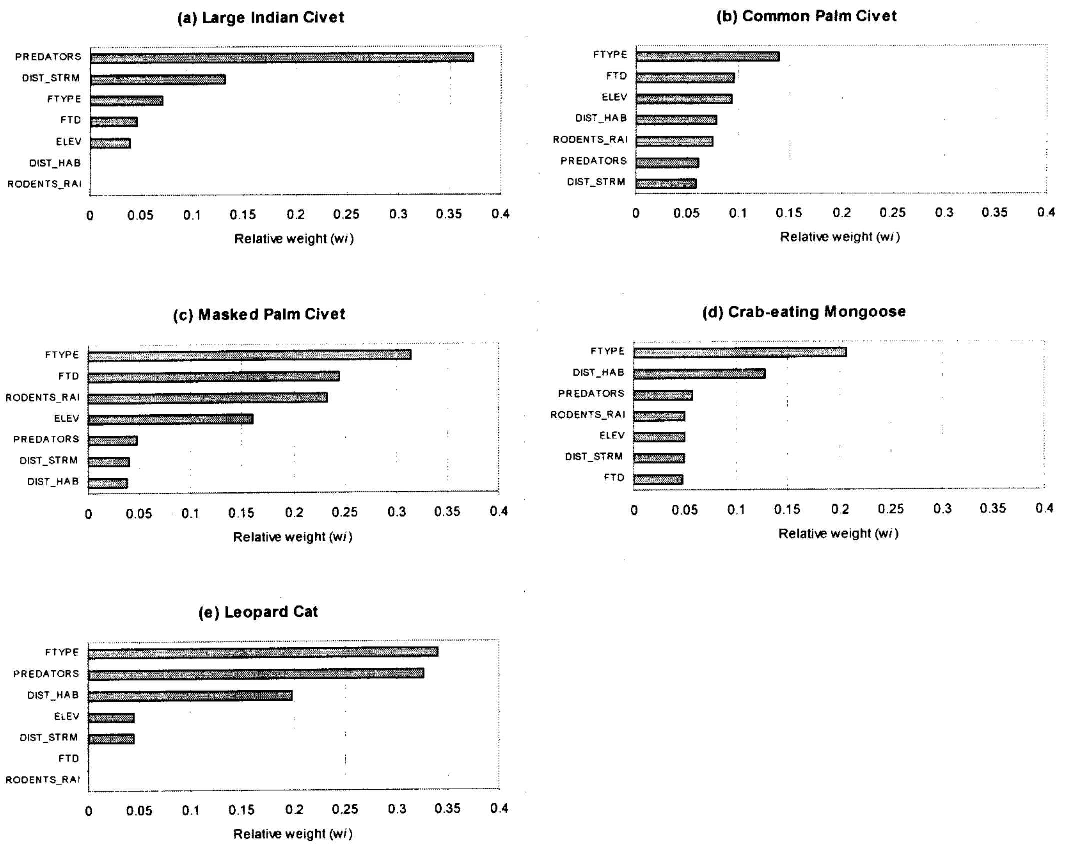
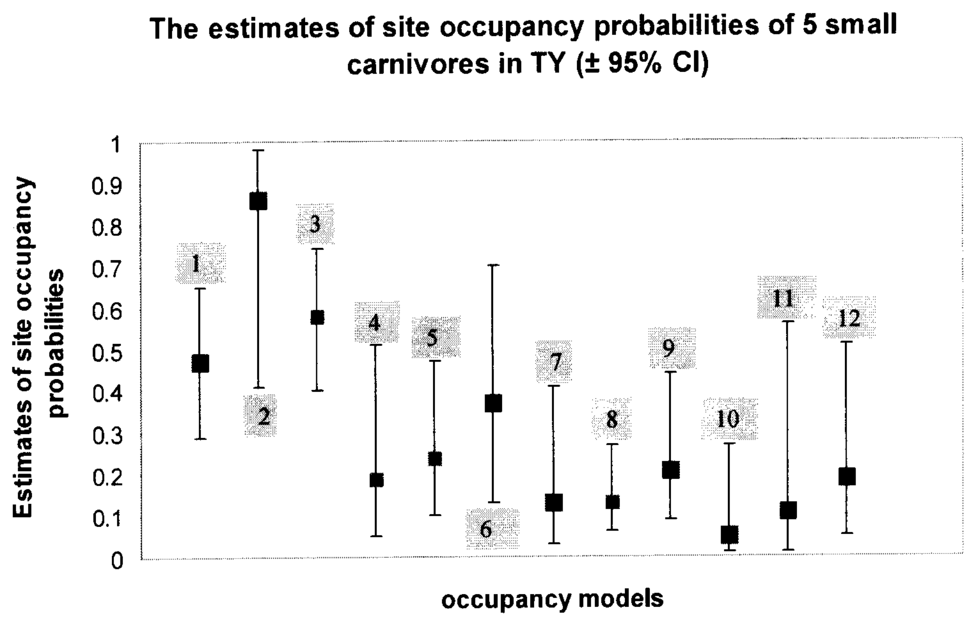


Figure 6 Occupancy probability estimates of 5 small carnivores in Thung Yai Naresuan Wildlife Sanctuary, western Thailand, 2007 and 2008. Bars represent 95% confident intervals of occupancy probabilities. Refers to *Methods* section for variables' codes.



<u>*Occupancy models refer to;*</u>

Large Indian Civet ψ(PREDATORS), p(.) – as a function of absence (1) and presence (2) of large predators, respectively, and (3) ψ(.), p(.);

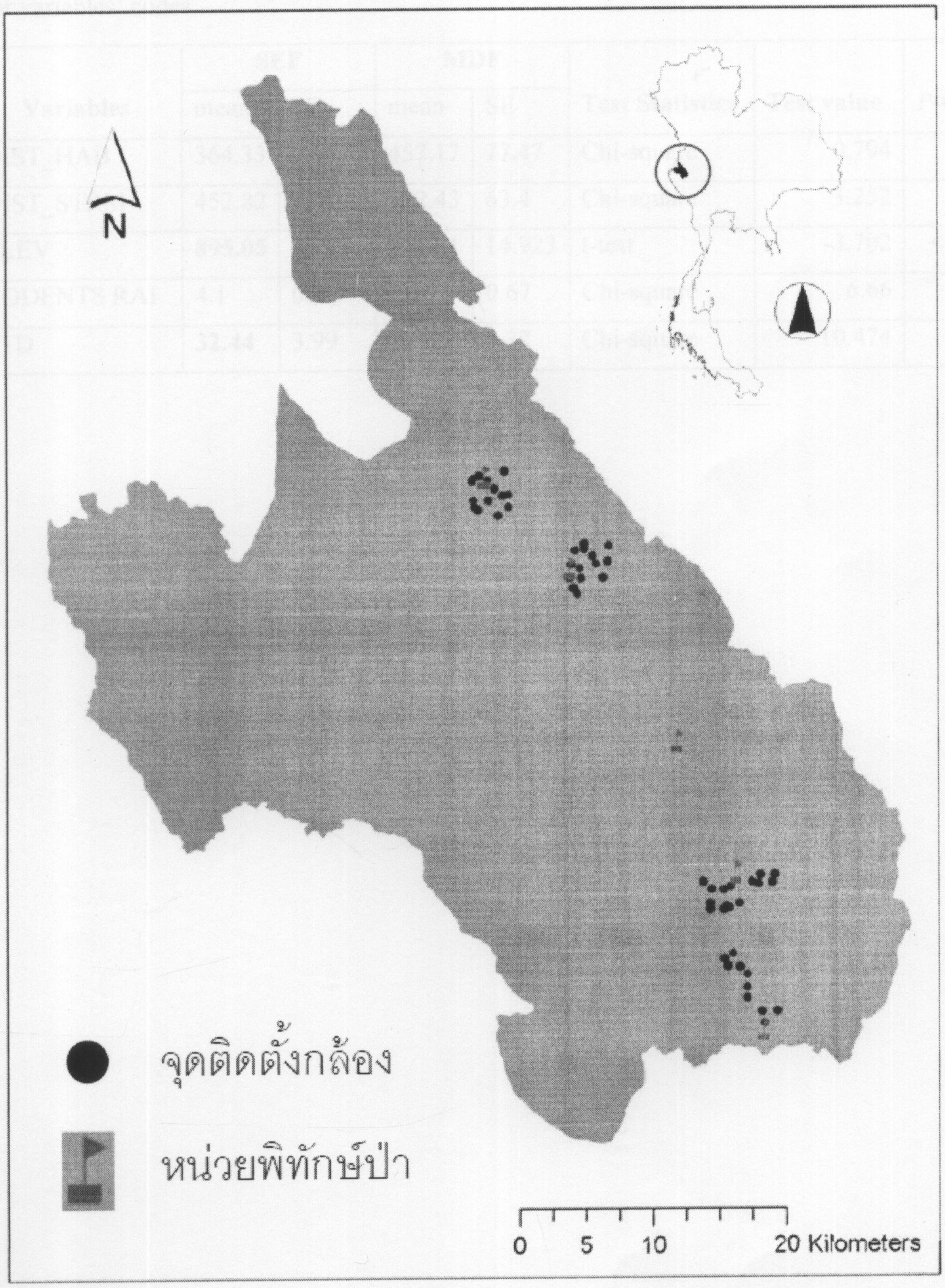
Common Palm Civet (4) ψ (.), p(.);

Masked Palm Civet (5) ψ (.), p(.), and ψ(FTYPE), p(.) – as a function of MDF/Savanna (6) and SEF (7), respectively;

Crab-eating Mongoose (8) ψ (.), p(.), and ψ(FTYPE), p(.) – as a function of MDF/Savanna (9) and SEF (10), respectively; and

Leopard Cat (11) ψ(FTYPE), p(.) – as a function of SEF and (12) ψ(PREDATORS), p(.) – as a function of absence of large predators.

Appendix A Map of Thung Yai Naresuan Wildlife Sanctuary (west) showing camera trap locations in 2 major forest types (Semi-evergreen Forest [SEF] and Mixed deciduous and Savanna Forest [MDF/Savanna])



Appendix B Bivariate comparisons (mean ±SE) of predictor variables between Semi-evergreen Forest (SEF) and Mixed deciduous and Savanna Forest (MDF/Savanna) at Thung Yai, western Thailand between Nov 2007 and Aug 2008. Refers to *Methods* section for variables' codes

Variables	SEF		MDF		Test Statistics	Test value	*P*-value
	mean	SE	mean	SE			
DIST_HAB	364.33	73.6	457.17	77.47	Chi-square	0.794	0.373
DIST_STRM	452.82	118.64	172.43	63.4	Chi-square	3.252	0.071
ELEV	**895.05**	15.79	814.61	14.923	t-test	-3.702	**< 0.001**
RODENTS RAI	4.1	0.6	**9.5**	0.67	Chi-square	6.66	**0.01**
FTD	**32.44**	3.99	14	2.27	Chi-square	10.474	**0.001**

Appendix C Bivariate comparisons (mean ±SE) of 5 small carnivores' detection and non-detection at camera trap locations of predictor variables used in modeling the probabilities of occupancy of 5 small carnivores (Large Indian Civet, Common Palm Civet, Masked Palm Civet, Crab-eating Mongoose and Leopard Cat) at Thung Yai, western Thailand Nov 2007 and Aug 2008. Refers to *Methods* section for variables' codes.

	All 5 species				Large Indian Civet				Common Palm Civet				Masked Palm Civet				Crab-eating Mongoose				Leopard Cat			
	Detection		Non Detection		Detection		Non Detection		Detection		Non Detection		Detection		Non Detection		Detection		Non Detection		Detection		Non Detection	
	n = 30		*n* = 23		*n* = 24		*n* = 29		*n* = 5		*n* = 48		*n* = 8		*n* = 45		*n* = 6		*n* = 47		*n* = 9		*n* = 44	
Variables	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE
DIST_HAB	380.93	68.58	455.7	85.93	395.37	81.81	428.29	71.85	270.95	100.71	428.22	57.99	384.97	128.71	418.43	59.31	230.76	86.94	436.69	58.7	313.36	62.45	433.84	63.01
DIST_STRM	299.52	91.72	282.09	99.5	209.37	84.99	360.3	99.54	477.75	320.48	272.6	66.87	407.65	227.76	271.39	68.54	335.6	210.9	286.38	71.28	269.95	181.31	296.46	72.55
ELEV	862.93	15.11	839.02	19.75	855.37	18.27	850.22	16.42	905.34	39.04	847.05	12.59	907.13*	23.52	842.85	13.19	849.48	34.93	852.94	13.03	853.82	22.59	852.29	13.92
RODENTS RAI	6.57	0.64	7.46	1.07	6.67	0.8	7.19	0.85	5.2	1.18	7.14	0.63	6.13	0.08	7.1	0.69	7.25	1.15	6.91	0.65	6.83	0.77	6.98	0.69
FTD	23.83	3.23	21.22	4.18	21.79	3.76	23.45	3.54	34.2	9.08	21.5	2.63	30	11.11	21.4	2.9	24	6.2	22.53	2.79	24	4	22.43	2.98
FTYPES	ns		ns		ns		ns		ns		ns		ns		ns		ns		ns		ns		*P* = 0.0191	
PREDATORS	*P* = 0.0189		ns		*P* = 0.0098		ns		ns		ns		ns		ns		ns		ns		*P* = 0.0041		ns	

Fisher's Exact Test (1 - tailed test) for categorical variables (FTYPES and PREDATORS)
For FTYPES, Detection refers to SEF (1) and Non Detection refers to MDF (0)
For PREDATORS, Detection = predators present (1) and Non Detection = predators absent (0)
* Means are significantly different (P = 0.0441)

Attachment 1: Budget Report

Project: Effects of forest structure and food availability on the small carnivore community in Thung Yai Naresuan Wildlife Sanctuary, western Thailand

Project number: BRT_T351001

Period: 1 October 2007 – 31 October 2008

Total budget: 200,000 baht

1st Payment: 90,000 baht....................................(1)
1st Expense: 131,212 baht...................................(2)
2nd Payment: 90,000 baht....................................(3)
2nd Expense: 78,433 baht....................................(4)
Balance = (1) – (2) + (3) – (4) = **-29,655** baht

Description	*(1)*	*(2)*	*(3)*	*(4)*	*Total*
(A) Stipend	60,000		60,000		
1) Stipend for field researcher					
1.1 Stipend for field research assistant (12 x 1 x 6,000 baht)		36,000		36,000	72,000
1.2 Stipend for field assistant (5 x 1 x 4,000 baht)				20,000	20,000
Sub-total (A)		**36,000**		**56,000**	**92,000**
(B) Field Equipments	30,000		30,000		
2) Equipments					
2.1 Stealth Cam camera trap (n=40)		69,531			69,531
2.2 Battery for camera traps		6,156		7,000	13,156
2.3 Films		5,250		3,210	8,460
2.4 Developed films				1,733	1,733
2.5 Flysheet, hammock, tape		3,175			3,175
2.6 Field supplies		3,000		3,000	6,000
Sub-total (B)		**87,112**		**14,943**	**102,055**
C) Other expenses					
c.1 Car rent		6,000		6,000	12,000
c.2 Photo copy/reporting/book		1,500		1,500	3,000
c.3 post service		600			600
Sub-total (C)		**8,100**		**7,500**	**15,600**
Grand Total		**131,212**		**78,443**	**209,655**

(Wanlop Chutipong)
September 10, 2010

LITERATURE CITED

Anderson, D. R., W. A. Link, D. H. Johnson, and K. P. Burnham. 2001. Suggestions for presenting the results of data analyses. The Journal of Wildlife Management **65**:373-378.

Andheria, A. P., K. U. Karanth, and N. S. Kumar. 2007. Diet and prey profiles of three sympatric large carnivores in Bandipur Tiger Reserve, India. Journal of Zoology **273**:169-175.

Anon. 1997. Application of remote sensing and GIS for monitoring forest land use changed in Thung Yai Wildlife Sanctuaries (in Thai). Page 140. Forest Research Centre, Faculty of Forestry, Kasetsart University, Bangkok, Thailand.

Anon. 2005. Dong Phayayen - Khao Yai Carnivore Conservation Project: 2nd Year Progress Report, October 2004 through September 2005. Page 63. Smithsonian, WildAid, and Khao Yai National Park.

Austin, S. C. 1999. Camera-trapping evidence of Large-spotted Civet (*Viverra megaspila*) in Xe Piane National Biodiversity Conservation Area (NBCA), Southern Lao PDR Nat. Hist. Bull. Siam Soc. **47**:255-257.

Boontua, P. 2004. Preliminary Surveys for Fishing Cat (*Prionailurus viverinus*) in Thailand. Pages 1-12. The Wildlife Research Division and The Smithsonian Insititution's National Zoological Park, Bangkok.

Boulinier, T., J. D. Nichols, J. R. Sauer, J. E. Hines, and K. H. Pollock. 1998. Estimating species richness: the importance of heterogeneity in species detectability. Ecology **79**:1018-1028.

Burnham, K. P., and D. R. Anderson. 2004. Multimodel inference: Understanding AIC and BIC in model selection. Sociological Methods & Research **33**:261-304.

Carbone, C., S. Christie, K. Conforti, T. Coulson, N. Franklin, J. R. Ginsberg, M. Griffiths, J. Holden, K. Kawanishi, M. Kinnaird, R. Laidlaw, A. Lynam, D. W. Macdonald, D. Martyr, C. McDougal, L. Nath, T. O'Brien, J. Seidensticker, D. J. L. Smith, M. Sunquist, R. Tilson, and W. N. W. Shahruddin. 2001. The use of photographic rates to estimate densities of tigers and other cryptic mammals. Animal Conservation **4**:75-79.

Chapman, C. A., L. J. Chapman, R. Wangham, K. Hunt, D. Gebo, and L. Gardner. 1992. Estimators of Fruit Abundance of Tropical Trees. Biotropica **24**:527-531.

Conforti, K. 1996. The status and distribution of small carnivores in Huai Kha Khaeng/Thung Yai Naresuan Wildlife Sanctuaries, west-central Thailand. Page 65. Graduate School of the University of Minnesota. University of Minnesota, Minnesota, USA.

Duckworth, J. W. 1997. Small carnivores in Laos: A status review with notes on ecology, behavior and conservation. Small Carnivore Conservation **16**:1-21.

Duckworth, J. W., and A. R. Nettelbeck. 2007. Observations of Small-toothed Palm Civets *Arctogalidia trivirgata* in Khao Yai National Park, Thailand, with notes on feeding techniques. Nat. Hist. Bull. Siam Soc. **55**:187-192.

Duckworth, J. W., C. M. Poole, R. J. Tizard, J. L. Walston, and R. J. Timmins. 2005. The Jungle Cat *Felis chaus* in Indochina: a threatened population of a widespread and adaptable species. Biodiversity and Conservation **14**:1263–1280.

Gerwing, J. J., S. A. Schnitzer, R. J. Burnham, F. Bongers, J. e. o. Chave, S. J. DeWalt, C. E. N. Ewango, R. Foster, D. Kenfack, M. Mart'ınez-Ramos, M. Parren, N. Parthasarathy, D. R. P'erez-Salicrup, F. E. Putz, and D. W. Thomas. 2006. A standard protocol for liana censuses. Biotropica **38**:256-261.

Grassman, L. I., Jr. 1997. Ecology and behavior of four sympatric carnivore species (Mammalia : Carnivora) in Kaeng Krachan National Park, Thailand. Page 94. MSc (Zoology), Depertment of Zoology. Kasetsart University, Bangkok.

Grassman, L. I., Jr. . 1998. Movements and fruit selection of two Paradoxurinae species in a dry evergreen forest in Southern Thailand. Small Carnivore Conservation **19**:25-29.

Grassman, L. I., Jr. . 1999. Ecology and behavior of the Indochinese leopard in Kaeng Krachan National Park, Thailand. Nat. Hist. Bull. Siam Soc. **47**:77-93.

Grassman, L. I., Jr., M. E. Tewes, and N. J. Silvy. 2005a. Ranging, habitat use and activity patterns of binturong *Arctictis binturong* and yellow-throated marten *Martes flavigula* in northcentral Thailand. Wildlife Biology **11**:49-57.

Grassman, L. I., Jr., M. E. Tewes, N. J. Silvy, and K. Kreetiyutanont. 2005b. Ecology of three sympatric felids in a mixed evergreen forest in north-central Thailand. Journal of Mammalogy **86**:29-38.

Grassman, L. I., Jr., M. E. Tewes, N. J. Silvy, and K. Kreetiyutanont. 2005c. Spatial organization and diet of the leopard cat (*Prionailurus bengalensis*) in north-central Thailand. Journal of Zoology **266**:45-54.

http://www.mbr-pwrc.usgs.gov/software/presence.html. 2006. PRESENCE2 - Software to estimate patch occupancy and related parameters USGS-PWRC

IUCN. 2008. 2008 IUCN Red List of Threatened Species. <www.iucnredlist.org> Downloaded on 26 July 2009.

Johnson, J. B., and K. S. Omland. 2004. Model selection in ecology and evolution. Trends in Ecology and Evolution **19**:101-108.

Joshi, A. R., J. L. David Smith, and F. J. Cuthbert. 1995. Influence of food distribution and predation pressure on spacing behavior in palm civets. Journal of Mammalogy **76**:1205-1212.

Karanth, K. U., and M. E. Sunquist. 1995. Prey selection by tiger, leopard and dhole in tropical forests. Journal of Animal Ecology **64**:439-450.

Kitamura, S., T. Yumoto, P. Poonswad, P. Chuailua, K. Plongmai, T. Maruhashi, and N. Noma. 2002. Interactions between fleshy fruits and frugivores in a tropical seasonal forest in Thailand. Oecologia **133**:559-572.

Kutintara, U., and N. Bhumpakphan. 1989. Management Plan for Thung Yai Naresuan Wildlife Sanctuary (Kanchanaburi and Tak Provinces) (in Thai). Page 263. Faculty of Forestry, Kasetsart University, Bangkok, Thailand.

Lekagul, B., and J. A. McNeely 1977. Mammals of Thailand. Association for the Conservation of Wildlife (as updated 1998), Bangkok, Thailand.

Linnell, J. D. C., and O. Strand. 2000. Interference interactions, co-existence and conservation of mammalian carnivores. Diversity and Distributions **6**:169-176.

Luck, G. W. 2002. The habitat requirements of the rufous treecreeper (*Climacteris rufa*). 1. Preferential habitat use demonstrated at multiple spatial scales. Biological Conservation **105**:383-394.

Lynam, A. J., K. Kreetiyutanont, and R. Mather. 2001. Conservation status and distribution of the Indochinese tiger (Panthera tigris corbetti) and other large mammals in a forest complex in northeastern Thailand. Nat. Hist. Bull. Siam Soc. **49**:61-75.

Lynam, A. J., M. Maung, S. H. T. Po, and J. W. Duckworth. 2005. Recent records of Large-spotted civet *Viverra megaspila* from Thailand and Myanmar. Small Carnivore Conservation **32**:8-11.

Lynam, A. J., P. D. Round, and W. Y. Brockelman 2006. Status of Birds and Large Mammals in Thailand's Dong Phayayen - Khao Yai Forest Complex. Biodiversity Research and Training (BRT) Program and Wildlife Conservation Society Bangkok, Thailand.

MacKenzie, D. I., and J. A. Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. Journal of Applied Ecology **42**:1105-1114.

Magurran, A. E. 1988. Ecological Diversity and Its Measurments. Princeton University Press, New Jersey, USA.

Maxwell, J. F. 1995. Vegetation and vascular flora of the Ban Saneh Pawng area, Lai Wo subdistrict, Sangklaburi district, Kanchanaburi province, Thailand. Nat. Hist. Bull. Siam Soc. **43**:131-170.

Maxwell, J. F., and S. Elliott 2001. Vegetation and Vascular Flora of Doi Sutep-Pui National Park, Northern Thailand. BRT, Bangkok, Thailand.

Mohd. Azlan, J. 2006. Mammal diversity and conservation in a secondary forest in Peninsular Malaysia. Biodiversity and Conservation **15**:1013-1025.

Mohd. Azlan, J., and D. S. K. Sharma. 2006. The diversity and activity patterns of wild felids in a secondary forest in Peninsular Malaysia. Oryx **40**:36-41.

Mukherjee, S., S. P. Goyal, A. J. T. Johnsingh, and M. R. P. L. Pitman. 2004. The importance of rodents in the diet of jungle cat (*Felis chaus*), caracal (*Caracal caracal*) and golden jackal (*Canis aureus*) in Sariska Tiger Reserve, Rajasthan, India. J. Zool. (Lond.) **262**:405-411.

Nakhasathien, S., and B. Stewart-Cox. 1990. Nomination of The Thung Yai-Huai Kha Khaeng Wildlife Sanctuary to be a UNESCO World Heritage Site. Page 128. Wildlife Conservation Division, Royal Forest Department, Bangkok, Thailand.

Ngoprasert, D. 2004. Effects of roads, selected environmental variables and human disturbance on Asiatic leopard (*Panthera pardus*) in Kaeng Krachan National Park Page 121. School of Bioresource and Technology. King Mongkut's University of Technology Thonburi, Bangkok, Thailand.

Nowell, K., and P. Jackson, editors. 1996. Status survey and conservation action plan: Wild Cats. IUCN, Gland, Switzerland.

O'Brien, T. G., M. F. Kinnaird, and H. T. Wibisono. 2003. Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. Animal Conservation **6**:131-139.

Rabinowitz, A. R. 1991. Behavior and movements of sympatric civet species in Huai Kha Khaeng Wildlife Sanctuary, Thailand. J. Zool. (Lond.) **223**:281-298.

Rabinowitz, A. R., and S. R. Walker. 1991. The carnivore community in a dry tropical forest mosaic in Huai Kha Khaeng Wildlife Sanctuary, Thailand. Journal of Tropical Ecology **7**:37-47.

Rajaratnam, R., M. Sunquist, L. Rajaratnam, and L. Ambu. 2007. Diet and habitat selection of the leopard cat (*Prionailurus bengalensis borneoensis*) in an agricultural landscape in Sabah, Malaysian Borneo. Journal of Tropical Ecology **23**:209-217.

Rao, M., T. Myint, T. Zaw, and S. Htun. 2005. Hunting patterns in tropical forests adjoining the Hkakaborazi National Park, north Myanmar. Oryx **39**:292-300.

Rexstad, E., and K. P. Burnham 1991. User's guide for interactive program CAPTURE. Abundance estimation of closed populations. Colorado State University, Fort Collins, Colorado, USA.
SAS Institute. 2007. JMP 5.0.1, Cary, NC, USA 27513.
Simchareon, S., P. Boontawee, and A. Phetdee. 1999. Home Range size, habitat utilization and daily activities of Large Indian civet (*Viverra zibetha*) (in Thai). Progress report in research activity 1999, Wildlife Research Section, RFD:43 - 64.
Srbek-Araujo, A. C., and A. G. Chiarello. 2005. Is camera-trapping an efficient method for surveying mammals in Neotropical forests? A case study in south-eastern Brazil. Journal of Tropical Ecology **21**:121–125.
Steinmetz, R., and S. Simcharoen. 2006. Observations of Banded Linsang Prionodon linsang at the northern edge of its range, with a review of recent northerly records. Small Carnivore Conservation:29-31.
Sukmasuang, R. 2001. Ecology of barking deer (*Muntiacus* spp.) in Huai Kha Khaeng Wildlife Sanctuary. Page 199. Kasetsart University, Bagkok.
The Thai Meteorological Department. 2005. Rainfall and Temperature of Thomg Pha Phum and Um Phang between 1997 and 2005. The Thai Meteorological Department, Bangkok, Thailand.
van de Bult, M. 2003. The vegetation and flora of the Western Forest Complex using rapid ecological assessment and vegetation types description in the WEFCOM area. Page 60. Western Forest Complex Ecosystem Management Project, National Park, Wildlife and Plant Conservation Department, Bangkok.
Van Rompaey, H. 1993. The Banded linsang, Prionodon linsang. Small Carnivore Conservation **9**:11-15.
Venkataraman, A. B., R. Arumugam, and R. Sukumar. 1995. The foraging ecology of dhole (*Cuon alpinus*) in Mudumalai Sanctuary, southern India. Journal of Zoology **237**:543-561.
Walker, S., and A. Rabinowitz. 1992. The small mammals community of a dry-tropical forest in central Thailand. Journal of Tropical Ecology **8**:57-71.
Walston, J. L., and J. W. Duckworth. 2003. The first record of Small-toothed Palm Civet Arctogalidia trivirgata from Cambodia, with notes on surveying this species. Small Carnivore Conservation **28**:12-13.
White, G. C., D. R. Anderson, K. P. Burnham, and D. L. Otis 1982. Capture-recapture and removal methods for sampling closed populations. LA-8787-NERP. Los Alamos National Laboratory, Los Alamos, New Mexico, USA.
Williams, B. K., J. D. Nichols, and M. J. Conroy 2002. Analysis and management of animal populations: modeling, estimation, and decision making. Academic Press.
Zaw, T., S. Htun, S. H. T. Po, M. Maung, A. J. Lynam, K. T. Latt, and J. W. Duckworth. 2008. Status and distribution of small carnivores in Myanmar. Small Carnivore Conservation **38**:2-28.
Zhou, Y., J. Zhang, E. Slade, L. Zhang, F. Palomares, J. Chen, X. Wang, and S. Zhang. 2008. Dietary shifts in relation to fruit availability among masked palm civets (*Paguma larvata*) in central China. Journal of Mammalogy **89**:435-447.

PHOTO APPENDIX

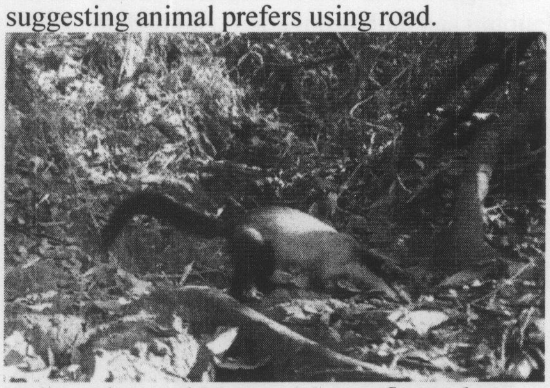
Wildlife of Thung Yai Naresuan Wildlife Sanctuary

camera trap surveys (Nov 2007 – Aug 2008)

Small carnivore of western Thung Yai Naresuan Wildlife Sanctuary

Golden Jackal *Canis aureus* photographed along the road in evergreen forest. This wild dog is fairy uncommon in the study area; tracks were found occasionally mostly along the road suggesting animal prefers using road.

Dhole or Asian Wild Dog *Cuon alpinus*. This picture took in an extensive grassy area of Mae Gatha after the area was partially burned. Dhole is active both day and night.



Yellow-throated Marten *Martes flavigula* actively searches for food. This marten active during day time but when in the bright moon phase it may increase foraging activity during night time.

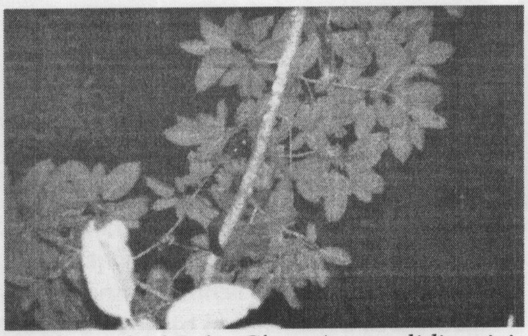
Only one photograph of Hog Badger *Arctonyx collaris* gained from the survey. Although tracks & signs of the animal was found consistently during field work mostly in mixed deciduous where this photographed taken.

This Ferret-badger *Melogale* sp. seems to be trap happy – the animal came back and forth in front of camera resulting in many photographs from this sole individual.

Otter species sometimes comes in a group of up to 6 individuals. Along less-disturbed streams in Thung Yai tracks and signs of species can be easily found. There are 3 species of otters living in sympatry in the waters of Thing Yai.

Large Indian Civet *Viverra zibetha* is the commonest small mammalian carnivore found in both forest types during this study. Large Indian Civet is habitat and food generalist; the animal can eat variety of foods ranging from fruits, small rodents and insects and also foraging in all available habitats. Each individual has uniquely pattern particularly at neck and tail which enables individual identification.

Common Palm Civet *Paradoxurus hermaphroditus*



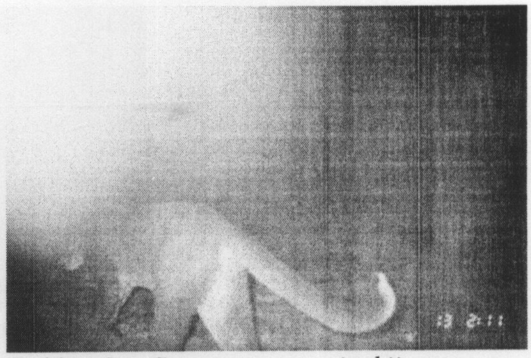
Small-toothed Palm Civet *Arctogalidia trivirgata* (photo by N. Seuaturien) None photograph of this highly arboreal civet taken from this study, however, the animals were frequently encountered almost every nights of spot-lighting surveys exclusively in trees.

Among other small carnivores found in this study Banded Linsang *Prionodon linsang* is truly carnivorous in its food habit; consuming mainly meat. The animal is a good climber thus many camera trap studies end up having very few photographs. Photographs and sighting records from other areas (including TY) suggested the association of Banded Linsang with stream where the animal can find its prey.

Masked Palm Civet *Paguma larvata* is the largest of palm civets foraging both in trees and on ground where it can find other foods - rodents, amphibians when fruits are scarce.

Crab-eating Mongoose *Herpestes urva* This animal sometimes comes in group of 2-6 individuals. Most of photographs came from camera traps set nearby streams suggesting species association with water body.

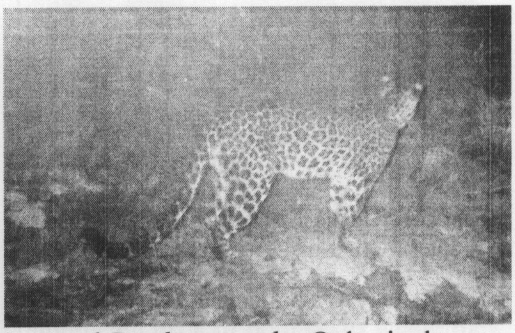
Leopard Cat *Prionailurus bengalensis* is the commoner of the two cats found in this study, however, it may not be as common as previously thought.



Golden Cat *Catopuma temminckii*

Large and medium carnivores

Tiger *Panthera tigris* At least 6 tigers, identified by unique stripe pattern, roamed the areas while the study took place.



Leopard *Panthera pardus* Only single photograph of this cat taken over the survey period of 9 months.

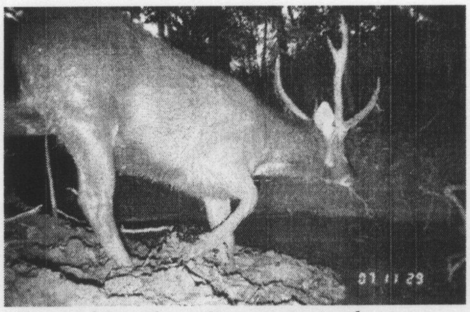
Clouded Leopard *Neofelis nebulosa* Two photographs of a single individual taken in semi-evergreen forest near Tikong. Clouded Leopard is considered as medium carnivore due to its weight.

Asiatic Black Bear *Ursus thibetanus*

Malayan Sun Bear *Ursus malayanus*

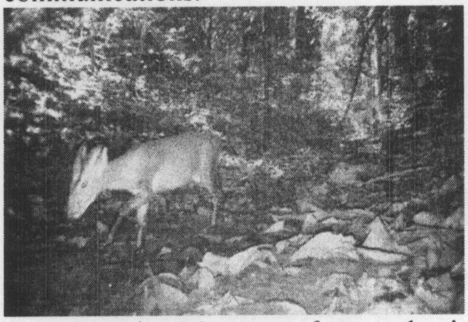
Other wildlife of Thung Yai

Gaur *Bos gaurus* a mother with her calf following closely



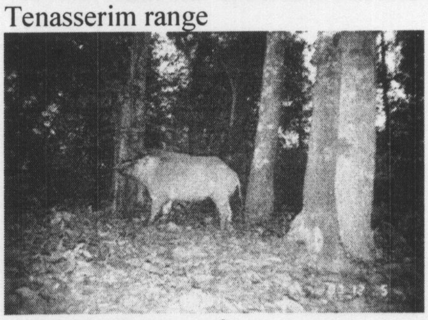
Most of Sambar *Cervus unicolor* photographs taken between Nov – Jan showed that animals were in a rut period (a period of sexual excitement) recognized by rubbed antler and hairless patch underneath neck of both sexes where they secrete liquid/smell used in communications.

Red Muntjac *Muntiacus muntjak*



Fea's Muntjac *Muntiacus feaes* endemic to Tenasserim range

Lesser Mouse Deer *Tragulus javanicus*

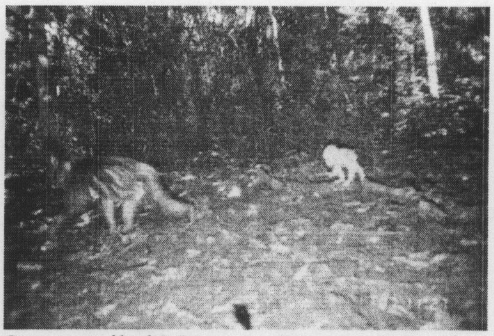


Wild Pig *Sus scrofa*

Asian Tapir *Tapirus indicus* This mother with her playful calf seems not frightened with flash released from camera. She hung around for a while with her calf walking back and forth in front of camera.

Southern Serow *Naemorhedus sumatraensis*

East Asian Porcupine *Hystrix brachyura*



Stump-tailed Macaque *Macaca arctoides*

Bar-backed Partridge *Arborophila brunneopectus*

Kalij Pheasant *Lophura leucomelana crawfurdii* – this sub-species has red legs and the other (*L.l. lineata*) legs are grayish. Both sub-species are found in Thung Yai.