

**VEGETATION CORRELATES OF GIBBON DENSITY IN THE
SEBANGAU NATIONAL PARK, CENTRAL KALIMANTAN,**



INDONESIA

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Abstract

Understanding the links between animal populations and the characteristics of their habitat is essential for their conservation. Following recent re-assessments of the conservation status of the Bornean agile gibbon (*Hylobates albibarbis*), the need to conserve the peat-swamp forests of Kalimantan, one of its main habitats, is more pressing than ever. Little information is available on gibbons in peat-swamp forest. The aim of this study was to investigate the relationship between vegetation characteristics and gibbon density in a newly protected, secondary peat-swamp forest in the Sebangau National Park. The study was conducted from 1st May to 28th July 2008, using auditory sampling methods and speed plotting. Gibbon densities and vegetation characteristics were recorded at 13 sites within the Natural Laboratory for the Study of Peat-swamp Forest. Gibbon densities were calculated after the number of groups in each area was determined by plotting all recorded calls on a map. Gibbon densities ranged from 1.39 to 3.92 groups/km², and were found to be correlated with canopy cover at 20m, median tree height, density and biomass of large trees and food availability. These results highlight the importance of large, tall trees and good canopy cover for the gibbon population in the Sebangau forest; they indicate that conservation efforts should be directed to the preservation of those large trees and the prevention of selective logging, which targets them. It is hoped that the results of this survey will contribute to the preservation of both Indonesia's peat-swamp forests and the gibbons that inhabit them.

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LIST OF ABBREVIATIONS

CIMTROP	Centre for the International Management of Tropical Peatlands
CITES	Convention on the International Trade in Endangered Species
DBH	Diameter at Breast Height
IUCN	International Union for the Conservation of Nature
LAHG	Laboratorium Alam Hutan Gambut (natural laboratory for the study of peat-swamp forest)
LPF	Low Pole Forest
MSF	Mixed-Swamp Forest
OUTrop	Orang-Utan Tropical peatland and conservation project
PCA	Principal Component Analysis
PSF	Peat-Swamp Forest
SNP	Sebangau National Park
TIF	Tall Interior Forest
UNPAR	University of Palangka Raya

Chapter I: INTRODUCTION

Surveying primate populations is a vital conservation tool, as it gives a better understanding of both remaining population numbers and, when associated with vegetation studies, of habitat requirements for the animals and conservation priorities (Brockelman and Ali, 1987; Sutherland, 2002; Ganzhorn, 2003). This study, complementing ongoing work in the area, investigated links between the density of Bornean agile gibbons (*Hylobates albibarbis*) and vegetation characteristics in a secondary peat-swamp forest.

1.1- Study species

Gibbons are small arboreal apes inhabiting the rainforests of South-East Asia, Northwest India and Bangladesh (Reichard and Sommer, 1997). The taxonomy of gibbons is under dispute, as the status of several taxa as species or subspecies is uncertain. Within the family Hylobatidae, there are four genera of gibbons: *Bunopithecus* (hoolock gibbon), *Hylobates*, *Nomascus* (crested gibbons) and *Symphalangus* (siamangs), and at least twelve species (Brandon-Jones et al., 2004). Apart from the sympatric *H. agilis*/*H. lar* and siamangs in Sumatra and peninsular Malaysia, gibbons are allopatric (Leighton, 1987; Marsh, 1987; Reichard, 2000). Some hybrids have been found within the genus *Hylobates*, including populations in Borneo (*H. albibarbis* and *H. muelleri*: Mather, 1992), in Thailand (*H. lar* and *H. pileatus*, Brockelman and Gittins, 1984) and in peninsular Malaysia (*H. lar* and *H. agilis*, Brockelman and Gittins, 1984). The Bornean agile or southern gibbon (*Hylobates albibarbis*) occurs in southern Borneo, between the Kapuas and Barito rivers (Brandon-Jones et al., 2004). Its taxonomic status is unclear, but recent molecular evidence identifies it as a separate species, rather than a sub-species of *Hylobates agilis* (Groves, 2001; Brandon-Jones et al., 2004, Geissmann, 2007).

Although their diet also includes young leaves and flower buds, gibbons are mostly frugivorous (Gittins and Raemaekers, 1980; Gittins, 1982; Gittins, 1983; McConkey et al., 2002; Cheyne 2008). Thus they appear to play a primary role in forest regeneration as high quality seed dispersers (Gittins, 1982; McConkey *et al.*, 2000; O'Brien *et al.*, 2003). Gibbons live in small family groups of two to six individuals (Gittins and Raemaekers 1980; Leighton, 1987) with an average group size of four (Gittins and Raemaekers, 1980). They are socially monogamous, with males and females forming stable pairs (Gittins and Raemaekers, 1980; Gittins, 1982; Leighton, 1987; Mitani, 1987; Mitani, 1990), but several long-term studies have reported extra-pair copulations and reproductive patterns may differ from the social system (Palombit, 1994; Reichard, 1995; Sommer and Reichard, 2000). All gibbon species exhibit territorial behaviour, with mated pairs defending exclusive territories (Gittins and Raemaekers, 1980; Reichard and Sommer, 1997). Home ranges may however overlap, especially in areas where gibbon densities are high (Gittins and Raemaekers, 1980; Mitani, 1990; Reichard and Sommer, 1997). Most gibbon pairs use a sequence of calls called a duet to defend their territory and strengthen their pair bond (Mitani, 1987; Cowlshaw, 1992; Geissmann and Orgeldinger, 2000): in the morning the resident pair of each territory utters a series of calls, the more characteristic and most easily recognisable one being the female's great call (Brockelman and Srikosamatara, 1993). It must be noted that the Kloss gibbon (*Hylobates klossii*) and the Moloch or Javan gibbon (*Hylobates moloch*) do not duet, though both sexes do still sing (Bartlett, 2007). This great call, which can be heard up to one kilometre away in flat, dense rainforest (Brockelman and Ali, 1987), can be used for auditory sampling method in surveys (Brockelman and Ali, 1987; Brockelman and Srikosamatara, 1993; Nijman and Menken, 2005; Buckley et al., 2006; Cheyne et al., 2008).

All Indonesian gibbons are faced with threats to their survival, both because of habitat loss through logging, encroachment and forest fires, and because of hunting for food or

capture for the pet trade, and are placed on the CITES Appendix 1. *Hylobates albibarbis* was listed, as a subspecies of *H. albibarbis*, as Lower Risk/near threatened as a sub-species of *H. agilis* in the IUCN Red list in the last assessment (IUCN Red List 2006). Following new genetic research and on the recommendation of the Asian Primate Red List Workshop, held in 2006 in Phnom Penh, Cambodia, the species' status has been recognised as *Hylobates albibarbis* and classified as Endangered, partly because of the rapid rate of destruction of peat-swamp forests, which constitute a large part of its range (Geissman, 2007). Although much is known about the behaviour and ecology of gibbons, limited data are available on the population status of *H. albibarbis*, and the Asian Primate Red List Workshop concluded that more recent population estimates and rigorous monitoring of those populations are needed for the species' conservation (Geissman, 2007). Although gibbons have been the focus of many behavioural and ecological studies (e.g. Gittins, 1980; Brockelman, 1984; Chivers, 1984; Mitani, 1990; Bartlett, 2007), there is little information on their habitat requirements, in particular in peat-swamp forests (Buckley et al., 2007). No clear explanation for the important variation in gibbon densities between field sites has been established (Leighton, 1987); since vegetation correlates of primate densities have been found for other species (e.g. Ross and Srivastava, 1994; Muoria et al., 2003; Wieczkowski, 2004; Nekaris et al., 2005; Rovero and Struhsaker, 2007), it is possible that they exist for gibbon populations as well.

I.2- Peat-swamp forests and study site

As acknowledged in recent workshops on the conservation status of gibbons in Indonesia (Geissmann, 2007, Campbell et al., 2008), one of the major habitats of the Bornean agile gibbon is peat-swamp forest. Peat-swamp forests (PSF) occur in the Indo-Malayan region, principally in Kalimantan and Sumatra (Page et al., 1997; Page, 2002). Kalimantan has extensive peatlands, covering about 6 million hectares of its lowlands (Rieley et al.,

1997), a very small proportion of which is protected within national parks (Morrogh-Bernard et al., 2003). Peat-swamp forests are seasonally flooded, waterlogged lowland forests. Because they were thought to harbour little biodiversity, and because they contain tree species of commercial interest (Rieley et al., 1997; Page, 2002; Morrogh-Bernard et al., 2003), PSF have received little conservation attention and have been extensively cleared and/or converted to cultivated land. Logging activities, in addition to the removal of large trees, are detrimental to the ecosystem as the canals dug within the forest to carry felled trunks to adjacent rivers drain the peat, making the soil dry and prone to wildfires (Morrogh-Bernard et al., 2003; Cheyne, 2007). However, more recent studies have highlighted the importance of PSF for conservation. Despite their waterlogged, highly acidic, nutrient-poor soil, PSF have a tree species diversity comparable to other forests on mineral soils, and feature a number of commercially valuable trees (Rieley et al., 1997; Felton et al., 2003). Reports on the fauna in PSF are scarce but surveys have recorded 57 species of mammals, 237 species of birds, 55 species of fish, as well as reptiles and amphibians (Page, 2002). In Central Kalimantan, between the Kapuas and Barito rivers, lies the protected peat-swamp forest of the Sebangau National Park (SNP). This area covers 5,300km² and was gazetted as a national park in November 2004, after having been allocated to logging companies for timber extraction for thirty years. Previous work in the area has focused on ecological and hydrological studies as well as forest regeneration monitoring (Page et al., 1999) and has shown that the Sebangau catchment harbours the largest remaining wild population of Bornean orang-utans (*Pongo pygmaeus*) (Morrogh-Bernard et al., 2003) and an extensive wild population of Bornean agile gibbons (*Hylobates albibarbis*) (Buckley et al., 2006; Cheyne et al., 2008). Ongoing work is being carried out on behavioural aspects and feeding ecology of gibbons and orang-utans in PSF, aiming to fill gaps in scientific knowledge about apes in this unique ecosystem (Page, 2002). Survey work is also ongoing on populations of nocturnal primates (Bornean slow loris

Nycticebus coucang menagensis and western tarsier *Tarsius bancanus borneanus* (Blackham, 2005; Nekaris et al., 2008), flying foxes (*Pteropus vampyrus natunae*) (Struebig et al., 2007) and wild felids (Cheyne, personal communication).

I.3- Research questions and hypotheses

Previous survey efforts on gibbons in the area primarily focused on a 4km² site which has been intensely studied (Buckley et al., 2006; Cheyne et al., 2008). However there was a lack of data on gibbon densities in other parts of the Sebangau peat-swamp forest. The first aim of this study was to extend survey efforts to a larger set of sites, encompassing several forest types within the Sebangau PSF, in order to obtain more reliable population estimates. Secondly, measurements of vegetation characteristics at each survey site were taken to help identify possible differences between forest types. Thirdly, as vegetation correlates of primate densities have been found in other species (Ross and Srivastava, 1994; Wieczkowski, 2004; Rovero et al., 2007), the final aim of this study was to investigate whether such correlates could be found between gibbon densities and vegetation characteristics in the Sebangau PSF and to identify the most influential of those correlates.

The hypotheses which were formulated prior to the study were:

- that gibbon density estimates within the main 4km² study area would be comparable between this study and the two previous surveys;
- that gibbon density would differ between study sites and between forest types;
- that vegetation characteristics would show some variation across sites and between forest types;
- that gibbon density could be correlated to vegetation characteristics, as shown in Table 1.

Table 1: Hypothesised relationships between vegetation variables and gibbon densities.

Variable name	Expected relationship to gibbon density	Justification	Reference
Mean canopy cover at 20m	Gibbon density higher where canopy cover is higher	Gibbon are exclusively arboreal and use continuous canopy for their locomotion	Johns, 1986; Bartlett, 2007
Median tree height	Gibbon density higher where trees are higher	Gibbon prefer to use higher canopy levels. High trees are used for singing and sleeping.	MacKinnon and MacKinnon, 1980; Whitten, 1982; Gittins, 1983; Mather, 1992
Mean DBH	Gibbon density higher where trees are larger	Large trees provide more canopy cover and represent more abundant food sources.	Cowlshaw and Dunbar, 2000
Density of large trees	Gibbon density higher where large trees are numerous		
Total cross-sectional area of all trees	Gibbon density higher where total biomass of trees is higher	Gibbons are exclusively arboreal. A high biomass of trees means a larger number of trees and/or the presence of large trees.	Bartlett, 2007
Total cross-sectional area of large trees	Gibbon density higher where biomass of large trees is higher		
Total cross-sectional area of gibbon food trees	Gibbon density higher where food availability is higher	Gibbon density has been found to be correlated to food availability at other field sites.	Mather, 1992; Chivers, 2001; Cheyne et al., 2006
Total cross-sectional area of top 20 gibbon food trees	Gibbon density higher where biomass of preferred food trees is higher	There are indications that the availability of a small number of tree species might be used as a correlate of gibbon density.	Mather, 1992

1 **CHAPTER II: RESEARCH ARTICLE**

2

3 **Vegetation correlates of gibbon density in the peat-swamp forest of**
4 **Sebangau national park, Central Kalimantan, Indonesia.**

5

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19

ABSTRACT

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Understanding the complex relationship between primates and their habitats is essential for effective conservation plans. Peat-swamp forest has recently been recognized as a major habitat for the Bornean agile gibbon (*Hylobates albibarbis*), but information is scarce on the factors that link gibbon density to characteristics of this unique ecosystem. The aims of this study were firstly to estimate gibbon density in different forest subtypes in a newly protected, secondary peat-swamp forest in the Sebangau National Park, Indonesia, and secondly to identify vegetation correlates of gibbon density. Data collection was conducted for three months at 13 survey sites, using auditory sampling methods and speed plotting. Gibbon densities were found to vary from 1.39 to 3.92 groups/km² between survey sites in different forest subtypes. Canopy cover, tree height, density of large trees and food availability correlated with gibbon density, identifying the preservation of tall trees and good canopy cover as a conservation priority for the gibbon population in the Sebangau forest. This survey indicates that selective logging, which specifically targets large trees and disrupts canopy cover, is likely to have adverse effects on gibbon populations in peat-swamp forests, and calls for greater protection of these little studied ecosystems.

Keywords: Bornean agile gibbon; habitat; auditory sampling

36 INTRODUCTION

37 Peat-swamp forests have received little conservation interest in the past, as their
38 richness in biodiversity is generally lower than other types of lowland rainforests (Page et al
39 1997). However, recent research has indicated that they harbor some of the largest remaining
40 populations of Bornean orangutans (*Pongo pygmaeus pygmaeus*) (Felton et al., 2003;
41 Morrogh-Bernard et al. 2003) and Bornean agile gibbons (*Hylobates albibarbis*) (Buckley et
42 al., 2006; Geissmann, 2007; Cheyne et al., 2008), two species of endangered primates
43 endemic to Borneo.

44 Large extents of peat-swamp forest exist in Kalimantan, but the level of protection of
45 these ecosystems is low. Because these forests contain commercially valuable timber at high
46 densities, they are often commercially logged, either legally or illegally (MacKinnon et al.,
47 1997a). In addition to the removal of large trees, logging also has severe consequences for the
48 ecosystem's balance, as canals are created to carry fallen trunks to the river, and lead to the
49 drainage of water from the peat, which is then very vulnerable to forest fires (Morrogh-
50 Bernard et al., 2003). Finally, large extents of peat-swamp forests are cleared for agriculture
51 (Rieley et al., 1997). To combat these threats, considerable research efforts were made in the
52 peat-swamp forest of the Sebangau catchment, Central Kalimantan, to highlight its
53 importance both as a biodiversity-rich ecosystem (Page et al., 1997; Morrogh-Bernard et al.,
54 2003) and as an important purveyor of ecological services such as carbon and water storage,
55 and climate regulation (Rieley et al., 1997; MacKinnon et al., 1997b; Morrogh-Bernard et al.,
56 2003; Cheyne, 2007). These efforts led to the creation of the Sebangau National Park, which
57 was gazetted in 2004, and the cessation of the legal logging activities which had been taking
58 place for thirty years. However, protection of the peat-swamp forest is not enforced in many
59 parts of the park where anthropogenic disturbance continues. Density and population
60 estimates yielded by previous studies in the area demonstrate its importance for gibbon

61 conservation, as the area was shown to host at least 25,000 wild gibbons (Buckley et al.,
62 2006; Cheyne et al., 2008).

63 The ability to assess accurately the population status of threatened species is of prime
64 importance to conservation strategies (Sutherland, 2000). Moreover, as the survival of
65 primates is connected to and dependent upon the protection of their rainforest habitats (Lucas
66 and Corlett, 1998; Chapman et al., 2006; Link and Di Fiore, 2006), understanding links
67 between primate abundance and the characteristics of their habitat is essential to effectively
68 conserve the resident primates.

69 The aims of this study were: first, to survey the population of Bornean agile gibbons
70 around the Setia Alam research station, in the north of the Sebangau catchment. Two density
71 estimates have been published so far for this gibbon population, with previous survey efforts
72 concentrating mainly on a 4km² study site (Buckley et al., 2006; Cheyne et al., 2008). This
73 study included a repeat of these survey efforts in order to monitor gibbon numbers in the area.
74 Secondly, this study was designed to identify relationships between gibbon density and
75 habitat quality, by extending survey efforts to several sites in the forest, which exhibit
76 different vegetation characteristics, in order to identify important habitat requirements for
77 gibbons in the unique peat-swamp forest ecosystem.

78

79 **METHODS**

80 **Study site**

81 The Sabangau National Park, designated in November 2004, covers 568 000 hectares of
82 peat-swamp forest between the Sabangau and Katingan Rivers in Central Kalimantan. The
83 study area is located within the Natural Laboratory for the Study of Peat-swamp Forest
84 (Laboratorium Alam Hutan Gambut, LAHG), a 500km² area situated in the north of the

85 national park, 20 km south-west of Palangkaraya, the provincial capital of Central
 86 Kalimantan (Fig. 1). This area is operated by the Centre for International Cooperation in
 87 Sustainable Management of Tropical Peatland (CIMTROP). Within this area, the main
 88 research station, Setia Alam Field Station, is located $2^{\circ} 20' 42''$ south and $114^{\circ} 2' 11''$
 89 east. At the time of the field surveys the area was protected and timber extraction had
 90 stopped at the survey locations. Small-scale harvesting of non-timber forest products (bark,
 91 rattan, orchids and latex) was still taking place. Previous studies have identified three main
 92 peat-swamp forest sub-types within the study area based on tree species composition and
 93 forest structure: a mixed swamp forest (MSF) at the periphery, which transitions into low
 94 pole forest (LPF) about 6km inside the forest, turning into tall interior forest at the centre
 95 of the peat dome, about 12km inside the forest (Shepherd et al., 1997; Page et al., 1999;
 96 Morrogh-Bernard et al., 2003). The forest is secondary closed-canopy evergreen forest,
 97 which is flooded for most of the year, and is home to a high diversity of mammals
 98 (Morrogh-Bernard et al., 2003) and birds (Page et al., 1997).

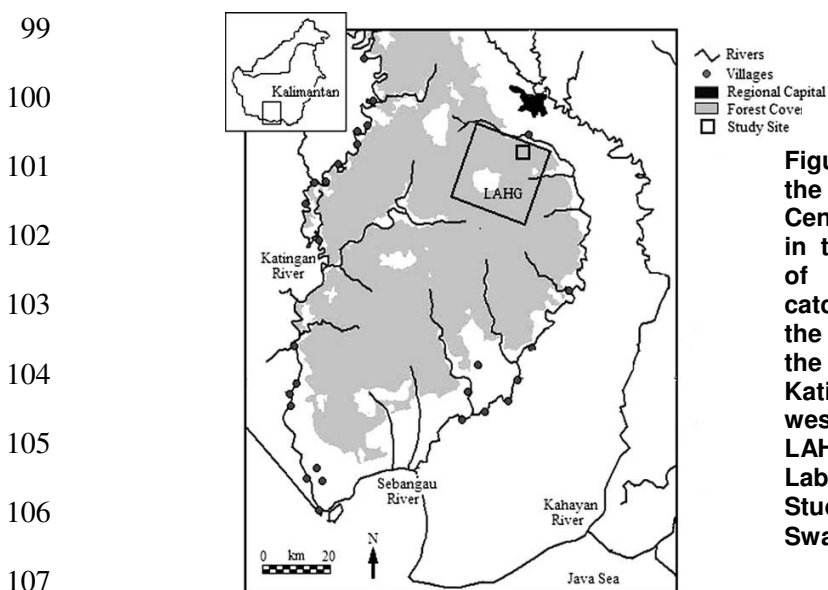


Figure 1: Location of the study area in Central Kalimantan, in the northern part of the Sebangau catchment, between the Kahayan river to the east and the Katingan river to the west
LAHG: Natural Laboratory for the Study of Peat-Swamp Forest.

108 The study area is on the site of a former logging concession, and the existing access route into
109 the forest, formerly a railway, is still used by the researchers. An additional network of
110 marked transects has been cut for behavioral studies and was also used for this study.

111 **Estimation of gibbon density**

112 Gibbon density was estimated using fixed-point counts, as described by Brockelman
113 and Ali (1987), at fourteen distinct survey sites within the research area (Figure 2). This
114 method has been recommended for the survey of gibbons for the following reasons: first,
115 because the gibbons' inconspicuous behavior and preference for high canopy makes the use of
116 line transects for surveying unsuccessful (Brockelman and Ali, 1987; Brockelman and
117 Srikosamatara, 1993; Nijman and Menken, 2005). Secondly, because the territorial behavior
118 of gibbons allows efficient mapping of triangulated points (Sutherland, 2000). The animals'
119 loud calls, audible from a considerable distance, allow their detection from greater distances
120 than by using sightings (Davies, 2002). Finally, fixed-point counts allow quick, time-efficient
121 surveys, with more reliable results than a line transect survey conducted within the same time
122 frame (Nijman and Menken, 2005). This method has proved efficient in several primate
123 surveys (e.g. Brockelman and Srikosamatara, 1993; Gursky, 1998; Estrada et al., 2002;
124 Estrada et al., 2004; Nijman, 2004). The method has also been successfully used in two
125 previous survey at the study site (Buckley et al., 2006; Cheyne et al., 2008), allowing the
126 comparison of their results to those yielded by the present survey.

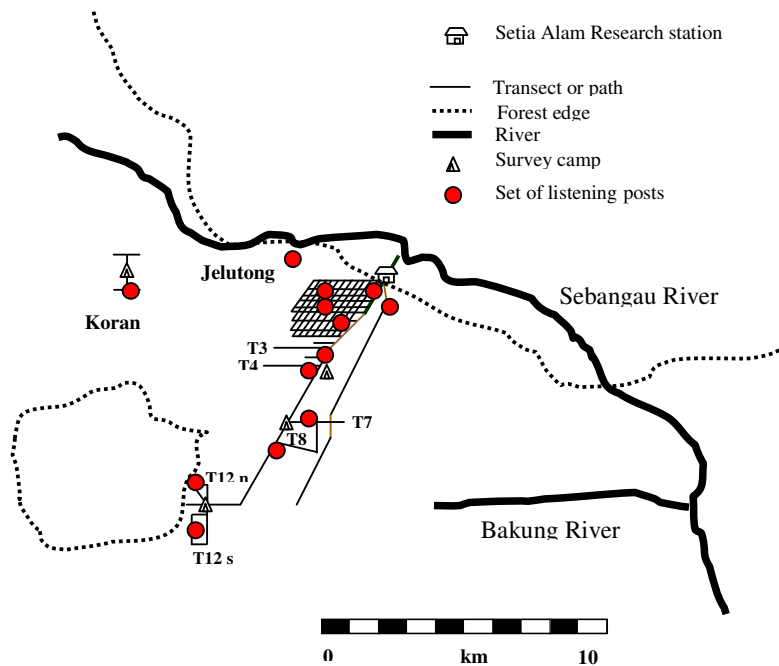


Figure 2: Detailed map of the study area, showing the thirteen sets of listening posts used for auditory sampling. Vegetation sampling was conducted at the same sites, along transects. Relevant transect names are indicated by the letter T.

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129 Data collection took place between May 7th and July 27th, 2008 at nine sets of listening
 130 posts. Additional data were obtained from previous studies for two of the sites within the
 131 main grid system (Cheyne et al., 2008), and collected in the summer of 2007 for the two
 132 remaining survey sites.

133 The compass bearings and estimated distances of gibbon calls were recorded from
 134 three listening posts situated in a triangle formation, with a distance of 300 to 600m between
 135 them, for four consecutive days at each survey site. Previous surveys have shown that the use
 136 of three listening posts for auditory sampling yields the best results as it allows better
 137 mapping of the gibbon groups (Nijman et al., 2005; Cheyne et al., 2008). Data collection took
 138 place between 04:30h and 08:00h each morning, excluding rainy mornings and mornings for
 139 which rain had stopped less than two hours before the planned start of data collection, as rain

140 has been found to influence negatively the gibbons' singing behavior (Brockelman and Ali,
141 1987; Brockelman and Srikosamatara, 1993). Because of this, the survey period was reduced
142 to three days at three of the survey sites, and two days at one survey site. However, correction
143 factors included in the formula to estimate density ensured the data were comparable between
144 all survey sites (Brockelman and Ali, 1987; Brockelman and Srikosamatara, 1993). All data
145 collection was conducted by experienced researchers and volunteers after a training period of
146 at least a week; whenever possible, teams of researchers rather than a single individual were
147 used to maximize the accuracy of compass bearings. After plotting all recorded singing bouts
148 on a map using Microsoft Excel, the number of groups within each surveyed location could be
149 determined by triangulation or quadrangulation. Only groups for which at least one great call,
150 indicating a family group, was heard during the survey time were included in the analysis, in
151 order to avoid counting solitary animals (Brockelman and Ali, 1987).

152 The density estimates were obtained with the following formula, developed by
153 Brockelman and Ali (1987): $D = n / [p(m) \times E]$, where n is the number of groups heard in an
154 area as determined by the mapping, $p(m)$ is the estimated proportion of groups expected to
155 sing during a sample period of m days, and E is the effective listening area. The correction
156 factor $p(m)$ was determined at each site with the formula $p(m) = 1 - [1 - p(1)]^m$, with $p(1)$
157 being the singing probability for any given day, and m being the number of survey days. The
158 effective listening area was calculated for each site using a fixed radius of 1km around each
159 listening post, and was defined by the area in which at least two of the listening posts could
160 hear gibbons singing. Areas which were not covered in forest (outside the forest edges and in
161 burnt areas) were deducted from the effective listening area using maps. The total survey
162 effort covered 37.1 km² across the three main forest types, during 49 survey days.

163 ***Measurements of vegetation characteristics***

164 Habitat characteristics were measured in plots of 10m x 10m situated along transects
165 around the listening posts, in the same time frame as the auditory sampling. Previous studies
166 investigating relationships between forest structure and primate densities have used small
167 plots (e.g. Rendigs et al., 2003; Blakham, 2005). Ten plots per site were analyzed, with the
168 exception of five sites within the grid system, for which six plots were analyzed because of
169 time constraints. In each plot the following data were recorded: 1/ canopy cover at 20m, at
170 each corner and in the middle of the plot, using visual estimation by the same observer
171 throughout the survey; 2/ diameter at breast height (DBH) of all trees exceeding 10cm DBH;
172 3/ height of all trees exceeding 10cm DBH, placing each tree into classes from 0-5m to 35m+
173 by visual estimation by trained researchers; 4/ local name of the species of all measured trees;
174 5/ total number of trees in the plot. Additional data were obtained for two of the sites (Koran
175 and Jelutong, see Figure 2) for which 100m x 5m plots were used by another team of
176 researchers in 2007 and only DBH and tree species were recorded. DBH was then converted
177 into cross-sectional area using the formula $\text{cross-sectional area} = (\text{DBH}/2)^2 \times \pi$ and used as an
178 indicator of tree biomass.

179 All the collected data were then summarized into nine variables for each plot: 1/ mean
180 canopy cover, 2/ median tree height, 3/ mean DBH, 4/ density of all trees $\geq 10\text{cm DBH}$, 5/
181 density of large trees ($\geq 20\text{cm DBH}$), 6/ total cross-sectional area of all trees $\geq 10\text{cm DBH}$, 7/
182 total cross-sectional area of large trees ($\geq 20\text{cm DBH}$), 8/total cross-sectional area of known
183 gibbon food trees, 9/ total cross-sectional area of trees belonging to the 20 species eaten most
184 frequently by gibbons in the area. Gibbon food trees were defined as tree species whose
185 edible parts (leaves, flowers, fruits, seeds) are known to be eaten by gibbons in the area.
186 Information to obtain the two last variables were based on long-term behavioral research on
187 the gibbons' feeding ecology in the area (Cheyne and Shinta, 2006; Cheyne, 2008). Tree

188 species were identified by Hendri Setia Sebangau, a local field assistant with extensive
189 knowledge of forestry in the area.

190 All vegetation characteristics were then averaged for each study site, except median tree
191 height which was directly calculated for all measured trees within a study site. Measures of
192 species diversity were then added to the analysis: species richness, defined by the number
193 of tree species identified in each study site; Shannon-Wiener's diversity index and
194 Simpson's diversity index, calculated as described in Ganzhorn (2003) and Douglas
195 (2006). Both Shannon-Wiener and Simpson's indexes were calculated, as both are biased
196 towards either dominant species (Simpson's index) or rare species (Shannon-Wiener
197 index) (Stiling, 2002).

198 **Statistics**

199 Vegetation characteristics between sites were compared using Kruskal-Wallis
200 ANOVA non-parametric test. Pair-wise comparisons of means for each of the variables were
201 carried out between forest types using Mann-Whitney's U test. After testing for the normality
202 of each variable using Kolmogorov-Smirnov test, potential correlation between gibbon
203 density and each of the variables obtained from vegetation characteristics was investigated
204 using Pearson's correlation test. Correlation was preferred to regression analysis, as no
205 relationship of cause and effect between vegetation characteristics and gibbon density was
206 assumed. A factor analysis was also performed to obtain a single component retaining most of
207 the variation contained in the vegetation data set. All tests were carried out using SPSS v.16,
208 with a significance level of $p < 0,05$. Standard error, which is used to assess the accuracy of
209 calculated means in the population (Fowler et al., 1998), was used to measure variability in
210 the analysis, rather than standard deviation.

211 **RESULTS**212 **Calling probabilities and calculations of gibbon density**

213 Based on the number of groups calling on each sampling day and the total number of
 214 groups heard for each site, the probability for a group to be calling on any given day $p(1)$ was
 215 calculated. The cumulative probability of hearing all gibbon groups during a sample period of
 216 m days, $p(m)$, was deducted from $p(1)$ as described in the methods section. Table 2
 217 summarizes the parameters of calling probabilities and effective listening areas for all survey
 218 sites, as well as resulting gibbon density estimates.

219 **Table 2: Parameters calculated for the estimation of gibbon density at each site, and resulting density**
 220 **estimates. Reduced sampling periods (m) were due to weather conditions. Reduced effective listening**
 221 **areas (E) were due to forest edges or areas of forest destroyed by wildfires.**
 222

Site name and site number	Number of groups heard	$p(1)$	m (days)	$p(m)$	E (km ²)	Gibbon density (groups/km ²)
Camp (MSF)	5	0.67	5	1.00	1.97	2.53
Middle (MSF)	8	0.53	4	0.95	3.12	2.69
Old Railway (MSF)	8	0.59	4	0.97	2.78	2.96
Hell (MSF)	7	0.67	5	1.00	2.85	2.81
Km 2 (MSF)	7	0.64	4	0.98	2.86	2.49
Km 3.5 (transition)	7	0.64	4	0.98	3.10	2.30
Km 4 (transition)	5	0.55	4	0.96	3.06	1.71
Km7 (LPF)	3	0.33	3	0.70	3.08	1.39
Km 8 (LPF)	4	0.50	2	0.75	3.13	1.70
Km 12 North (TIF)	8	0.54	3	0.90	2.26	3.92
Km 12 South (TIF)	8	0.54	3	0.90	3.04	2.91
Koran (MSF)	6	0.5	4	0.94	3.00	2.41
Jelutong (MSF)	7	0.5	4	0.94	2.86	2.61

223

224 The density estimates given above are in groups per square kilometer, as no determination of
 225 the average group size in the area was attempted during this survey. However, previous
 226 research in the main study area has established an average group size of 4.05 for gibbons in
 227 the MSF (Cheyne et al., 2008). Using this group size, the density estimate yielded by this
 228 study for the MSF is 10.70 ± 0.19 individuals/km².

229 **Vegetation characteristics and determination of forest types**

230 Species richness and diversity indicators for each of the survey sites are shown in
 231 Table 3. Only sites for which vegetation information was obtained from 10x10m plots are
 232 included in the analysis. A total of 61 species or groups of species of trees were identified
 233 during this study, representing 33 families (Appendix III).

234 **Table 3: Tree species richness and diversity at each study site**

235

Site name	Species richness S	Shannon-Wiener index H	Evenness J	Simpson's index C
Camp (MSF)	24	3,04	0,96	0,03
Hell (MSF)	20	2,79	0,93	0,06
Old railway (MSF)	27	3,05	0,93	0,05
Middle (MSF)	34	3,22	0,91	0,04
km2 (MSF)	32	3,11	0,90	0,05
km3,5 (transition)	29	2,81	0,84	0,09
km4 transition)	31	3,11	0,91	0,05
km7 (LPF)	20	2,66	0,89	0,07
km8 (LPF)	22	2,60	0,84	0,09
km12N (TIF)	26	2,68	0,82	0,11
km12S (TIF)	26	2,43	0,74	0,19

236

237 Three main forest types can be identified in the Sebangau peat-swamp forest: a low pole
 238 forest (LPF) with short, small trees, a very scarce canopy cover at 20m and few large trees (\geq
 239 20cm DBH); a tall interior forest (TIF) with high, large trees, high canopy cover and high
 240 gibbon food availability; and a mixed-swamp forest (MSF), situated closest to the river, with
 241 a more heterogeneous vegetation. Two survey sites, situated between MSF and LPF, were
 242 labeled transition forest. Overall, the vegetation in sites situated in the MSF exhibits high
 243 species richness (average $s = 27.4$) and contains evenly distributed, relatively rare species
 244 (average $J = 0.92$), which results in high Shannon-Wiener indexes (average $H = 3.04$) and low
 245 Simpson's indexes (average $C = 0.05$). Sites in LPF exhibit poor species richness (average $s =$
 246 21) and low species diversity (average $H = 2.63$; average $C = 0.08$). Finally, TIF vegetation is
 247 species-rich (average $s = 26$) but unevenly distributed (average $J = 0.78$), with notably
 248 *Palaquium leiocarpum* (hangkang) trees dominating in both sites and representing 29% and

249 43% of the trees in sites km12N and km12S, respectively. This results in a high average
 250 Simpson's index ($C = 0.15$) and a low Shannon-Wiener index ($H = 2.65$) for TIF.

251 All vegetation variables, averaged for each forest type, are presented in Table 4.

252 **Table 4: Average vegetation characteristics for the forest types of the Sebangau peat-swamp forest. All**
 253 **values are given with standard errors.**
 254

Forest type	Mean canopy cover (%)	Median tree height (m)	Mean DBH (cm)	Density large trees (trees/ha)	Biomass all trees (cm ²)	Biomass large trees (cm ²)	Biomass food trees (cm ²)	Biomass top20 food trees (cm ²)
MSF (n=42)	40.9 ±3.8	11-15	16.3 ±0.5	231.2 ±24.9	2546 ±190	1443 ±178	2018 ±167	1012 ±107
Transition (n=20)	20.8 ±3.9	11-15	15.5 ±0.7	220.0 ±49.5	3332 ±569	1852 ±545	2469 ±404	1113 ±200
LPF (n=20)	10.0 ±1.6	11-15	16.0 ±0.7	150.0 ±28.0	2094 ±254	1067 ±218	1712 ±251	572 ±93
TIF (n=20)	61.8 ±3.4	16-20	19.4 ±0.9	385.0 ±41.8	4198 ±419	3104 ±442	3455 ±357	1037 ±210
Kruskal-Wallis	$\chi^2 = 49.0$ p=0.001	$\chi^2 = 22.5$ p=0.001	$\chi^2 = 14.0$ P=0.003	$\chi^2 = 18.2$ p=0.001	$\chi^2 = 17.4$ p=0.001	$\chi^2 = 16.4$ p=0.001	$\chi^2 = 16.9$ p=0.001	$\chi^2 = 8.1$ p=0.04
χ^2 and p								

255

256 Significant differences were found between forest types for all variables. Pair-wise
 257 analysis revealed that MSF and transition forest had similar floristic characteristics except for
 258 canopy cover, which was significantly higher in MSF ($U=173.5$, $p=0.004$). MSF also had
 259 significantly higher canopy cover ($U=72$, $p=0.01$) and median tree height ($U=189$, $p=0.01$)
 260 than LPF and contains more of the top 20 gibbon food trees ($U=231$, $p=0.004$). Canopy cover
 261 ($U=126$, $p=0$), median tree height ($U=181.5$, $p=0.007$), density of large trees ($U=187$, $p=0$),
 262 total biomass of trees ($U=197$, $p=0.001$) and large trees ($U=189.5$, $p=0.001$) were all
 263 significantly higher in TIF than in MSF, as was total biomass of gibbon food trees ($U=174$,
 264 $p=0.01$). The biomass of the top 20 gibbon food trees did however not differ between TIF and
 265 MSF.

266

267 **Relationship between vegetation characteristics and gibbon density**

268 Average gibbon densities were calculated for each forest type identified previously, as
 269 presented in table 5.

270 **Table 5: Average gibbon densities for the forest types of the Sebangau peat-swamp forest. The values**
 271 **obtained for transition forest, LPF and TIF are indicative values only, as the sample size is too small to**
 272 **be able to calculate a standard error.**
 273

Forest type		Gibbon density (groups/km ²)
MSF	(n=7)	2.64 ± 0.07
Transition	(n=2)	2.00
LPF	(n=2)	1.54
TIF	(n=2)	3.42

274

275 All vegetation variables had a normal distribution, as did gibbon density ($Z = 0.6$, $p = 0.864$
 276 for gibbon density). Gibbon density was found to be correlated to all the measured vegetation
 277 variables, except the density of all trees and the biomass of the top 20 gibbon food trees
 278 (Table 6).

279 Table 6: Correlation between gibbon density and habitat characteristics across study sites

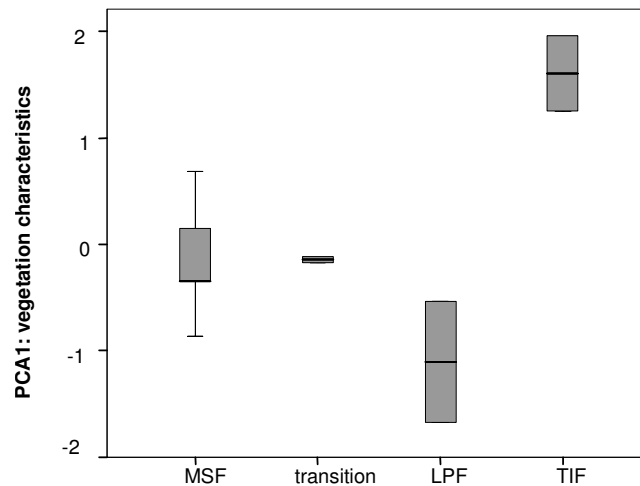
280

		Mean canopy cover (%)	Median tree height	mean DBH	Density of trees >10cm DBH	density of trees >20cm DBH	total x-sectional area of trees >10cm DBH	total x-sectional area of trees >20cm DBH	total x-sectional area of gibbon food trees	Total x-sectional area of top20 gibbon food trees
Gibbon density (gp/km ²)	Pearson Correlation	.802**	.768**	.591*	.255	.664*	.633*	.657*	.573*	.463
	Sig. (2-tailed)	.003	.006	.034	.401	.013	.020	.015	.041	.111
	N	11	11	13	13	13	13	13	13	13

281 ** correlation is significant with $p < 0.01$ *correlation is significant with $p < 0.05$

282

283 Factor analysis on all vegetation variables identified one component, called PCA1,
 284 composed of nine vegetation characteristics and retaining 77% of the variation in the data set.
 285 The three variables with the highest matrix score in PCA1 were density of large trees, cross-
 286 sectional area of large trees and cross sectional area of gibbon food trees. PCA1 allowed easy
 287 discrimination between forest types (Figure 3).



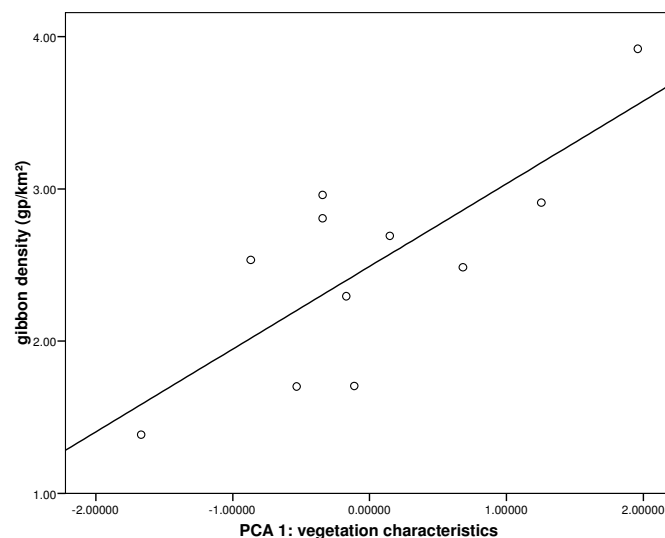
288

289

Figure 3: Vegetation characteristics, as summarised by the principal component PCA1, between forest types

290

291 The distribution of PCA1 was found to be normal ($Z = 0.577$, $p = 0.893$) and strongly
 292 correlated to gibbon density (Pearson's correlation coefficient = 0.762, $p = 0.006$) (Figure 4).



293

Figure 4 : Correlation between vegetation characteristics, as summarized by the principal component PCA1, and gibbon density across survey sites.

294 **DISCUSSION**295 **Gibbon density estimates**

296 The gibbon densities found in the MSF during this study were similar to the two
 297 previous estimates published for the same area, showing that the auditory sampling method is
 298 replicable. Gibbon density was highest in the TIF, which also harbors the greatest diversity of
 299 animal species in the Sebangau (Page et al., 1997) and the highest density of orangutans
 300 (Morrogh-Bernard et al., 2003). Overall, gibbon density estimates found during this study are
 301 within the mid-range of published estimates for other field sites and compare to estimates at
 302 sites with similar forest types (Table 7).

303 Table 7: Comparison between Bornean agile gibbon density estimates in Kalimantan.
 304 Numbers between brackets are calculated from given estimates and published mean group
 305 sizes.*calculated with a mean group size of 3.4 (Buckley et al., 2006).**calculated with a
 306 mean group size of 4.1 (Mitani, 1990, Cheyne et al., 2008).*** calculated with a mean group
 307 size of 2.3 (Cheyne, personal observation).
 308

Site name	Species studied	Group density per km ²	Individual density per km ²	Forest type(s) surveyed	Reference
Sebangau National Park, Central Kalimantan	<i>H. albibarbis</i>	2.2	7.5*	Peat-swamp forest (MSF)	Buckley et al. (2006)
		2.6	10.7**		Cheyne et al. (2008)
		2.6	[10.7]**	Peat-swamp forest (TIF)	This study
		3.1	[12.8]**		Cheyne et al. (2008)
		3.4	[13.9]**		This study
1.5	[3.5]***	Peat-swamp forest (LPF)	This study		
Gunung Palung National Park	<i>H. albibarbis</i>	3.6	14.9	Montane forest, mangrove forest, peat-swamp forest, lowland rainforest	Mitani (1990)
Tanjung Puting National Park	<i>H. albibarbis</i>	[2.1]**	8.7	Lowland rainforest, mangrove forest, peat-swamp forest	Mather (1992b)
Barito Ulu	<i>H. albibarbis</i>	[3.0]**	12	Lowland dipterocarp forest	Mather (1992b)
		[2.6]**	10.5		
		[4.4]**	18		
		[2.0]**	8.2		McConkey (2002)
	<i>H. albibarbis</i> x <i>H. muelleri</i>				

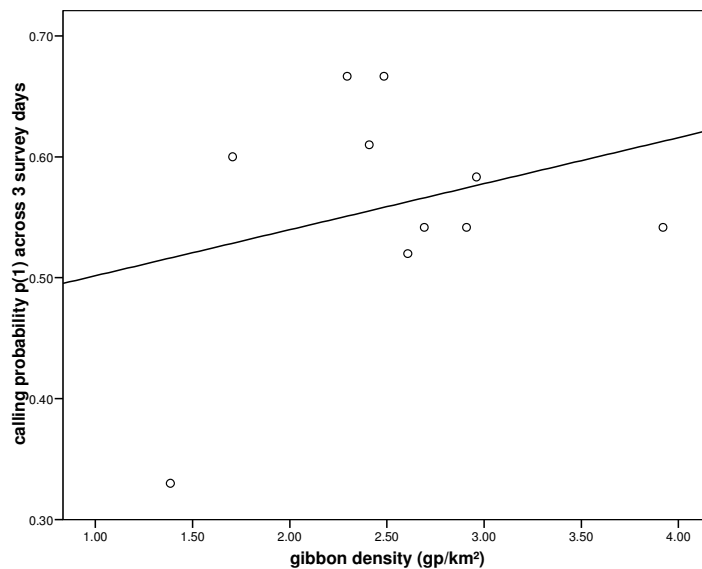
309

310 Moreover, the density estimate yielded by this study for the MSF gives a number of gibbon
 311 groups of 11 in a 4km² area, which is exactly the number of groups present in the 4km² main
 312 study area, where behavioral research is conducted (Cheyne, pers. comm.).

313 Fixed point counts using auditory sampling do have a number of biases associated
314 with the method. Firstly, the method excludes lone animals from the estimate, as only duets
315 are taken into account into the analysis. A study of the proportion of lone animals, mostly
316 sub-adult individuals, in a population of *H. albibarbis* in West Kalimantan (Cowlshaw, 1992)
317 found that unpaired individuals represented approximately 5.5% of the paired population.
318 This problem only affects estimates of individual density however; estimates of density of
319 groups per square kilometer, which are included in this study, remain unchanged. Secondly,
320 auditory sampling is dependent on weather conditions during data collection, which can affect
321 singing frequency (Raemaekers et al., 1984; Brockelman and Ali, 1987; Leighton, 1987;
322 Brockelman and Srikosamatara, 1993). Rain has been shown to affect the time when the
323 gibbons started singing in the study area but not the singing frequency (Buckley et al., 2006),
324 although other studies (e.g. O'Brien et al., 2004) did not find any effect of rain on singing
325 start times or frequency. Although no detailed weather data were collected during this study,
326 efforts were made to avoid data collection on rainy mornings and on mornings directly
327 following heavy rain during the night, which restricted data collection to three or even two
328 days at some survey sites. The duration of data collection was also extended well beyond the
329 last singing bout heard, to avoid missing groups that could have sung later because of weather
330 conditions. Despite cloud cover having been found correlated with singing frequency in
331 pileated gibbons (Brockelman and Srikosamatara, 1993) and to a lesser extent, in a population
332 of agile gibbons (O'Brien et al., 2004), it was found to have no effect on singing in the study
333 area (Buckley et al., 2006, Cheyne, 2007). Consequently, cloud cover was not recorded during
334 this survey. Finally, wind has been shown to affect singing in pileated gibbons (Brockelman
335 and Srikosamatara, 1993) and siamangs (O'Brien et al., 2004), but not agile gibbons (O'Brien
336 et al., 2004; Cheyne, 2007). Wind conditions were calm on every survey morning, and thus

337 are unlikely to have had any effect on singing, even though no wind measurements were
 338 recorded.

339 It has been proposed that low densities (less than two groups per square kilometre)
 340 may affect singing probability, as singing can be stimulated by other duets from neighbouring
 341 groups (Mitani, 1987; Brockelman and Srikosamatara, 1993). Brockelman and Ali (1987)
 342 found however that singing was not stimulated by other groups in agile gibbons. Correlation
 343 was tested between calling probability ($p(1)$, see Table 2) and gibbon density in this study
 344 (Figure 5), and there was no significant effect of gibbon density on calling probability
 345 (Pearson's correlation coefficient = 0.276, $p = 0.44$).



346

Figure 5: Relationship between the probability of calling on any given day $p(1)$ and gibbon density across survey sites.

347 Gibbons sing preferentially from large, high trees (Mather, 1992a) and calling probability has
 348 been found to have decreased after selective logging which specifically targets those large
 349 trees (Johns, 1985). Relationship between calling probability $p(1)$ and vegetation
 350 characteristics, and particularly the density of large trees (≥ 20 cm DBH) was tested. No
 351 significant correlation was found between calling probability and either density of large trees

352 (Pearson's correlation coefficient = 0.322, $p = 0.363$) or all vegetation characteristics as
353 summarized by PCA1 (Pearson's correlation coefficient = 0.221, $p = 0.539$).

354 Finally, as this study's aim was to compare densities between survey sites sharing the
355 same methodology and surveyed in the same period of time, rather than to obtain exact
356 density estimates, any bias associated with the method that could have affected the calculation
357 of gibbon density did not affect the subsequent comparative analysis.

358 **Habitat characteristics and vegetation correlates of gibbon density**

359 The use of a large number of small plots for habitat measurements proved efficient in
360 this study and allowed the detection of fine-scale differences in vegetation characteristics.
361 This is a time-efficient method that can easily be associated with auditory sampling, as a
362 small number of plots can be measured each day after the collection of the singing data,
363 making vegetation sampling less fastidious and labor-intensive than larger plots.
364 Gibbon density was found to be highly correlated to vegetation parameters, in particular
365 canopy cover and tree height. As gibbons preferentially use high canopy layers throughout
366 their activity budget (Johns, 1986; Brockelman and Ali, 1987; O'Brien et al., 2004; Nijman,
367 2001), this result is not surprising, although gibbons have proved to be relatively adaptable to
368 disturbances of canopy cover following logging by shifting their use of canopy layers to the
369 lower canopy (Johns, 1985; Johns, 1986; Nijman, 2001). Canopy cover and tree height have
370 been found to influence the density of other arboreal primates (Tana red colobus and crested
371 mangabey: Medley, 1993; orangutans: Felton et al., 2003), as gaps in canopy impair their
372 travelling. Other variables that were found to be correlated with gibbon density in this study
373 were the density of large trees and the availability of food trees. Felton et al. (2003) reported a
374 similar correlation between orangutan density and density of large trees in a peat-swamp
375 forest in West Kalimantan. Similar results were reported for greater dwarf lemurs (Lehman et
376 al., 2006) and primate species along the Tana river (Wieczowski, 2004). All the authors

377 proposed that this relationship was due to greater availability of food where more large trees
378 were present, which is in conformity with results linking food abundance to primate densities
379 (e.g. Wiczowski, 2004; Mather, 1992a; Mather, 1992b). Although the correlation between
380 cross-sectional area of food trees was weak in this study, primarily due to large variations
381 between plots, it is supported by the results of other studies on gibbons (Mather, 1992a)
382 which found that gibbon density was strongly influenced by the availability of their preferred
383 food trees. No correlation was found however between the availability of the Sebangau
384 gibbon's top 20 food trees. This could be due to the fact that the list of preferred food items
385 was compiled based on data from the MSF only, and may thus not be applicable to other
386 forest types. Alternatively, this could be due to the gibbons' extensive range of food trees in
387 the study area. Their diet includes at least 65 species of trees, of which relative importance
388 varies seasonally (Cheyne and Sinta, 2006; Cheyne, 2008), in which case a list of 20 preferred
389 food species should be adapted according to the months during which the survey was
390 conducted in order to account for the animals' dietary flexibility.

391 **Implications for conservation**

392 The influence of logging on gibbon populations has been the focus of several studies
393 (e.g. Wilson and Wilson, 1975; Johns, 1986; Meijaard et al., 2005), as it constitutes a major
394 threat to gibbons. Selective logging, which targets large, commercially valuable trees, has
395 been shown to reduce canopy cover and continuity, as well as to restrict the availability of
396 food for the gibbons (Meijaard et al., 2005; Johns, 1988). The damage on forest trees also
397 exceeds the sole trees that are felled, as it was found that selective removal of 3.3% of trees
398 resulted in the destruction of over 50% of surrounding trees (Johns, 1988). Because of their
399 dietary flexibility, gibbons may be relatively resilient to logging: Meijaard et al. (2005) listed
400 five studies having found gibbon densities equal or higher after selective logging. Six studies
401 cited in the same review found decreased gibbon densities after logging. Since gibbon density

402 was highly correlated to canopy cover and tree height, the results of the present study seem to
403 indicate that gibbons in the Sebangau may have been negatively affected by logging, even
404 though the population survived thirty years of timber extraction in the area. Moreover,
405 logging activities in the Sebangau catchment have resulted in disruptions in the ecosystem's
406 hydrology, as water is drained from the peat by logging canals (Morrogh-Bernard et al.,
407 2003). As a result the region is prone to recurrent wildfires, which have been found to
408 drastically increase tree mortality, decrease fruit availability (Kinnaird and O'Brien, 1998;
409 O'Brien et al., 2003; Barlow and Peres, 2006; Fredriksson et al., 2007) and to affect
410 negatively the density of large vertebrates, such as siamangs, which are particularly
411 vulnerable because of their territorial nature (O'Brien et al., 2003).

412 **Conclusions and recommendations**

413 The main results yielded by this study are:

- 414 • Gibbon densities in the research area ranged from 1.39 to 3.92 groups/km², with the
415 highest density observed in the tall interior forest, and the lowest density observed in the
416 low pole forest.
- 417 • Vegetation characteristics correlated strongly with gibbon density, in particular canopy
418 cover at twenty meters and tree height. Food availability was also found to be a correlate
419 of gibbon density.

420 The following recommendations can be drawn from this study:

- 421 • Because gibbon density can vary over two-fold across survey sites less than five
422 kilometers apart, as shown by this study, surveying several locations within the same
423 forest, for example a national park, is essential for effective conservation management.
424 Extrapolations based on one or a few survey sites could prove largely inaccurate if
425 vegetation characteristics vary within the forest.

- 426 • Assessing microhabitat variations within forested ecosystems can be conducted quickly
427 and efficiently using speed plotting, in order to design conservation strategies adapted to
428 forest subtypes with differential importance to gibbon populations.
- 429 • In order to protect the extensive gibbon population of the Sebangau forest, conservation
430 actions should focus on the prevention of logging and of wildfires, and the enforcement of
431 existing protection measures in the whole of the Sebangau national park, in order to allow
432 complete regeneration of the forest after its exploitation for timber.
- 433 • Finally, as peat-swamp forest are able to support healthy populations of Bornean agile
434 gibbons and Bornean orangutans, protection should be extended to other Indonesian peat-
435 swamp forests to reduce the threat to these species' habitat.

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CHAPTER III: GENERAL DISCUSSION

III.1- Interdependence of primates and tropical forests

Kalimantan's rain forests are threatened by deforestation. Encroachment for agriculture is responsible for 80% of the forest loss in Indonesia, logging and fire destruction constituting the remaining 20% (Bodmer et al., 1991; Cowlshaw and Dunbar, 2000, Geissmann, 2007). This loss of habitat is the main threat to Indonesia's forest primates. Hunting and capture for the pet trade also constitutes an ongoing problem (Geissmann, 2007; Nijman, 2005), even though there is no hunting or capture in the study area at the moment (Cheyne, pers. comm.). Primates appear particularly vulnerable to habitat loss (Cowlshaw and Dunbar, 2000), even if the effect on their survival may be delayed (e.g. Cowlshaw, 1999) because of their long life histories. In many cases, surviving primate populations are confronted with smaller-scale disturbances that may not result in the total destruction of their habitat, but may lead to modifications in the structure and composition of forests. This can have severe consequences on primate populations, as canopy cover and continuity, tree mortality and fruit production are affected by both selective logging and wildfires (Johns, 1988; Kinnaird and O'Brien, 1998; Slik et al., 2002; Barlow and Peres, 2006; Fredriksson et al., 2007). These changes in forest quality and composition have been shown to affect not only primates, but also birds (e.g. Wilson and Johns, 1982; Kinnaird and O'Brien, 1998), sun bears (Kinnaird and O'Brien, 1998; Fredriksson et al., 2007) and other large terrestrial mammals (Barlow and Peres, 2006).

Primate species are differentially affected by habitat modification: lar gibbons (*Hylobates lar*) and banded leaf monkeys (*Presbytis melalophos*) were found to be negatively affected by selective logging, as they modified their behaviour to adopt a strategy of concealment, altered their diet towards lower quality food such as mature leaves, and shifted their use of the canopy when high trees became unavailable (Johns, 1985; Johns, 1986). In

contrast, pig-tailed macaques were found at higher densities in disturbed forest, having adopted a strategy of opportunistic foraging in logging debris (Johns, 1985; Johns, 1986). Tolerance to threats seems related to dietary flexibility, with highly frugivorous species being more vulnerable than folivorous species (Cowlshaw and Dunbar, 2000), as both logging and fire have been found to lower the availability of fleshy fruit (Meijaard et al., 2005; Fredriksson et al., 2007), although the availability of young leaves and lianas may increase in the short term, sometimes leading to a short-lived increase in primate densities (Wilson and Wilson, 1975; Chivers, 2001). As the results of this study show that gibbon density is correlated to both canopy cover and, to a lesser extent, to food availability, and because gibbons are highly frugivorous (Gittins and Raemaekers, 1980; Gittins, 1982; Gittins, 1983; McConkey et al., 2002; Cheyne, 2008), they may be particularly vulnerable to habitat modification, especially in the short term (Cowlshaw and Dunbar, 2000). Furthermore, high territoriality in gibbons makes them more likely to remain in disturbed areas (O'Brien et al., 2003) where lower food availability causes high infant mortality and lower reproduction rates (O'Brien et al., 2003), which has also been observed in other primate species (Grieser Johns and Grieser Johns, 1995; Felton et al., 2003). Encouragingly, in the long term, gibbon populations seem to be able to recover after habitat loss or habitat modification by logging (Grieser Johns and Grieser Johns, 1995; O'Brien et al., 2003), as seems to be the case in the study area. Ultimately, it is the scale and intensity of the disturbance that are likely to determine chances of primate survival in disturbed forests (Cowlshaw and Dunbar, 2000). Gibbons and orang-utans have survived thirty years of selective logging at the study site, and are found in areas where habitat quality is relatively poor, such as the Sebangau's low pole forest, indicating that they are indeed capable of tolerating some disturbance and of colonising a variety of habitats. The density of both species of primates supported by these areas of poor habitat quality is however very low (this study; Morrogh-Bernard et al., 2003; Buckley et al.,

2006; Cheyne et al., 2008), and conservation efforts should be made to preserve high quality habitat in order to preserve as many animals as possible.

Many primates species are dependent upon rain forests for their survival, but they can also contribute to the functioning of their ecosystem, either as pollinators (e.g. lemurs and South-American monkeys, Cowlshaw and Dunbar, 2000), or as seed dispersers. Seed dispersal by primates is well documented, especially amongst highly frugivorous species (Cowlshaw and Dunbar, 2000; Chapman and Russo, 2007). Gibbons have been found to be important seed dispersers in Asian forests, through spitting and defecating seeds (Bartlett, 2007; Chapman and Russo, 2007). Studies of seed dispersal by gibbons have shown that gibbons disperse most of the consumed seeds (McConkey, 2000) and that passage in their gut significantly improves seed germination of some of their food species, in particular figs (McConkey, 2000). The correlation between vegetation characteristics and gibbon density identified in this study may therefore result from the complex interplay between gibbons and their habitat, rather than a one-way relationship only with vegetation influencing primate density.

III.2- Recommendations for future research

In order to gain further understanding into the links between gibbons and peat-swamp forest, further study is needed. Suggestions for future research include:

- Continued long-term surveys and monitoring of the gibbon population in the study area, in order to identify long-term population trends, and determine reliable average group sizes for forest types outside the mixed-swamp forest to obtain accurate population estimates.
- From the results on the present study we can predict that logging is likely to affect gibbon density. However, anthropogenic disturbance could not be measured at the study site as it has stopped in the area. Similar studies investigating the effects of ongoing disturbance on gibbons in peat-swamp forests are needed.

- Investigation of other factors which can limit primate population, but were not included in this study, including predation pressure by leopards, raptors, snakes and humans (Bartlett, 2007), and competition for food or territory with other primate taxa such as orang-utans, red langurs and macaques (Bartlett, 2007), and other frugivorous animal species such as hornbills (Johns, 1987).

CHAPTER IV: CONCLUSIONS AND PROPOSED CONSERVATION MEASURES

The results of this very short survey may not be definitive, as more data is needed from other survey sites to confirm its findings. It was intended to address the lack of information concerning the interactions between gibbons and their habitat in the unique ecosystem of peat-swamp forest, as a part of a long-term project begun by Dr Susan Cheyne in 2005. It is hoped that the outcome of this study will provide resources on which further research can rely to improve our understanding of conservation priorities in the region.

The following conclusions could be drawn from this study:

- Gibbon densities in the Sebangau National Park were found to range from 1.39 groups per square kilometre to 3.92 groups per square kilometre. They varied up to two-fold between survey sites situated in different forest subtypes.
- The tall interior forest was found to harbour the greatest density of gibbons, whereas the low pole forest had a very scarce gibbon population. The mixed-swamp forest harboured an intermediate gibbon density.
- The variation in gibbon density was found to be highly correlated to vegetation parameters, particularly canopy cover at twenty metres and tree height. A principal component analysis factor accounting for over three quarters of the variation in vegetation characteristics was found to explain 58% of the variation in gibbon density, showing that habitat quality is indeed correlated to the density of gibbons in the area.
- Apart from canopy cover and tree height, which correlated with gibbon density on their own, the density and biomass of large trees ($\geq 20\text{cm}$ DBH) constituted a large part of the total vegetation characteristics after factor analysis, suggesting that these variables may be linked to gibbon density as well.

Based on these conclusions, gibbon conservation action in the area should focus on protecting large, high trees and good canopy cover as well as preserving sufficient food resources for the animals. These goals may be attained by enforcing existing protected areas to prevent logging and wildfires and training more conservation workers to monitor primate populations in the area. In order to provide resources to local conservation organisations wishing to monitor gibbon populations, a video was produced during the course of this project, in English and in Indonesian, to explain the auditory sampling method used in this study (see Appendix IV).

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**APPENDIX III :LIST OF ALL IDENTIFIED TREE SPECIES
DURING THE SURVEY**

BOTANICAL NAME	LOCAL NAME	INCLUDED/NOT INCLUDED IN THE DIET OF <i>H.albibarbis</i>
ANACARDIACEAE		
<i>Camptosperma coriaceum</i>	Terontang	Yes *
<i>Camptosperma squamatum</i>	Nyating	Yes
ANISOPHYLLACEAE		
<i>Combretocarpus rotundatus</i>	Tumih	Yes
ANNONACEAE		
<i>Cyathocalyx biovulatus</i>	Kerandau	Yes
<i>Mezzetia umbellata</i>	Pisang Pisang Kecil	Yes *
<i>Mezzetia leptopoda / parviflora</i>	Pisang Pisang Besar	No
<i>Polyalthia glauca</i>	Kayu Bulan	No
<i>Polyalthia hypoleuca</i>	Alulup	No
<i>Xylopiya fusca</i>	Jangkang Kuning	Yes
<i>Xylopiya malayana</i>	Tagula	Yes
APOCYNACEAE		
<i>Dyera lowii</i>	Jelutong	Yes *
AQUIFOLIACEAE		
<i>Ilex hypoglauca</i>	Sumpung	Yes
BURSERACEAE		
<i>Santiria laevigata</i>	irat	Yes
CHRYSOBALANACEAE		
<i>Licania splendens</i>	bintan	Yes
CLUSIACEAE (GUTTIFERAE)		
<i>Calophyllum hosei</i>	mentangor / bintangor	Yes *
<i>Calophyllum sclerophyllum</i>	Kapurnaga	Yes
<i>Garcinia bancana</i>	Manggis	Yes *
<i>Garcinia</i>	Aci	Yes
<i>Mesua</i>	Tabaras/ pasir pasir	Yes *
CRYPTERONIACEAE		
<i>Dactylocladus stenostachys</i>	Mertibu / matang	No

DIPTEROCARPACEAE		
<i>Cotylebium lanceolatum</i>	Rasak	No
<i>Shorea</i>	Meranti	No
EBENACEAE		
<i>Diospyros bantamensis</i>	Malam Malam	Yes *
<i>Diospyros siamang</i>	Ehang	No
ELAEOCARPACEAE		
<i>Elaeocarpus mastersii</i>	Mangkinang / blueberry	Yes *
EUPHORBIACEAE		
<i>Baccaurea bracteata</i>	Rambai Hutan	Yes
<i>Blumeodendron elateriospermum / tokbrai</i>	Kenari	Yes *
<i>Cephalomappa</i>	Kerandau	Yes
<i>Neoscortechinia kingii</i>	Pupu Palanduk	Yes
FABACEAE (LEGUMINOSAE)		
<i>Adenantha pavonina</i>	Tapanggung	No
<i>Koompassia malaccensis</i>	Bungaris	Yes
FAGACEAE		
<i>Lithocarpus</i>	Pampaning	Yes
HYPERICACEAE		
<i>Cratoxylon</i>	Geronggang	No
ICACINACEAE		
<i>Platea excelsa</i>	Kambalitan	Yes
<i>Stemonorus scorpiodes</i>	Tabaras/ pasir pasir	Yes *
LAURACEAE		
<i>Alseodaphne coriacea</i>	Gemur	No
<i>Cryptocarya / Litsea</i>	Medang	Yes *
<i>Litsea rufo-fusca</i>	Tampang	Yes
MELASTOMATACEAE		
<i>Memecylon</i>	Milas	Yes
MELIACEAE		
<i>Aglaia rubiginosa</i>	Kajalaki	Yes
<i>Sandoricum beccanarium</i>	Papong	Yes *

MORACEAE		
<i>Parartocarpus venenosus</i>	Lilin Lilin	Yes *
MYRISTICACEAE		
<i>Gymnacranthera / Horsfieldia</i>	Mendarahan	Yes
MYRSINACEAE		
<i>Rapanea borneensis</i>	Mertibu	No
MYRTACEAE		
<i>Eugenia spicata</i>	Kayu Lalas/Galam Tikus	No
<i>Syzygium havilandii</i>	Tatumbu/Jambu jambu	Yes *
<i>Syzygium</i>	Jambu Burung	Yes *
<i>Syzygium</i>	Hampauk Galaget	Yes
<i>Tristaniopsis</i>	Blawan	No
RHIZOPHOREACEAE		
<i>Carillia brachiata</i>	Gandis	No
RUTACEAE		
<i>Tetractomia tetrandra</i>	Rembangun	No
SAPINDACEAE		
<i>Dimocarpus longan</i>	Kajalaki	Yes
<i>Nephellium maingayi</i>	Kelumun Buhis	Yes
<i>Nephellium lappaceum</i>	Rambutan Hutan	Yes *
SAPOTACEAE		
<i>Isonandra/Palaquium</i>	Nyatoh spp	Yes *
<i>Madhuca mottleyana</i>	Katiau	Yes *
<i>Palaquium leiocarpum</i>	Hangkang	Yes
TETRAMERISTACEAE		
<i>Tetramerista glabra</i>	Ponak	Yes *
THEACEAE		
<i>Ternstroemia magnifica</i>	Tabunter	Yes
THYMELEAEACEAE		
<i>Gonystylus bancanus</i>	Ramin	No
TILIACEAE		
<i>Microcos (Grewia)</i>	Brania himba	Yes *

* species included in the top 20 food trees in the diet of *H. albibarbis*. (Cheyne and Shinta, 2006)

APPENDIX IV : TRAINING VIDEO PROJECT

As a side project and as part of the Environmental Education module of the MSc in Primate Conservation, the production of a training video was started at the field site.

The aim of the video is to explain the method of fixed-point counts which relies on using primate vocalisations to determine their density. As the method is seldom used, it is not part of most reviews of survey methodology and does not appear in the curriculum of the MSc. Students who wish to use this method are confronted with a lack of information and resources and consequently often find the prospect of using the method daunting. Similarly, conservation workers and field assistants in habitat countries, who have little or no access to scientific literature, cannot use the method without being directly trained by a visiting researcher. The video aims to make the method easily understandable by showing a team of researchers and Indonesian field assistants using it to determine the density of agile gibbons in the Sebangau National Park.

During the time of the field work (May to July 2008), footage was obtained using a Sony camcorder. Two versions were recorded, one in English and one in Indonesian, in order to produce a bilingual DVD that will subsequently be distributed both internationally and in Indonesia. The tapes were then brought back to the UK where the video will be edited and produced.

It is hoped that this training video, that will be made available to the MSc in Primate Conservation, will help students, researchers and conservation workers feel more confident to use auditory sampling as a quick and efficient survey method for vocal primates.