ZSL Conservation Programmes

LIVING CONSERVATION

Rapid Survey

of the

PT. Asiatic Persada / PT. Asialog

Oil Palm / Forest Matrix

by the

Zoological Society of London

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ZSL

LIVING CONSERVATION

Contents

Executive summary

Between February and April 2005 an extensive survey of medium/large mammal distribution was conducted throughout 900km^2 of PT Asiatic Persada (an oil palm concession) and PT Asialog (a logging concession), primarily to determine whether tigers still existed in the landscape following the fall in encounters reported in the plantation concession (ZSL 2004). The survey was conducted using 36 3x3 km foot transects across four habitat types to search for tiger and other wildlife sign supported by camera traps. Surveys were repeated to calculate measures of detectability for individual species which were then used to calculate the proportion of the study site occupied by each species.

1296 man-hours were spent searching for wildlife, recording 1362 independent ‘encounters’ (primarily animal tracks). 20 cameras were deployed in 71 positions for a total of 860 trap nights, recording 1102 subjects, 63% of which were wildlife or people.

In total 28 terrestrial mammal species were recorded, as well as 5 primates and 2 endangered bird species. Tiger were shown to be still present, as were elephants, but cameras only showed evidence of three individual tigers, none of which were individuals that had previously been recorded within the plantation. No species was detected on every survey repeat, showing the importance of using repeated surveys. Consequently, adjusted estimates of ‘true’ occupancy were higher than the naïve estimates obtained from a single survey. The results showed tigers occupy less than 10% of the landscape, despite 90% of the area being suitable. Prey levels appeared healthy, with sambar and muntjacs estimated to occupy nearly 90% of the area and wild pigs occupying 100%. Occupancy estimates were more precise for the more detectable species (tigers, deer, tapir and various small mammals). Evidence of humans was high, with settlements and illegal logging occurring in over 80% of the landscape.

There were insufficient transects to accurately model the effect of the most important explanatory factors on occupancy of most species, however interpolating encounter rates on GIS showed that, with the exception of wild pig, all species tended to prefer the forest habitat. Even species that occurred within oil palm such as civets and leopard cats appeared to be more common in the forest. Land within the oil palm concession was still used by species of conservation interest, including sun bears, tapir and dhole, although only in the unplanted areas. However, compared to previous years, evidence of species in either of the plantation ‘conservation’ areas was very low. Tigers were shown to occur in two areas of the forest, one of which also showed high levels of human disturbance and is not included in the new conservation-focussed ‘restoration area’ land classification.

The survey therefore showed that tigers and other species of conservation concern still existed in the commercially-dominated landscape but that the role of the oil palm plantation concession as species habitat was greatly reduced compared to previous years, probably due to large increase in human activity in the set aside conservation areas. However, the low occupancy levels show the local tiger population was in extremely poor shape and occupying a fraction of the area previously though to be occupied. Distribution of key prey species suggest prey availability was not a key concern leaving direct human activity (poaching or land disturbance) as the more likely reasons.

The survey was also a key step in the development of rapid survey methods. Key points learned were the importance of repeated surveys, their suitability for more detectable species, and the need for large sample sizes to allow modelling of likely explanatory factors. These points will be incorporated into further rapid surveys to be conducted at the same and additional sites in the future.

Introduction

Survey background

Sumatran tigers are critically endangered, with only a few hundred thought to survive in a fragmented landscape comprising mountainous protected areas separated by agricultural / forestry dominated regions. Approximately three quarters of the habitat remaining classified as suitable for tigers lies in these unprotected and commercially managed areas, yet almost nothing is known of how many tigers they can support or how the tigers can survive. Furthermore, the situation is unlikely to be unique to tigers; as a flagship species tigers are on of the best understood and largest ranging species. However, where tigers survive it is likely that many more species of conservation importance exist.

Between 2001-2004 ZSL has been studying a tigers and other large mammals existing on and around a working oil palm plantation in the province of Jambi, Sumatra. Initial results showed at least nine individuals using land on or near the plantation, with the tigers thought to be exploiting the unplanted scrub areas to feed on the high densities of wild pigs that occur around plantations. However, between 2003-4 the tigers showed a marked decline, corresponding with increasing land use conflict in the unplanted areas of the plantation.

The first question that needed to be answered was whether the tigers were disappearing outright or whether they were simply moving further into the forest. A rapid survey technique was therefore designed, based on existing tiger survey methods and recent advances in presence/absence/occupancy approaches, to answer this question. Since tiger surveys can also survey additional factors without much additional effort, the survey was also designed to survey other species and also human presence, in attempt to build an overall picture of the status of large mammals across the plantation-logging concession landscape.

The survey was part of a research programme carried out by ZSL under the Indonesian Institute of Sciences (LIPI). The survey was carried out with funding from 21st Century Tiger and carried out by a conservation team funded by The Zoological Society of London, PT Asiatic Persada and the Rhino and Tiger Conservation Fund together with seconded staff from the Indonesian Department of Forestry (PHKA).

Survey objectives

The aim of the survey was to provide a rapid assessment of the status of tigers, other large mammals and human disturbance within a landscape of commercial activities. To achieve this the survey had five objectives:

1. To determine whether tigers were still present within the oil palm plantation or the forest block that bordered it.
2. To determine which other large mammals were present in the same forest/oil palm block
3. To determine relative abundance and distributions for the key species of conservation importance.
4. To assess the degree of human disturbance
5. To refine the rapid survey methodology and make recommendations for future survey work.

Survey site

The survey was conducted within the province of Jambi on the island of Sumatra, Indonesia. Specifically the survey was carried out within the boundaries of two commercial areas: the PT Asiatic Persada oil palm plantation (27,000 ha) and the neighbouring PT Asialog forestry concession (67000 ha); a total area of approximately 94,000 ha or 940 km2 (see Figure 1).

Figure 1 - Position of study site within Sumatra

Survey timing

The survey ran in two phases from late February 2005 to early May, 2005. Both phases of the survey were completed within two months (the recommended maximum allowed whilst still assuming negligible change in a tiger population), but since they were running out of sync, the overall survey took longer.

Methodology

Survey structure

Layered surveys

The survey was conducted in two layers. Firstly, teams of surveyors were used to conduct *repeated* foot transects, recording all evidence of wildlife and human activity. The reason for the repeats is explained below. Secondly, once surveyors had finished an area, automatic cameras were set up within the same transects to provide supporting and supplementary data to the survey. Initially the camera survey was intended to be a complete sweep of the site according to the methods of Karanth (2002), however, camera shortages and logistical problems meant the camera survey had to be reduced to a supporting component of the foot surveys.

Species lists were compiled from the raw data from each method. Species distribution and relative abundance was investigated using three methods. Firstly estimates of occupancy were calculated. These estimate the proportion of the study site that is occupied or used by a given species during the survey. Secondly, factors affecting occupancy were investigated, primarily to look at the influence of habitat. Thirdly, encounter rates were used as a measure of relative abundance and results mapped and interpolated to try and identify which areas were the most important for different species.

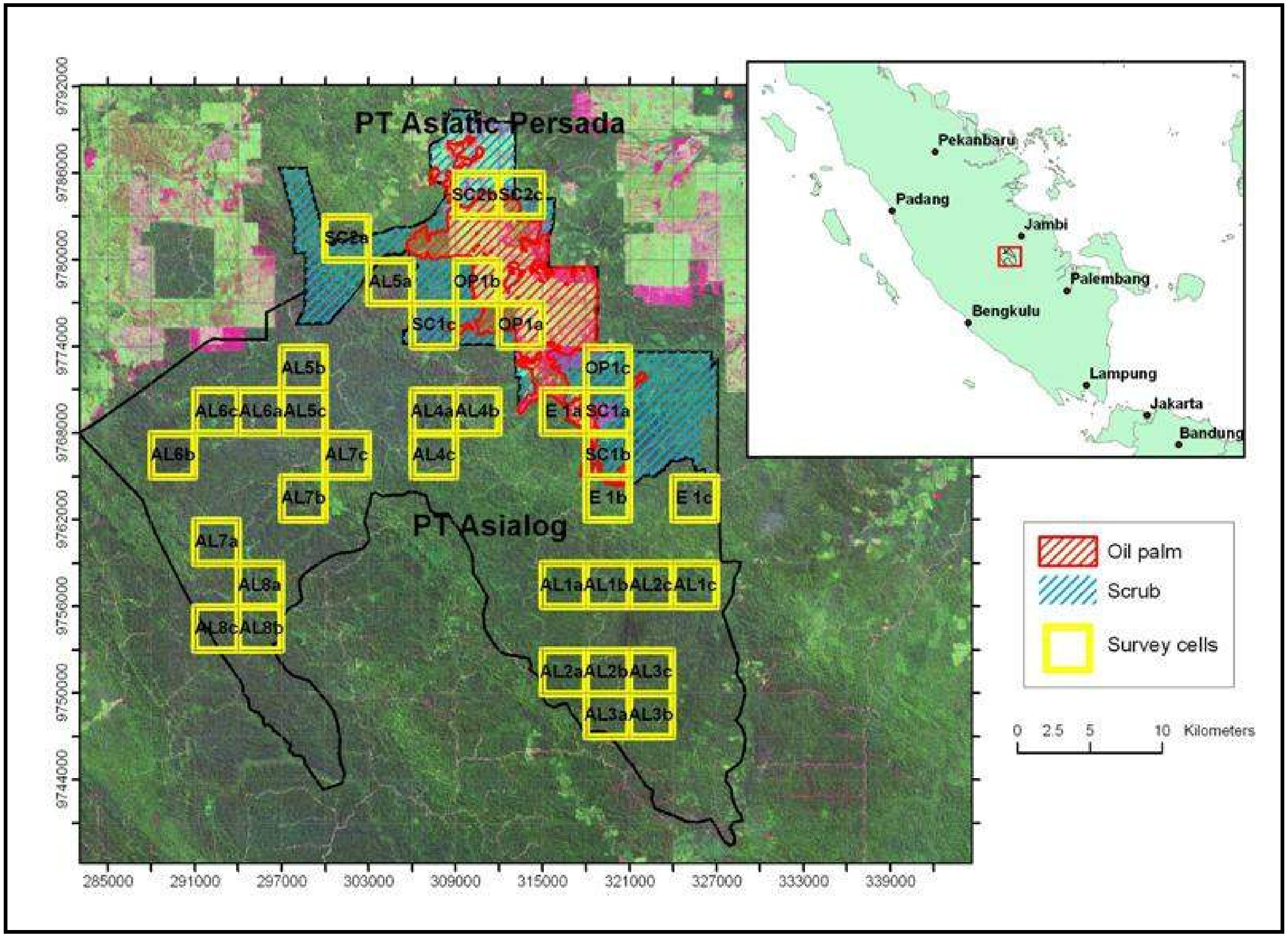
Transect cell placement

Both phases of the survey were based on a sample of 36 transects or cells distributed across the site, covering about 30% of the site. Cells were based upon a 3x3 km (9km²) UTM grid projected over the research site. Grid cells were then allocated to one of four habitat classes (oil palm, scrub, forest, edge) according to the dominant vegetation, as identified from 2004 SPOT 5 satellite imagery. 30% of cells in each habitat were then selected at random, with the exception of the forest habitat which was divided into nine blocks of nine cells and then cells selected at random within each block, to ensure a fairly even coverage of the area.

Table 1 - Survey cell distribution across habitats

Habitat	Total cells	Total area (km^2)	No. cells surveyed	Surveyed area (km^2)	% of habitat surveyed	% of total area
Oil palm	10	90	3	27	30%	2.5%
Scrub	22	198	6	54	27%	5%
Forest	81	729	24	216	29%	20%
Edge	9	81	3	27	33%	2.5%
Totals	122	1098	36	324	29.5%	29.5%

Figure 2 - Map of survey area including position within Sumatra and the location of the 36 survey cells



Foot transect survey

Occupancy theory

One of the most common problems when trying to determine whether a species is present in a given area is knowing how reliable negative results are. Finding evidence of a species means it is definitely present; not finding any evidence might mean the species is not present, or it might mean it was present but the survey did not pick it up. Because of this problem it is extremely difficult to know how reliable a survey is and thus it is also difficult to compare surveys. Recently various analytical techniques have been put forward to solve this problem. All rely on the same basic principle. By repeating surveys they enable a 'detectability' value to be calculated for each species. For example, an elephant is usually fairly easy to detect when present; so almost all repeat surveys of a transect where elephants exist would be expected to record their presence, giving a probability of detection (p) close to 1 or 100%. A clouded leopard on the other hand is a much harder species to detect and repeated surveys of a given transect might show that they are missed more than half of the time, giving a probability of detection (p) below 0.5. This detection value will vary from case to case dependent on the species, habitat, weather, survey type, surveyor skill *etc.* Without knowing detection probabilities a survey will produce a simple 'naïve' estimate of occupancy. For example, if 30% of areas revealed presence of tigers, the naïve occupancy estimate for tigers is 0.3 but with no measure of how accurate this is. However, if repeats of surveys show that in fact tigers are only detected 70% of the time when they are present, the naïve occupancy estimate can be adjusted to give a final probability of occupancy (Ψ) or proportion of area occupied (PAO) that accounts for tigers that probably were present but were missed together with confidence levels that show how accurate the estimate is. This not only improves the value of the estimates but also allows comparison with other surveys.

It is important to clarify at this point that the terms probability of occupancy (Ψ) and proportion area occupied (PAO) are interchangeable within the context of occupancy theory. MacKenzie *et al*. (2006) suggest that the *probability of occupancy* can be considered as the expectation that a particular site will be occupied by a species while the *proportion of area occupied* reflects the realization of this probability within an area of interest. The PAO by a species can in turn be used as a state variable in efforts to monitor changes in population status over time. It has been suggested that occupancy can be used as a substitute for abundance if employed at an appropriate scale in which the two are positively correlated (Karanth and Nichols 2002; MacKenzie 2002; Mackenzie and Nichols 2004; MacKenzie and Royle 2005). Identifying the appropriate scale for tigers and other species is a key question still under discussion.

Protocol

The survey design was based on recommendations by MacKenzie *et al.* (2002), with the aim of surveying all 36 cells three times each. Foot surveys were conducted in six day blocks with three teams of two surveying one cell each every day, thus six cells could be surveyed independently three times in each six day block. Repeats were carried out as quickly as possible to reduce the possibility that population changes during the survey affected results. It was also assumed that species were never falsely detected at a site when absent and that detection of a species was independent of detecting the species at all other sites. To carry out a survey, each team was given the following equipment:

Survey equipment
1 motorbike
1 GPS
1 VHF radio
1 pocket camera
1 tape measure
1 guide to mammal tracks
1 notebook
Specimen jars
Map of general area / cell

The map of their cell was derived from 5m resolution SPOT 5 satellite imagery taken in June 2004. Teams were then given six hours to find as much large mammal sign as possible within a cell, with the time starting as soon as they entered the cell. Team-mates stayed together and did not search independently. Each team decided independently where and how to spend six hours of search effort within the available $9km^2$. The objective was not to achieve total coverage of a given cell, rather to find wildlife sign if it was present. Thus teams targeted effort to areas considered to have the highest probability of finding tiger or prey sign using the maps and their own field skills. Each of the 36 cells was independently surveyed for six hours per day on three consecutive days (T=3) totalling 18 hours of search effort per cell.

Data recorded

During the survey, two types of data were recorded. The first was all independent signs of mammals larger than a mongoose were recorded, together with measurements and a ranking for identification confidence (1:confident 2; fairly confident, 3:unsure). Sign could be footprints, direct observation, identifiable calls/sounds or other secondary signs such as scrapes and nest sites. Faeces were also recorded when encountered, but were not included in the detection/non-detection analysis as they were often collected for dietary analysis. Independence was taken to be a sign at least 100 metres from the next closest sign, unless it was particularly clear two signs were related (for example a trail of footprints interrupted for 100m). The second level of information recorded was all evidence of human activity – human presence, clearing, logging, evidence of hunting. Whenever evidence of hunting was discovered (such as snares), it was removed and destroyed so, like faeces, could not be included in the repeat analyses. Data were recorded as seen and later classified into groups for analysis. Due to the abundance of a) pig tracks and b) human activity, neither was recorded every time it was encountered. Only presence or absence was recorded.

Analysis

Detection history matrices were constructed from footprint and observation data for each cell and recorded as a vector of 1's and 0's, representing detection and non-detection respectively, for each of the occasions on which a cell was sampled. For the analysis, all wildlife signs with confidence = 3 were excluded. Confidence = 2 records were checked using the measurements taken and only included if the measurements supported the identification.

Program PRESENCE version 2.0 (Hines) was used to analyse the detection histories compiled for species encountered during the survey. For each species with sufficient data the naïve estimate of occupancy, detection probability and proportion of area occupied was calculated using the "single group, constant *p*" model (Pledger, 2000). This is the simplest of six models available in PRESENCE and assumes that there is just one "group" of occupied cells within the overall sample and that detection probabilities are constant across all of the cells. Models representing more than one group and varying detection probabilities were also tested but the basic model always fitted as well or better.

Once occupancy values had been calculated, PRESENCE was also used to build logistic regression custom models to look at the effect of different environmental covariates. The models were built by fitting habitat type, settlement presence and illegal logging presence to occupancy results and rainfall on detection probability results. Since the dataset was limited, custom models were only built for selected species.

Camera trapping survey

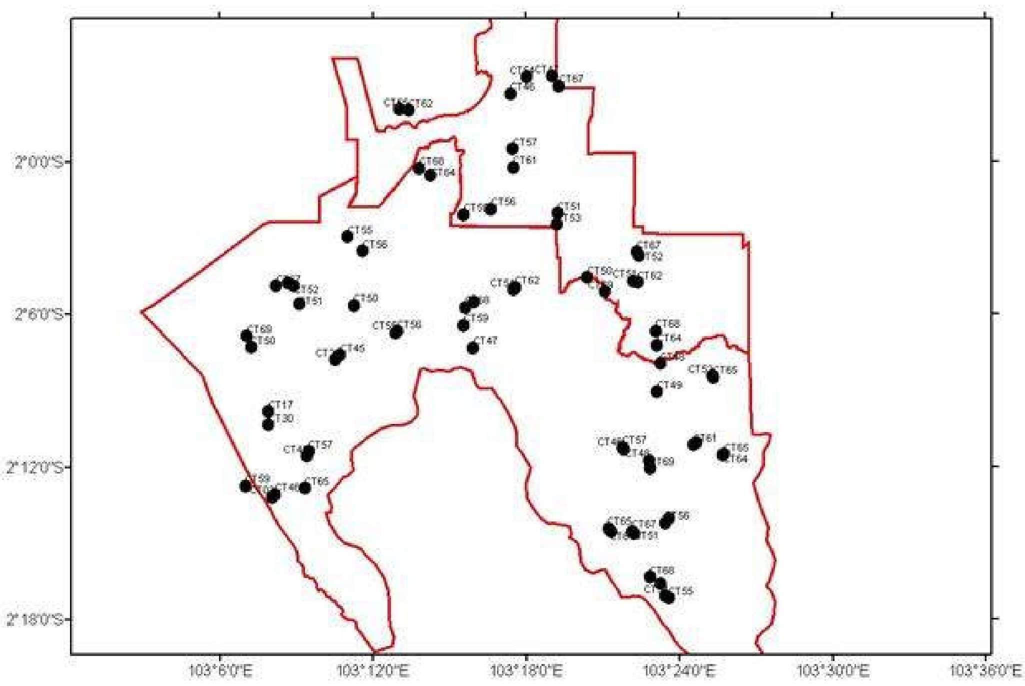
Camera trapping theory

Camera traps are rapidly becoming the tool of choice for a variety of tropical studies due to their ability to pick up cryptic and shy species not usually encountered by human observers and because of the extra information a photograph can provide (individual identification, age and sex, activity times). Consisting of a basic 35mm camera that is triggered by a movement trigger, in this case a passive heat and movement sensor, a web of cameras is spread across the study site, ideally spaced so as not to allow any species to have a 0% chance of detection and thus allowing capture mark recapture analysis (Karanth and Nichols 2002). If there are insufficient cameras to cover an area with the maximum allowed trap spacing, the web is moved periodically until the entire area of interest has been covered.

Protocol

It was known from the outset that the number of trap nights possible from a two month survey with 20 cameras would be limited and that the number of individually recognisable photographs would almost certainly not be sufficient for capture mark recapture analysis. The camera trapping study was therefore carried out as a supporting method to the occupancy survey. Firstly, survey teams were asked to note good camera locations for tigers as they searched for mammal sign. Having completed four groups of three cells in one area, two Photoscout cameras were then deployed in each of these cells for 14 days using pre-identified positions where possible. Cameras were made to take a “test card” photograph when being set up which recorded the location onto the film as a back up and also when taking cameras down to confirm they were still working. Cameras were also not set up in pairs to increase the coverage. Cameras were then re-set up in tiger areas after the survey to specifically get both sides of individuals that had been recorded.

Figure 3 - Position of camera traps



Data recorded

During the survey, the position of every camera was recorded together with a unique film identifier. Following the completion of the survey all camera films were developed and photographs scanned into a database where they could be matched to the camera location and dates records. The total number of camera trap nights was the total number of 24 hour periods each camera was left out for. The effective number of trap nights was counted as the number of 24 hour periods between the first and last photograph for each camera in each position therefore any periods when we could not be sure the camera was operating, or periods lost due to damaged film or cameras, were not counted

Analysis

In theory, occupancy analysis could be carried out on camera trapping data, however, the latter is still at a very early stage of development and for this report only foot transect data were analysed using occupancy analysis. Instead cameras were used to individually recognise tigers photographed and to support distribution data. All data were entered into a database which was in turn linked to a GIS map of the study site, allowing the photographs to be combined with mapping data to illustrate distribution.

Results

Survey effort

The survey ran from 21st February to 14th April 2005, covering an area of 960 km^2. Of this, 324 km^2 were surveyed in 36 3x3km cells (Table 1). Each cell was surveyed for mammal and human sign three times for six hours by three, independent, two-man survey teams, therefore a total of 648 hours or 1296 man hours were spent surveying the area.

In total, 1362 signs of large mammals were recorded; 1081 animal tracks and 281 other signs (scratch marks, direct sightings *etc*). 278 faeces were also recorded, however, many were taken as samples so these did not form part of the repeated occupancy survey.

For the camera phase, 20 cameras were deployed in 71 positions for a total of 860 effective trap nights[1] over 84 days which represents a 51% efficiency rate when considering the maximum number of trap nights possible (20 Cameras x 84 days). Much of the lost efficiency was due to four cameras being stolen or damaged beyond repair during the survey and their photographs lost and two further films being damaged through water leaking into the cameras. Trap nights were also lost due to the time required to take down and re-set up the camera grid as it was moved across the site. During this time, 1102 subjects were photographed (a photo with two individuals counted as two subjects), of which 697 (63%) were of wildlife or people. The remaining photos were mainly accounted for by 'misfires' (where no subject appears in the photograph, usually due to changing temperatures or moving vegetation triggering the sensor or occasionally because the camera did not trigger until the subject had already passed by). Misfires accounted for 23% of all photographs. Other non-wildlife photographs included test cards (a photograph of a card showing the location) and photographs that were too blurred to be analysed.

Species richness

In total, 28 terrestrial (*i.e.* predominantly ground-living, in this case including clouded leopards) mammals were recorded, ranging in size from the moon rat to the Asian elephant (Table 2). In addition, 5 primate species were recorded. The foot surveys were the most sensitive method, identifying 86% more terrestrial species than the cameras with cameras only picking up 53% of the terrestrial species. Four bird species were also recorded (see Other species summary p. 32 and Summary of all wildlife encounters and photographs p. 42).

[1] Effective trap nights are defined as a 24 hour period throughout which a camera was definitely working – trap nights for a camera which ran out of batteries or film before being taken down were calculated to the date of the last photograph.

Table 2 - Summary of all mammal species detected on the survey and the methods used to identify their presence

Order	Family	Common name	Binomial/Trinomial	Track	Faeces	Observation	Photograph
Artiodactyla	Bovidae	Domestic goat	*Capra aegagrus hircus*		1	1	
Artiodactyla	Bovidae	Water buffalo	*Bubalus arnee*	1	1		
Artiodactyla	Cervidae	Muntjac	*Muntiacus muntjak*	1	1	1	1
Artiodactyla	Cervidae	Sambar	*Cervus unicolor*	1	1	1	1
Artiodactyla	Suidae	Bearded pig	*Sus barbatus*				1
Artiodactyla	Suidae	Wild pig	*Sus scrofa*	1	1	1	1
Artiodactyla	Tragulidae	Greater mouse deer	*Tragulus napu*	1			
Artiodactyla	Tragulidae	Lesser mouse deer	*Tragulus javanicus*	1		1	1
Carnivora	Canidae	Dhole	*Cuon alpinus*	1		1	1
Carnivora	Canidae	Domestic dog	*Canis lupus familiaris*	1	1	1	1
Carnivora	Felidae	Clouded leopard	*Neofelis nebulosa*	1		1	
Carnivora	Felidae	Domestic cat	*Felis silvestris cattus*			1	
Carnivora	Felidae	Fishing cat	*Felis viverrina*	1			
Carnivora	Felidae	Golden cat	*Catopuma temminckii temminckii*	1			
Carnivora	Felidae	Leopard cat	*Felis bengalensis*	1	1	1	1
Carnivora	Felidae	Tiger	*Panthera tigris sumatrae*	1	1	1	1
Carnivora	Herpestidae	Short-tailed mongoose	*Herpestes brachyurus*	1			
Carnivora	Mustelidae	Small-clawed otter	*Amblonyx cinereus*	1		1	
Carnivora	Mustelidae	Yellow-throated marten	*Martes flavigula*	1	1		
Carnivora	Ursidae	Sun Bear	*Helarctos malayanus*	1	1	1	1
Carnivora	Viverridae	Common palm civet	*Paradoxurus hermaphroditus*	1	1		1
Carnivora	Viverridae	Malay civet	*Vivera tangalunga*	1	1		1
Insectivora	Erinaceidae	Moon rat	*Echinosorex gymnura*	1			
Perissodactyla	Tapiridae	Malayan tapir	*Tapirus indicus*	1	1		1
Pholidota	Manidae	Malayan pangolin	*Manis javanica*	1	1	1	
Primates	Cercopithecidae	Long tailed macaque	*Macaca fascicularis fascicularis*	1		1	1
Primates	Cercopithecidae	Pig tailed macaque	*Macaca nemestrina*	1		1	1
Primates	Cercopithecidae	Silvered leaf monkey	*Trachypithecus cristatus*			1	
Primates	Hylobatidae	Agile gibbon	*Hylobates agilis*		1	1	
Primates	Hylobatidae	Siamang	*Symphalangus syndactylus*			1	
Proboscidea	Elephantidae	Sumatran elephant	*Elephas maximus sumatrensis*	1	1		
Rodentia	Hystricidae	Brush-tailed porcupine	*Atherurus macrourus*	1			
Rodentia	Hystricidae	East Asian porcupine	*Hystrix brachyura*	1	1	1	1

Species distribution and relative abundance

Estimates of occupancy

Due to limited data for some species, occupancy estimates were only calculated for the twelve species with sufficient data. In addition, some species were amalgamated due to a lack of confidence in distinguishing them in the field. The species grouped were:

Porcupines: *Hystrix brachyura* and *Trichys fascilulata* have both been recorded in camera surveys and can be distinguished by footprints but were not consistently distinguished when recorded.
Civets: *Vivera tangalunga*, *Paradoxurus hermaphroditus* and *Diplogale derbyanus* have been photographed in the past and again can be distinguished by tracks but were not consistently distinguished when recording.

Detection probabilities (*p)* and occupancy estimates were estimated using PRESENCE 2.0 using the single group, constant *p* model. Although the predefined model used may not provide the most accurate estimates of PAO, it is used here as a broad brush indictor of different occupancy and detection probabilities between species/taxonomic groups. Analysis was restricted to the eleven species or species groups for which data were most complete, as well as tigers which were include despite sparse data. The results are shown in Table 3 and the following figures and show the average detection probability (*p*) and standard errors (Figure 4) the naïve (raw) occupancy estimates and the adjusted estimate for proportion of area occupied (PAO) also with standard errors (Figure 5).

Table 3 - Occupancy analysis for twelve main species

Species	Naïve occupancy estimate	PAO	SE	Detection probability (*p*)	p(SE)
Leopard cat	0.92	0.95	0.05	0.69	0.052
Porcupine sp.	0.89	0.91	0.05	0.71	0.050
Muntjac	0.83	0.88	0.07	0.62	0.059
Sambar	0.83	0.87	0.07	0.65	0.057
Sun bear	0.67	0.87	0.14	0.38	0.077
Pig-tailed macaque	0.47	0.82	0.26	0.25	0.089
Mouse deer sp.	0.42	0.77	0.28	0.23	0.093
Tapir	0.69	0.75	0.09	0.58	0.067
Civet sp.	0.61	0.65	0.09	0.59	0.071
Clouded leopard	0.39	0.55	0.15	0.34	0.100
Long-tailed macaque	0.22	0.43	0.23	0.22	0.125
Tiger	0.08	0.09	0.05	0.63	0.049

Figure 4 - Variation in detectability between primary species

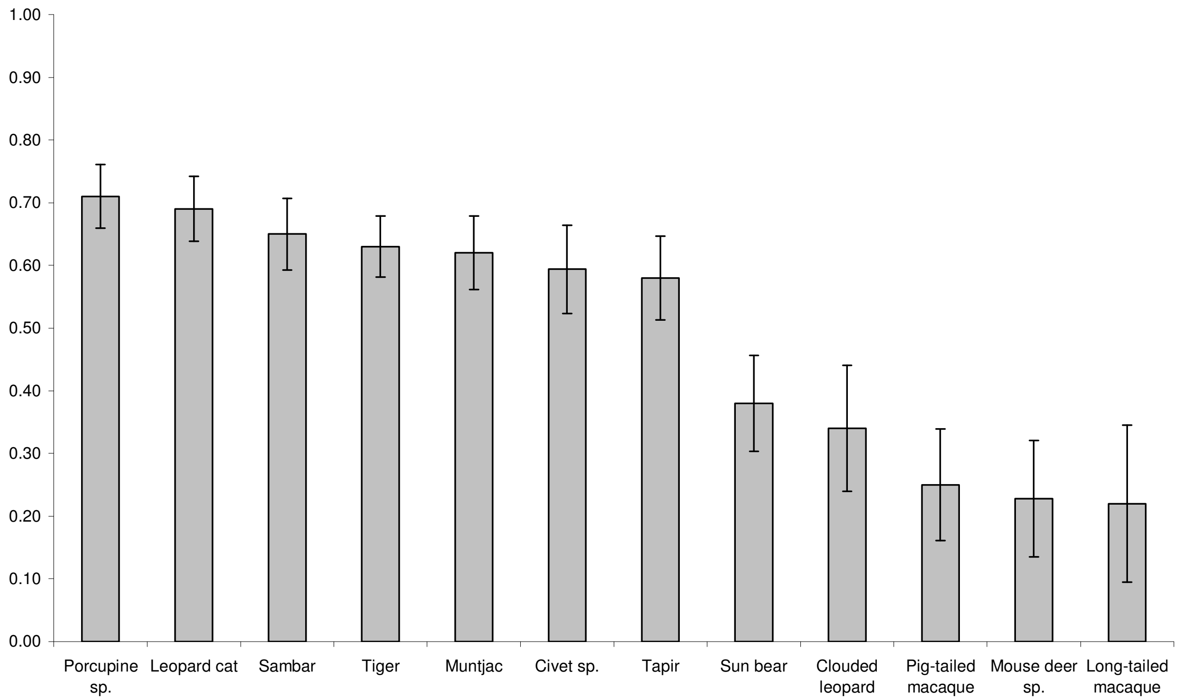
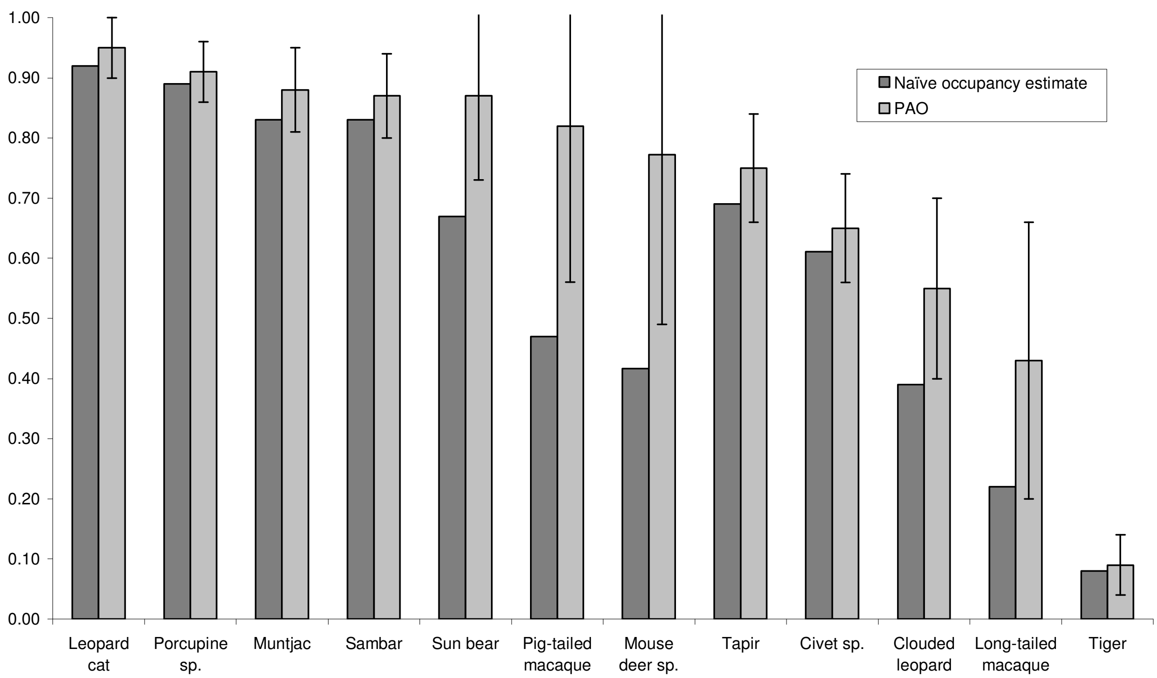


Figure 5 - Naive and adjusted occupancy estimates for wildlife sign



Human activity occupancy

Human activity was grouped into five categories for analysis:

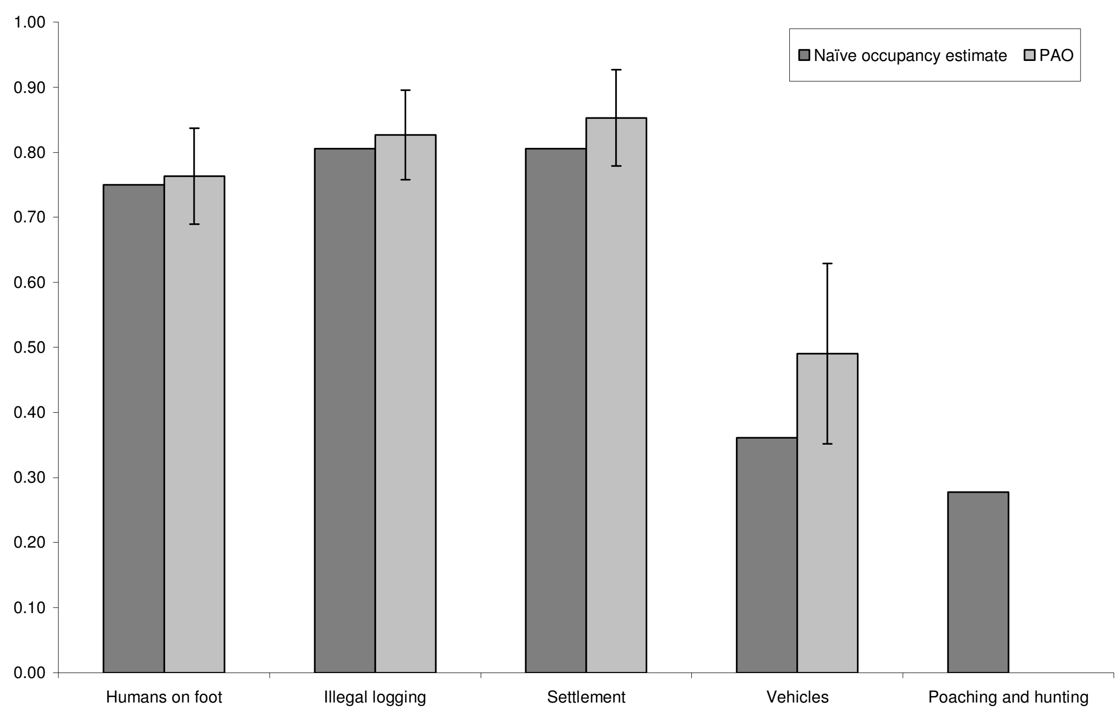
Humans on foot: shoe prints, bare foot prints, people seen, human trails, recent fire
Vehicles: car tracks, motorbike tracks, truck tracks, trucks seen, cars seen
Settlement: houses/huts, old camps, camps in use, small holder oil palm, small holder rice, land clearance and small holder rubber plantations
Illegal logging: workers seen, chainsaws heard, timber stock piles
Poaching and hunting: snares, hunters seen, pig hunts

Encounters were then analysed in the same manner as for wildlife, except for snares which were removed as soon as they were found which mean detection probabilities could not be reliably calculated.

Table 4 - Occupancy analysis of human sign

Human activity category	Naïve occupancy estimate	PAO	(SE)	Detection probability (*p*)	*p*(SE)
Humans on foot	0.75	0.76	0.07	0.74	0.05
Illegal logging	0.81	0.83	0.07	0.71	0.05
Settlement	0.81	0.85	0.07	0.62	0.06
Vehicles	0.36	0.49	0.14	0.36	0.10
Poaching and hunting	0.28	-	-	-	-

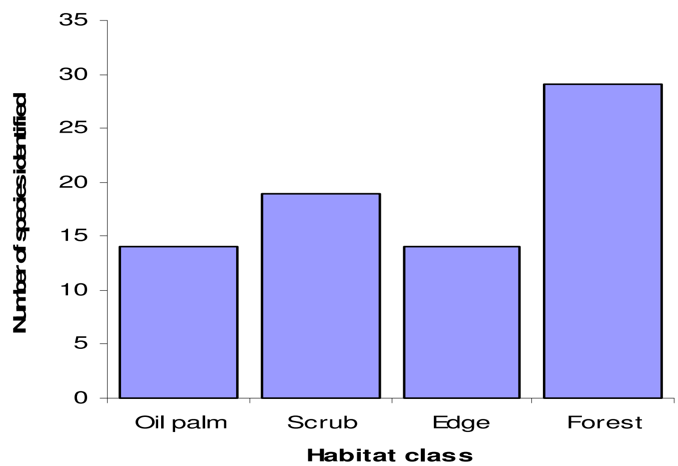
Figure 6 - Naive and adjusted occupancy estimates for human sign



Factors determining occupancy

Species richness was not uniform throughout the study area, with most species recorded on the foot transects occurring in the forest habitat (Figure 7).

Figure 7 - Number of species recorded in each habitat



However, attempts to quantify the impact of habitat and other likely explanatory variables on occupancy were restricted by the small number of transects in the non-forest habitats compared to forest. Consequently attempts to fit explanatory parameters to most of the occupancy data were unsuccessful. However, tapir and clouded leopard occupancy could be explained by the available factors, with tapir shown to be 31 times more likely to be detected in forest cells than non-forest and clouded leopard 8 times more likely in forest. Both results were significant ($p<0.05$). and details of the models are presented in the appendix (p.44) Effects of other parameters, such as the effect of humans through settlement or logging were not significant.

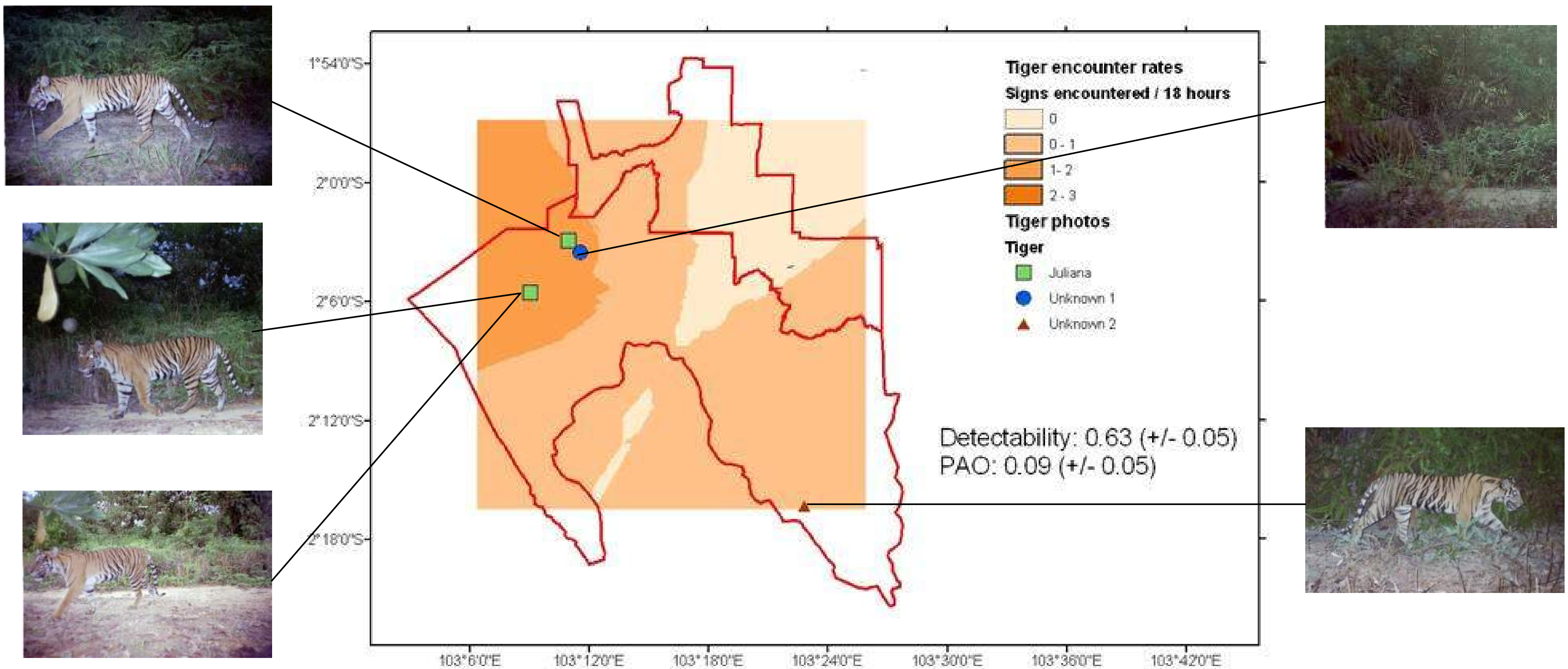
Encounter rates

The occupancy levels calculated above do not include any explanation of where each species was distributed. A crude description of distribution was therefore calculated using encounter rates; simply the rate of encountering sign of each species within each survey cell. Using the encounter rates as a z value (with the grid reference of the cell giving the x and y values) the results were interpolated with GIS to give approximate distribution maps for the key species. These results were combined with the occupancy results when available and with supporting photographic data to give a summary distribution map for each species, presented below.

Distribution summary maps

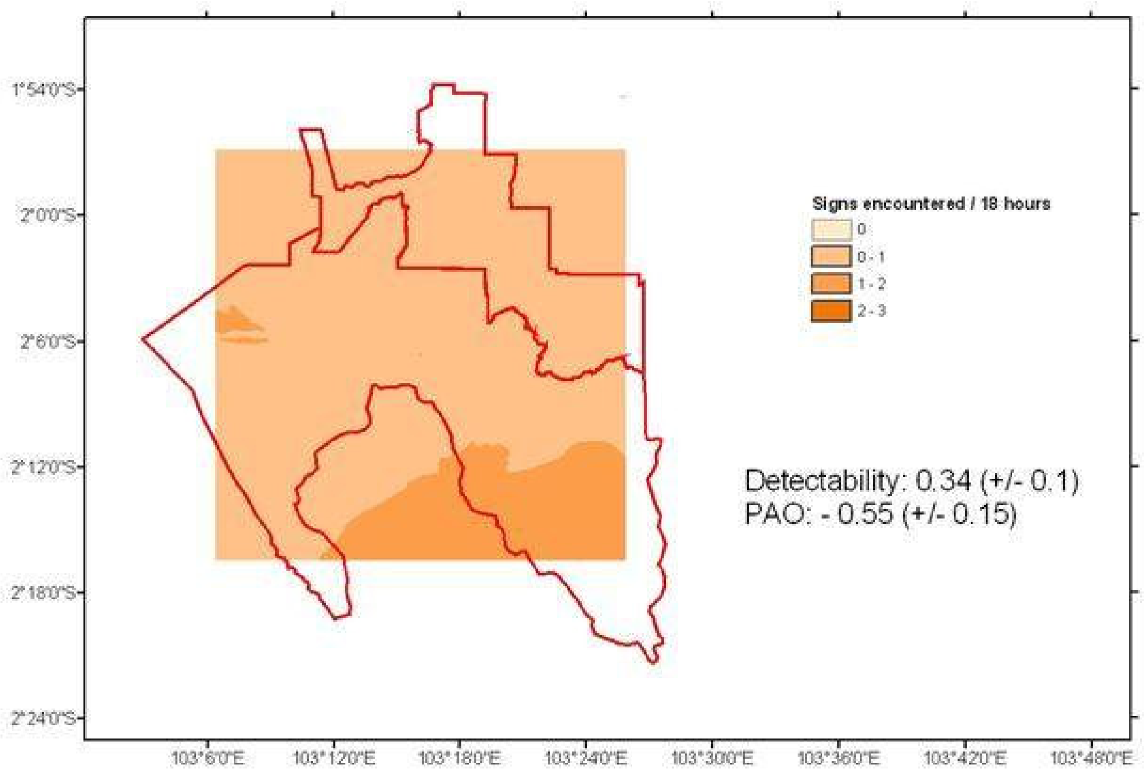
Tiger summary

Tiger foot prints were recorded in two cells, (AL5b AL6a) and a tiger was heard calling in one cell (AL1c) and faeces were found in one other cell (AL1b) and the resulting estimate of proportion of area occupied was below 10%. Encounter rates showed an area in the north west and south east to be the best areas for tigers. Five photographs of tigers were recorded in three cells, roughly matching the foot transect results. However, using stripes to individually recognise tigers, show the photographs represent a maximum of three individuals, with three photographs of an adult female (left) and a probable male in the west and a single adult female in the east (assumed to be different to the first female due to the distance). No evidence of tigers was found on the plantation concession.



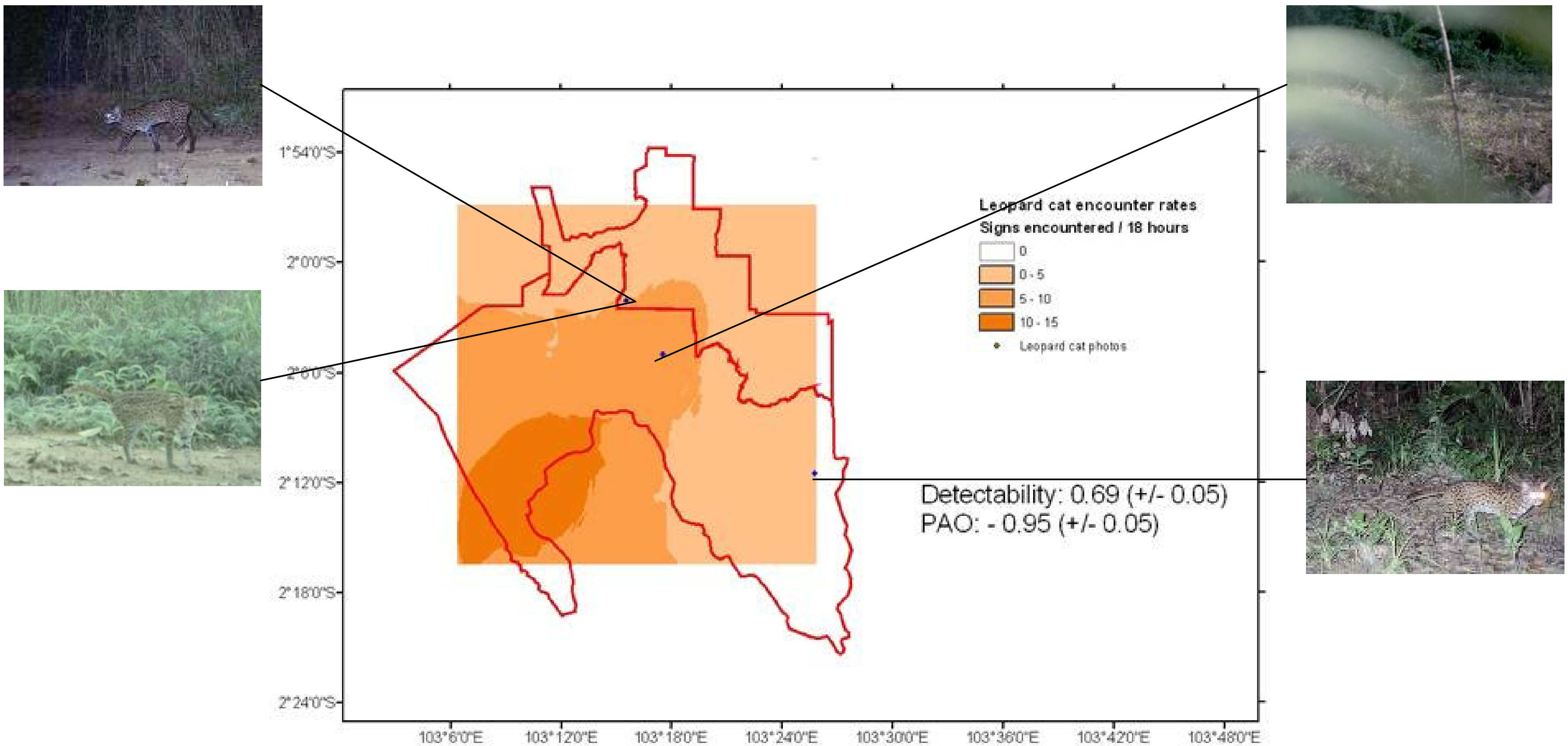
Clouded leopard summary

Clouded leopard tracks were recorded relatively frequently, with a total of 28 encounters (including repeats) which was surprising since they had only been recorded very infrequently before the survey. Furthermore, detectability was low which boosted the estimate of PAO to over 50% occupancy, although the standard errors were relatively large. Most of the encounters were within the forest, with most of these in the south east and north west, roughly matching the tiger distribution. Tracks were recorded within oil palm transects, but not in the oil palm crop itself. No photographs of clouded leopard were obtained. Indeed, over the three years and 10,000 trap nights that the overall project has been running, only three photographs of clouded leopard have been taken.



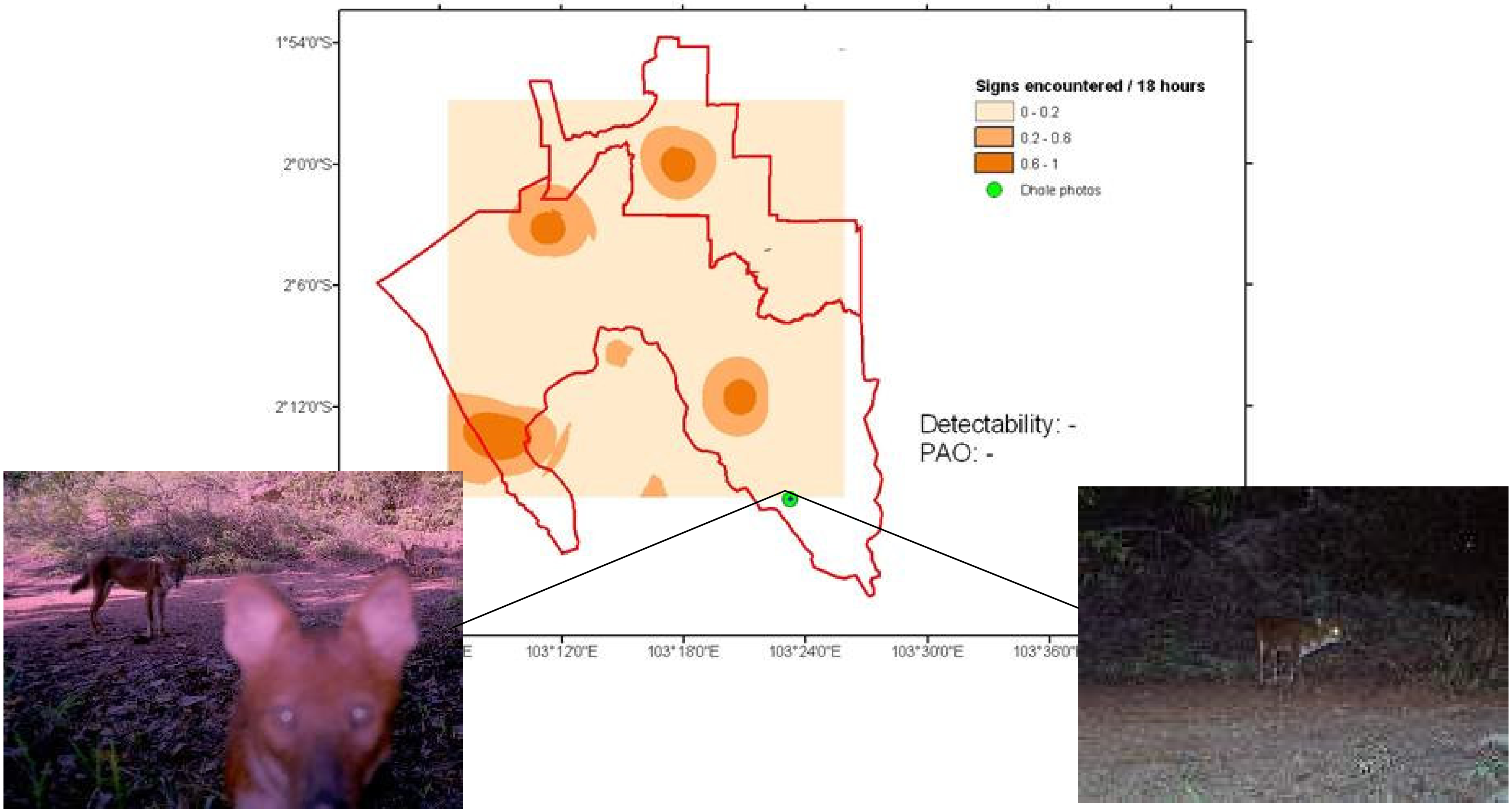
Leopard cat summary

Leopard cats were recorded 229 times with fairly high detectability on the foot surveys in almost all areas, giving a high occupancy of 95%. Encounter rates show the most signs were recorded in the south west of the area, but that distribution covered the whole of the site, including the oil palm crop. Only four photographs were taken, probably of three individuals, but no photographs were taken in the area with the most encounters from transects.



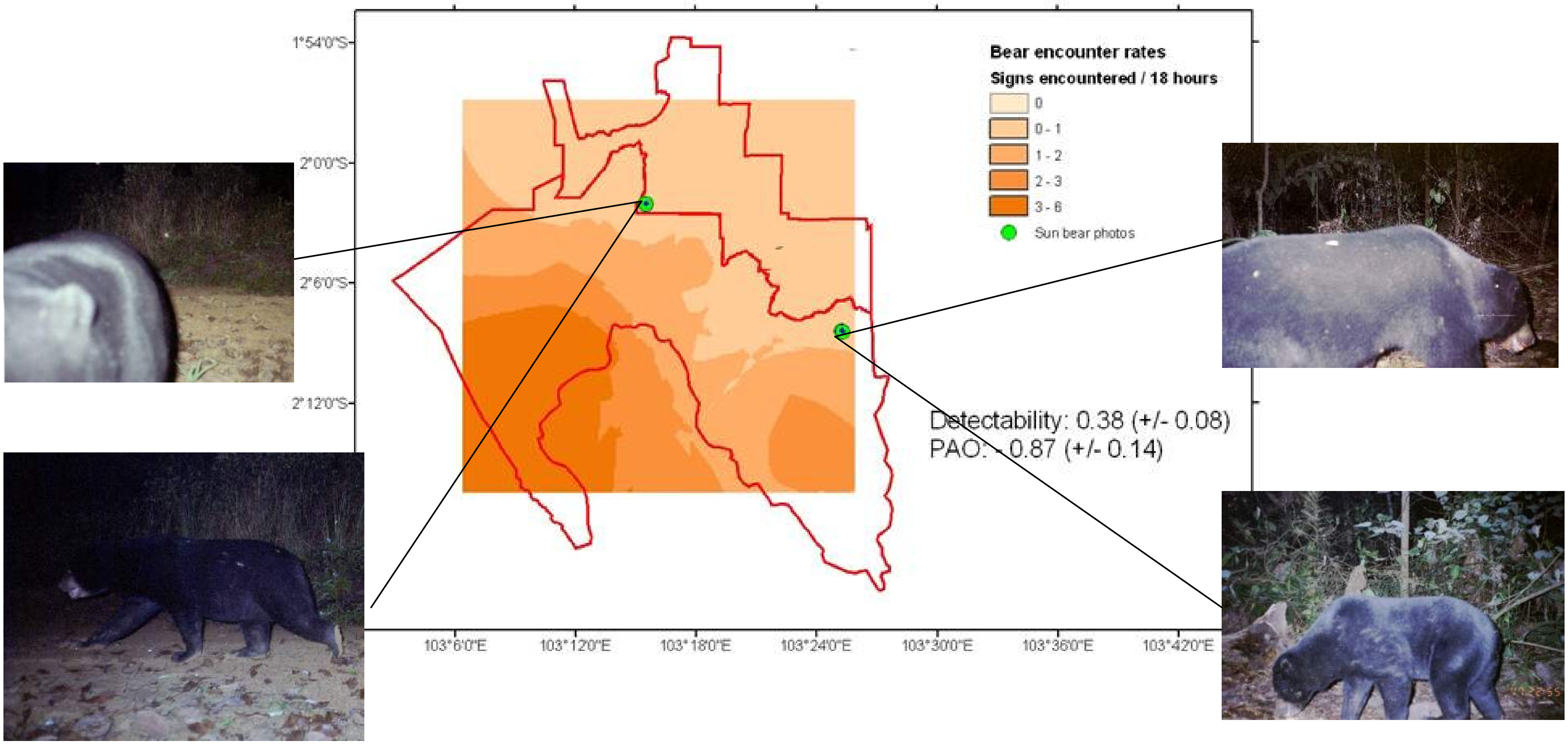
Dhole summary

Dhole were recorded with confidence so rarely that detectability or occupancy values could not be calculated. The difficulty of distinguishing dhole and domestic dog was probably a contributor to this, with a large number of domestic dog records being recorded, some of which may well have been dhole. Mapping the encounter rates of the few confident encounters shows a very discontinuous distribution, although crucially encounters were made within the plantation, a fact supported by camera trapping outside the survey. However, camera traps set during the survey only recorded dhole at one location in the far south east of the logging concession.



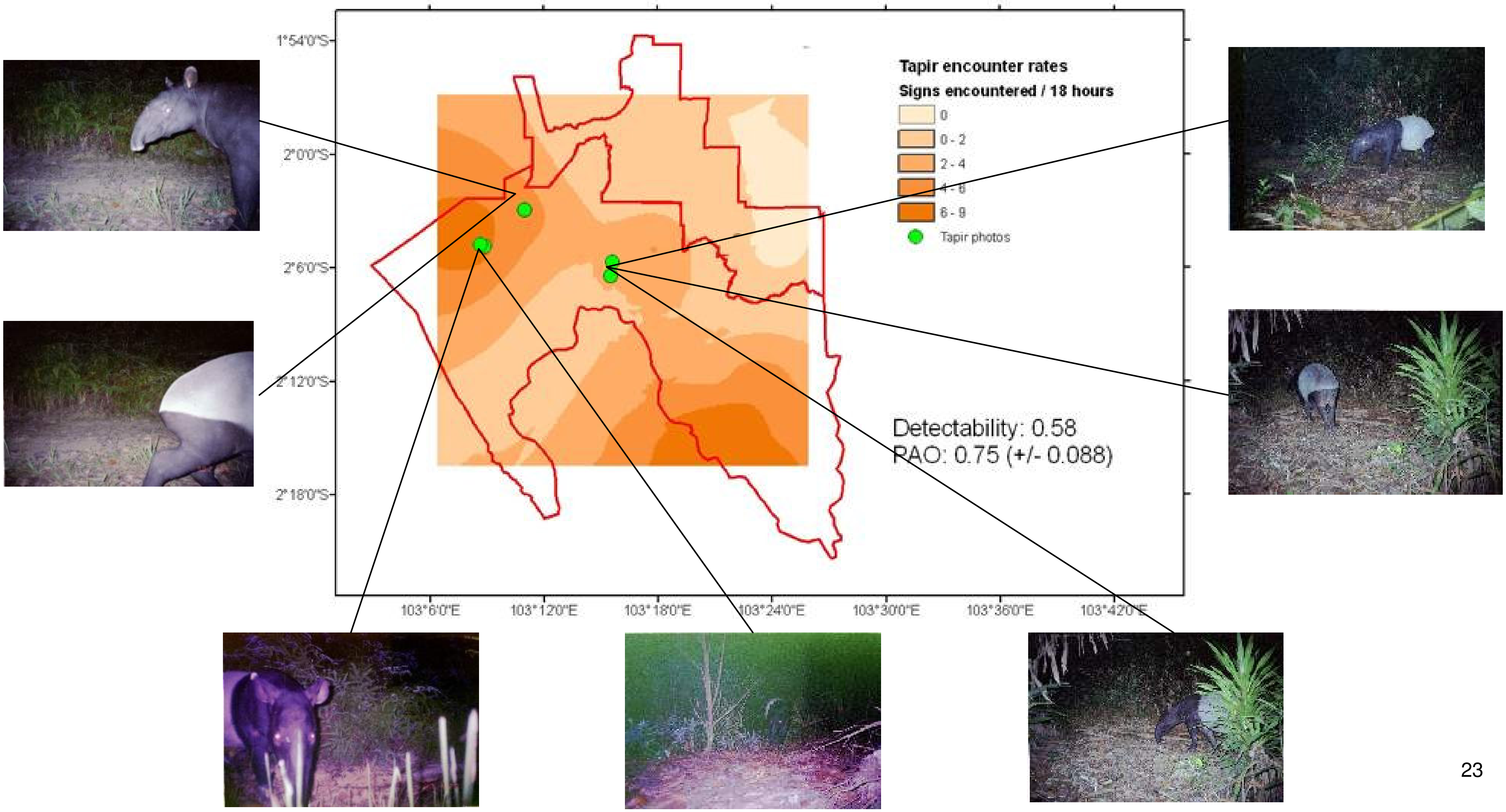
Sun bear summary

Sun bear recorded a surprisingly low detectability considering the size of their footprints and spoor; they are usually are fairly obvious when present (G. Friedreksson, *pers. com.*). This might be explained by the fact that bear signs included footprints as well as claw marks on trees and raided ants nests, with the latter signs more difficult for less experienced observers to spot, meaning some survey teams were much better and finding bear signs than others. Consequently, naïve estimate of 67% occupancy was translated into a high occupancy estimate of nearly 90%, albeit with fairly large standard errors. Encounter rate mapping of the 66 encounters recorded showed that the bulk of encounters were far away from the plantation and decreased closer to the plantation, although bears were still recorded within the plantation concession. Interestingly, photographic data did not match the foot transects, with four photos from two locations both close to or within the plantation. The individual photographed in the south west of the plantation appears to be a pregnant female.



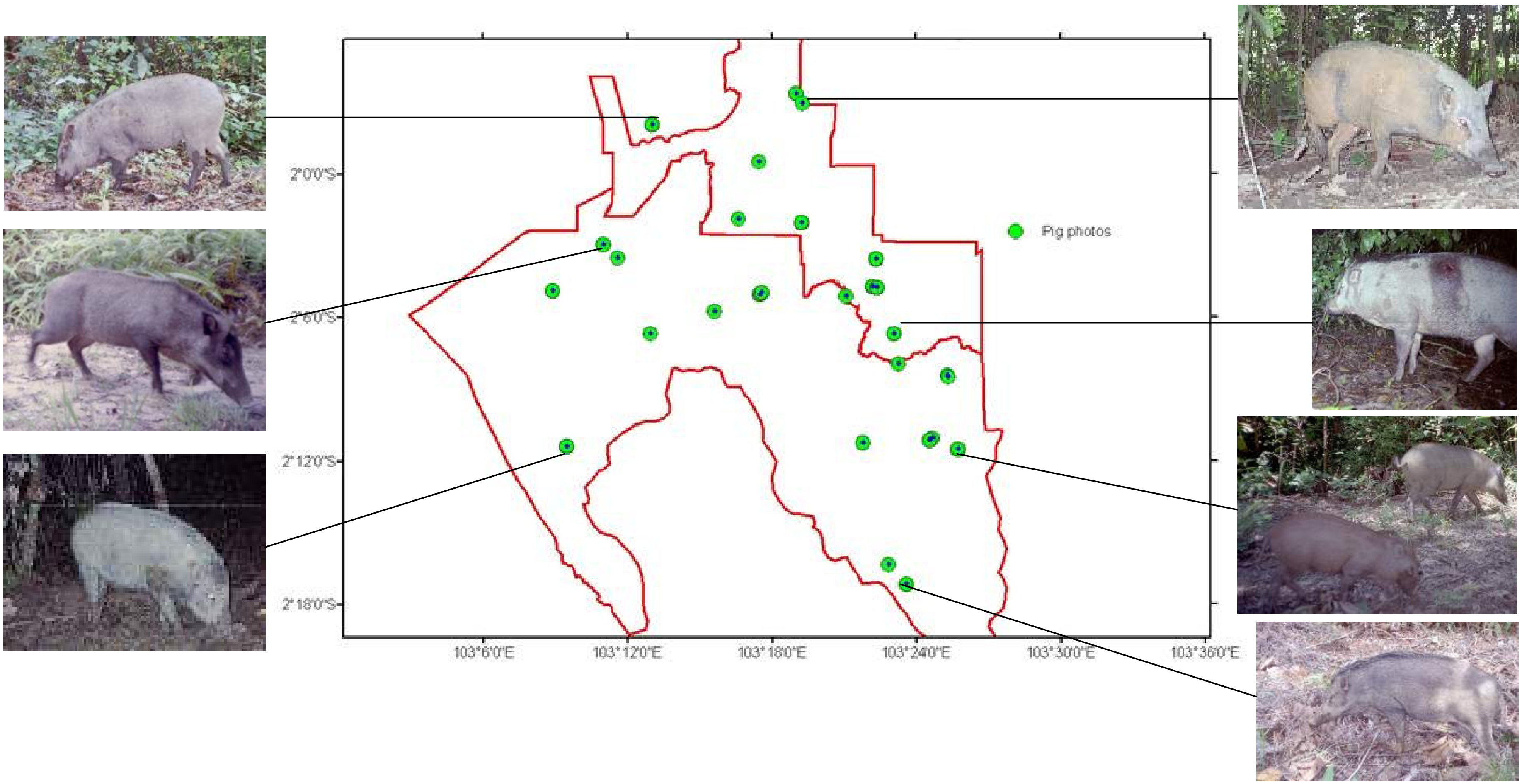
Tapir summary

The 114 records of tapir sign showed a fairly high detectability of 0.58 and a fairly precise estimate of 75% occupancy across the site, indicating a widespread distribution. However, encounter rates showed that most signs were seen outside the plantation, with areas in the north west and south east of the logging concession especially good for tapir. However, distribution included the plantation concession, primarily due to the number of signs (9) recorded in plantation scrub transects. Several photographs of tapir were taken in the north west hotspot where most tracks were recorded but none were photographed in the south east.



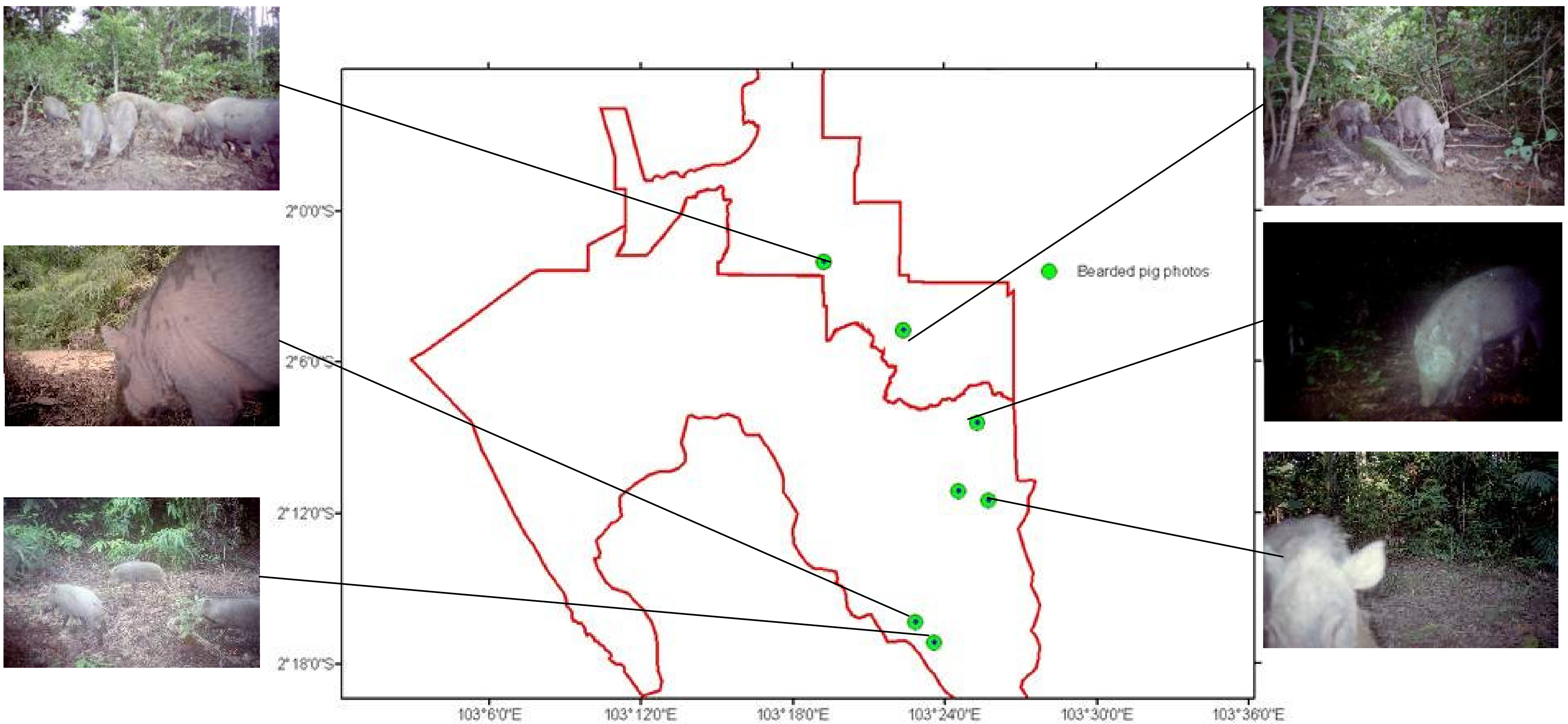
Wild pig summary

Due to the number of pig tracks, recording encounter rates were infeasible for the large transects searched; pigs were recorded in every cell on every repeat, and the two species were indistinguishable through tracks. The only information on pig distribution therefore comes from the cameras. During the survey there were 164 photographs of wild pigs, making them the second most photographed species after pig tailed macaques, although macaques were frequently photographed more than once. The distribution of photos show a fairly universal distribution, with high numbers photographed in all habitat types.



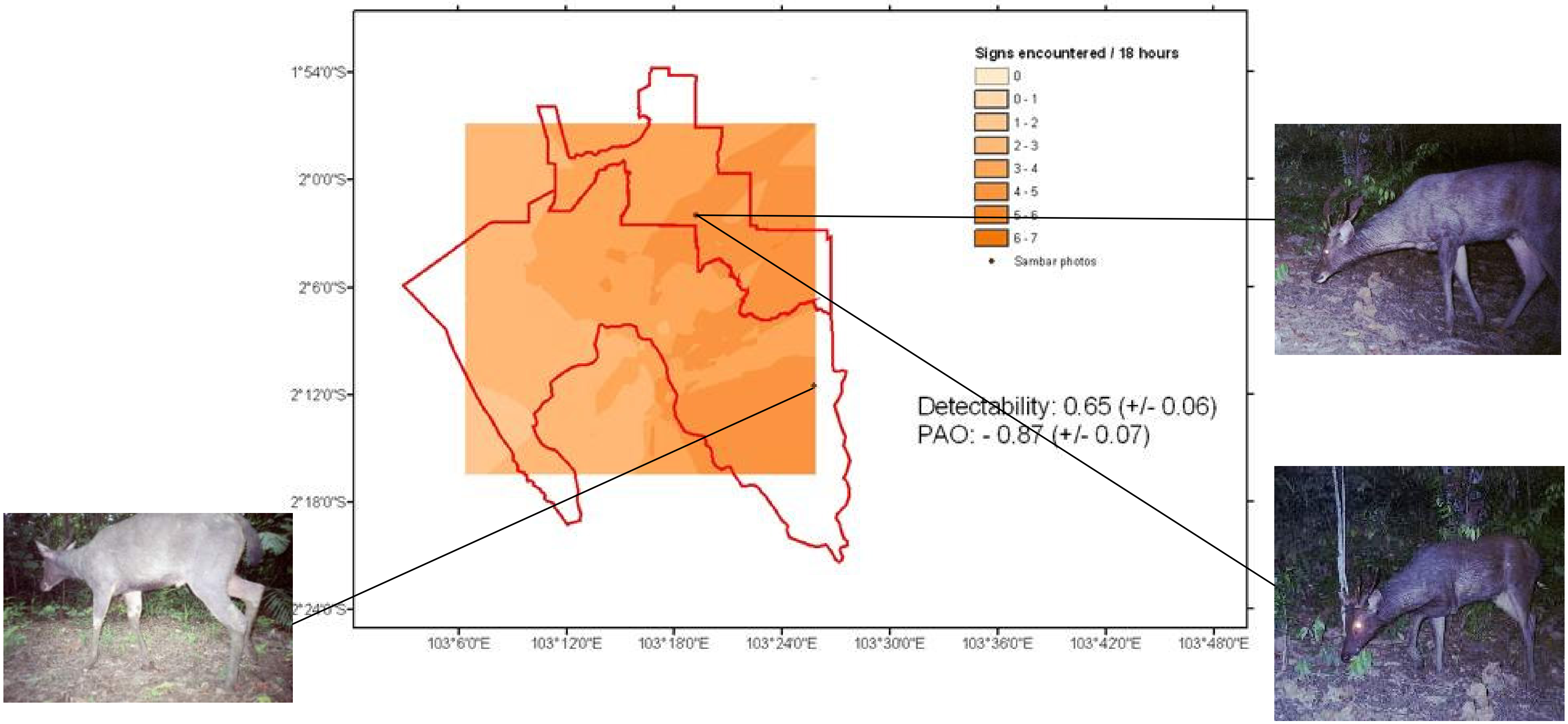
Bearded pig summary

Occupancy estimates for bearded pigs could not be calculated from foot transects for the same reason as *Sus scrofa*). However, bearded pigs were photographed about four times less frequently than wild pigs (41 photographs), with all photographs coming from the east of the site. Like wild pigs they occurred in all habitat types with most photographs in the oil palm crop and scrub transects. However, since bearded pigs move in large groups (see example photo below) which repeatedly triggered cameras, numbers are probably exaggerated.



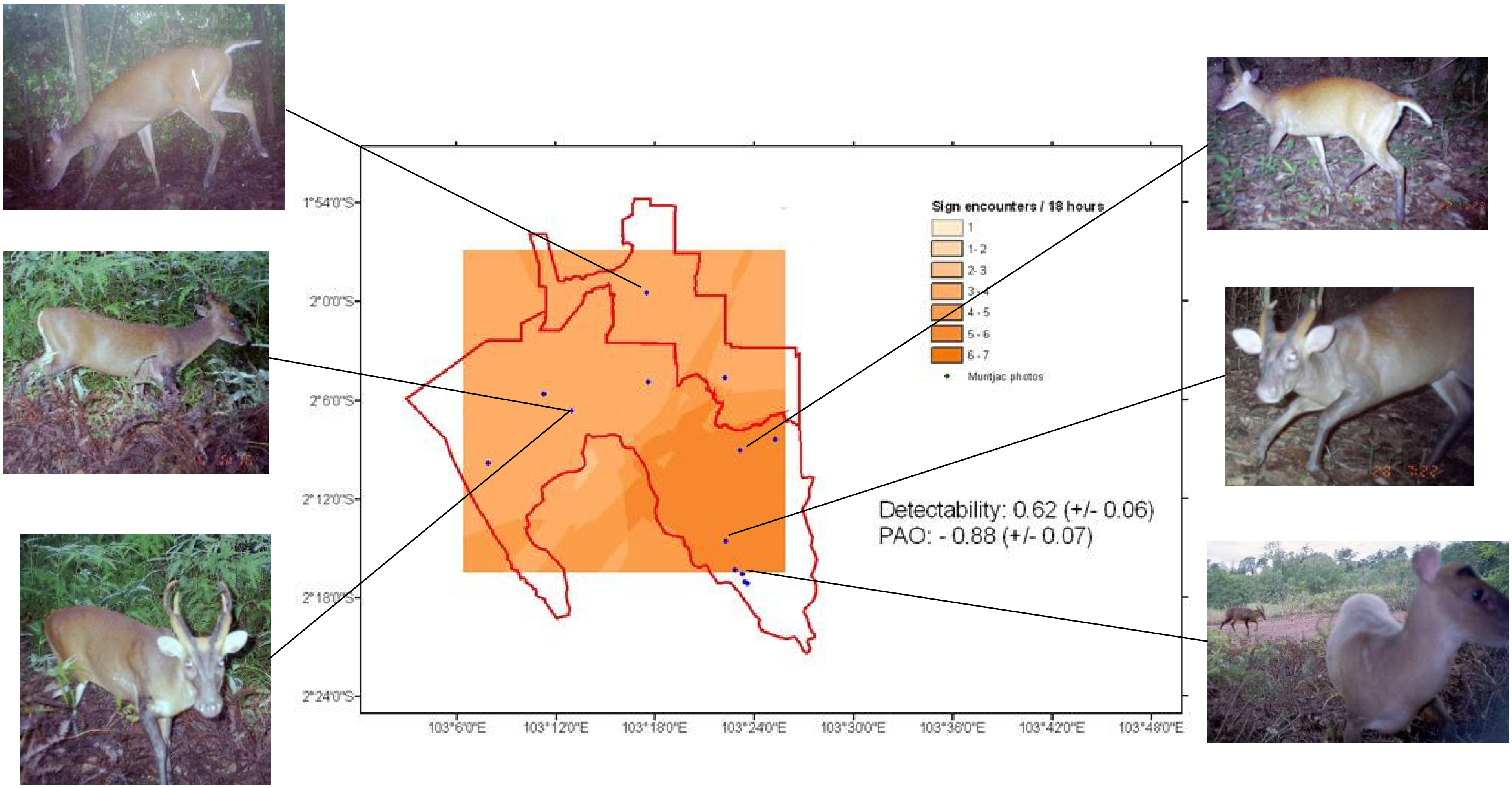
Sambar summary

125 sambar encounters were recorded with 65% detectability giving a widespread distribution of nearly 90% of the study area with sign found in every habitat type. Encounter rates showed sambar sign were found slightly more frequently in the east of the area, but occurred both in the forest and plantation concessions. Only three photographs of two individuals were taken, both in the areas where most sign were recorded.



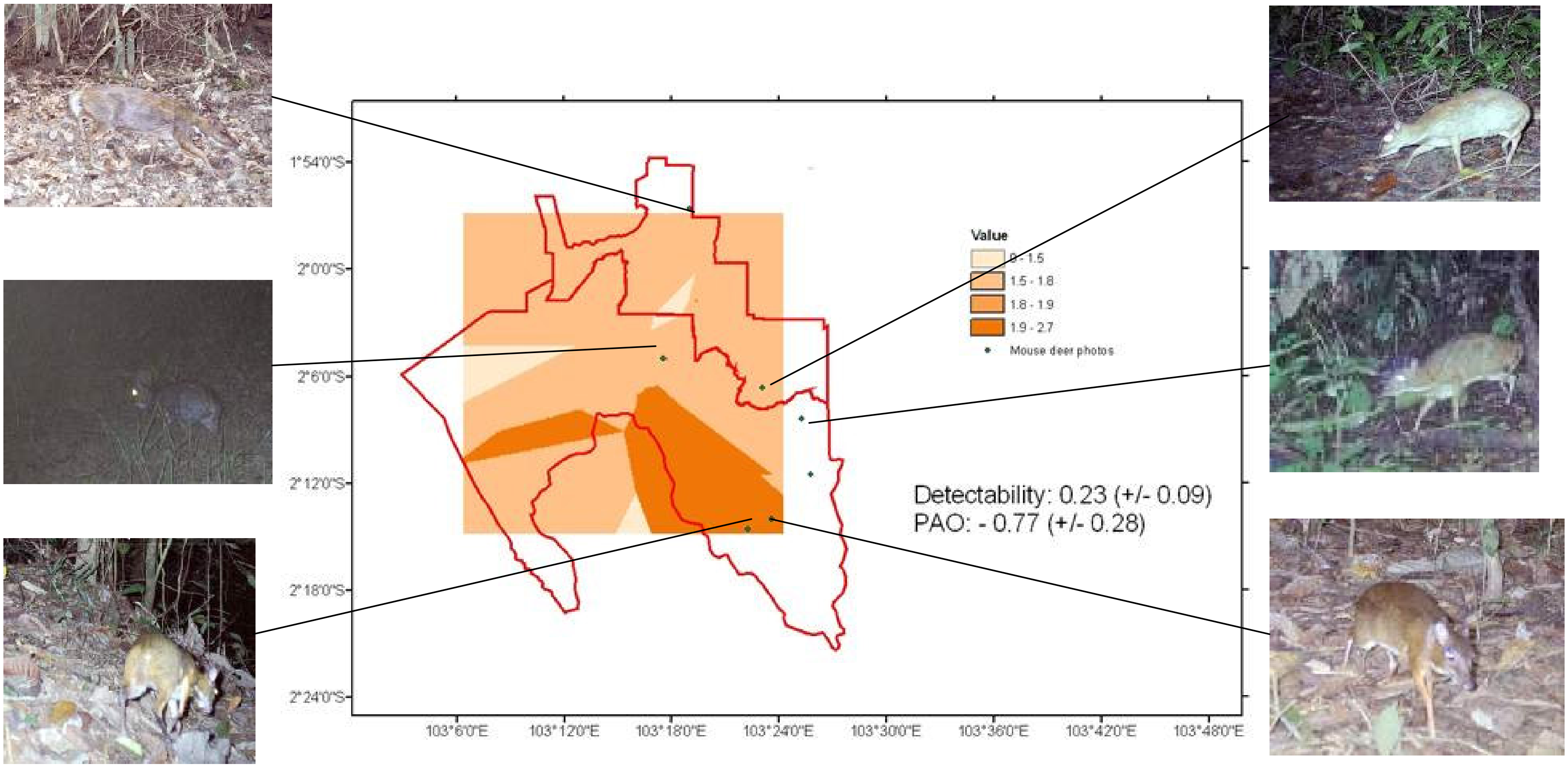
Muntjac summary

Muntjac showed very similar patterns to sambar, with 121 signs recorded (sambar=125), a detectability of 62% (sambar = 65%) and close to the same 90% occupancy estimate with identical standard errors. However, muntjac were found far less frequently in the oil palm (only 1 sign was recorded in the whole survey) and encounter rate mapping showed that although also more frequent in the east, muntjac prefer the southern forest habitats compared to the plantation concession. Photographic results were also different with more muntjacs photographed, again most in the forest.



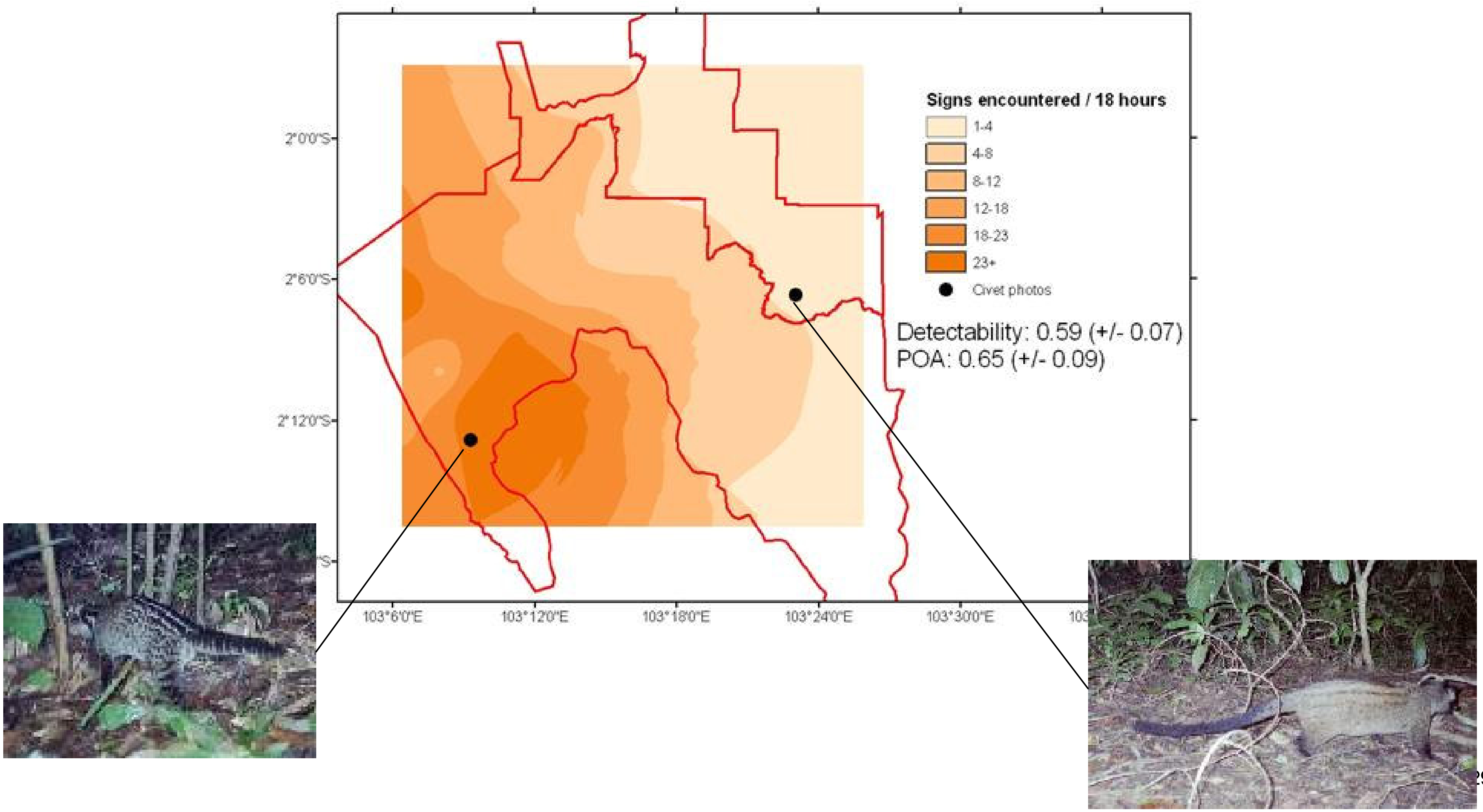
Mouse deer sp. summary

Mouse deer were detected 26 times in total but detectability was very low at 0.23. Occupancy estimates were high, around 80%, but precision of the estimates were low because of the detectability. Mouse deer were detected in all habitat types although encounter rates and photographs showed more detections in the forest habitats.



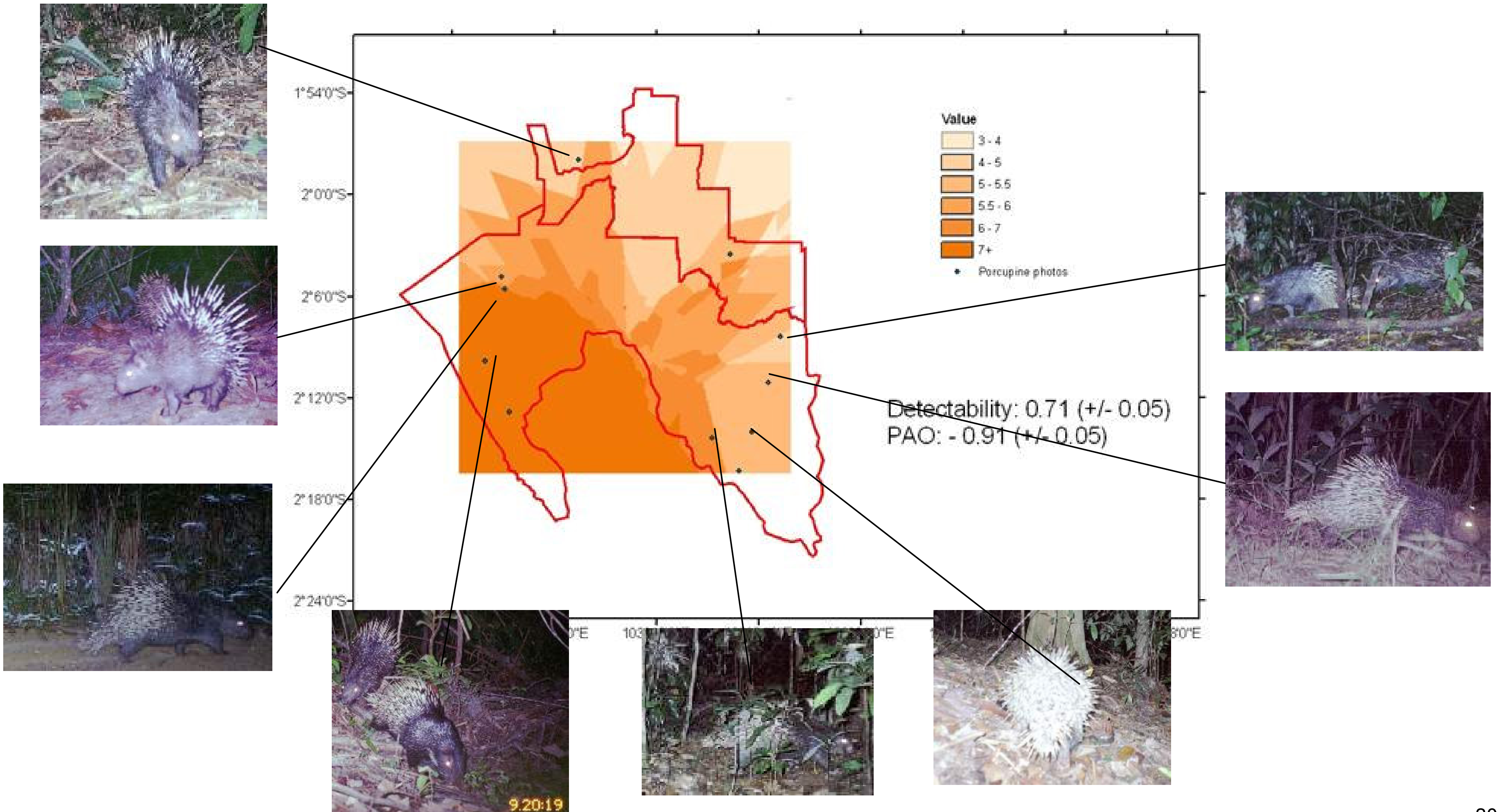
Civet sp. summary

Although some civet sign were recorded by species, results were combined into a single category with 289 recorded encounters. Detectability was medium at about 0.6 although occupancy was surprisingly low, estimated at 65%, with encounter rates showing an apparently strong increase in sign at increasing distance from the plantation. Despite this, civet species were recorded in all habitats, including the oil palm crop. Only two photographs of civet were taken, one of a Malay civet (*Vivera tangalunga*, bottom left) and one of a common palm civet (*Paradoxurus hermaphroditus*).



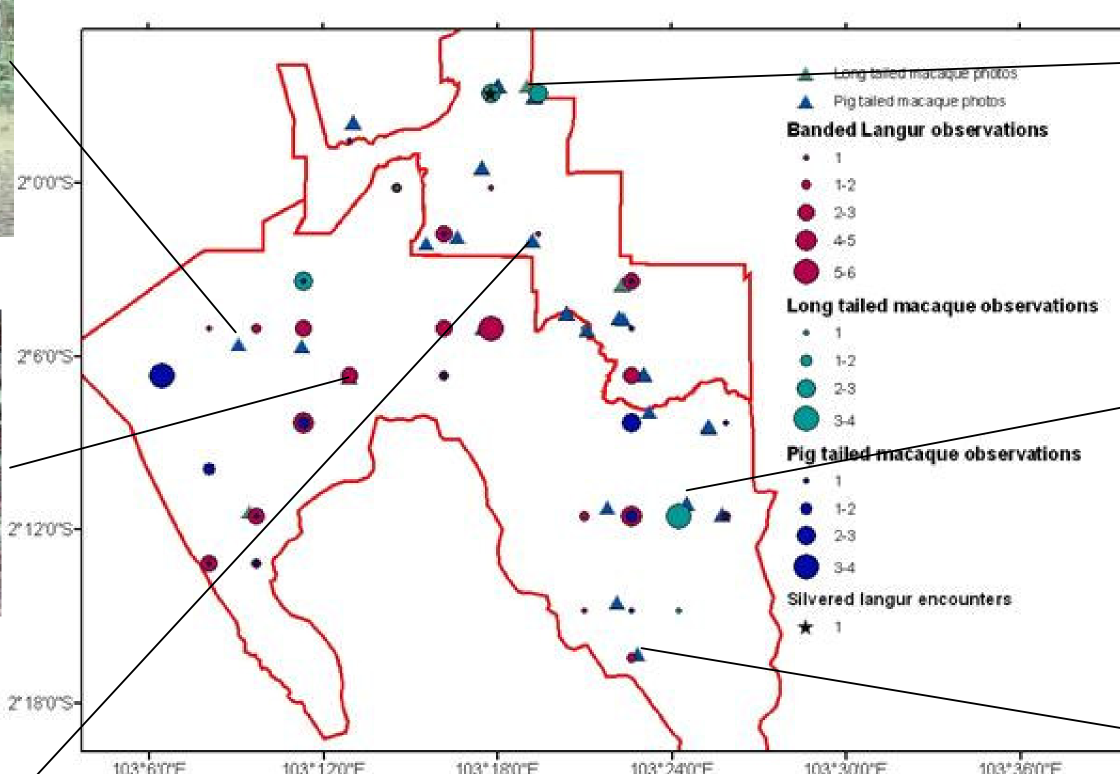
Porcupine sp. summary

Porcupines were one of the most frequently encountered species, after civets and small cats, with 182 recorded signs recorded across all habitat types, although encounter rates showed that most signs were recorded in the forest, particularly in the south west. Porcupine sign had a fairly high detectability and one of the highest occupancy estimates at over 90% showing them to be one of the most widespread species present. Camera trap results showed 22 photographs, mostly in the forest, but all of the East Asian Porcupine (*Hystrix brachyura*). Track records and photographs from other work also recorded the presence of the brush tailed porcupine (*Atherurus macrourus*).



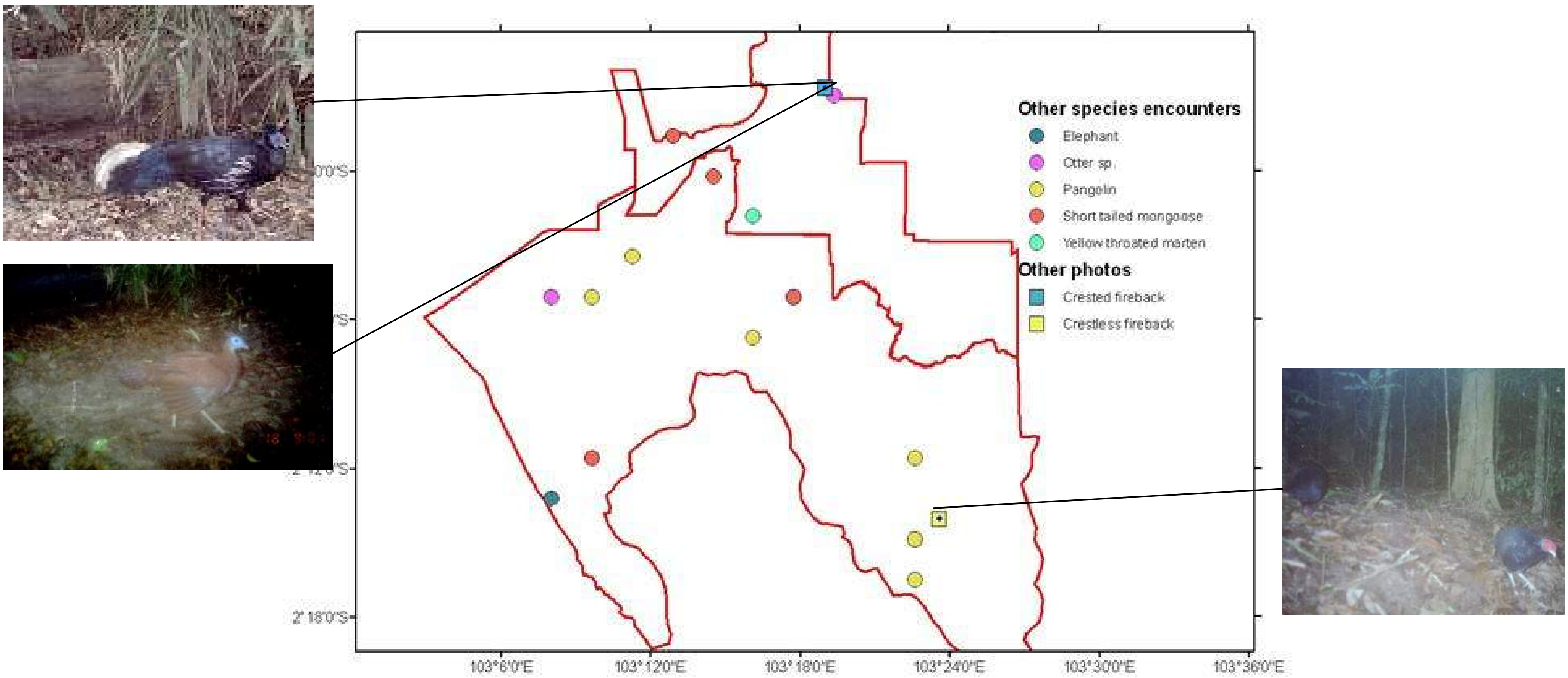
Primates summary

Although the most frequently photographed subject (pig tailed macaques; 247) the survey was not designed for primates and so results are presented together. Encounter rates are therefore not mapped and symbols representing encounter rates for different species are used instead. Occupancy analysis was not carried out for primates. Six species were recorded on the survey, 2 by camera traps. The mapped results show all species occurring in all habitats, but banded langurs in particular occurring more in the forest. Pig tailed macaques occurred throughout the site on camera and foot surveys but long tailed macaques, particularly in photographs, appeared to favour the areas on either side of the plantation/forest border.



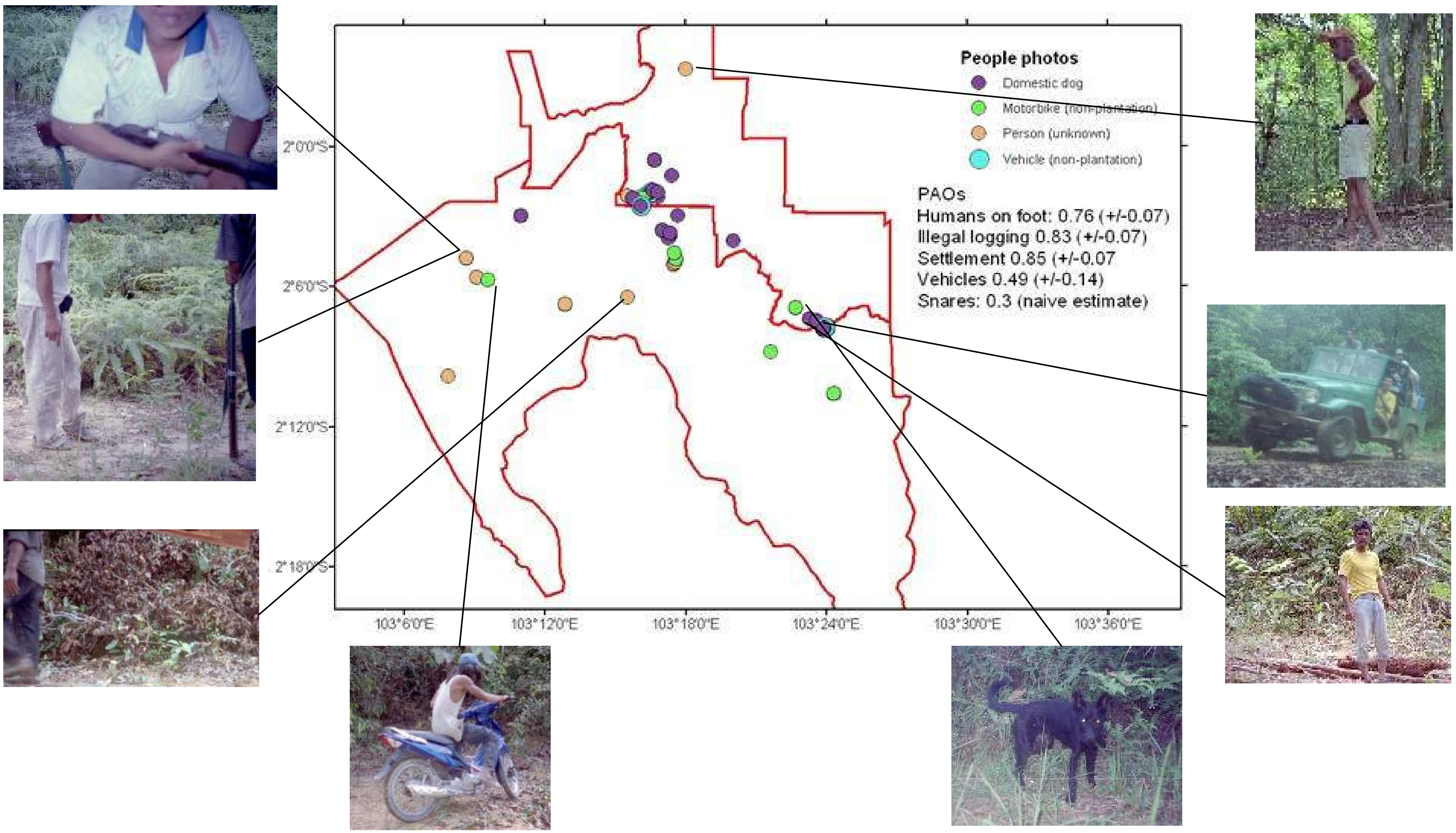
Other species summary

Several other species were recorded on foot transects with insufficient data for occupancy analysis, the most important for conservation being the elephant, which was recorded in a single transect on the south west border of the study site, but also the pangolin of which several signs were recorded in the forest (but not the plantation, although previous work has shown them to exist in the scrub habitats too). Camera traps did not pick up any mammals not recorded by the foot transects, but they did pick up several bird species, two of which are of particular interest to conservation; the crested and crestless firebacks. The crestless fireback is of particular interest. It has only once been photographed in the wild before and that was also on this project, but previously it was photographed in the area marking the yellow throated marten below.



Human influence summary

Human influence was recorded in various forms throughout the survey and across all habitat types with evidence of people, logging and settlements estimated at around 80% of the study area and snares occurring in a third of all transects (because snares were removed on sight, detectability estimates could not be made reliably). On this survey, encounter rates were not recorded, but camera trap photographs revealed a particularly high number of human / human sign photographs around the border of the plantation and forest and less evidence of people in the south east and south west peninsulas of the forest concession. Cameras also revealed people carrying guns (from the same camera where a tiger was photographed) and illegal logging.



Discussion

Tiger population

Crucially it was confirmed that tigers still inhabit the area, but no signs were detected in or particularly close to the plantation confirming that the tigers previously monitored in the plantation appear to have gone. None of the three tigers recorded matched records previously held which suggest tigers have not simply moved further into the forest but have in fact disappeared altogether. The low PAO estimate for tigers is a major cause for concern. The transect cell size was chosen to be 9 square kilometres to represent the minimum area known to be possible for a tiger to inhabit. The fact that tigers were only detected in 8% of the transects and, taking into detectability, were thus estimated to occupy only 9% of the total area is a major conservation concern. The distribution maps increase the concern, showing tigers to be entirely absent from areas they inhabited as recently as two years ago. A frequent factor limiting tiger distribution and success is prey availability, usually determined by habitat availability. In this case habitat availability is not limiting; over 90% of the study area consists of habitat (forest, scrub and edge) theoretically suitable for tigers (tigers have been recorded as occupying and even breeding in all three habitats in previous years). Consequently prey availability also appears to be high. Suidae and Cervidae species and even Tapiridae, the prime species for tigers to eat, were widely distributed across the study area. Wild pigs in particular appeared to be widespread and abundant. However, neither was there a clear relationship between human occupancy and tiger sign. Although the tiger in the south east occurred in a particularly quiet area with regards to humans, the two tigers in the north west lived in a heavily inhabited area, indeed their photos were interspersed on the film with human photographs. This may be an indication that simple presence of humans is not the key factor and that perhaps behaviour, such as poaching and hunting, are the key factors.

Other mammal diversity and distribution

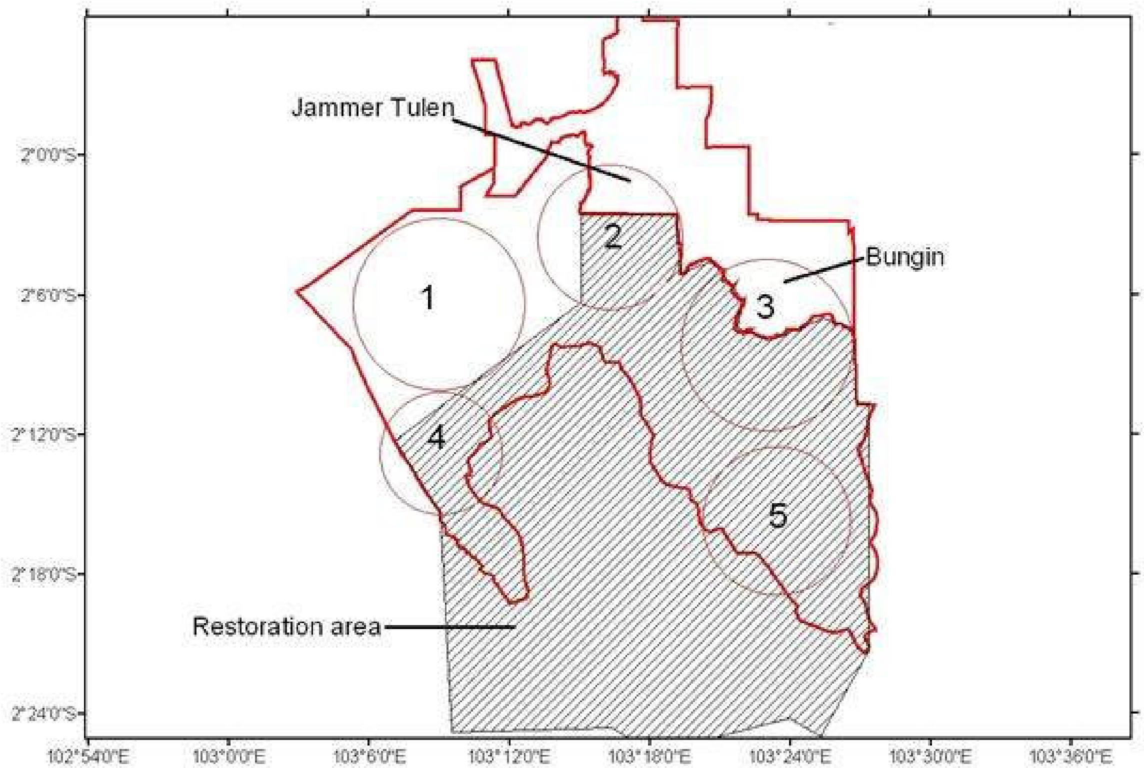
In total, 28 terrestrial mammal species, 5 primates and 4 bird species were recorded over a two month survey. Overall, the mammal species list for the forest concession shows that most of the species expected to be in lowland forest are still present. Of particular interest was the Asian elephant which had not been officially recorded previous to this survey. Notable exceptions that might have been expected to be recorded are various medium-sized cats; previous records have shown fishing cats in the area and golden and possibly flat-headed cats would also be expected. Since the Indonesian language does not readily distinguish between several cat species, and encounters are so rare so identification practice difficult, there is a risk that some of these species were encountered and were incorrectly recorded, particularly as clouded leopard had higher than expected records. Camera trapping would be one way around this problem, but with trapping rates expected to be low the number of trap nights would probably have to be very high to get a reasonable chance of a photograph.

The estimates for proportion of area occupied shows that the most widespread species were the leopard cats and porcupines, followed closely by the deer species. Camera data showed that wild and to some extent bearded pig were similarly widely distributed. Since these species have fairly small ranges, each detection in a cell probably represents more than one individual and thus abundance for all of these species is probably high which has important implications for tigers which prey on most of these species. Once corrected for detectability, sun bears were also predicted to inhabit nearly 90% of the area whilst tapir were predicted to occupy 75% which likely represents fairly healthy numbers, particularly in the forest since both appeared to avoid the 10% of the area covered by oil palm. Tapir were still evident in the plantation scrub habitats however, contrasting the traditional belief that they can only survive in dense forest due to their sensitivity to light.

Important areas for conservation

The negative impact of the oil palm plantation on the environment is demonstrated by the distribution of almost every species recorded. With the exception of the wild pig and possibly long tailed macaques, every species showed higher levels of occupancy in areas away from the oil palm. Even species that are known to live in the oil palm crop such as leopard cats, civets and porcupines were encountered more frequently away from the plantation. However, previous research has shown that unplanted areas of the plantation do have a conservation role and this appears to be supported by some of the distribution maps, with sambar, tapir, bear and dhole all occupying scrub areas within the concession to some degree. The appearance of the crested fireback was also within the plantation concession. However, the unplanted, south western portion of the plantation (the Jammer Tulen Conservation area – see Figure 8) where tigers and other species were so frequently recorded in recent years showed very little beyond a few encounters on the border. Evidence of people, however, was very high in this area.

Figure 8 – Areas of conservation importance within PT Asiatic and Asialog and an approximate estimation of the restoration area boundary



Within the forest concession there appeared to be five main areas. Of particular interest was the north west of the concession (1). This area was very easy to access, had a large number of roads but also high levels of wildlife activity and was the area where tigers were most evident together with clouded leopard and tapir. However, the area was also well cleared and showed high evidence of people. Importantly, this area is the only part of the forest concession not included in the new conservation-focussed restoration area, the boundaries of which were set by ministerial decree in mid 2005. Although the restoration area includes the areas with the least disturbed forest and lowest human activity levels, area 1 shows that several species of conservation importance can survive even when habitat condition appears poor. The central area (2) including the plantation conservation area also showed high levels of human activity reflecting the ease of access however was not as strong for mammals whilst the north east area (3) was also relatively poor for species of conservation interest and their prey – bears, sambar and muntjac appeared there but many species were not recorded whilst levels of human activity were high. However, the scrubby area in the plantation within 3 was the best area within the plantation. The bottom of the western peninsular (4) was more important for various species, particularly bear, tapir, civet and porcupine and was the only area with evidence of elephant but this was the area currently being commercially logged. The south eastern peninsula (5) also showed strong potential for mammal conservation with evidence of tigers, clouded leopard, dhole, bear, tapir, mouse deer, muntjac and sambar and where the rare crestless fireback bird was also photographed. This area was also much quieter with regards to human disturbance, probably due to the difficulty in accessing it.

Impacts of human disturbance

Analysis of the impacts of human disturbance were limited because initially the survey did not expect to find such high levels of human activity and recording protocols were not built into the survey methodology. As soon as it was realised how important human presence was, transects were modified to record presence/absence but encounter rates, as for other sightings, were never recorded. The survey appeared to coincide with a period of particular high human activity, possibly a product of the lack of clarity over the future of the forestry concession (talks were and still are underway to transfer control of the concession) and also a crackdown on illegal logging in other areas as part of the manifesto of the new president. Anecdotal evidence from the plantation told of wood shortages as illegal sawmills were closed and the number of small logging camps seen certainly appeared far higher than at any time outside the survey.

Because data were insufficient to accurately model occupancy estimates against human activity parameters, it cannot be stated that human activity was significantly correlated with species presence or absence. However, the initial results certainly appear to indicate this, particularly in the plantation conservation areas where various human, dog and motorbike photographs were taken but the tigers, tapir and other species that used to be regularly recorded were entirely absent.

Methodology refinement

Several key points came out of the first survey that will be important in designing repeat surveys in the future. The key comments are listed below:

Repeated surveys are important
Firstly, the detection probability results show that the repeated survey design is important, with no species able to be detected on every visit to a given transect. A one-off survey for presence/absence or distribution would therefore have underestimated the distribution of every species, as can be seen by the large differences between the naïve and PAO estimates on the appropriate graphs.

The surveys in their current format are best suited to large, easily detectable, terrestrial mammals
The same graphs also show detectability values falling into two distinct groups, with the semi-arboreal species recording a lower detectability, presumably because they leave fewer footprints and are harder to find. The exceptions were the mouse deer species, which leave such small tracks that detectability would be expected to be low. However, the relationship between detectability and precision for occupancy estimates should also be noted; the species that were harder to detect, such as clouded leopards, had far less precise estimates of overall occupancy with large standard errors. However, the species that were easier to detect, particularly those that were frequently encountered such as the Cervidae, leopard cats and civet species, resulted in far more confident occupancy estimates.

Foot surveys obtained more complete results than camera surveys but both are important
The foot surveys were the most sensitive method, identifying 86% more terrestrial species than the cameras with cameras only picking up 53% of the terrestrial species. However, the cameras were important in distinguishing pig species, which could not be distinguished from tracks. Additionally, they played an important role in determining relative abundance and crucially the minimum number of tigers present as well as providing photographic data to illustrate the foot survey results. However, the return on the hours invested in each method was similar. Assuming each camera takes two hours to set up and two hours to take down, approximately 284 hours were invested into the camera survey to reveal 15 species, giving a return of 18.9 hours per species. Foot surveys invested 648 hours to reveal 33 species, giving a return of 19.6 hours per species.

Foot surveys should be based on more repeats
An increased number of cells (>=80) and an additional sampling occasion (4 in total) will improve the precision of the PAO estimates and increase the chance of explaining occupancy patterns with covariates such as habitat, human activity *etc.* More cells will probably mean smaller cells; 2x2km will probably be used in future which will also improve the ability to correlate explanatory factors. 3x3 cells are so large that the existence of illegal logging may be very remote from the presence of a given species. Larger sample sizes within each of the habitat types will also allow comparisons of relative species abundance, detection probability and probability of occupancy/PAO between the different habitat strata.

A wider range of occupancy explanatory factors should be recorded
Future surveys should record the variables recorded in this survey as well as:

- Length of medium/large dirt roads in each cell
- Distance to riverine habitat
- Distance to large settlement
- Relative prey abundance (encounter rates of secondary sign)
- Rainfall
- Effect of survey team

These factors can then be modelled against occupancy estimates to determine the key variables determining species distribution which will in turn lead to great potential for predicting species status in un-surveyed areas.

Improve habitat classification
Habitat classification can be improved using the Land Cover Classification System (LCCS) (Jansen & Gregario 2002) and use colour satellite imagery to help compile environmental covariates such as average NDVI values. Comparison of satellite images will also allow calculation of clearing rates.

Improve camera trapping
Camera trapping, although expensive, has great potential for carrying out surveys where manpower is limited and/or foot access is difficult, as well as their potential for providing data on a range of additional factors. Future camera trapping should be arranged for more complete coverage and results should be analysed as occupancy data to allow comparisons with foot transect occupancy data.

References

Hines, James E., 2006, PRESENCE v.2, USGS Patuxent Wildlife Research Centre, USA (http://www.mbr-pwrc.usgs.gov/software/presence.html)

Jansen, J.M. and Di Gregario (2002) Parametric land cover and land-use classification as tools for environmental change detection. *Agriculture, Ecosystems and Environment*. **91.** 89-100.

Karanth, K.U., Nichols, J.D. (Eds.), 2002. *Monitoring tigers and their prey: A manual for researchers, managers and conservationists in tropical Asia*. Centre for Wildlife Studies, Bangalore, India.

Kawanishi, K. and Sunquist, M. E. 2004. Conservation status of tigers in a primary rainforest of Peninsular Malaysia. *Biological Conservation*. **120:** 329-344.

MacKenzie, D.I., Nichols, J. D., Lachman, G. B., Droege, S., Royle, J. A., Langtimm, C. A. 2002. Estimating site occupancy rates when detection probabilities are less than one. *Ecology*, **83(8)** 2248-2255.

MacKenzie, D.I. & Nichols, J. D. 2004. Occupancy as a surrogate for abundance estimation. Animal Biodiversity and Conservation. 27.1. 461-467.

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

MacKenzie, D. I., Nichols, J. D., Royle, J. A., Pollock, K. H., Bailey, L. L., Hines, J. E. 2006. Occupancy estimation and modelling: Inferring patterns and dynamics of species occurrence. Elsevier. UK.

Otis, D.L., Burnham, K.P., White, G.C., Anderson, D.R. 1978. Statistical inference from capture data on closed animal populations. *Wildlife Monographs,* **62**: 1-135.

Rexstad, E., Burnham, K.P. 1991. User's guide for an interactive program CAPTURE. Abundance estimation of closed animal populations. Colorado State University. Fort Collins, Colorado, USA, 21 pp.

Thompson, S. K. 1992. Sampling. Wiley, New York, NY, USA.

White, G.C., Anderson, D.R., Burnham, K.P., Otis, D.L. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory Publication LA-8787-NERP. Los Alamos, New Mexico, USA.

Zoological Society of London. 2004. Pigs, palms, people and tigers: survival of the Sumatran tiger in commercial landscape, London.

Appendices

Transect cell and camera positions

Table 5 - Positions of survey cells

Cell	Habitat	UTM East	UTM North
OP 1a	Oil palm	313500	9775500
OP 1b	Oil palm	310500	9778500
OP 1c	Oil palm	319500	9772500
SC 1a	Scrub	319500	9769500
SC 1b	Scrub	319500	9766500
SC 1c	Scrub	307500	9775500
SC 2a	Scrub	301500	9781500
SC 2b	Scrub	310500	9784500
SC 2c	Scrub	313500	9784500
E 1a	Edge	316500	9769500
E 1b	Edge	319500	9763500
E 1c	Edge	325500	9763500
AL 1a	Forest	316500	9757500
AL 1b	Forest	319500	9757500
AL 1c	Forest	325500	9757500
AL 2a	Forest	316500	9751500
AL 2b	Forest	319500	9751500
AL 2c	Forest	322500	9757500
AL 3a	Forest	319500	9748500
AL 3b	Forest	322500	9748500
AL 3c	Forest	322500	9751500
AL 4a	Forest	307500	9769500
AL 4b	Forest	310500	9769500
AL 4c	Forest	307500	9766500
AL 5a	Forest	304500	9778500
AL 5b	Forest	298500	9772500
AL 5c	Forest	298500	9769500
AL 6a	Forest	295500	9769500
AL 6b	Forest	289500	9766500
AL 6c	Forest	292500	9769500
AL 7a	Forest	292500	9760500
AL 7b	Forest	298500	9763500
AL 7c	Forest	301500	9766500
AL 8a	Forest	295500	9757500
AL 8b	Forest	295500	9754500
AL 8c	Forest	292500	9754500

Table 6 - Positions of all cameras. Cameras were out for a total of 1317 trap nights

Deployment round	Camera.	Cell	Date up	Date down	Days in position	UTM E	UTM N	Film Name	ID No.	Notes
1	CT50	E 1a	09/03/2005	26/03/2005	17	315379	9770445	CT50240704	1089	
1	CT69	E 1a	10/03/2005	26/03/2005	16	316662	9769429	CT69100305	1084	
1	CT48	E 1b	10/03/2005	26/03/2005	16	320664	9764207	CT48090305	1093	
1	CT49	E 1b	09/03/2005	26/03/2005	17	320435	9762140	CT49240704	1106	
1	CT52	E 1c	09/03/2005	26/03/2005	17	324437	9763306	CT52240704	1097	
1	CT65	E 1c	11/03/2005	26/03/2005	15	324500	9763200	CT65100305	1099	
1	CT51	OP 1a	10/03/2005	26/03/2005	16	313202	9775116	CT51240704	1091	
1	CT53	OP 1a	09/03/2005	26/03/2005	17	313133	9774264	CT53240704	N/A	Camera and film stolen
1	CT57	OP 1b	12/03/2005	26/03/2005	14	309939	9779766	CT57111104	1085	
1	CT61	OP 1b	10/03/2005	26/03/2005	16	309987	9778427	CT61261004	190	
1	CT56	SC 1c	11/03/2005	26/03/2005	15	308390	9775411	CT56110305	1087	
1	CT59	SC 1c	10/03/2005	26/03/2005	16	306392	9774982	CT59090305	1103	
1	CT55	SC 2a	09/03/2005	26/03/2005	17	301747	9782651	CT55090305	1083	
1	CT62	SC 2a	11/03/2005	26/03/2005	15	302396	9782576	CT62150205	1090	
1	CT46	SC 2b	11/03/2005	26/03/2005	15	309783	9783751	CT46151104	1105	
1	CT54	SC 2b	09/03/2005	26/03/2005	17	310971	9784955	CT54240704	1095	
1	CT47	SC 2c	10/03/2005	26/03/2005	16	312813	9785022	CT47100305	1100	
1	CT67	SC 2c	11/03/2005	26/03/2005	15	313310	9784312	CT67110305	1104	
1	CT64	SC1b	11/03/2005	26/03/2005	15	320435	9765557	CT64110305	1088	
1	CT68	SC1b	10/03/2005	26/03/2005	16	320322	9766559	CT68250704	1081	
2	CT46	AL 1a	28/03/2005	16/04/2005	19	318015	9758008	CT46270305	1420	Film damaged
2	CT57	AL 1a	28/03/2005	16/04/2005	19	317952	9758151	CT57270305	1406	
2	CT48	AL 1b	28/03/2005	16/04/2005	19	319865	9757199	CT48270305	1391	
2	CT69	AL 1b	28/03/2005	16/04/2005	19	319912	9756601	CT69270305	1428	
2	CT64	AL 1c	29/03/2005	16/04/2005	18	325244	9757574	CT64270305	1422	
2	CT65	AL 1c	29/03/2005	16/04/2005	18	325309	9757622	CT65270305	1402	
2	CT54	AL 2c	28/03/2005	16/04/2005	19	323300	9758464	CT54270305	1423	
2	CT61	AL 2c	28/03/2005	16/04/2005	19	323060	9758309	CT61270305	1401	
2	CT49	AL 4a	30/03/2005	16/04/2005	17	307144	9768708	CT49270305	N/A	Camera and film stolen
2	CT68	AL 4a	30/03/2005	16/04/2005	17	306503	9768300	CT68270305	1408	
2	CT47	AL 4c	28/03/2005	16/04/2005	19	307084	9765329	CT47270305	N/A	Camera and film stolen
2	CT59	AL 4c	28/03/2005	16/04/2005	19	306382	9766995	CT59270305	1368	
2	CT55	AL 5b	28/03/2005	16/04/2005	19	297953	9773399	CT55270305	1372	Tiger photographed
2	CT56	AL 5b	28/03/2005	16/04/2005	19	299048	9772349	CT56270305	1427	Tiger photographed

2	CT50	AL 5c	28/03/2005	18/04/2005	21	298426	9768411	CT50270305	1376	
2	CT52	OP 1c	28/03/2005	16/04/2005	19	319112	9772012	CT52270305	1413	
2	CT67	OP 1c	28/03/2005	16/04/2005	19	318961	9772248	CT67270305	1383	
2	CT51	SC 1a	28/03/2005	16/04/2005	19	318743	9770191	CT51270305	1424	
2	CT62	SC 1a	28/03/2005	16/04/2005	19	319019	9770109	CT62270305	1390	
3	CT54	AL 4b	19/04/2005	12/05/2005	23	310020	9769560	CT54180405	1382	
3	CT62	AL 4b	19/04/2005	12/05/2005	23	310129	9769708	CT62180405	1395	
3	CT64	AL 5a	19/04/2005	12/05/2005	23	303989	9777836	CT64180405	1392	
3	CT68	AL 5a	19/04/2005	12/05/2005	23	303188	9778357	CT68180405	1407	
3	CT51	AL 6a	19/04/2005	12/05/2005	23	294449	9768548	CT51180405	1405	Tiger photographed
3	CT52	AL 6a	19/04/2005	12/05/2005	23	294057	9769840	CT52180405	1371	
3	CT50	AL 6b	19/04/2005	12/05/2005	23	290936	9765384	CT50180405	1414	
3	CT69	AL 6b	19/04/2005	12/05/2005	23	290642	9766195	CT69180405	1378	
3	CT61	AL 6c	19/04/2005	12/05/2005	23	293610	9770035	CT61180405	1421	
3	CT67	AL 6c	19/04/2005	12/05/2005	23	292777	9769840	CT67180405	1412	
3	CT17	AL 7a	21/04/2005	13/05/2005	22	292210	9760724	CT17151104	1957	
3	CT30	AL 7a	21/04/2005	13/05/2005	22	292223	9759772	CT30180405	1389	
3	CT29	AL 7b	21/04/2005	13/05/2005	22	297094	9764499	CT29200405	1419	
3	CT45	AL 7b	21/04/2005	13/05/2005	22	297417	9764831	CT45200405	1381	
3	CT55	AL 7c	21/04/2005	12/05/2005	21	No Cover	No Cover	CT55180405	1396	
3	CT56	AL 7c	21/04/2005	12/05/2005	21	No Cover	No Cover	CT56180405	1380	
3	CT48	AL 8a	21/04/2005	13/05/2005	22	295031	9757503	CT48180405	1384	
3	CT57	AL 8a	21/04/2005	13/05/2005	22	295127	9757825	CT57180405	1403	
3	CT59	AL 8b	21/04/2005	13/05/2005	22	No Cover	No Cover	CT59180405	N/A	Film damaged
3	CT65	AL 8b	21/04/2005	13/05/2005	22	294850	9755157	CT65180405	1379	
3	CT02	AL 8c	21/04/2005	13/05/2005	22	No Cover	No Cover	?	N/A	Camera and film stolen
3	CT46	AL 8c	21/04/2005	13/05/2005	22	292677	9754725	CT46180405	1388	
4	CT64	AL 2a	17/05/2005	01/06/2005	15	317120	9752063	CT64130505	2402	
4	CT65	AL 2a	17/05/2005	01/06/2005	15	316921	9752254	CT65160505	2398	
4	CT51	AL 2b	17/05/2005	01/06/2005	15	318811	9751907	CT51130505	2393	
4	CT67	AL 2b	17/05/2005	01/06/2005	15	318628	9752044	CT67130505	2403	
4	CT52	AL 3a	17/05/2005	01/06/2005	15	320722	9748265	CT52130505	2396	
4	CT68	AL 3a	17/05/2005	01/06/2005	15	319912	9748728	CT68130505	2400	Tiger photographed
4	CT54	AL 3b	17/05/2005	01/06/2005	15	321027	9747355	CT54130505	2405	
4	CT55	AL 3b	17/05/2005	01/06/2005	15	321303	9747216	CT55130505	2394	
4	CT50	AL 3c	17/05/2005	01/06/2005	15	321308	9752972	CT50130505	2395	
4	CT56	AL 3c	17/05/2005	01/06/2005	15	321025	9752651	CT56130505	2392	

Summary of all wildlife encounters and photographs

Table 7 - Total encounters from all foot surveys

					Total number of encounters of signs				
Class	**Order**	**Family**	**Species**	**Latin name**	**Edge**	**Forest**	**Oil palm**	**Scrub**	**Total**
Mammals	Artiodactyla	Bovidae	Domestic buffalo	*Bubalus arnee*	0	4	0	0	4
			Domestic goat	*Capra hircus*	0	3	0	0	3
		Cervidae	Muntjac	*Muntiacus muntjak*	6	96	1	18	121
			Sambar	*Cervus unicolor*	7	82	19	17	125
		Tragulidae	Greater mouse deer	*Tragulus napu*	0	3	6	0	9
			Lesser mouse deer	*Tragulus javanicus*	2	9	1	5	17
	Carnivora	Canidae	Dhole	*Cuon alpinus*	0	4	1	0	5
			Domestic dog	*Canis familiaris*	13	9	23	37	82
		Felidae	Clouded leopard	*Neofelis nebulosa*	0	25	2	1	28
			Domestic cat	*Felis cattus*	0	1	0	1	2
			Leopard cat	*Prionailurus bengalensis*	24	167	17	21	229
			Tiger	*Panthera tigris*	0	14	0	0	14
		Mustelidae	Yellow throated marten	*Martes flavigula*	0	0	0	1	1
		Ursidae	Sun bear	*Helarctos malayanus*	6	57	1	2	66
		Viverridae	Common palm civet	*Paradoxurus hermaphroditus*	5	60	0	3	68
			Short tailed mongoose	*Herpestes brachyurus*	0	5	0	2	7
	Insectivora	Erinaceidae	Moon rat	*Echinosorex gymnurus*	1	4	0	1	6
	Perissodactyla	Tapiridae	Malayan tapir	*Tapirus indicus*	2	102	1	9	114
	Pholidota	Manidae	Pangolin	*Manis javanica*	0	8	0	0	8
	Primate	Cercopithecidae	Banded langur	*Presbytis melalophos*	14	64	6	10	94
			Long tailed macaque	*Macaca fascicularis*	1	11	0	6	18
			Pig tailed macaque	*Macaca nemestrina*	4	17	1	3	25
			Silvered langur	*Presbytis cristata*	0	0	0	1	1
		Hylobatidae	Siamang	*Hylobates syndactylus*	3	15	1	0	19
	Proboscidae	Elephantidae	Elephant	*Elephas maximus*	0	2	0	0	2
			Canid sp.		0	2	7	2	11
			Civet sp.		4	205	4	8	221
			Felid sp.		1	24	3	3	31
			Otter sp.	*Amblonyx cinereus*	2	6	0	4	12
			Porcupine sp.	*Atherurus macrourus, Hystrix brachyura*	11	149	10	12	182

			Squirrel sp.		1	5	0	1	7
Grand Total					107	1153	104	168	1532

Table 8 - Summary of photographs of individuals taken in each habitat

					No. individual photographs / habitat				
Class	**Order**	**Family**	**Subject**	**Latin name**	**Edge**	**Forest**	**Oil palm**	**Scrub**	**Total**
Mammals	Artiodactyla	Cervidae	Muntjac	*Muntiacus muntjak*	2	16	1	1	20
			Sambar	*Cervus unicolor*	0	1	2	0	3
		Suidae	Bearded pig	*Sus barbatus*	1	6	15	19	41
			Pig (wild)	*Sus scrofa*	4	71	37	52	164
		Tragulidae	Lesser mouse deer	*Tragulus javanicus*	3	4	0	4	11
	Carnivora	Canidae	Dhole	*Cuon alpinus*	0	3	0	0	3
			Domestic dog	*Canis familiaris*	0	2	0	1	3
		Felidae	Leopard cat	*Prionailurus bengalensis*	0	2	0	2	4
			Tiger	*Panthera tigris*	0	5	0	0	5
		Ursidae	Sun bear	*Helarctos malayanus*	2	0	0	2	4
		Viverridae	Common palm civet	*Paradoxurus hermaphroditus*	0	1	0	1	2
	Perissodactyla	Tapiridae	Malayan tapir	*Tapirus indicus*	0	7	0	0	7
	Primate	Cercopithecidae	Long tailed macaque	*Macaca fascicularis*	4	1	7	39	51
			Pig tailed macaque	*Macaca nemestrina*	74	29	14	130	247
	Rodentia	Hystricidae	East Asian porcupine	*Hystrix brachyura*	3	17	1	1	22
Birds			Crested fireback	*Lophura ignita*	0	0	0	2	2
			Emerald Dove	*Chalcophaps indica*	1	0	0	0	1
			Jungle fowl	*Gallus gallus*	0	5	0	0	5
			Salvadori's Pheasant	*Lophura inornata*	0	2	0	0	2
Grand Total					94	172	77	254	597

Custom models for explaining occupancy results

Data were only sufficient for custom models to be built for tapir and clouded leopard results. The models were developed following an approach outlined for the estimation of occupancy and detection probabilities for the Mahoenui Giant Weta by MacKenzie *et al*. (2006).

Three site-specific covariates (forest/non-forest habitat, logging/no-logging, settlement/no-settlement) and one sampling-specific covariate (rain/no-rain) have been combined with detection histories for tapir (*Tapirus indicus*) and clouded leopard (*Neofelis nebulosa*). All covariate data are categorical, for example survey cells dominated by forest were scored as "1" or "0" if they were not (i.e. they were dominated by another vegetation such as oil palm). Signs of illegal logging activities and human settlement were recorded during the surveys and the associated cells scored as "1" when these activities were detected and "0" otherwise. When heavy rain was recorded during a survey, or in the 24 hours preceding a sampling occasion, the relevant cell and sampling occasions were scored "1" or "0" otherwise.

Tests using the global model from each candidate set, *psi*(*Forest+Logging+Settlement)p*(*Rain*) do not indicate a lack of fit using 10 000 bootstrap samples for the tapir data set (X2 = 3.7421, P-value = 0.7917, c hat = 0.56) or for the clouded leopard example (X2 = 8.1701, P-value = 0.2850, c hat = 1.1890).

The candidate model sets (Table 9, Table 10) each contain 16 models without considering interactions between factors. Each model is ranked by AIC and listed with the relevant factors indicated in parentheses. For example, *psi*(*Forest*) indicates the probability of occupancy being different between forest dominated and non-forest dominated cells.

Table 9 - Summary of models compiled for tapir occupancy

Model	ΔAIC	*w*	*Npar*	*-2l*	*Forest*	SE
psi(Forest)p(.)	0	0.29	3	129.30	3.42	1.66
psi(Forest)p(Rain)	0.99	0.17	4	128.29	3.38	1.56
psi(Forest+Settle)p(.)	1.13	0.16	4	128.43	3.14	1.29
psi(Forest+Logging)p(.)	1.96	0.11	4	129.26	3.44	1.80
psi(Forest+Settle)p(Rain)	2.16	0.10	5	127.46	3.15	1.27
psi(Forest+Logging)p(Rain)	2.95	0.07	5	128.25	3.40	1.67
psi(Forest+Logging+Settle)p(.)	3.13	0.06	5	128.43	3.14	1.31
psi(Forest+Logging+Settle)p(Rain)	4.16	0.04	6	127.46	3.14	1.29
psi(.)p(.)	8.95	0.00	2	140.25		
psi(Settle)p(.)	9.16	0.00	3	138.46		
psi(Logging+Settle)p(.)	9.88	0.00	4	137.18		
psi(.)p(Rain)	10.1	0.00	3	139.38		
psi(Logging)p(.)	10.4	0.00	3	139.66		
psi(Settle)p(Rain)	10.5	0.00	4	137.84		
psi(Logging)p(Rain)	11.4	0.00	4	138.65		
psi(Logging+Settle)p(Rain)	11.4	0.00	5	136.69		

Table 10 - Summary of models compiled for clouded leopard occupancy

Model	ΔAIC	*w*	*Npar*	*-2l*	*Forest*	SE
psi(Forest)p(.)	0	0.26	3	96.03	2.05	1.16
psi(Forest+Logging)p(.)	1.37	0.13	4	95.40	2.34	1.29
psi(Forest+Settle)p(.)	1.84	0.10	4	95.87	2.16	1.27
psi(Forest)p(Rain)	1.92	0.10	4	95.95	1.99	1.13
psi(.)p(.)	2.03	0.09	2	100.06		
psi(Forest+Logging+Settle)p(.)	3.24	0.05	5	95.27	2.37	1.29
psi(Forest+Logging)p(Rain)	3.31	0.05	5	95.34	2.28	1.28
psi(Forest+Settle)p(Rain)	3.76	0.04	5	95.79	2.09	1.22
psi(.)p(Rain)	3.9	0.04	3	99.93		
psi(Logging)p(.)	3.97	0.04	3	100.00		
psi(Settle)p(.)	4.02	0.03	3	100.05		

psi(Forest+Logging+Settle)p(Rain)	5.15	0.02	6	95.18	2.31	1.26
psi(Logging)p(Rain)	5.83	0.01	4	99.86		
psi(Settle)p(Rain)	5.89	0.01	4	99.92		
psi(Logging+Settle)p(.)	5.96	0.01	4	99.99		
psi(Logging+Settle)p(Rain)	7.81	0.01	5	99.84		

In both examples the AIC model weight is distributed across a number of models suggesting that no one model stands out as the best fit to the data. The highest ranked models share *Forest* as a feature of occupancy probability. These *psi*(*Forest*) models represent 98% and 75% of the combined model weights for the tapir and clouded leopard examples respectively, showing that habitat is an important explanatory factor for both species. Program PRESENCE outputs -2log likelihood values and the number of parameters used for each model which can be used in likelihood ratio tests to determine whether a specific covariate has a significant effect. Likelihood ratios can be calculated by taking the difference between the -2log likelihood values from two models which differ only by the parameter of interest *e.g.* the difference between the -2log likelihood values for models *psi*(.)*p*(.) and *psi*(*Forest*)*p*(.) As an example, likelihood ratio tests were used to determine whether there was a significant difference in occupancy probability between forest and non-forest cells. For the tapir and clouded leopard examples, occupancy of both species was significantly ($p<0.05$) higher in forest habitats compared to non forest.

Interpreting the effects of covariates on occupancy and detection probabilities can be complicated because covariate coefficients represent the factor by which the odds of occupancy or detection changes for every 1 unit increase in a given covariate (PRESENCE). Consequently it is often easier to interpret covariate effects in terms of odds and odds ratios (PRESENCE, MacKenzie et al 2006). As an example, the coefficients for the forest/non-forest covariate from the tapir and clouded leopard examples (model *psi*(*forest*)*p*(.)) are 3.42 and 2.05 respectively. When expressed as odds these coefficients suggest that the odds of forest cells being occupied are 30.6 times and 7.8 times greater than for non-forest cells for tapir and clouded leopards respectively.

With regard to detection probability, the models that share *p*(*Rain*) as a factor are consistently ranked below equivalent models without *p*(*Rain*). For the tapir example, models with *p*(*Rain*) have a combined model weight of 38%, while for clouded leopards these models represent just 28% of the total weight. This suggests that *Rain* does not greatly affect detection probabilities for these species'. The direction of the relationship between the factor *Rain* and occupancy probability differs between the two examples. The associated parameter estimates are positive for the tapir and negative for the clouded leopard suggesting that rain increases the detection probability of tapir while decreasing detection probability of clouded leopards. Rain will have a mixed effect on detectability. For fresh tracks, they will be more obvious after rain. However, older tracks will be washed away. The difference between tapir and clouded leopard may reflect their different sizes. Tapir prints are large and deep and unlikely to be lost after a single rainfall, and fresh prints on harder substrates will become easier to detect. Clouded leopards on the other hand have smaller, shallower tracks which could be lost after a single night of rain, cancelling out the increase in detectability of fresh prints.

Results indicate that the remaining site-specific covariates are of low importance within the model since the confidence intervals include zero (Hines pers. comm.) However, these parameter estimates do tentatively indicate the direction of the relationships between factors.

One might expect occupancy probabilities for these species to be negatively associated with both logging activities and human settlement given that both species are shy and threatened by human persecution. However, parameter estimates associated with *psi*(*Logging*) models for the tapir are generally positive (the one exception being the *psi(Forest+Logging+Settle)p(.)* model) and similarly *psi*(*Settlement*) models for clouded leopards show positive parameter estimates.

These unexpected findings may be explained by the fact that within the large survey cells ($9km^2$) it was possible to detect a species presence in a discrete region of favourable habitat that lay a considerable distance from the illegal logging activities and human settlements also attributed to that cell. Continuous variables such as distance to settlements and encounter rates of illegal logging signs will be collected in 2006 to increase the explanatory power of further covariate based modelling.