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A preliminary assessment of using conservation drones for Sumatran orang-utan (*Pongo abelii*) distribution and density

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Abstract

To conserve biodiversity scientists monitor wildlife populations and their habitats. Current methods have constraints such as the costs of ground or aerial surveys, limited resolution of freely-available satellite images, and expensive high resolution satellite images. Recently researchers started to use unmanned aerial vehicles (aka UAVs or drones) for wildlife and habitat monitoring. Here we tested whether we could detect nests of the critically endangered Sumatran orang-utan on imagery acquired from camera mounted drone to determine distribution and density. Our results show that the distribution of nests compares well between aerial and ground based surveys and that relative density (nest/km) shows a significant correlation between these two survey types. The results also indicate that both methods can be used to detect significant differences in relative density between previously degraded reforested and enriched areas. We conclude that orang-utan nest surveys from drones are a promising survey method to determine distribution and (relative) density of this and perhaps other ape species.

Introduction

A central task of conservation science is the monitoring of species abundance and their habitat. Generally such monitoring is conducted by ground surveys or from small manned airplanes (Buckland *et al.* 1993; Buckland *et al.* 2004). The former are often costly and take considerable effort when areas are large. Aerial surveys have the advantage of being able to cover large areas, but are often very costly, risky due to crashes (Sasse 2003), not always possible due to unavailability of aircraft, and cannot be used for species ranging under thick vegetation.

Habitat monitoring is often undertaken by a combination of ground-truthing and land-cover classification on medium resolution satellite images, which are freely available (Hansen *et al.* 2013). The advantage of this approach is that large areas can be classified, however due to the medium resolution of the imagery not all land-covers can be classified accurately. Differences between logged and unlogged forests for example are very subtle and thus are practically undetectable (Szantoi *et al.* in review). In addition, areas in the tropics often have thick cloud cover which can interfere with obtaining a clear satellite image.

Because of this, conservation workers have recently started to use unmanned aerial vehicles or drones (hereafter drones) for wildlife surveys and habitat monitoring. Drones have been used for a variety of wildlife distribution and density studies ranging from terrestrial to marine species. In addition studies have assessed species in a variety of habitats ranging from savannahs to dense tropical rainforests (Jones, *et al*. 2006; Koski, *et a*l. 2010; Getzin *et al*. 2012; Koh & Wich 2012; Anderson & Gaston 2013; Hodgson *et al.* 2013; Vermeulen *et al.* 2013; Chabot *et al*. 2014).

In this paper the focus is on preliminary data that were gathered to assess the usefulness of drones in determining Sumatran orang-utan distribution and density. Sumatran orang-utans are a critically endangered great ape species that has seen a huge decline over the past decades as a result of habitat loss and degradation (van Schaik *et al*. 2001; Wich *et al.* 2008; Wich *et al.* 2011; Wich *et al.* 2012). Traditionally orang-utan distribution and density are assessed by conducting linear transects and counting their nests along the transect (van Schaik, Priatna & Priatna 1995; Buij *et al.* 2003). On average an adult Sumatran orang-utan builds a nest between 1.7-1.9 times a day, for resting during midday and at night. These nests can be constructed at different positions in a tree such as on top of the canopy, inside the canopy close to the trunk, and atop a large branch (Buij *et al*. 2003). The ground based nest survey method is expensive and time-consuming due to the relatively large areas that orang-utans range through, as well as the difficulty of traversing the often mountainous or swamp terrain in which they occur. Studies have shown that human observers can detect orang-utan nests from manned helicopters (Ancrenaz *et al.* 2005), and that birds nests can be observed from drones (Mulero-Pázmány *et al*. 2014). However such aerial surveys require the cost and availability of a professional pilot, aircraft, and flight infrastructure, and are not without risk of catastrophe. Therefore we aimed to determine whether these same surveys could be derived from images acquired from a camera mounted drone, at a much lesser cost and risk of serious accident.

Methods

This study was conducted in October and November 2013 in the Leuser Ecosystem, North Sumatra, Indonesia (Fig 1). The research area consists of a formerly illegally cleared area that had been planted with oil palm by two local plantation companies, which has been in the process of assisted reforestation since 2008. The region to the south of the formerly cleared area consists of national park forest that has been illegally selectively logged (Fig 2).

Ground surveys

To determine orang-utan distribution and relative density, 16 transects were randomly planned in the area using the design function in Distance 6.2 (Thomas et al. 2010). Transects had varying lengths with a mean of 0.8km (sd = 0.5). Along each transect, two experienced observers walked slowly and recorded the perpendicular distances of all identified nests from the transect line (Fig 3). Perpendicular distances were measured with a rangefinder or measuring tape. In addition the height of the nest was estimated to the nearest meter, the circumference of the tree at breast height (cm) was measured with a measuring tape, and a botanist (RA) identified nesting trees to the species or genus level. For comparisons between the regenerated forests of different ages, transects were split into 5 for the area planted in 2008, 6 for 2009, 2 for 2010, 4 for 2011, 11 for 2013, and 8 transects in the slightly less degraded area that only underwent enrichment planting (~400 seedlings planted per hectare instead of ~1,100+).

Aerial surveys

We flew over the ground transects with a Skywalker 2013 drone that used an HK 2.7 autopilot. For ground control software we used Mission Planner software (http://planner.ardupilot.com/) on a standard Windows-based laptop. Two types of missions were conducted: nest transects and mapping. For the transect missions the exact same coordinates of the ground transects were used to program the mission waypoints. We flew two missions to cover all nests along the transects, at an altitude of 80m above ground level (agl). For the mapping missions, we flew a lawnmower pattern mission over the whole study area at an altitude of 150m agl.

The drone was equipped with a top forward facing Canon S100 camera, with a Canon Hack Development Kit (CHDK: http://chdk.wikia.com/wiki/CHDK) firmware enhancement. The CHDK package allows for additional functionality, with in this case the primary use being a script that allows for images to be taken automatically at 2 second intervals. Images were obtained without using the zoom function of the camera.

Orthomosaic

The internal GPS of the camera was used to geotag the images. A total of 2,238 images were used to produce a 5.22 km^2 orthomosaic, with a ground resolution of

5.36cm/pixel. The orthomosaic was produced with Pix4Dmapper software (https://pix4d.com/).

Nest detection

Two observers manually examined the aerial transect images for nests (Fig 3), with subsequently the location each determined on the compiled orthomosaic. In order to compare the relative density of nests from the aerial and ground based surveys, we only included those from the air that were within the maximum perpendicular distance at which nests were able to be seen on the ground (25m).

Data analyses

The data were not normally distributed, thus non-parametric analyses were applied. All analyses were conducted in R and ArcGIS ArcMap. Medians and 25th and 75th percentiles are presented where applicable. For analyses comparing the nest densities between areas, the transects that covered more than one area were split into sub-transects so that that each was comprised of the same classification. Therefore, the sample size on those tests is larger than the initial number of transects. The Kernel Density Estimation (KDE) tool within the Spatial Analysis extension for ArcMap was used to determine areas of detected nest concentration. Kruskall-Wallis post-hoc comparisons were adjusted using the Dunn-Sidak procedure (Dunn 1964).

Results

The number of nests observed along transects during ground surveys varied from 0/km to 36.7/km (median = 11.5/km; 0, 11.68; n = 16). The aerial surveys also yielded a highly variable number of nests, ranging from 0/km to 10.7/km (median = 0.5/km; 0, 1.63; n = 16). As expected the number of nests observed per kilometre surveyed was significantly higher in ground than aerial surveys (Wilcoxon-signed rank test: v = 36; $p = 0.014$; n = 16), with the overall number detected from the air being just 17.4% of the nests found during the ground surveys. The number of nests per kilometre surveyed showed a significant correlation between ground and aerial surveys (Spearman's rho = 0.89; $p < 0.0001$; n = 16). A preliminary comparison of factors that might influence detectability of the nests from the air showed that the mean tree circumference for nesting trees for which the nest was only observed during ground surveys was 69.2cm (sd = 10.9, n = 84) and was 70.0cm (sd = 18.5, n = 9) for nesting trees in which nests were observed on the aerial images. Nest height was 10.3m (sd = 2.8) and 10.2m (sd = 3.1) respectively. Of the total number of nests observed on aerial images for which tree species was determined 55.5% occurred in pioneer species from the genus *Macaranga* and *Mallotus*. Of nests that were only observed from the ground this percentage was 38.0.

The number of ground nests/km varied significantly between the different areas (Kruskall-Wallis test: $X^2 = 14.50$, df = 5, $p = 0.013$, Fig 4). Post-hoc tests showed that the number of nests/km is significantly higher in the enriched area than the sector replanted in 2008 ($p = 0.04$). A similar significant pattern was found for aerial nests/km (Kruskall-Wallis test: $X^2 = 23.89$, df = 5, $p < 0.001$). Here post-hoc tests again showed that the enriched area had significantly more nests than the area reforested in 2008 ($p = 0.008$), but also more than in the area reforested later in 2011 ($p = 0.04$) and 2013 ($p < 0.001$).

We calculated Kernel distributions for both the ground and aerial nests to obtain an impression of the areas where most nests were found, and how they compared between the ground and aerial surveys. Although no formal comparison of the distributions was attempted, Figure 5 shows that the distributions are similar.

Discussion

This preliminary study shows that orang-utan nests can be detected from the air using a small drone mounted with a standard consumer-grade camera. Although the number of nests/km were significantly higher for the ground than the aerial surveys, results show that the number of nests observed during each survey type is significantly correlated. In general, both survey methods detected more nests in the area that were degraded but not fully cleared, and thus only underwent enrichment planting, than in the other areas that were fully replanted with indigenous forest tree species. Although no formal testing was conducted, the nest distributions of ground and aerial nests seem comparable. Although it is not known yet which factors influence whether a nest will be observed on aerial images or not mean tree circumference and nest height seemed similar between nests that were observed from the air compared to those only observed from the ground. Although no formal statistical comparison was feasible, the percentage of nests in pioneer species seemed a factor that might be of influence because the percentage of nests in pioneer species was 55.5% for nests observed on aerial images compared to 38.0% of nests that were only observed from the ground. Because the canopy in areas with more pioneer species seemed more open it could be that canopy openness influences nest detectability. This hypothesis is supported by a study on chimpanzee nests found that canopy openness was the most important factor determining nest detectability (van Andel *et al*. 2015).

The current study provides evidence that orang-utan nests can be detected from still images obtained from a drone. During aerial surveys with manned aircraft it was possible to correlate aerial nest data to ground nest survey data and derive orang-utan densities from those (Ancrenaz *et al.* 2005). We have not yet tested this for orang-utans, but the fact that the number of nests/km did correlate significantly between ground and aerial surveys indicates that the latter for orang-utan nests from drones might also allow for such estimates. Caution is needed here though, as the number of nests detected per transect during the drone survey was much lower than those from the ground survey. It could potentially be that drone surveys lead to a higher number of transects with zero nests than do ground surveys, which could influence density estimates in a way that is difficult to correct for. We detected nests in the aerial surveys from all but one of the ground transects, with the exception being a transect where only one nest was observed on the ground survey, so potentially this is not a concern. More comparative studies are needed to determine whether transects with low nest numbers in ground surveys also yield few detected nests from the air.

The nest density distribution maps showed similarity in distribution between the ground and aerial nest densities. Future studies are currently underway to assess in detail whether orang-utan nest density can be directly derived from aerial images obtained from a drone.

These results corroborate recent findings from another study that used drones to detect chimpanzee (*Pan troglodytes*) nests (van Andel *et al.* 2015). Because in some chimpanzee populations there are a varying proportion of nests built on the ground (Koops *et al.* 2007), estimating density is potentially challenging and needs to incorporate location specific parameters. These findings suggest that drones can also be used to determine the distribution and potentially the density of other great apes.

The overall effectiveness of using drones for great ape surveys and in general for wildlife survey work, depends on whether the large number of still images need to be assessed manually for the presence of nests, or whether this can be done via computer vision algorithms that detect nests automatically. An early pilot on this for orang-utan nests shows promising results (Chen *et al.* 2014), but more research needs to be conducted to develop a user-friendly method that can detect ape nests.

An important next step is to carefully evaluate the full costs of using drones for aerial surveys compared to ground surveys. Such comparisons need to not only take into account the cost of equipment, but also the necessary time for training to operate and maintain the drone system, as well as in analysing data. Such comparisons are however necessary for wildlife surveys in general (Vermeulen *et al.* 2013).

In conclusion, using drones for orang-utan nest detection seems feasible to determine their distribution and relative density in the three land covers assessed; but more studies need to be conducted to determine their applicability for estimating orang-utan density.

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Figure legends

Fig 1: Map that shows the location of the restoration site in Sumatra. The forest layer was produced by WWF.

Fig 2: Orthomosaic of the study area. The orthomosaic was processed with Pix4Dmapper by Pix4D.

Fig 3: Photo of nests as observed from the ground (left) and from the air (right)

Fig 4: Box plots showing the ground (a) and aerial (b) nest density for the different areas. Refor = fully reforested area, Enrich = Enrichment planted area. Note: the scales are different in the two plots and the overall density from the drone photographs is 1/6 of the ground counts.

Fig 5: Maps showing the Kernel nest densities for the nests observed from the ground (a) and from the air (b).

Figure 1

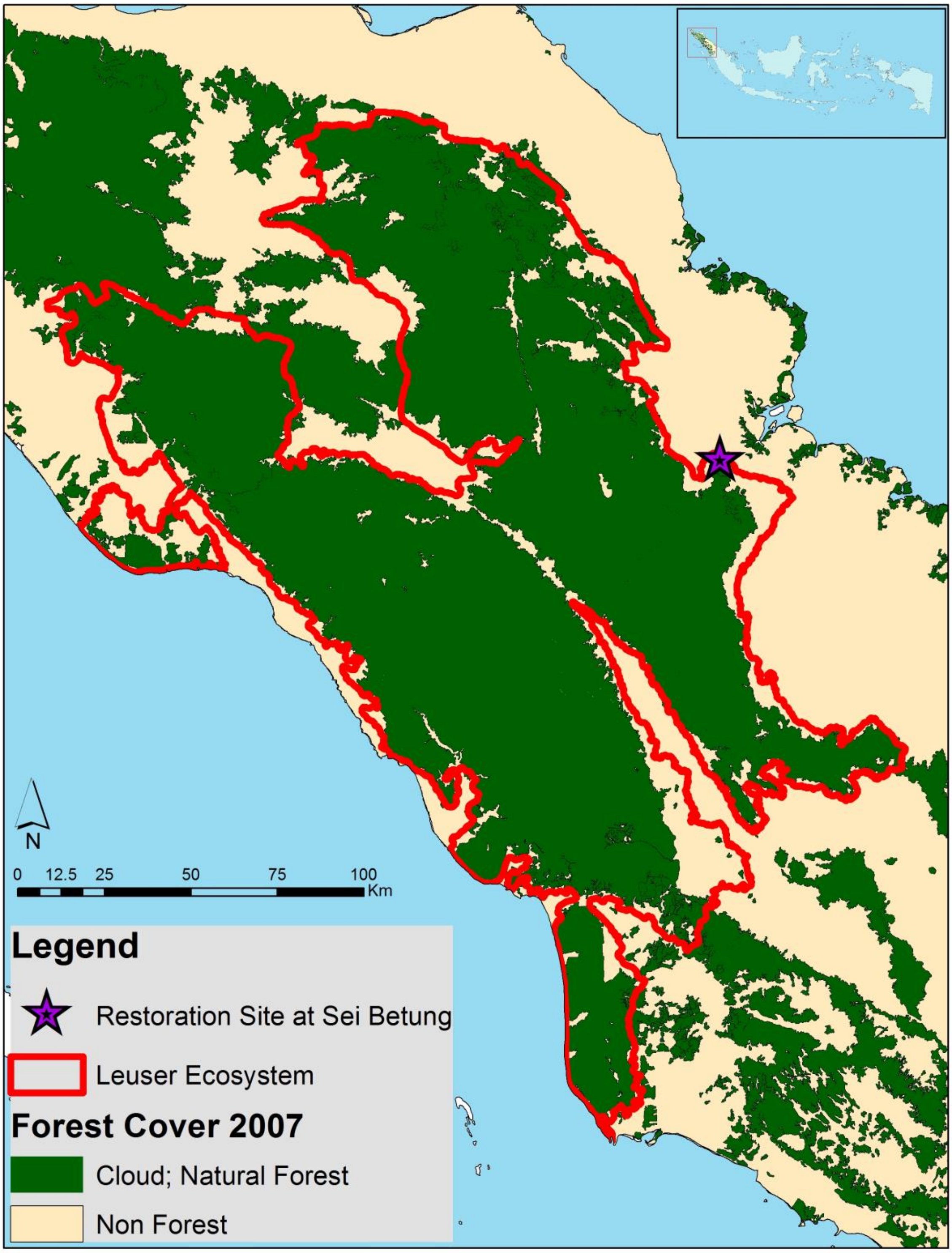

N
0 12.5 25 50 75 100
Km
Legend
Restoration Site at Sei Betung
Leuser Ecosystem
Forest Cover 2007
Cloud; Natural Forest
Non Forest

Figure 2

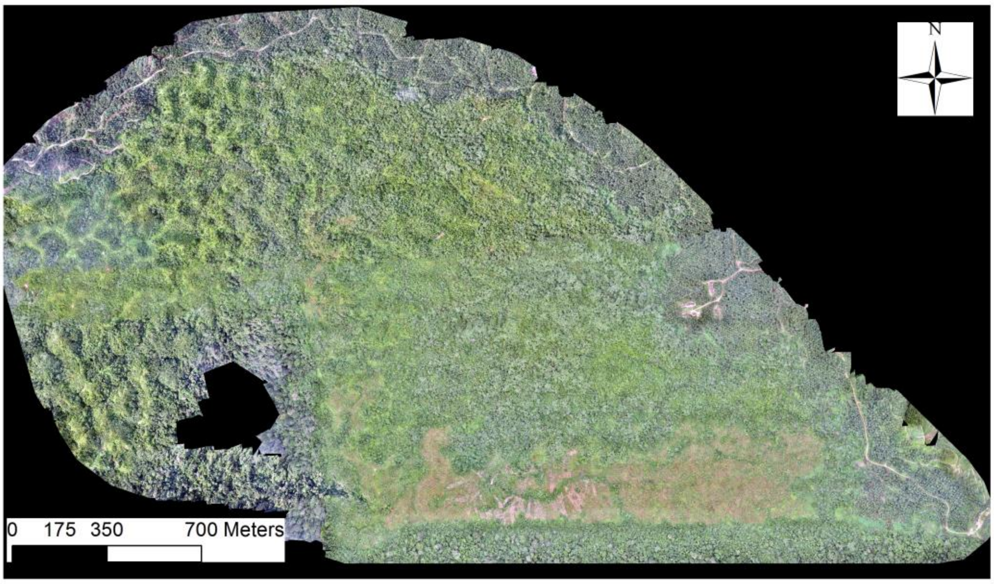
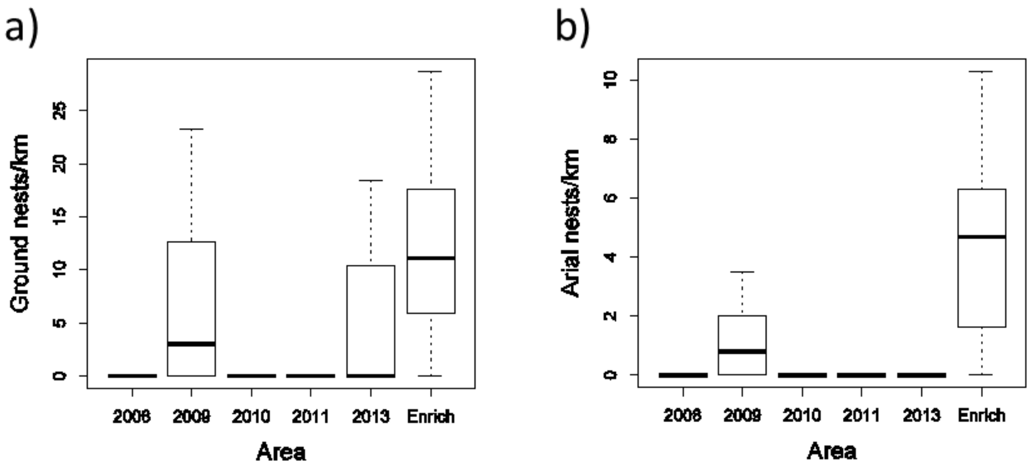


Figure 3

Figure 4



a)
Ground nests/km
0
5
10
15
20
25
2006
2009
2010
2011
2013
Enrich
Area
b)
Arial nests/km
0
2
4
6
8
10
2006
2009
2010
2011
2013
Enrich
Area

Figure 5