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ORIGINAL ARTICLE

Density and population estimate of gibbons (*Hylobates albibarbis*) in the Sabangau catchment, Central Kalimantan, Indonesia

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Abstract We demonstrate that although auditory sampling is a useful tool, this method alone will not provide a truly accurate indication of population size, density and distribution of gibbons in an area. If auditory sampling alone is employed, we show that data collection must take place over a sufficient period to account for variation in calling patterns across seasons. The population of *Hylobates albibarbis* in the Sabangau catchment, Central Kalimantan, Indonesia, was surveyed from July to December 2005 using methods established previously. In addition, auditory sampling was complemented by detailed behavioural data on six habituated groups within the study area. Here we compare results from this study to those of a 1-month study conducted in 2004. The total population of the Sabangau catchment is estimated to be about in the tens of thousands, though numbers, distribution and density for the different forest subtypes vary considerably. We propose that future density surveys of gibbons must include data from all forest subtypes where gibbons are found and that extrapolating from one forest subtype is likely to yield inaccurate density and population estimates. We also propose that auditory census be carried out by using at least three listening posts (LP) in order to increase the area sampled and the chances of hearing groups. Our results suggest that the Sabangau catchment contains one of the largest remaining contiguous populations of Bornean agile gibbon.

Keywords Bornean agile gibbon · Population density · Quadrangulation sampling · Sabangau catchment · Peat-swamp forest

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Introduction

Gibbon numbers have been in dramatic decline over the past 30–40 years, primarily due to habitat destruction and fragmentation through timber felling, charcoal burning, encroachment cultivation, general bush burning for hunting (Bodmer et al. 1991), rubber plantations (Haimoff et al. 1987) and tea and pine plantations (Nijman and van Balen 1998). Other factors contributing to their demise include the illegal wildlife trade (which involves capturing infant gibbons by shooting the mother), the use of their body parts in the manufacture of traditional medicines, and poaching for sale as pets or to bar owners for tourist attractions (personal observation). The forest fires of 1997–1998 also devastated a large part of the gibbons' distribution in Sumatra and Borneo: it is estimated that 4 million hectares of land, comprising various different vegetation types, were destroyed by these fires (IFFM 1998). Current knowledge of gibbon distribution, population size and conservation status is incomplete. Long-term conservation strategies for all species and subspecies of gibbon are urgently required, as is identification of all viable populations.

Recently, it has been shown that the Sabangau peat-swamp forest (5,300 km^2), Central Kalimantan, is home to the world's largest orangutan population, estimated at 6,910 individuals in 2003 (Morrogh-Bernard et al. 2003; Husson et al. 2007). The Sabangau catchment is the largest contiguous area of land in the historical range of *Hylobates agilis albibarbis*, but a pilot study in 2003 revealed that gibbons in this area were living at much lower densities than in areas of pristine forest (Cheyne 2007). Thus, a detailed survey of gibbon density, distribution and population demography is vital to determine the importance of this area for gibbon conservation.

The Sabangau catchment is characterised by deep peatland and low elevation. The area is flooded for 8 months of the year, and there are very few hill ridges from which gibbons can sing. The apes are threatened by illegal logging, hunting for the pet trade and habitat conversion throughout the catchment. In terms of habitat type and topography, our study areas are representative of the rest of the catchment, though these threats are less at the Natural Laboratory of Peat Swamp Forest (NLPSF) where the bulk of this study was conducted. The Sabangau catchment comprises three different forest types: mixed swamp forest (MSF), low pole forest (LPF) and tall interior forest (TIF). Only the MSF has been surveyed for gibbons, by Buckley et al. (2006), who estimated the gibbon population in this forest type at about 19,000. The MSF occupies only 40% of the total area of the Sabangau forest (Husson et al. 2007). Thus, extrapolation from this subtype is likely to give inaccurate numbers without conducting surveys in these other forest types.

Gibbon singing can be affected by many factors, including weather, human disturbance and topography of the area (Cheyne et al. 2007; Cheyne 2007). Thus, each location must be surveyed as thoroughly as possible, primarily by quadrangulation of calls using three listening posts (LPs), but sightings are also of great importance. This study involved intensive auditory sampling in all three forest subtypes of the Sabangau catchment. In addition, we note distinct differences in home-range size, group size and distribution between the Sabangau area and pristine forests, highlighting the unique nature and conservation importance of this population of gibbons.

Methods

Site location

Within the NLPSF research area (Fig. 1), three principal peat-swamp forest subtypes have been identified: a relatively diverse MSF found at the perimeter of the dome, a lower-canopy, species-poor LPF near the centre of the swamp and, unique to the Sabangau, a species-rich TIF, at the watershed of the peat dome (Page et al. 1999). This study was carried out in all three major forest subtypes. The area was a logging concession prior to the establishment of the research site, with the majority of the disturbance occurring in the more accessible MSF. Although gibbons can tolerate some disturbance (Chivers 1977; Johns 1989), it is likely that logging and fires have caused the MSF habitat to become more fragmented.

Proportion of groups calling for each set of LPs

Calling is density dependent, with groups calling less at lower densities (Brockelman et al. 1974; Chivers 1974; Nijman 2004), sometimes not singing for days despite favourable weather conditions (Cheyne et al. 2007; Cheyne 2007). For this reason, researchers in disturbed/secondary forest must ensure that they census each area long enough to hear all groups in the vicinity. In order to estimate the minimum number of days required for censusing a particular sample area, Brockelman and Ali (1987) and Brockelman and Srikosamatara (1993) found that the total number of groups heard stabilises after 4 days (assuming no adverse weather conditions to affect groups singing). In our study, the census area in MSF was surveyed for 10 days and the LPF and TIF were for 6 days each (3 days in August and December 2005, respectively). Proportion of groups calling [as heard from each set of LPs (Fig. 2) once the data from all study days were combined] was calculated using the formula devised by Brockelman and Srikosamatara (1993), with the assumption that singing on successive days is independent. Thus, the cumulative number of groups singing in m -days is

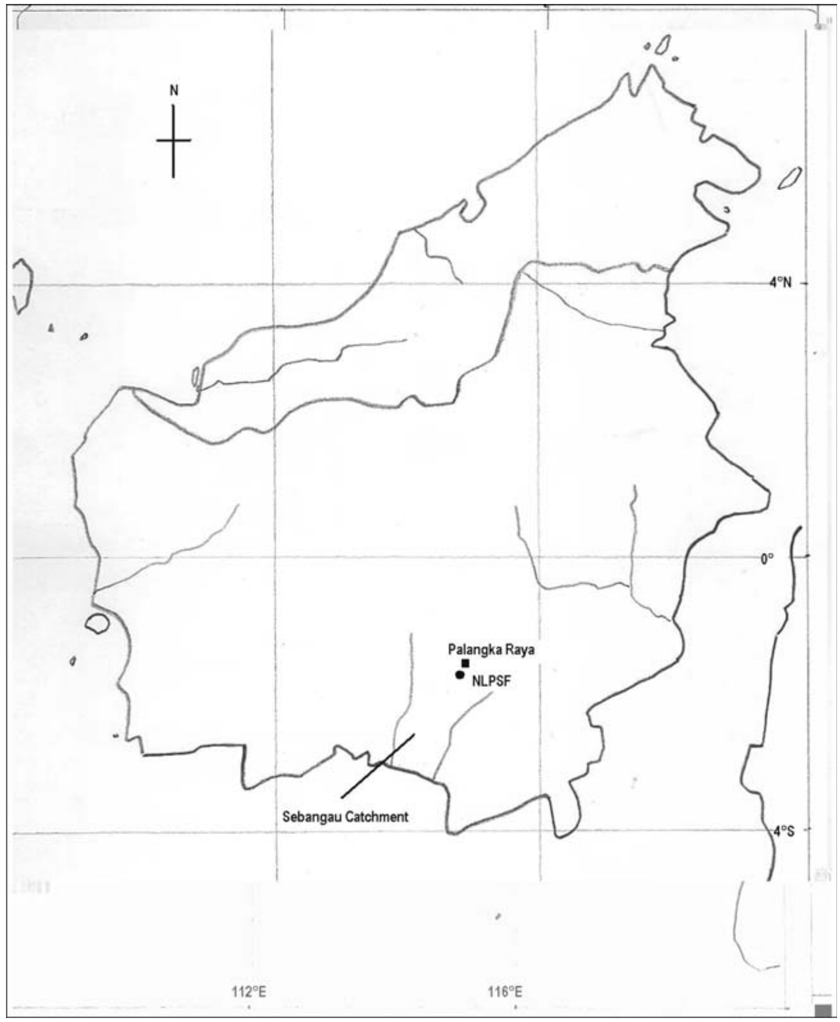
$$p(m) = 1 - [1 - p(1)]^m$$

The proportion of groups calling reached 1.0 for MSF and TIF after 5 days. Average probabilities of one group calling on a given day varied between forest types (Table 1).

Mapping

In total, 15 separate LPs were used in five sets of three 300- to 500-m apart (Brockelman and Srikosamatara 1993), and

Fig. 1 Location of the research area within the Sabangau catchment



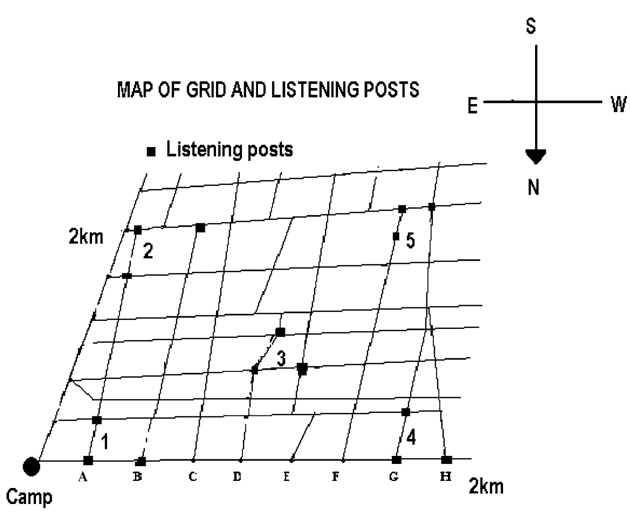


Fig. 2 Map of the grid system with the five groups of listening posts (LPs) marked

sets were surveyed in two blocks of 5 days. Researchers (two per post) independently estimated distance and compass bearing to the gibbon group and compared results. Results from each LP set were mapped daily and weekly. Using Excel 2003, LPs could be accurately plotted, and all recorded gibbon groups from each post could be plotted relative to where the data were recorded. Distance and bearing were converted to *x* and *y* coordinates to produce the map. This method allows accurate maps to be produced, which can be compared to hand-drawn maps. As the area is flat and we have accurate maps of the area and all the listening posts, we believe that the Excel programme is a helpful tool. The main sources of error in quadrangulation arise from determining the listening area and hearing groups from only one LP. These problems are commoner in hilly terrain, and we feel that the flat terrain in this study site allows us to predict the listening area with reasonable certainty.

The final map for each forest subtype was used to estimate the number of gibbon groups in the effective listening area. The use of data from three simultaneous LPs, rather than one or two, permits census of a larger listening area and allows better location of groups. Following (Brockelman and Ali 1987; Brockelman and Srikosamatara 1993;

Table 1 Average proportion of groups singing for mixed swamp forest and tall interior forest subtypes (only one group was heard in the low pole forest, so data are not included)

Forest subtype	Number of days	Number of groups	Number of simultaneous listening posts	Average proportion of groups calling per day in total study period	Day 1	After 5 days
Mixed swamp forest	50	12	3	0.67	0.60	1.00
Tall interior forest	6	5	3	0.77	0.73	1.00

O'Brien et al. 2004) points mapped more than 500 m apart were considered to be different groups. This figure is based on the approximate diameter of a group's range and determines the maximum distance that agile gibbons might move between calls (O'Brien et al. 2004). The songs of lone gibbons were excluded. We aimed to construct a map of known territories from the quadrangulation data in order to assist with the habituation and identification of individual groups. Thus, only data were used when a duet was heard, as the duet indicates a mated pair engaged in territorial defense and, therefore, inhabiting an exclusive home range (Raemaekers and Raemaekers 1984; Mitani 1985).

Group sightings

Since July 2005, Cheyne has been searching for, and following, gibbon groups in order to habituate them for behavioural studies. There are six habituated gibbon groups in the MSF that can now be followed from sleeping tree to sleeping tree and are expressing normal behaviour. Habituation of more gibbon groups is in progress. Estimates of number of animals/group are based on sightings within the 2-km^2 grid system where the MSF study was conducted. In addition, transect walks were conducted in areas where the gibbons were not habituated to obtain group numbers.

Home-ranging size

Using GIS maps of all sightings of all the groups, the average home-range size was calculated. Maps were created, using a GIS map of the entire study area, on which group sightings were overlaid. Polygons were then created to estimate home range size for each group, and an average area was obtained using data from the 12 groups in the study area. The GIS programme Arc View GIS version 3 was used.

Density from quadrangulation

Density estimates of gibbons were obtained using the following formula (Brockelman and Srikosamatara 1993):

$$D = \frac{n}{E}$$

where D is density, n the cumulative total number of groups heard in the listening area and E effective listening area. E is defined as the area in which groups could be heard singing up to 1 km away from two or more listening posts (Brockelman and Ali 1987). Groups had to be heard from at least two listening posts in order to be mapped accurately and included within the listening area. The determination of n was based on six listening days to ensure that all groups present were heard singing. It has been proposed that the proportion of groups singing on any given day should be accounted for in density calculations. If surveyers return to the same listening posts for 5 consecutive days, they are likely to hear all the gibbons within the effective listening area.

Due to time constraints, it was not possible to spend 10 days in the LPF and TIF as was done in the MSF. It is assumed that all groups present called and were heard within 5 days of listening. Singing starting times differed between forest subtypes. For all forest subtypes together, 6% of singing occurred before 0500 hours, 85% during 0500–0730 hours, 7% during 0730–0900 hours and 1% after 0900 hours.

Results

Home-ranging size

Average home-range size for the MSF is calculated as 53 ha [compared with 47 ha reported by Buckley et al. (2006)]. This difference in home-range size is not significant and can be attributed to the fact that they found seven more groups in the study area. There is low degree of overlap of home range in the MSF. Gibbons in the MSF have an average of 15% overlap (based on 252 days of following gibbons where territorial encounters and overlap of tagged feeding trees have been recorded (Cheyne 2007). This low degree of overlap is explained by low density, and there are areas of forest south of base camp where there do not appear to be any gibbon groups defending a home range, which explains the low overlap.

Gibbon duets, sighting and density

The maps were compiled based on duets heard and from sightings (transect walks) of gibbon groups (Table 2). In this area, six habituated groups, one lone male and six additional groups were sighted (12 groups). In addition, encounters with gibbon groups prior to habituation were used (data from November 2004–June 2005). We obtained a mean group size of 4.05, whereas Buckley et al. (2006) reported a mean group size of 3.4, although they recognise that individuals may have been missed, as the gibbons were unhabituated at the time of their study.

Lone animals (whose singing is not very predictable) were not included in the quadrangulation analysis, but lone animals sighted by gibbon behaviour teams were included in density calculations. Such animals appeared to be encountered mostly in areas not occupied by mated pairs, where they are more likely to find mates and set up new territories. A conservative estimate of one lone animal for ten mated individuals would boost the population estimate. Such animals are not breeding, nor are nondispersed offspring, but we believe that they should be included in overall population estimates.

During 6 days in the LIF, gibbons were heard to sing only once and were encountered once while not singing. These are sparse data on which to base density estimates, and more surveys are clearly needed to determine whether this forest type supports resident groups year round or only during times when food is available.

Discussion

Mapping of duets and information on group size from habituated groups and sightings during systematic searching through the study areas were combined. From this study, we conclude that the quadrangulation of gibbon duets is the best method for estimating gibbon density, especially in areas where the animals are not habituated, as actual sightings of animals are not necessary. In areas where gibbons are habituated (as in the MSF), visual observations substantially boost the accuracy of density estimates from quadrangulation mapping.

Although lone gibbons may be included in range mapping and line transects, they are not included in duet quadrangulation studies. We recognise that exclusion of lone gibbons will affect our population estimate. Widowed females have been found to solo sing with high frequency in *H. pileatus* (Brockelman and Srikosamatara 1984) and *H. lar* (Caldecott and Haimoff 1983). The most accurate study on lone (nonterritorial adult) gibbons is that of Cowlishaw (1992), who estimated a density of one population of *H. albibarbis* in west Kalimantan to be 0.33

Table 2 Density estimates for all forest types and total number for the catchment

Location	Size of listening area (based on number of simultaneous LPs) km^2	Dates of data collection (n = number of study days in each forest subtype)	Number of duet bouts recorded	Number of groups heard in the study area	Groups km^{-2} (density)	Home range (ha)	Average number of gibbons/group (sightings)	Gibbons/km^{-2}
Mixed swamp forest	4.62 (3)	June–September 2005 (n = 50)	210	12	2.59	53	4.05	10.38
Low pole[a]	1.54 (1)	August and December 2005 (n = 6)	48	1 (visual sighting)	NA	NA	3	NA
Tall pole[a]	3.08 (3)	August and December 2005 (n = 6)	48	5	NA	NA	4.14	NA
Totals			260	18				

LPs listening posts, *NA* not available

[a] For the low pole forest and the tall interior forest, the numbers of groups heard and sighted were too small to estimate numbers of animals, groups or density

individuals km^{-2} for a group density of 3.3 groups km^{-2} (5% of the mated adult population). Given the low group density in Sabangau (2.59 groups km^{-2}), it is reasonable to assume, based on Cowlishaw's (1992) data, that the lone gibbon density will also be low. An approximate estimate, based on lone animal numbers being 10% of the mated adult population, would give a lone gibbon density for Sabangau of 0.518 individuals km^{-2}. Thus, including lone gibbons in the density estimate will add more than 2,000 individuals to the total number of wild gibbons in this area.

Density estimates

Brockelman and Srikosamatara (1993) consider a density of less than two groups km^{-2} as low, and the estimates from MSF and LPF are below this number. Whereas density in the MSF does exceed this number (and in the TIF also), it is reasonable to assume that not all areas of the MSF or TIF can support gibbons. Both areas have undergone extensive disturbance (legal and illegal logging and fire). The LPF is poor-quality habitat, and a low to zero density is to be expected. Habituation of gibbons is vital to obtain accurate group sizes (3.4 for Buckley et al. (2006) and 4.05 for this study). Whereas auditory sampling is useful for obtaining group locations and number of groups in a study area, without accurate group sizes, population numbers are not as reliable. We recognise that relying on only one method of estimating density is problematic (Nijman and Menken 2005), hence the use of sightings and quadrangulation to support our results.

Density estimates for the Sabangau catchment

Due to the very different forest subtypes in this study, each area must be addressed separately. Calling probability and singing behaviour are different in each forest subtype and cannot be combined to give an accurate estimate of gibbon numbers. TIF supports the highest diversity of plants and animals in the catchment (Page et al. 1999) and the highest density of orangutan (Husson et al. 2007). Gibbons are frequently heard and seen there (SMC, personal observation). Thus, gibbon density in this forest subtype is expected to be higher than that recorded in MSF. LPF, by contrast, has a much lower species diversity and orangutan density than MSF (Page et al. 1999; Morrogh-Bernard et al. 2003; Husson et al. 2007), and gibbons are very rarely heard calling there. Buckley et al. (2006) assumed a density of zero for LPF, which we have found to be inaccurate. Gibbons sang infrequently in the LPF, but duets were heard and one individual was seen. We recommend a minimum of three LPs per set for quadrangulation to cover a larger effective listening area, and that 5 days is sufficient to hear all groups in the effective listening area.

We estimate that the total gibbon population in the Sabangau will be higher than the 25,000 individuals proposed by Buckley et al. (2006). The effective listening area refers to the area in which at least two of the three teams could hear duets up to 1 km away (Brockelman and Ali 1987). Gibbons in the Sabangau can be heard up to 1 km from the LPs (Cheyne 2007). The effective listening area will be affected by the terrain in the study area, which is flat here, with elevation changing no more than 1 m over 1 km (Cheyne 2007). Mean group size was obtained through an analysis of all sightings and follows of gibbons (17 groups sighted and identified) and this was used to calculate an individual density.

The area of MSF where this study was carried out is now well protected and logging no longer occurs, so the numbers for this area may be higher than other areas of the MSF. Other areas of the catchment are less well protected and, although the gibbon population estimated from this study is healthy, threats to gibbons have not been addressed. Hunting for the illegal pet trade, fires, logging and forest conversion remain widespread problems. The Sabangau catchment is a unique area with probably the largest orangutan, and one of the largest gibbon, populations in Indonesia. Action must be taken now to safeguard this area and the wildlife: prevention is better than the cure. Whereas ape populations may not be immediately in danger, threats to the habitat have one inevitable outcome: these populations will be seriously threatened in the future unless action is taken now.

The Sabangau catchment is 5,300 km^2 in size and the largest contiguous area within *H. a. albibarbis* range. Given the small size of the study area compared with the catchment, and the three different forest types, it is impossible to offer an accurate population size for the gibbons based on this work. Extrapolation, based on such a small area of the catchment, is likely to be inaccurate [see Buckley et al. (2006)], and using such specific numbers should be avoided without further studies in different parts of the catchment. What we can say with confidence is that the area supports a significant population in the order of tens of thousands of gibbons. Even accounting for higher densities of gibbons in the other main sites (Bukit Baka/Bukit Raya and Tanjung Puting), the vast size of the Sabangau catchment means that it is probably home to the largest population of Bornean agile gibbon in the world. More surveys are needed in different areas of the catchment to explore fully the population size of this important area.

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