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Research article

Which factors determine orangutan nests' detection probability along transects?

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Abstract

Effective conservation needs a solid baseline of animal distribution, density, and abundance data to base management strategies on and evaluate the effectiveness of conservation efforts on the species of interest. For many species it is not feasible to directly count individuals, and scientists are forced to use indirect methods that can provide estimates of density and abundance. For orangutans nest counts are the most often used indirect sign of presence. Models used for density and abundance estimates are based on a set of assumptions about the observations. Here we analyze the effect of several factors (distance to transect, height, decay stage, and observer experience) on the probability that an orangutan (*Pongo abelii*) nest is found along a line transect. The results indicate that all factors significantly influence nest detection. Orangutan density estimates varied between the teams with the lowest estimate being approximately 83% of the highest estimate and orangutan density showed a positive correlation to experience level. We use these results to propose a new approach to determine orangutan density that should reduce variation between density estimates from nest surveys and therefore should lead to more reliable between-survey comparisons for orangutans and potentially other great-ape species.

Keywords: distance sampling, density, *Pongo abelii*, conservation, density-estimation comparison

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Introduction

Key ingredients for conservation work are solid data on the density, abundance, and distribution of animal species. Because for most species it is not possible to directly count all individuals that occur in an area, scientists resort to methods that provide estimates for density and abundance without counting all individuals living in an area. Although several such estimation methods exist [1], for many researchers the method of choice has been to conduct line transects that either directly count individuals or groups of a species (e.g., [2]) or count indirect signs of presence that can provide an estimate, such as dung (e.g., [3]) and nests (e.g., [4,5]).

To obtain data on great-ape density and abundance, nest counts have become the method of choice and are also the recommended method in a recent best-practice guidelines document on great-ape census techniques by the IUCN [6]. From these counts, estimates of density and/or abundance can then be derived following increasingly sophisticated models [1,7].

The line transect method requires that nests on or near the line transect are detected, but the method allows for some of the individuals or indirect signs to be missed within a certain distance from the transect (μ) and uses equations to correct for those missed nests. The critical assumption underlying the line transect method, regardless of which equation is used to account for missed nests, is that all nests located directly on the transect are found [8].

Previous orangutan studies have indicated that experience is important when conducting line transect nest counts [9]. More experienced teams locate more nests along transects, but do not differ in the percentage of nests they add on a second pass in the opposite direction [9]. In the same study it was found that experienced teams still observe only 64-73% of all nests observed by all teams in that study. Numbers rise to 70-76% after the second pass [9]. The van Schaik et al. [9] study showed that, in general, experienced teams' data led to higher densities than those of inexperienced teams. There is, however, a need to replicate this study in primary forests because the van Schaik et al. [9] study was conducted in a logged forest where detection probability likely differs from that in a primary forest. From the above it is clear that experienced teams also tend to miss nests and can potentially underestimate the best density estimate available [9]. Similar results have been found by a second study in Borneo where a second count led to approximately 30% higher orangutan density estimates [10]. It is, however, not known which factors of a nest determine its probability of being observed, although it has been suggested that factors such as nest decay state and height will have an effect on nest detection probability [6]. Determining what those factors are could lead to more focus on those aspects during nests counts and therefore to fewer nests being missed.

This study therefore has two aims. The first aim is to examine factors that influence the detection probability of orangutan nests in a primary forest on Sumatra. To examine this we compare detection of nests by several teams ranging in experience with nest counts and determine how distance to transect, height of nest, and decay stage affect detection probability. The second aim is to determine whether orangutan density differs between the teams. We conclude with a recommendation for a nest count method that seems to be less sensitive to sampling team experience levels and therefore might lead to less variation in nest counts.
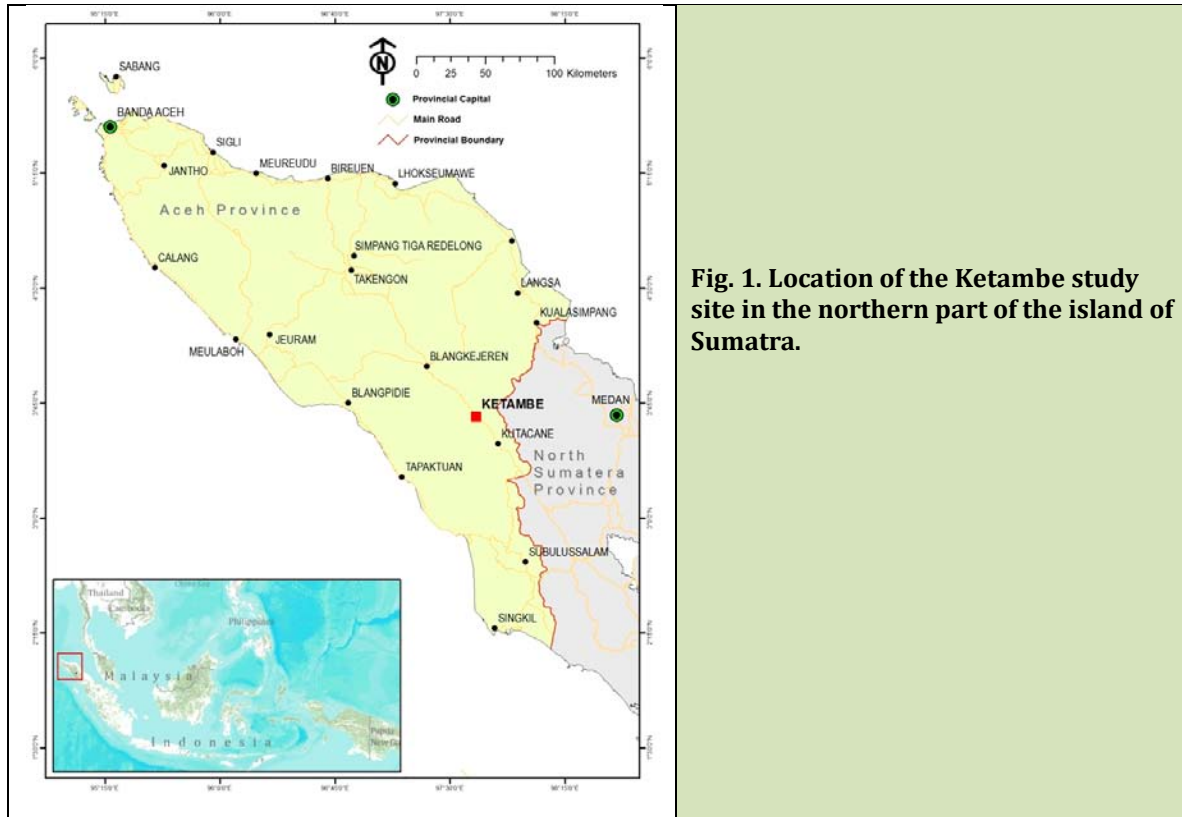
Fig. 1. Location of the Ketambe study site in the northern part of the island of Sumatra.

Methods

The study was conducted at the Ketambe research site (3 ° 41' N, 97 ° 39' E) in the Gunung Leuser National Park, Leuser Ecosystem, Aceh Province (Indonesia) in November 1997 (Fig. 1). The forest at the site consists of mostly primary rainforest [11,12]. For the nest counts a 1.5 km straight line transect was laid out in the forest. The forest along the transect consisted of primary forest and details of this area have been provided by [11,12]. The terrain in the area was relatively flat and homogenous in terms of habitat. Six two-person teams slowly walked the transect in one direction and counted all nests observed. For each nest observed the perpendicular distance from the transect in meters, was measured with a measuring tape, the height of the nest was estimated in 5-meter interval classes, and the decay stage of the nest was recorded. Nest decay was measured in a four-class system: (A) fresh, some leaves still green; (B) nest is brown but remains intact; (C) leaves missing and holes are appearing in nest; (D) leaves are gone, only branch structure of nest remains. All teams counted the nests on the same day, but had no communication during the counts. The light conditions under which each team walked the transect were similar. Teams differed in nest counting experience, with team 1 being the most experienced and team 6 being the least experienced. The most experienced nest counting team consisted of two individuals with 10 years of experience on orangutan behavior and nesting behavior, after which the teams decreased in steps of two years experience per team to the least experienced team which had no experience at all with orangutan nest counts or orangutan research, but had experience with studying monkeys in the same forest.

We conducted a logistic regression in R (Version 2.8.1 for Windows; R Development Core Team 2008), using the logit link function, to determine the significance of each of the identified independent variables (team, perpendicular path distance, height, and decay class) in determining whether a given team had found a given nest. We treated team and decay class as categorical variables. We also re-ran the regression four times with one less independent variable, holding out each variable in turn and then used the Akaike Information Criterion (AIC) to choose the best model [13]. We used the Design package for R to calculate the Nagelkerke pseudo-R^2 and area under the Receiver Operating Characteristc curve (ROC) as goodness of fit and discrimination tests. The Spearman correlation was also conducted in R. We also tried a model using interaction terms between team and the other independent variables, but found that the data points were not dense enough within the parameter space to gain meaningful results with the interaction terms. Using these interaction terms made all terms highly insignificant, as the number of terms in the model increased from 10 to 35 (since some of the variables are categorical, they represent more than one term in the model).

Orangutan density was calculated using the computer program Distance 6.0 [14]. We followed the procedures in Buckland et al. [1,7] for model selection, model evaluation, and data truncation (largest 10%). Several models were tested and the one with the lowest Akaike's information criterion (AIC) was selected [1] The equation used to calculate orangutan density from nest counts was: $\widehat{D} = N/2\hat{\mu}L\hat{p}\hat{r}\hat{t}$; where $\widehat{D}$ is orangutan density, N is the number of observed nests along the transect, $\hat{\mu}$ is the effective strip width of the transect, L is the transect length (km), $\hat{p}$ is the proportion of nest builders in the population (0.9 for this study), $\hat{r}$ is the nests built per individual per day (1.7 for this study), and $\hat{t}$ is the nest decay time (180 days for this study: Wich, unpublished data). We used parameter values from another study in the same area [15].

This research adhered to the legal requirements of Indonesia and was approved by the Indonesian Institute of Science (LIPI).

Results

Detection probability

The teams observed a different number of nests (team 1: 94; team 2: 89; team 3: 84; team 4: 84: team 5: 80; team 6: 82). Teams missed an average of 11% of the total number of observed nests; this varied from 17% missed by Team 5 to 2% missed by Team 1.

The factors team, perpendicular path distance (PPD), height and decay class were all significant predictors of whether or not a nest was found (Table 1). The model including all four factors had a lower AIC value than any model formed by excluding one of the factors, indicating that all of the factors are important explanatory variables (AIC values: Full model: 233.63; without team: 251.13; without PPD: 361.51; without height: 248.68; without class: 239.3). The full model's pseudo-R^2 statistic was 0.554. The area under the Receiver Operating Characteristic curve (ROC) was 0.933, relatively close to the maximum possible value of 1.

As expected, performance quality decreased with decreasing experience (Fig. 2). Team 1, the most experienced team, was significantly better than each of the other teams (P < .05). Teams 3

and 4 both performed worse than Team 2 and Teams 5 and 6 were even less effective than Teams 3 and 4. The best team (Team 1) found 19% more nests than the worst team (Team 5).

A nest's height had a highly significant and large impact on its detectability, with higher nests being harder to find (Fig. 3; P < .001). For every 5-meter increase in height, a given nest was 55% more likely to be missed. The four nests in the lowest height class (10m) were found 100% of the time while the five nests in the two highest height classes (30m and 35m) were only found 67% of the time. Nest decay stage also significantly affected discovery rates (Fig. 4). The freshest nests, Stage A nests, were actually the hardest to find, though Stage D nests were not found significantly more often than Stage A nests. Both Stage B and Stage C nests were found significantly more often than Stage A nests (P < .02). Stage B and C nests were found at nearly identical rates.

Table 1. Results of the logistic regression model

	Estimate	Std. Error	Z-value	Pr(>|z|)	P-value
(Intercept)	10.44	1.56	6.68	<0.001	***
Team 2	-1.97	0.98	-2	0.045	*
Team 3	-2.99	0.96	-3.13	0.002	**
Team 4	-2.99	0.96	-3.13	0.002	**
Team 5	-3.59	0.95	-3.77	<0.001	***
Team 6	-3.3	0.95	-3.47	0.001	***
PPD	-0.14	0.02	-8.3	<0.001	***
Height	-0.16	0.04	-4.02	<0.001	***
Stage B	1.86	0.73	2.54	0.011	*
Stage C	1.58	0.66	2.41	0.016	*
Stage D	0.63	0.65	0.98	0.329	

Note: * = 0.05 > P > 0.01; ** = 0.01 > P > 0.001; *** = P < 0.001.

The perpendicular path distance (PPD), or the distance of the nest from the nearest point on the transect, also had a highly significant and large effect on nest detectability (Fig. 5; P < .001). For every 5-meter increase in PPD, a given nest was 49% more likely to be missed. The 44 nests within 10 meters of the transect had a 99.6% chance of being observed, while the seven nests further than 40 meters from the transect had only a 36% chance of being observed. However, this measure likely underestimates the total effect of PPD, given that the number of nests included in the study also decreased with PPD, which suggests that all six sampling teams missed several nests further from the trail. The strip 0-10m from the transect was found to contain 2.1 nests per strip-meter while the strip 11-20m from the transect was found to contain only 1.0 nests per strip-meter. Assuming nest density is actually independent of transect placement, nests 11-20m from the transect were discovered only 45% of the time (and nests further away

were found even less often). While with this dataset it is not possible to determine whether all nests that existed at even the closest distances were found, the high concordance in nests found by all teams within 10 meters of the transect suggests that nearly all nests within that distance were found. Additionally, a Spearman's correlation found that, for nests within 10 meters, the number of nests found in a given meter distance from the transect did not correlate with its distance from the transect (Spearman correlation r = - 0.374, P = 0.29, N = 10).
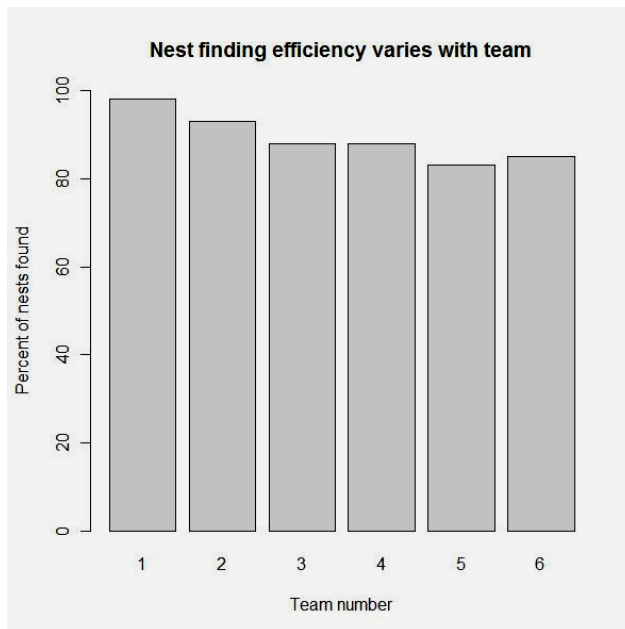

Fig. 2. The percentage of nests found by teams varied with their experience levels. Teams were numbered according to their experience level, with Team 1 being the most experienced and Team 6 being the least. Team 1 found significantly more nests than any other team (98%; P < .05). Team 5 found the fewest nests (83%).
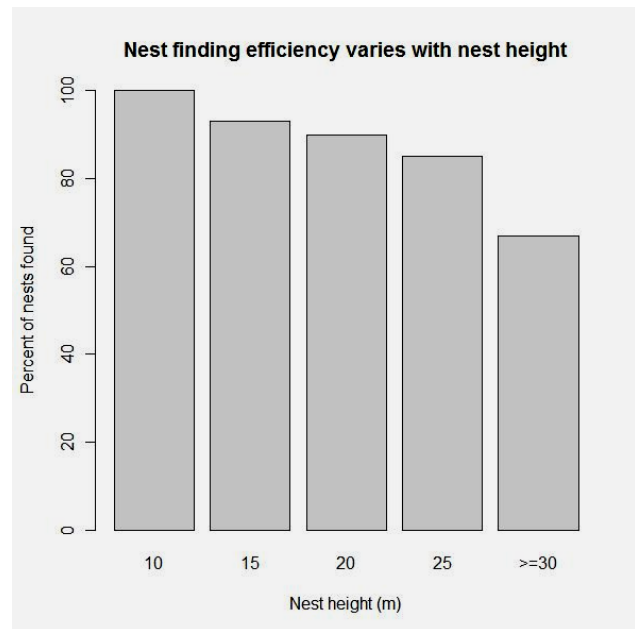

Fig. 3. Nests lower in the canopy were significantly easier to find than nests further from the ground (P < .001). While 100% of the nests at 10 meters were found, only 67% of the nests at 30 meters or higher were found.

Orangutan density

The model with the lowest AIC value was a half-normal model with a cosine expansion. Orangutan density estimates varied from 5.24 – 6.32 orangutans/km^2 (median = 6.26, Table 2). The teams' experience level and orangutan density were significantly correlated, with less experienced teams estimating lower densities (Spearman correlation r = -0.93, P = 0.008, N=6).

As an alternative to truncating at the largest 10% of the perpendicular distances, we examined what densities were if only the nests within 10m from the transect were included. Team 1-5 found the same number of nests within 10m (N = 44) and using only those nests results in a density of 5.33 orangutans/km^2. Team six observed 43 nests within 10m, which results in a density of 5.23 orangutans/km^2.
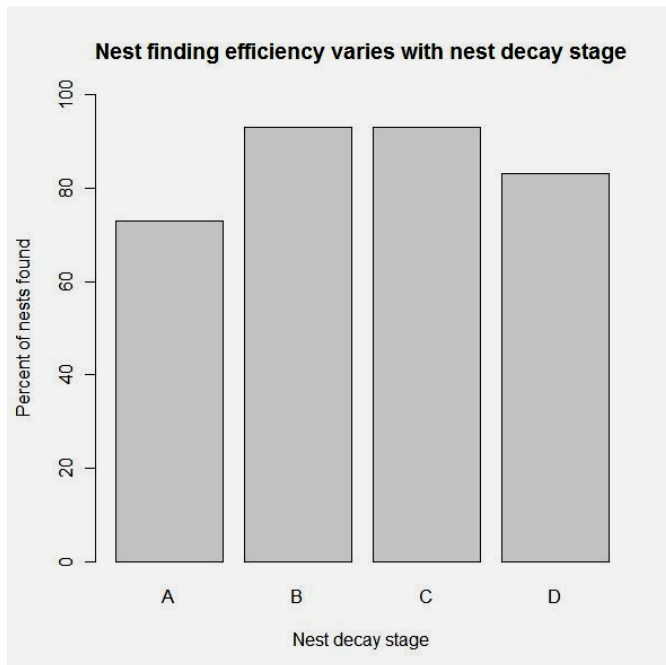
Fig. 4. Decay stage had an important impact on the ability of teams to find a nest. Nests in Stage A were significantly more difficult to find than nests in Stages B or C (P < .02) while Stage D nests were intermediate between those in detectability.
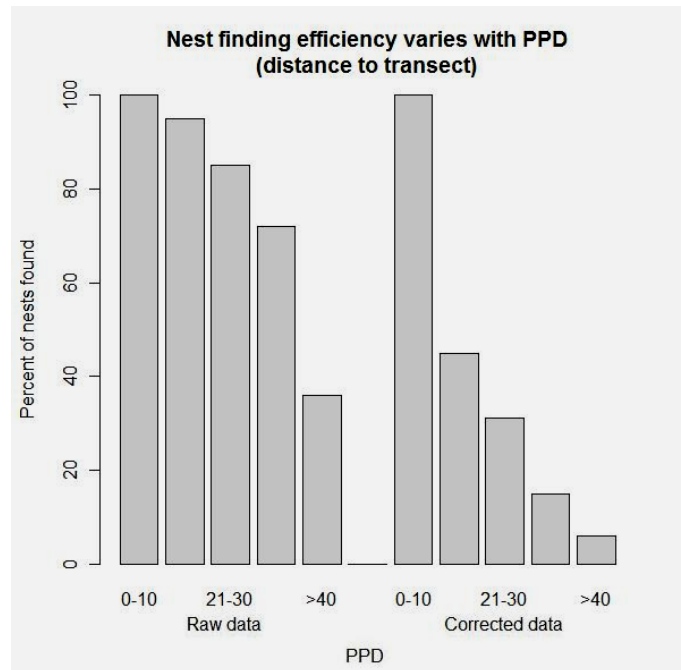
Fig.5. Nests further from the transect were significantly more difficult to find than nests nearer to the transect (P < .001). From the raw data, nests gradually became more difficult to find as their location from the transect increased. The corrected data, which corrects for nests missed by all teams, demonstrates a sharp drop-off in nest detectability after 10 meters.

Discussion

For many questions concerning a species' ecology and conservation management, it is relevant to obtain accurate density and abundance data. For several species, such as the great apes, indirect observations of their presence have been preferred to estimate density and abundance above direct observations because of their low density (Fig. 6). Because not all nests can be detected along transects, methods that rely on indirect observations need modeling to determine density estimates. Here we examined which factors influence the detection probability of orangutan nests along a transect in a Sumatran rainforest. All variables (experience of survey team, perpendicular distance, decay class, and height) examined in this study significantly affected a team's ability to find orangutan nests on survey.

The results of this study therefore corroborate an earlier study by van Schaik et al. [9] that indicated that sampling team experience influences nest detection. In addition, this study supports the suggestion (based on aerial surveys) of Ancrenaz et al. [16] that nests in decay class 1 and 4 might have a lower detection probability then 2 and 3. Nests in decay class 1 still carry green leaves, which therefore blend in more with the overall green background in the tree canopy and tend to be missed more often than nests in decay class 2 and 3 which contain mostly brown leaves. Nests in decay class 4 do not contain leaves anymore and this remaining

skeleton of branches also can be hard to detect as indicated by the results of this study. That nest height influences detection is no surprise as observers are on the ground and nests that are high are therefore further away from them and, in many cases, behind additional foliage or branches in the canopy.

Table 2. Results of DISTANCE model

Team	Orangutan density (ind/km^2)	LCL	UCL	f(0)	p	ESW
Team 1	6.32	4.84	8.24	0.061	0.479	16.27
Team 2	6.27	4.74	8.28	0.066	0.477	15.25
Team 3	6.26	4.72	8.29	0.068	0.475	14.71
Team 4	6.26	4.72	8.27	0.068	0.475	14.71
Team 5	5.24	4.36	6.32	0.059	0.624	16.84
Team 6	6.1	4.5	8.27	0.068	0.524	14.69

Note: LCL and UCL are the lower and upper 95% confidence limits for orangutan density, f(0) is the probability density function evaluated at distance zero, p is the detection probability, and ESW is the effective strip width.

Although models of detection probability can deal fairly well with the reduction of nest detection probability with increasing perpendicular distance [1], it is interesting to examine this more closely. Assuming the transect in this study was placed randomly with respect to orangutan nests, there was a sharp drop in nest detection after only 10 meters. Nests even just beyond 10m were found less than half the time by every team. This suggests that surveyors may want to greatly restrict transect width in their studies to obtain proper density estimates, as nests further than about 10 meters from the transect are unlikely to add much useful information. The teams' orangutan density estimates vary substantially when all nests (with the largest 10% truncated) are included, with the lowest density estimate being approximately 83% of the highest estimate. Despite the truncation, orangutan density also showed a significant positive correlation with experience. When only nests up to 10m are included, density estimates are similar for team 1-5 (5.33 orangutans/km^2) and only slightly lower for team 6 (5.23 orangutans/km^2). Thus restricting transect width to 10 meters largely diminishes the importance of all the other factors despite the nests being at all heights and decay stages and the survey teams having vastly different levels of experience.

While the results of this study indicate that no variable can be disregarded as unimportant in determining nest detection, it also allows for more flexibility in making trade-offs between variables by those conducting these surveys. For example, restricting the transect width could have effects similar to using much more experienced sampling teams, and the surveys may, in some circumstances, be much easier to do. Indeed, if nest detection drops as much with increasing distance in other studies as in this one, including the nests found more than than 10 meters from the transect adds almost no useful information to the density estimate, while creating the possibility for significant estimation error if the form of the detection probability

function is not accurate. However, before there can be a firm set of recommendations the results of this study need to corroborated in other forest types such as peat swamps to determine if similar results will be found.

Since for other great-ape species density is often determined by using nest counts, we also recommend that researchers on those species assess whether using short cut-off distances can lead to density estimates that show less variation between teams.
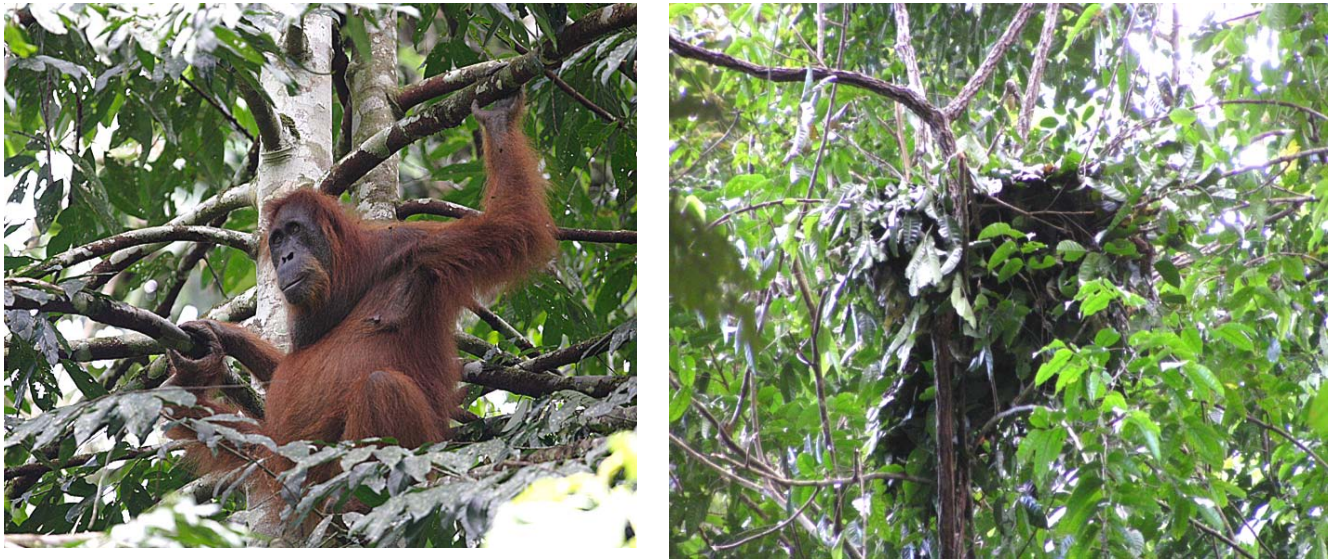

Fig. 6. A) Orangutan female in the Ketambe study area. B) Orangutan nest in the Ketambe study area. Photo (A) by Perry van Duijnhoven, (B) by Serge Wich.

Implications for conservation

Great-ape conservation needs density estimates that are reliable irrespective of the experience of survey teams. The results of this study have important applications for conservation because they indicate how experience-related variation between survey teams can be reduced and thus lead to more easily comparable density estimates.

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