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**(*Ursus thibetanus*)**

Estimating population size with correlated species presence area: an application

of Asiatic black bears (*Ursus thibetanus*) conservation

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**ABSTRACT**

Assessing the conservation status of species of concern is greatly aided by unbiased estimates of population size, as population size is one of the primary parameters determining urgency of conservation action and provides baseline data to measure potential recovery. Asiatic black bears (*Urus thibetanus*) and sun bears (*Helarctos malayanus*) are both threatened with extinction, but no practical and statistically rigorous method exists to estimate their abundance in the wild. We developed a novel approach to reliably estimate abundance of these sympatric bear species. Based on a blind experiment with captive animals, we demonstrate that both species of bear can be individually identified with a high degree of

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accuracy using their white chest marks. We developed a technique to photograph bear chest marks, using three camera traps mounted on trees facing each other in a triangular arrangement with bait in the center. We then tested the effectiveness of this technique to estimate abundance and density of black and sun bears, at two sites in Khao Yai National Park in northeastern Thailand. Trapping areas were 33-km$^2$ and 40-km$^2$. Eighteen baited camera-trap stations per site were used. At site 1 we recorded 13 black bears (8 males, 4 females, 1 unknown sex) and 8 sun bears (1 male, 5 females, 2 unknown sex). At site 2, we recorded 10 black bears (6 males, 4 females) and 6 sun bears (4 males, 2 females). Estimates of abundance at the 2 sites, based on closed population capture-recapture models were 14.0 (SE 3.0) and 19.3 (SE 3.8) black bears, and 8.2 (SE 1.9) and 6.5 (SE 1.9) sun bears. Capture probabilities for each species at each site ranged from0.34–0.57. Density at the two sites, based on a spatially explicit maximum likelihood method, was 8.55 (SE 2.75) and 5.98 (SE 2.11) black bears, and 5.26 (SE 2.05) and 3.59 (SE 1.59) sun bears per 100 km$^2$. Our method shows much potential for wider application. We believe this chest mark based photographic capture-recapture method provides a reliable and cost-effective method for monitoring population sizes for both species of bear in the wild.

**INTRODUCTION**

Population size is a primary determinant of extinction risk (O'Grady et al. 2004; Reed 2008; Reed et al. 2003) and thus is an important metric for assessing the conservation status of threatened species. Temporal estimates of population size provide important information about changes in extinction risk and can be used to indicate whether population management choices have been effective (O'Grady et al. 2004; Skalski et al. 2005). Asiatic black bears (*Ursus thibetanus*) and sun bears (*Helarctos malayanus*) co-occur widely throughout Southeast Asia (Steinmetz et al. 2011) and both are similarly threatened with extinction, yet reliable abundance estimates do not exist anywhere across their ranges (IUCN 2010). This is at least partly because currently available methods of estimating population size have been too expensive to employ, or have not proven practical or effective in the field in this region. In this paper we develop and describe a new method for estimating population abundance of black bears and sun bears in tropical forest ecosystems, which rectifies this long-standing limitation to bear research and management in Southeast Asia.

Mark-recapture, and capture-recapture, techniques offer a powerful method for estimating abundance. Population estimates of bears have mostly been conducted by using mark-recapture with radio-collared animals (Garshelis et al. 1999), camera-trapping, or re-sighting of bears marked with ear tags (Mace et al. 1994). In addition to direct-sighting methods, genetic methods, using DNA extracted from hair, have been used to estimate population size, but this technique faces difficulties in that hair samples are typically difficult to obtain and there is often a low success rate extracting DNA from hair samples obtained from the field (Boulanger et al. 2004a; Roon et al. 2003; Taberlet & Luikart 1999).

Capture-recapture sampling using automatic cameras is well-suited for estimating abundance of cryptic mammals that have unique identifiable coat patterns (Carbone et al. 2001), and this technique is now commonly used on such species as tiger (Karanth & Nichols

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1998), snow leopard (Jackson et al. 2006), jaguar (Silveira et al. 2009), ocelot (Trolle & Kery 2003), and bobcats (Heilbrun et al. 2003). Until recently, bears have not been amenable to this technique because the lateral photographs usually taken by trail cameras capture parts of the bear's body that almost always lack uniquely-identifiable features. Facial and pelage patterns of Andean bears (*Tremarctos ornatus*) have recently been used as unique marks to estimate bear abundance (Rios-Uzeda et al. 2007). Here, we present a new approach to identify individual Asiatic black bears and sun bears, as a basis for capture-recapture population estimation. We asked the following questions: (1) Are the chest marks of individual Asiatic black bears and sun bears distinguishable? (2) What technique is most practical for obtaining camera-trap photographs of these chest marks in the field? (3) Can the method be applied to estimating bear abundance in the wild?

**STUDY AREA**

The study was conducted in Khao Yai National Park (Khao Yai), the third largest national park in Thailand, and designated as a World Heritage site in 2005. Khao Yai (2,168 km$^2$) is in central Thailand (N 14° 05′– E 101° 50′); elevation ranges from 100 to 1350 meters above sea level. Annual precipitation ranges between 2,000 to 3,000 mm; the dry period (December–January) averages less than 15 mm of rain per month. From 1993 to 2002 average monthly temperature ranged from 21°C (December–January) to 32°C (April–May), and year-round average humidity was 78.6 percent (range: 52.1–89.6 %) (Kitamura et al. 2005; Savini et al. 2008). The dominant vegetation is seasonal evergreen forest (also known as semi-evergreen forest). Mixed deciduous forest occupies a small proportion of the northern part of the park (1% of land cover) (Lynam et al. 2006).

We then conducted the primary camera trap studies in two areas, Khlong E-Tow (KET) and Khlong Samor-Pun (KSP), both located in the west of Khao Yai (Fig 1). Elevation

of camera locations ranged from 700–860 meters (mean = 771 m) in KET, and from 373–561 meters (mean = 439 m) in KSP. Khlong E-Tow is within old growth semi-evergreen forest. Khlong Samor-Pun is comprised of a mosaic of semi-evergreen forest, regenerating forest, and grassland.

## METHODS

### Individual identification from chest marks

Asiatic black bears and sun bears have distinctive chest marks; we used these to differentiate individuals. We initially observed and analyzed bear chest marks at Banglamung Wildlife Breeding Center, where captive bears (confiscated by government agencies) are kept. We took 30 photographs that included the chest marks of 15 black bears and 11 sun bears, randomly selected from the population at Banglamung. We were able to identify each individual based on its markings. We then conducted a blind experiment, using 9 graduate students unrelated to the project, to test the practicality of differentiating individual bears. All 9 participants correctly identified all black bear and sun bear individuals. We concluded that both black bears and sun bears can be individually identified with a high degree of accuracy using their chest marks.

Chest marks of both bear species varied in pattern and size. Pattern variation among black bears included: (i) angle of V-shaped collar, (ii) thickness of middle tip, (iii) length of V-shaped projection, (iv) presence of a jagged or smooth edge, and (v) the arrangement of the two tips of the V-shaped projection (Fig. 2a). Sun bears had three major pattern variations: (i) both sides of chest mark white separated by black in the middle at the throat, (ii) a U-shaped collar and (iii) an O-shaped collar (Fig. 2b). Further pattern variation for sun bears was based on the shape of the collar and whether there was a smooth or ragged edge. We did not use

color variation to identify individuals because flash reflection obscured the color under the low light conditions of the forest.

**Camera system and preliminary test**

We conducted semi-wild trials of camera trap arrangements in outdoor enclosures at Banglamung to assess how best to obtain chest mark photos from free-ranging bears. We used passive, infrared-triggered, digital video scouting cameras (Stealth Cam STC-I590, Stealth Cam, Grand Prairie, TX, USA) to photograph bears in the enclosures. Three camera traps were mounted on trees approximately 3–4 m apart and facing each other in a triangular arrangement (Fig 3). We suspended bait, bananas mixed with honey, 2 m above the ground at the center point between the three cameras. The infrared beams were set below the bait, one meter above the ground. Camera-traps were set on burst mode to take multiple exposures of 4 sequential still pictures, with a 1 minute delay between triggering. The camera trap trial was successful in getting images of chest marks, from at least 1 of the 3 cameras, as the bears stood to reach the suspended bait.

We also conducted trials of the camera trap arrangement in natural forest at Khao Yai during September to December 2009, to assess how wild animals would respond to bait (fresh beef) and camera traps. Camera traps were set at sites that we determined had been regularly used by bears, based on a preliminary survey of claw marks and other signs. Twelve baited camera trap stations, mounted as in the semi-wild trials, were deployed (251 trap nights). We obtained 440 photos of black bears and 34 photos of sun bears; most photos were of bears walking into, around, and out of the station. Of these, 13 photos of black bear were of standing bears that clearly showed their chest marks, enabling individual identification of 5 bears, including 4 males and 1 female (in all cases we could also ascertain sex). We obtained one photo of 2 individual sun bears. There were additional unique identifying features that we

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used in conjunction with chest marks to identify individuals, particularly for black bears; these included body size and condition, muzzle color pattern, scars, and coat color.

Photographs were examined for individual identification based on guidelines modified from (Heilbrun et al. 2003):

1) A photograph was considered an "initial capture" if the chest marks could be clearly seen and did not match any other bear's chest-mark patterns.

2) A photograph was considered a "recapture" based on either chest-mark patterns and/or on distinct characteristics (scars, coat color or body condition) matching previous initial captures.

3) An image was classified as "unidentified" if no identical spots on the chest mark, or other distinct characteristics matched with initial capture or recapture images.

4) Any obvious, distinct characteristic or a matching identical part of a chest mark was considered sufficient to classify different individuals.

**Density estimation**

We applied the techniques above to estimate abundance and density of black bears and sun bears at two sites in Khao Yai: Khlong E-Tow and Khlong Samor-Pun. We surveyed in Khlong E-Tow from December 2009 to February 2010 and in Khlong Samor-Pun during March to May 2010. We set baited stations 1.5 to 2 km apart. This spacing was a compromise between covering a larger area to capture as many bears as possible, and maintaining a tightly-spaced network of cameras to ensure no holes in which a bear would have zero probability of capture. We used 6 kg of meat for bait at each station. Bait was hung 2 m above the ground. Camera traps were active 24 hr a day and left in the forest for a 2-month period. Bait and the camera batteries were changed every 3 weeks. Baits removed by bear in the meantime were not re-baited until the next occasion. The total trapping effort was

partitioned into 2-week sampling intervals corresponding to the bait and battery changes. A total of 3 sampling occasions were used to make the capture matrix.

We estimated bear abundance using *k*-sample capture-recapture methods (Williams et al. 2002). We estimated abundance under the conventional closed population modeling, with heterogeneous detection probabilities ($M_h$ jackknife) (Rexstad & Burnham 1991). Bear abundance was estimated using software DENSITY (Efford 2009). We used spatially explicit capture-recapture modeling (SECR) to estimates bear density using "secr" package version 2.0 (Borchers & Efford 2008) with R software (R Development Core Team 2011). SECR is a newly developed method that uses maximum likelihood to integrate the capture probability for each animal at each trap site in order to estimate the area of the survey region (effective trapping area). Estimation of density is therefore straightforward in SECR, whereas with conventional closed population modeling, density estimates depend strongly on the effective trapping area [*A(W)*], which is usually calculated by adding an arbitrary buffer strip width (*W*). SECR uses the detection histories of individually marked bears within the trapping array to estimate the activity center and movement of individuals.

The detection probability is modeled as a function of distance from the capture locations to the animal's home range center. Detection function has two parameters, where $g_0$ is the probability of detection at a single trap within the center of the home range, and sigma (σ) is the spatial scale of movement which is not comparable between detection functions (Efford et al. 2009). We used conditional likelihood to select a detection model (Borchers & Efford 2008), the choice of model was conditional on the number of bears detected in all surveys. The advantage of conditional likelihood is that individual covariates can use to compare between different detection models (Efford et al. 2009). The null detection model was estimated from pooled data using individual capture histories from both species of bear and both study areas combined. The null detection model was then compared to a detection

model using sites (KET and KSP) as covariates, a detection model using species (black and sun bears) as a covariate, and a detection model using both sites and species as covariates. We used the best fit detection model to calculate density in both sites separately after that. We conducted surveys during low natural food availability in Khao Yai (Ngoprasert et al. 2011). Bear movements were assumed to follow a half-normal or negative exponential probability density function around capture locations. We selected a detection function for our dataset by comparing model fit using Akaike's information criterion (AIC) (Akaike 1973). We calculated density using a full-likelihood model, with animals distributed according to a Poisson process.

A bias in estimating effective sample area (ESA) will also bias density estimation. Effective sample area is dependent on trap layout, number of sampling occasions and distance between traps, because these effect scale of movement $\sigma$ (Efford et al. 2009; Royle & Dorazio 2008). We used simulation testing to assess possible bias in our estimates of $\sigma$ that might bias our density results. We estimated the value of $g_0$ and $\sigma$ derived from the best fit detection model (see previous section). We then used KET dataset with pooled species of bear to perform the simulation test, because KET had a smaller trapping area and greater trap saturation. Simulation results are mean $\pm$ SE of $g_0$ and $\sigma$ for 100 replicates. Relative percentage bias is estimated by 100 x (mean ($\hat{s} - s$)/$s$, where $s$ represent of the parameters $g_0$ and $\sigma$.

We determined the accuracy of the chest mark method by comparing the probability of missing an animal using chest marks, with that from studies that used the DNA hair-trap capture-recapture method. We evaluated the probability of missing a bear in the sampling area using the formula (1 - $M_{t+1}$/N-hat) where $M_{t+1}$ is the total number of individual bears captured by camera-traps during the entire study period and *N-hat* is the estimated abundance (Karanth & Nichols 1998). We compared this estimate with estimates of the expected

probability of missing a bear from hair-trap studies of grizzly bears (*Ursus arctos*) and American black bears (*Ursus americanus*) (Boulanger & McLellan 2001; Boulanger et al. 2004a; Boulanger et al. 2004b; Boulanger et al. 2002; Mowat & Strobeck 2000; Poole et al. 2001), (Boersen et al. 2003; Gardner et al. 2010; Immell & Anthony 2008). We compared our results with the studies based on ≥3 sampling occasions, and that estimated abundance based on the most appropriate model from model selection criteria (Rexstad & Burnham 1991).

**RESULTS**

Nineteen baited camera trap stations were set in KET during December 2009 – February 2010 (1,100 trap-nights). Camera traps were deployed for $20.8 \pm 0.3$ (SE) nights with range of 14 to 24 trap-nights at each baited station per occasion. A camera-trapping polygon, created by drawing a line connecting the outermost locations, covered an area of 33 km$^2$. We obtained photos of 13 black bears (8 males, 4 females, 1 unknown sex) and 8 sun bears (1 male, 5 females, 2 unknown sex). Five black bears and five sun bears were recaptured at least once (Table 1). The number of bears captured on the 3$^{rd}$ occasion increased for both black bear and sun bear compared to the 1$^{st}$ and 2$^{nd}$ occasions, respectively (Table 2). We photographed black bears at 16 stations (84%) and sun bears at 9 stations (47%). Two individual black bears were captured at 6 different stations, and 1 individual sun bear was captured at 4 stations. The conventional closed population ($M_h$) estimate of bear abundance at KET was 19.3 (95% CI: 15.1–31.9) black bears and 8.2 (95% CI: 8.0–20.7) sun bears (Table 3).

Eighteen baited camera trap stations were set in KSP during Mar–May 2010 (1,190 trap-nights). Camera traps were deployed for an average of $22.3 \pm 0.5$ (SE) trap-nights with a range of 16 to 30 trap-nights at each baited station. The camera-trapping polygon covered an area of 40 km$^2$ in KSP. We obtained photos of 10 black bears (6 males, 4 females) and 6 sun bears (4 males, 2 females). Four black bears and two sun bear were recaptured at least once.

However, the number of recaptured bears in KSP was constant after the second occasion (Table 2). We photographed black bears at 8 stations (44%) and sun bears at 9 stations (50%). One individual black bear, and one individual sun bear were captured at 3 baited stations each; no individuals of either species were captured at more than 3 stations. Abundance at KSP was estimated at 14.0 (95% CI: 11.1–24.9) black bears and 6.5 (95% CI: 6.0–18.6) sun bears.

The null detection model was the best fit model to estimate $g_0$ and $\sigma$, having about 2.5 times as much support as the next best model (Table 4). The model including site was the second best model and have almost three times as much support as the third best model. The capture probability ($g_0$) under the null model was estimated as 0.25 (95% CI: 0.16–0.35) and scale of movement ($\sigma$) was estimated to be 2.24 km (95% CI: 1.77–2.84 km). Our estimated 95% home range radius of bear in Khao Yai was 5.49 km or home range size 94.74 km$^2$ by assuming a half-normal model. We chose the null detection model for calculating density. A half-normal detection function fit our data set better than a negative exponential function, having about three times as much support as the latter.

Density estimates using SECR in KET were 8.55 black bears/100 km$^2$ (95% CI: 4.62–15.83) and 5.26 sun bears/100 km$^2$ (95% CI: 2.52–10.99). Density estimates in KSP were 5.98 black bears/100 km$^2$ (95% CI: 3.05–11.70) and 3.59 sun bears/100 km$^2$ (95% CI: 1.58–8.14). The model estimated the ESA as 152 km$^2$ and 167 km$^2$ respectively. Bootstrapping suggests that our estimates of $\sigma$ were unbiased. Estimates of capture probability also show little bias, with the mean of the bootstrapped values being only 1.27% higher than the estimates from the null model. Thus, our estimates of density were unbiased due to trap layout.

The probability of missing bears in KET and KSP were 0.32 and 0.29 for black bear, and 0.02 and 0.08 for sun bear, respectively (Table 3). From our literature review of hair-

trap-based estimates for North American bears, the average probabilities of missing animals was 0.42 (range 0.25–0.58), which is similar to or generally higher than observed in our study.


## DISCUSSION

This research has the following major findings: (1) Asiatic black bear and sun bear can be individually identified with a high level of certainty, allowing for noninvasive mark-recapture estimation using trail cameras. (2) Baited stations can be used to attract bears and proper positioning of the bait encourages the animals to stand upright and expose chest marks used to identify individuals. (3) The chest mark-based method capture-recapture is a feasible and reliable method to estimate abundance and density. A further minor finding is that the density of Asiatic black bear is not significantly different than the density of sun bear in our study area, based on 95% CIs. We elaborate on these points below.

Though sample sizes were small, naive individuals with no bear experience were able to identify individual Asiatic black bears and sun bears by their chest markings with 100% success. Wild bears were usually identifiable if photos captured the full chest mark. In addition, assessment of body condition from photos obtained from other side cameras increased our ability to identify individuals. This improved recapture rates, and also revealed additional individuals, including cubs, standing on the edge of baited stations as the first bear triggered the camera. We suggest a distance of ≥4 m to obtain full body photos in areas with coexisting black bear and sun bear and ≤4 m in sun bear only habitat, however this may also depend on the camera model. Testing distances to obtain full body photos could be accomplished by researchers during camera trap installation by checking test photos with a compact digital camera. Three camera traps arranged at slightly different heights above ground allows for better estimation of body size such as for cubs and yearlings.

Our camera traps method permits simultaneous monitoring of both Asiatic black bears and sun bears. Being able to provide abundance data for both species simultaneously is a major benefit for management, monitoring, and ecological studies of these coexisting species.

Using chest marks for individual identification is both more reliable and requires less technical knowledge than the alternative of using genetic methods by obtaining DNA from hair or scat. This is especially true in the tropics where the heat, humidity, and rainfall patterns of the tropics causes DNA or scat to degrade quickly (Roon et al. 2003). We had earlier attempted to hair-trap bears in Khao Yai, at KET, using hair-trap stations affixed to trees (D. Ngoprasert *unpublished data*). Although we were able to obtain hair from black bears, it proved difficult to obtain hair from sun bear hair because of their short coat.

With this camera-trap method we were also able to photograph multiple visits of the same individual, and also different individuals of both species after the first bear had already eaten the bait, allowing for greater flexibility in determining sampling period length. In the absence of multiple collection periods, which may be logistically difficult in remote areas, multiple individuals or multiple species depositing hair on the same hair sampling device could lead to confounded identifications of individuals or species (Kendall & McKelvey 2008).

Another disadvantage with hair sampling methods is that age cannot easily be determined from DNA. In addition, cubs and yearlings are often not detected in hair sampling stations where barbed wire is set at a height for adult  bears (Boulanger et al. 2004a). In contrast, with photographs we were able to easily categorize individuals into age classes (Fig 4). Even coarse classification such as juvenile (cub with mother), subadult, adult or older adult can be useful for population analysis. However, the chest mark-based technique did not allow sex determination of subadults, because male juvenile bears have undeveloped reproductive organs. The proportion of adult females with cubs recorded by camera traps has

the potential to be used as an indicator of population health. However, we found that, for both species, rubbing behavior on the ground below baits aided in sex determination, because bears lay down on the ground.

Of course genetic methods have many benefits as well, such as estimating current and historical rates of gene flow, estimating population size, inferring past demographic trends, and reliably sexing individuals. The methods are not mutually and both can mutually support each other.

The effectiveness of various baits at attracting bears should be tested further. Other types of bait could potentially increase detection probability over what we achieved. The scale of movement may be used to determine changes in the distance over which bears are attracted to a bait station from the animal's home range center. However, the detection probability is also related to trap layout and this must be considered during the experimental design. In addition, bait attractiveness reduces the effect on bears of researchers' own human scent (Schlexer 2008), and increases the detection space which enlarges the effective sampling area (Stanley & Royle 2005). Time of year and natural food availability also influences visitation rates at bait stations (Clark et al. 2005; Koerth & Kroll 2000). Thus, more work is needed to assess the attractiveness of baits in relation to natural food availability, to determine how season affects detection probability and resulting population estimates.

Our results indicated bears were more likely to detect bait after the first occasion, especially in KET where numbers of bears caught did increase after the second occasion (Table 2). Conversely, the number of captured bears continued to constant in KSP. We surveyed during the dry season, which is typically low in natural food availability for bears in our study area (Ngoprasert et al. 2011; Savini et al. 2008). It is possible that poor habitat quality of the forest at KSP (particularly the secondary forest) forced bears to search more

widely for food and thereby encounter baits more frequently. It has been suggested that bait stations be moved frequently in order to increase the number of captured and recaptured bears and to reduce trap-happy interactions (Boulanger et al. 2006).

We did not detect a statistically significant difference in density between Asiatic black bear and sun bear in this study (based on overlapping 95% CIs). However, statistical power to detect such a difference, given our current sample size, was low. In absolute terms, the density of Asiatic black bears was 1.65 times higher than the density of sun bears. This apparent preponderance of black bears relative to sun bears is similar to the findings from a previous sign survey in the same area in 2008, in which black bear signs (claw marks on climbed trees, identified to bear species) were about five times as abundant as those of sun bear (Ngoprasert et al. 2011). Based on these observations, we speculate that the true abundance of black bears is higher than sun bears in Khao Yai. The densities of both bear species were not significantly different between Khlong E-Tow and Khlong Samor-Pun. However, statistical power was low for this comparison. Estimated sun bear densities at KET were nearly twice that of KSP.

We provided a new approach for estimating the abundance and density of sympatric Asiatic black bear and sun bear, as well as the first population estimates for these species from Southeast Asia. This study demonstrates how camera traps can be used to obtain population estimates of two coexisting bear species in a tropical forest. With larger sample sizes to improve precision, we believe this technique may be useful for monitoring population trends in bear abundance. This method could also be used to monitor the movements of individual bears between patches, and fates of individual bears in a population. This information would greatly enhance our knowledge of the conservation status, ecology, and demography of these threatened but little-known bear species.

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Table 1 Capture history of Asiatic Black Bear (BB) and Sun Bear (SB) in Khlong E-Tow and

Khlong Samor-Pun areas, Khao Yai National Park, Dec 2009-May 2010.

| ID no. | sex | Capture history (occasions) | | | maximum distance moved[a] |
|--------|-----|---|---|---|---|
| Khlong E-Tow | | 1 | 2 | 3 | (km) |
| BB 01 | unknown | 0 | 0 | 1 | - |
| BB 02 | male | 1 | 1 | 1 | 6.4 |
| BB 03 | male | 1 | 0 | 1 | 0.0 |
| BB 04 | male | 1 | 1 | 0 | 1.6 |
| BB 05 | male | 0 | 1 | 1 | 4.1 |
| BB 06 | male | 0 | 1 | 0 | - |
| BB 07 | male | 0 | 1 | 0 | - |
| BB 08 | male | 0 | 0 | 1 | - |
| BB 09 | male | 0 | 0 | 1 | - |
| BB 10 | female | 1 | 1 | 1 | 3.9 |
| BB 11 | female | 0 | 1 | 0 | - |
| BB 12 | female | 0 | 0 | 1 | - |
| BB 13 | female | 0 | 0 | 1 | - |
| SB 01 | unknown | 0 | 1 | 1 | 2.0 |
| SB 02 | unknown | 0 | 0 | 1 | - |
| SB 03 | male | 1 | 1 | 1 | 6.7 |
| SB 04 | female | 1 | 0 | 1 | 0.0 |
| SB 05 | female | 1 | 0 | 1 | 0.0 |
| SB 06 | female | 0 | 1 | 1 | 0.0 |
| SB 07 | female | 0 | 0 | 1 | - |
| SB 08 | female | 0 | 0 | 1 | - |
| | | | | | |
| Khlong Samor-Pun | | | | | |
| BB 14 | female | 1 | 1 | 0 | 0.0 |
| BB 15 | male | 1 | 0 | 0 | - |
| BB 16 | female | 1 | 1 | 0 | 3.8 |
| BB 17 | male | 1 | 0 | 0 | - |
| BB 18 | male | 1 | 1 | 1 | 3.8 |
| BB 19 | male | 1 | 0 | 0 | - |
| BB 20 | female | 0 | 1 | 0 | - |
| BB 21 | male | 1 | 1 | 0 | 0.0 |
| BB 22 | female | 0 | 1 | 0 | 4.1 |
| BB 23 | male | 1 | 0 | 0 | - |
| SB 09 | female | 1 | 1 | 0 | 0.0 |
| SB 10 | male | 1 | 1 | 0 | 6.1 |
| SB 11 | male | 0 | 1 | 0 | - |
| SB 12 | female | 0 | 1 | 0 | - |
| SB 13 | male | 0 | 1 | 1 | 4.3 |
| SB 14 | male | 0 | 1 | 0 | - |

[a] maximum distance between recaptures

Table 2 Summary of capture-recapture statistics for Asiatic Black Bear and Sun Bear obtained from chest marks in Khlong E-Tow and Khlong Samor-Pun areas of Khao Yai National Park, during Dec 2009–May 2010. Note that $n_t$, $u_t$, and $M(t+1)$ are always equivalent on occasion 1.

| Numbers of individual bears | Khlong E-Tow Occasion | | | Khlong Samor-Pun Occasion | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| Asiatic black bear | | | | | | |
| caught at time $t$ ($n_t$) | 4 | 7 | 9 | 8 | 6 | 1 |
| 1st caught at time $t$ ($u_t$) | 4 | 4 | 5 | 8 | 2 | 0 |
| marked animals at $t+1$ [$M(t+1)$] | 4 | 8 | 13 | 8 | 10 | 10 |
| Sun bear | | | | | | |
| caught at time $t$ ($n_t$) | 3 | 3 | 8 | 2 | 6 | 1 |
| 1st caught at time $t$ ($u_t$) | 3 | 2 | 3 | 2 | 4 | 0 |
| marked animals at $t+1$ [$M(t+1)$] | 3 | 5 | 8 | 2 | 6 | 6 |

Table 3 Abundances (N) and capture probabilities ($P$), estimated using the $M_h$ jackknife model from a conventional closed population model, of Asiatic Black Bear and Sun Bear at two study sites (Khlong E-Tow, Khlong Samor-Pun), Khao Yai National Park, Dec 2009–May 2010. $M_{t+1}$ is the total number of individual bears captured by camera-traps during the

| Species | Khlong E-Tow | | | | | Khlong Samor-Pun | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $M_{t+1}$ | $P$ | $N$(SE[$N$]) | 95% CI | 1-($M_{t+1}/N$) | $M_{t+1}$ | $P$ | $N$(SE[$N$]) | 95% CI | 1-($M_{t+1}/N$) |
| Black bear | 13 | 0.34 | 19.3 (3.8) | 15.1 – 31.9 | 0.33 | 10 | 0.35 | 14.0 (3.0) | 11.1 – 24.9 | 0.29 |
| Sun bear | 8 | 0.57 | 8.2 (1.9) | 8.0 – 20.7 | 0.02 | 6 | 0.46 | 6.5 (1.9) | 6.0 – 18.6 | 0.08 |

entire study period.

Table 4 Summary of detection models of Asiatic Black Bear and Sun Bear at two study sites

(Khlong E-Tow, Khlong Samor-Pun), Khao Yai National Park, Dec 2009–May 2010.

| Model name | Detect function | Number of parameter | Log Likelihood | AIC | AICc | Δ AICc | $w_i$ |
|---|---|---|---|---|---|---|---|
| null model | Half-normal | 2 | -259.153 | 522.306 | 522.659 | 0.000 | 0.654 |
| Site variation | Half-normal | 4 | -257.624 | 523.247 | 524.497 | 1.838 | 0.261 |
| Species specific | Half-normal | 4 | -258.736 | 525.472 | 526.722 | 4.063 | 0.086 |
| Species and site | Half-normal | 8 | -256.651 | 529.301 | 534.444 | 11.785 | 0.000 |

ΔAICc is the absolute difference in the Akaike's information criterion (AIC) value adjusted for small sample sizes (AICc) between the best fit model and the model under consideration, $w_i$ is the Akaike weight which provides a measure of relative support for each model.
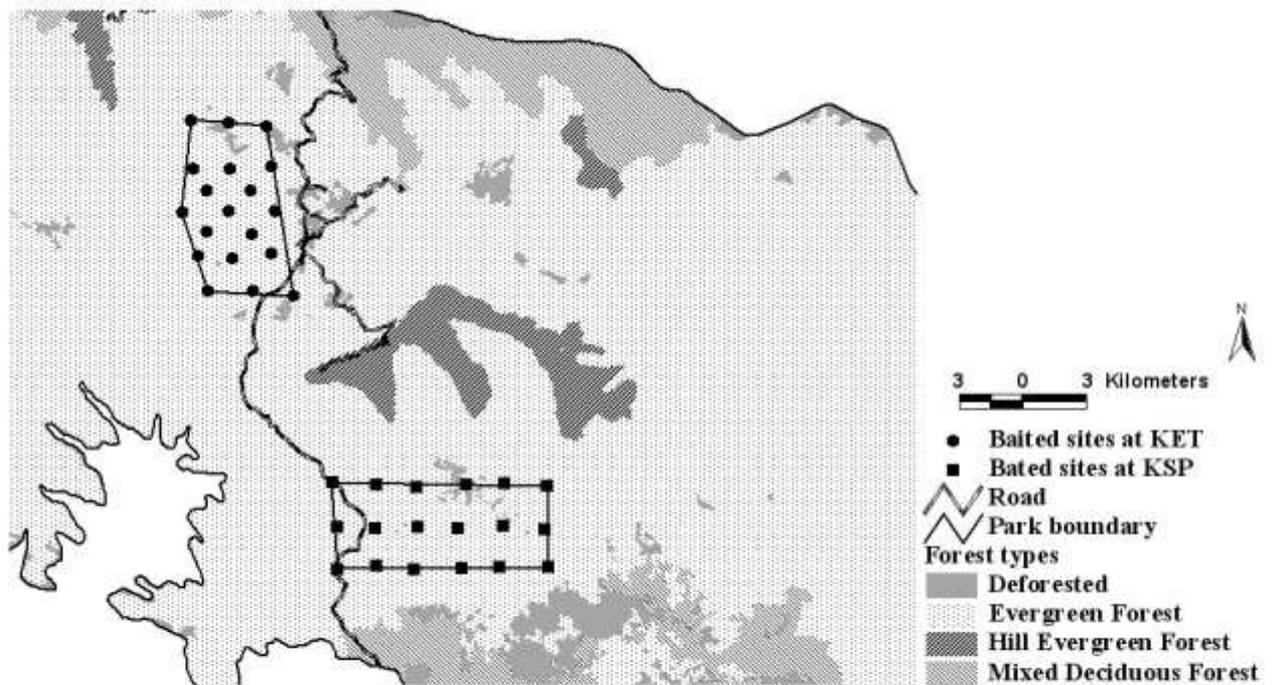
Figure 1 Camera trap locations in Khlong E-Tow and Khlong Samor-Pun study areas, Khao Yai National Park during Dec 2009–May 2010.
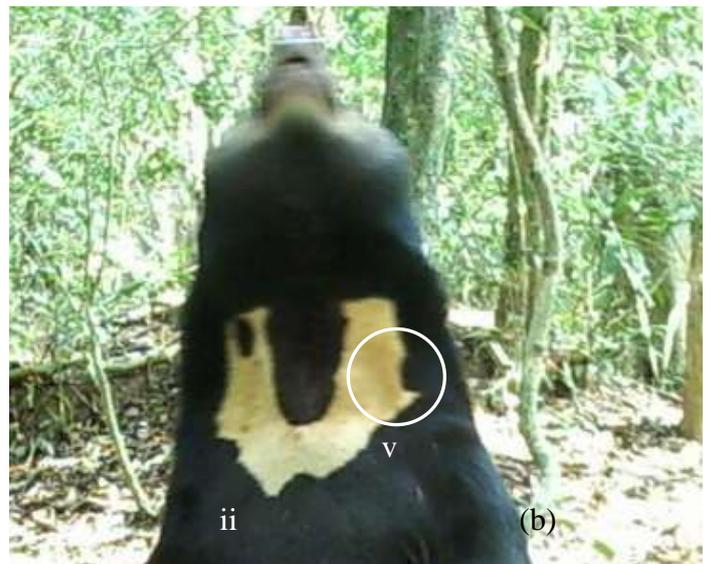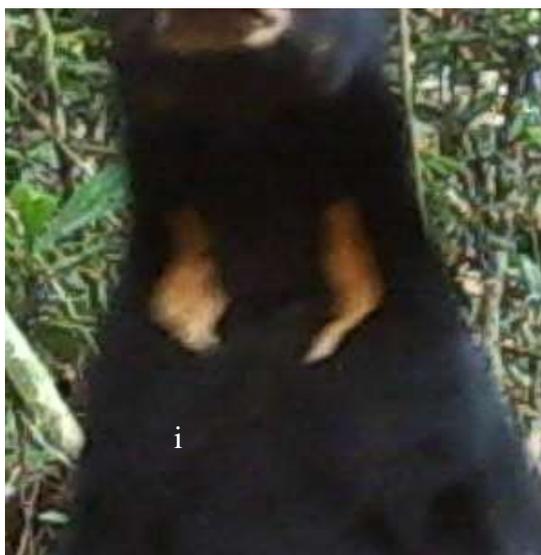
Figure 2 Identification of bear pattern variation among (a) black bears included: (i) angle of V-shaped collar, (ii) thickness of middle tip, (iii) length of V-shaped projection, (iv) presence of a jagged or smooth edge, and (v) the arrangement of the two tips of the V-shaped projection, (b) sun bears included: (i) both sides of chest mark white separated by black in the

middle at the throat, (ii) a U-shaped collar and (iii) an O-shaped collar, (v) shape of the collar
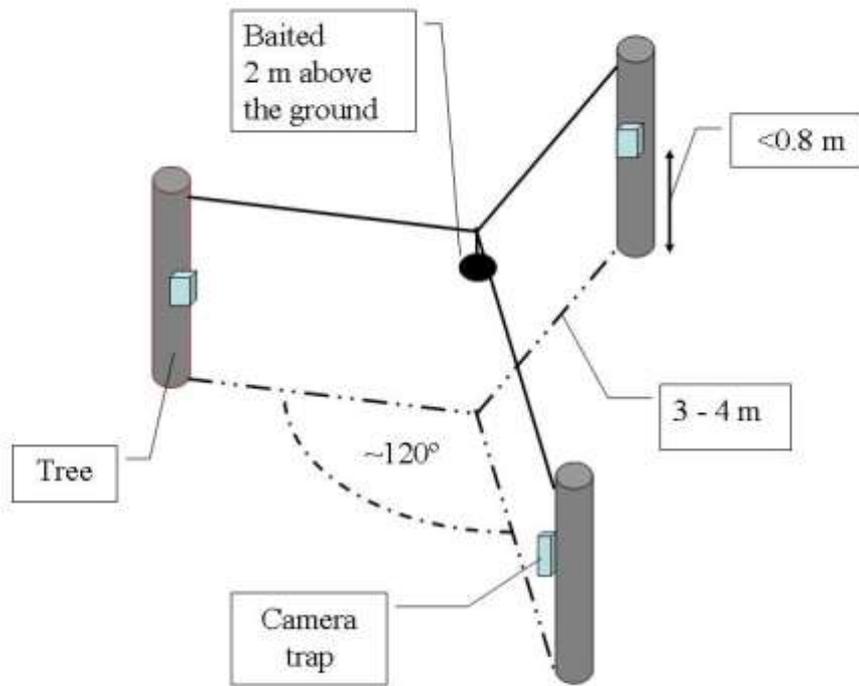
and whether there was a smooth or ragged edge.

Figure 3 Bait station diagram for chest mark detection.

(a)



(b)

Figure 4 Photographs of two individual black bears: (a) a subadult male, and (b) an adult

male, in Khao Yai National Park.