

BRIEF REPORT

Use of Limestone Karst Forests by Bornean Orangutans (*Pongo pygmaeus morio*) in the Sangkulirang Peninsula, East Kalimantan, Indonesia

ANDREW J. MARSHALL^{1,2*}, LEONARDO A. SALAS³, SUZETTE STEPHENS⁴, NARDIYONO², LINDA ENGSTRÖM², ERIK MEIJAARD², AND SCOTT A. STANLEY²
¹Arnold Arboretum of Harvard University, Cambridge, Massachusetts
²Nature Conservancy, East Kalimantan Portfolio Office, Indonesia Program, East Kalimantan, Indonesia
³Wildlife Conservation Society, Papua New Guinea Program Goroka, Papua New Guinea
⁴Center for Biodiversity Conservation, Conservation International, Melanesia Program Waigani, Papua New Guinea

The Indonesian province of East Kalimantan is home to some of the largest remaining contiguous tracts of lowland Dipterocarp forest on the island of Borneo. Nest surveys recently conducted in these forests indicated the presence of a substantial population of Eastern Bornean orangutans (*Pongo pygmaeus morio*) in the Berau and East Kutai regencies in the northern half of the province. The Sangkulirang Peninsula contains extensive limestone karst forests in close proximity to the lowland Dipterocarp forests inhabited by orangutans in these regencies. Orangutans have been sighted in these limestone karst forests, but the importance of this forest type for orangutans has been unclear. Therefore, we conducted 49 km of nest surveys in limestone karst forest to obtain the first quantitative estimates of orangutan densities in this habitat, and walked 28 km of surveys in nearby lowland Dipterocarp forests for comparison. We also gathered basic ecological data along our transects in an attempt to identify correlates of orangutan abundance across these habitat types. Undisturbed limestone karst forests showed the lowest orangutan densities (147 nests/km², 0.82 indiv/km²), disturbed limestone forests had intermediate densities (301 nests/km², 1.40 indiv/km²), and undisturbed lowland Dipterocarp forests contained the highest density (987 nests/km², 5.25 indiv/km²), significantly more than the undisturbed limestone karst forests. This difference was not correlated with variation in liana abundance, fig stem density, or stump density (an index of forest disturbance). Therefore, other factors, such as the relatively low tree species diversity of limestone karst forests, may explain why

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*Correspondence to: Andrew J. Marshall, Arnold Arboretum of Harvard University, 22 Divinity Ave., Cambridge, MA 02138. E-mail: amarshall@oeb.harvard.edu

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orangutans appear to avoid these areas. We conclude that limestone karst forests are of low relevance for safeguarding the future of orangutans in East Kalimantan. *Am. J. Primatol.* 69:1–8, 2007. © 2006 Wiley-Liss, Inc.

Key words: limestone karst forest; nest survey transects; *Pongo pygmaeus morio*

INTRODUCTION

Bornean orangutans (*Pongo pygmaeus*) are confined to the lowland and mid-elevation forests of the large Southeast Asian island of Borneo [Rijksen & Meijaard, 1999]. At all locations for which we have reliable data, orangutan populations appear to be in dramatic decline [Singleton et al., 2004]. Along with hunting for food and pets, habitat degradation and loss appear to be the major threats to orangutan populations [Rijksen & Meijaard, 1999; Singleton et al., 2004]. It is therefore imperative that conservationists interested in preventing the extinction of these taxa ascertain which habitat types are suitable for orangutans and what densities they support.

Recent nest surveys that we conducted at a large number of sites in East Kalimantan [Marshall et al., 2006] indicated that the Berau and East Kutai regencies support a sizeable population of orangutans. We placed the majority of our transects in lowland Dipterocarp forests (hereafter termed lowland forest), a habitat type known to sustain moderate densities of Bornean orangutans [e.g., Ancrenaz et al., 2005; Rijksen & Meijaard, 1999; Rodman, 1988]. We also conducted several surveys in the Sangkulirang Peninsula, which contains extensive tracts of forest growing on limestone karst formations (hereafter termed karst forest; see Proctor et al. [1983] for a detailed description of Bornean karst forest and comparison with lowland forest). Reports of sightings suggest that orangutans use karst forests [e.g., Rijksen & Meijaard, 1999], and cave deposits in mainland Asia suggest that orangutans inhabited forests on limestone during the Pleistocene [Schepartz et al., 2000]. However, to date no systematic surveys of orangutans have been conducted in karst forest, so the importance of this habitat for orangutans has been unclear.

Ascertaining the suitability of karst forest for orangutans is important to conservationists for several reasons. First, it would help determine the extent of suitable orangutan habitat remaining in East Kalimantan. Most conservationists incorporate models of population and habitat viability into their long-term management plans [Beissinger & Westphal, 1998; Roloff & Haufler, 1997]. Such models are strongly sensitive to initial population size, rely on habitat-specific estimates of population density and sizes of blocks of different habitat types, and assume some level of connectivity between these blocks [e.g., Singleton et al., 2004]. Because karst forests are extensive in East Kalimantan (but not in other parts of *Pongo* spp. range), erroneously including or excluding them as orangutan habitat would lead to inaccurate population estimates. Second, evidence that karst forests support large orangutan populations could provide additional incentive and resources to protect these forests, which are of substantial conservation importance because of their high levels of floristic endemism [Vermeulen & Whitten, 1999]. The karst forests of East Kalimantan are among the most extensive sets of karst formations in the world [MacKinnon et al., 1996]. They are highly susceptible to fires during drought conditions because they are surrounded by areas that have been logged [Siegert et al., 2001; Yeager

et al., 2003], and the high permeability of the limestone bedrock causes water to drain out, leaving fire-prone dry soil and abundant tinder [Vermeulen & Whitten, 1999].

We conducted orangutan nest surveys in limestone karst forest and in nearby lowland forests to compare the population densities of orangutans in these two forest types. In addition, we gathered basic ecological data and estimated habitat disturbance in order to determine whether there were any ecological correlates of orangutan abundance across these forest types.

MATERIALS AND METHODS

We conducted surveys at four locations (see Fig. 1), as described below:

1. Gunung Nyapa (GN) is a pristine limestone karst forest on steep hills. GN has suffered little logging impact and has not been affected by fire. The lowland forests (<400 m a.s.l.) on this formation are dominated by Dipterocarpaceae trees. Although GN lacks the dramatic pinnacles and dolines that are typical of many karst landscapes, the limestone bedrock is evident in numerous large cliffs and caves. The nearest human settlement is a day away on foot, and at present the area is largely undisturbed by human activities.

2. The Baai formation is much smaller than GN and has burned several times in the last 15 years. The karst is exposed in pinnacles, sinkholes, cliffs, and dolines throughout the formation. Baai is surrounded by secondary vegetation, e.g., the exotic shrub *Piper aduncum* and *Acacia angustifolia* plantations. Some native trees survive in small pockets among the pinnacles. Although Baai is readily accessible from the nearby town, it is too degraded to be of interest to most local people and consequently is rarely visited.

3. Marang (MR) has also suffered extensive damage. Most of the forests on pinnacles and dolines burned down during the fires in 1997–1998, but native vegetation survived in riparian forests and in pockets inside dolines. *Macaranga* spp. trees dominate the disturbed areas. MR is accessible within 1 day by boat from several towns, and is frequently visited by swift bird nest collectors, illegal loggers, and hunters.

4. Gunung Gajah (GG) is a 32,000 ha block of lowland Dipterocarp forest on sedimentary soils. Selective logging has occurred near GG, and nearby areas are dominated by shrubs and secondary vegetation. Hunting is very limited and the nearest settlement is 1 day away by car. This site is denoted as GG7 in our larger analysis [Marshall et al., 2006].

We collected nest data along transects set perpendicular to 1-km midlines (see Johnson et al. [2005] and Marshall et al. [2006] for details of the methodology). The midlines were separated from each other by at least 1 km. We placed seven midlines at GG between September and October 2003, 12 midlines at GN between April and June 2003, and one midline each at Baai and Marang in August 2004. We placed two transects on the midline at Baai, four on the midline at MR and one midline at GN, and eight on the remaining 11 midlines at GN and on all seven midlines at GG. All transects on the same side of the midline were at least 100 m apart. We walked a total of 154 transects, yielding a total survey effort of 77 km.

To minimize error in nest counts due to missed nests, each transect at GG and GN was walked twice by a different team comprised of two trained assistants. We recorded all orangutan nests along each transect. We affixed a small aluminum tree tag bearing a unique sequential number to each tree to ensure that the nests would not be counted twice. Whenever a nest was sighted, we

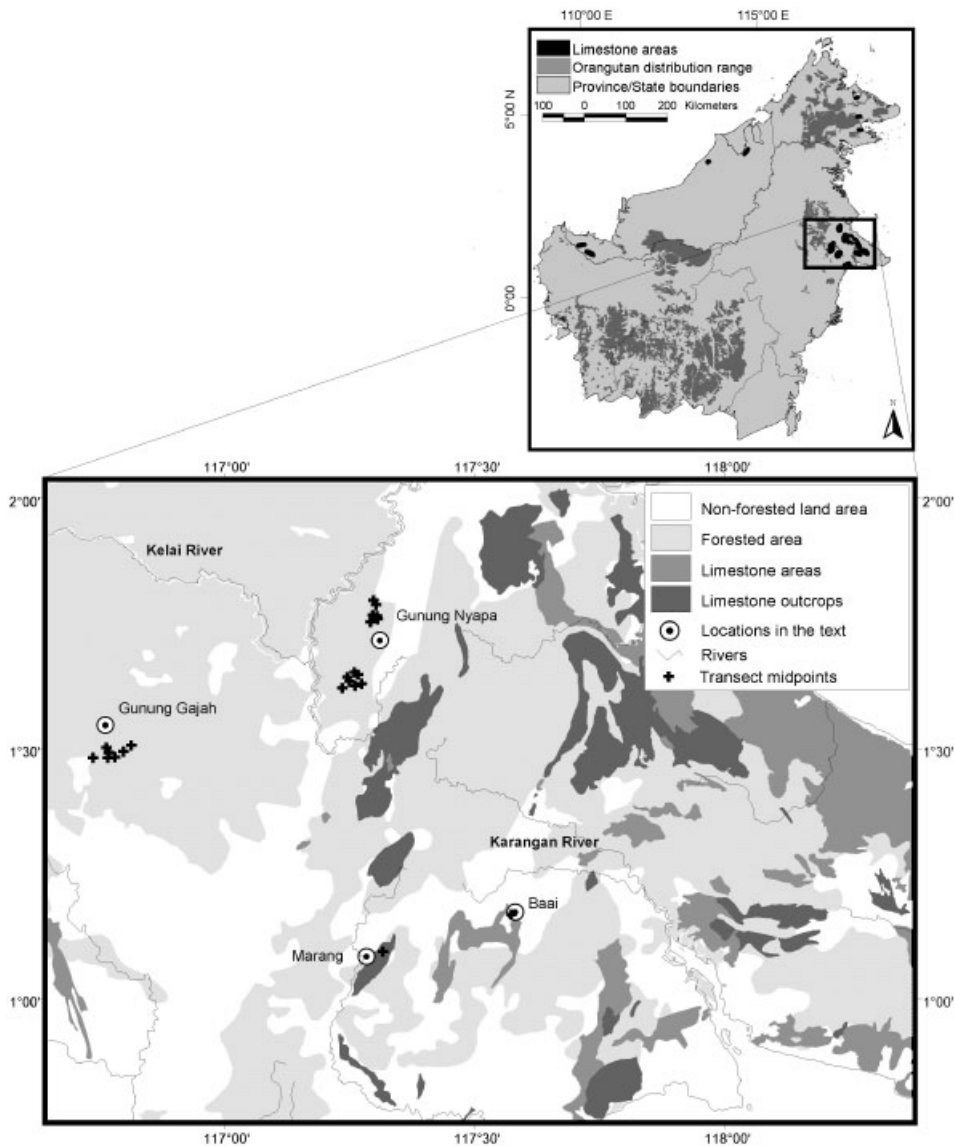


Fig. 1. Top: Map of Borneo showing the location of limestone areas, province and state boundaries, and current orangutan distribution range (after Singleton et al. [2004]). Bottom: Map of survey area showing non-forest areas (white), forest areas (light gray), and forests on limestone (gray) and limestone outcrops (dark gray). The locations of the survey areas and all transects are also listed.

recorded the following information: the side of the transect where it was found (e.g., north, south, etc.), the diameter at breast height (dbh) of the host tree, the local name of the tree (if known), and a qualitative estimate of nest age class.

We used Distance 4.0 Release 2 [Thomas et al., 2002] to estimate the nest and orangutan density at each midline. Data analysis followed standard methods [Buckland et al., 2001]. The specifics and a discussion of the parameters are provided in Marshall et al. [2006]. To avoid possible spatial autocorrelation due to the proximity of transects, we used midlines as independent sampling units. Since

the transects at MR and Baai were walked only once, bias was likely incurred by missing nests that would have been detected in a second walk [Johnson et al., 2005]. To correct for this potential bias, we calculated the linear relationship between the numbers of nests counted on the first and second walks of a transect at each midline in GG and GN, and scaled up the number of nests recorded at MR and Baai accordingly.

We systematically measured the abundance of trees, lianas, figs (subgenus *Conosycea* only), and stumps from felled trees in several size classes along all transects at GG and GN (see Marshall et al. [2006] for details). Large lianas and figs are important orangutan food resources and may therefore set carrying capacity [Leighton & Leighton, 1983]. We used the number of tree stumps resulting from chainsaw cuts as a measure of logging intensity.

RESULTS

We walked 49 km of transects in karst forest and 28 km in lowland forest. We counted a total of 1,504 nests, 269 of which were found in karst forest (Table 1). There were no differences between sites in the diameter of trees in which nests were built (mean nest tree dbh Baai = 39.8 cm, MR = 35.8 cm, GN = 35.4 cm, GG = 25.5 cm). Orangutan density estimates were higher in lowland forest (GG, mean = 5.3 indiv/km²) than in undisturbed karst forest (GN, mean = 0.82 indiv/km², Mann-Whitney $U = 0$, $n_1 = 12$, $n_2 = 7$, $P = 0.0004$). The two most disturbed karst sites (Baai and MR) had higher densities (mean = 1.4 indiv/km²) than any midline at GN, but less than half of those found at GG (Table 1).

Liana abundance did not differ between GG and GN (Table 1). Figs with dbh > 10 cm were more abundant at GN than GG ($U = 16$, $n = 19$, $P < 0.05$), although neither the density of smaller figs nor the total fig abundance differed significantly between the two sites. Logging intensity at GG and GN was comparable and low (roughly 1.2 trees/ha). Orangutan density was uncorrelated with any ecological measure or logging intensity.

DISCUSSION

Our results show that orangutan densities were lowest in relatively undisturbed karst forests (GN), intermediate in highly disturbed karst areas (Baai and MR), and highest in lowland forests (GG). Since logging intensity at both the lowland site (GG) and the undisturbed karst forest (GN) was equally low, the differences in nest density between these two forest types are unlikely to be due to the effects of logging. An alternative possibility is that the differences in density are due to differences in hunting intensity between sites. Marshall et al. [2006] showed that distance to the nearest village known to hunt orangutans has a significant effect on the density of orangutans, particularly in non-karst forests. Although karst forests in East Kalimantan are generally more difficult to access than lowland forests, hunting pressures may have varied between the sites we surveyed. However, this is unlikely to explain the differences between sites since the site with the lowest orangutan nest density (GN) was much less accessible to hunters than any of the other sites. Finally, because our surveys were not conducted at the same time, and we have no measurements of temporal variation in food availability, it is possible that phenological variation between karst and lowland sites may explain some of the variation we found. However, since nests are visible for many months and therefore integrate temporal fluctuations in density, nest surveys are less susceptible to this source of bias than

TABLE 1. Orangutan Density Estimates and Ecology Data from Lowland Forest (Gunung Gajah, GG), Undamaged Karst Forest (Gunung Nyapa, GN), and Karst Forest Damaged by Logging and Fire (Baai and Marang, MR)*

Forest type	Midline	Nests	Nest density (nests/km ²)	Nest density CV	Estimated orangutan density (indiv/km ²)	Midline coordinates (UTM)		40–59cm dbh trees/ha	60–79cm dbh trees/ha	>80cm dbh trees/ha	5–9.5cm dbh lianas/ha		5–9.5cm dbh lianas/ha		>10cm dbh lianas/ha	>10cm dbh figs/ha	
						Start	End				dbh	figs/ha	dbh	figs/ha			
Lowland forest	GG-1	188	1051	11.2	5.41	487779–174025	487114–175012	25.8	10.8	4.3	17.5	5.5	1.3	0.8	0.8	0.8	
	GG-2	172	962	10.9	4.99	488301–173036	487327–173014	26.3	16.0	7.5	15.3	7.8	1.5	0.8	0.8	0.8	
	GG-3	102	570	16.5	3.30	489486–172736	489156–172113	22.5	10.5	3.9	12.3	6.8	2.5	0.8	0.8	0.8	
	GG-4	235	1314	19.8	6.90	490252–174241	490926–174850	28.8	26.0	8.3	21.3	9.8	2.0	0.0	0.0	0.0	0.0
	GG-5	188	1051	11.2	5.51	491004–173575	491800–173127	21.5	7.0	1.6	17.0	5.5	1.5	0.5	0.5	0.5	0.5
	GG-6	194	1085	17.5	5.65	485296–174223	484985–174135	29.8	20.3	10.6	20.5	9.5	2.0	0.8	0.8	0.8	0.8
	GG-7	156	872	21.1	5.02	492020–170828	492722–171460	23.8	8.0	4.6	17.5	6.3	2.3	0.0	0.0	0.0	0.0
	Mean	176	987	15.5	5.25			25.5	14.1	5.8	17.3	7.3	1.9	0.5	0.5	0.5	0.5
	GN1-1	9	77	30.0	0.47	533207–198579	532002–199441	25.5	17.8	3.1	22.8	9.5	1.5	1.8	1.8	1.8	1.8
	GN1-2	7	60	41.4	0.34	533739–197554	533880–197442	28.3	15.8	6.3	24.0	15.5	1.3	2.3	2.3	2.3	2.3
	GN1-3	23	197	36.9	1.09	533959–195130	534536–195486	25.8	17.0	5.5	21.8	14.3	1.0	1.0	1.0	1.0	1.0
	GN1-4	22	188	33.7	1.05	534097–194433	534893–194419	25.8	16.0	7.1	16.8	12.3	0.8	0.5	0.5	0.5	0.5
	GN1-5	51	436	33.1	2.46	533021–195292	533222–192555	30.3	12.0	5.1	11.5	7.3	0.8	0.5	0.5	0.5	0.5
	GN1-6	10	86	26.1	0.51	532521–193783	531523–193232	33.0	16.8	5.8	16.0	17.0	0.3	0.8	0.8	0.8	0.8
Mean	20	174	33.5	0.99			28.1	15.9	5.5	18.8	12.6	0.9	1.1	1.1	1.1	1.1	
GN2-1	19	111	47.0	0.61	530456–182080	531301–182061	23.8	13.5	2.3	22.8	10.8	0.5	0.8	0.8	0.8	0.8	
GN2-2	1	12	66.2	0.06	528323–181357	529136–181299	29.0	11.0	1.3	22.5	10.5	1.5	1.0	1.0	1.0	1.0	
GN2-3	37	216	18.1	1.16	527390–183117	527410–183925	21.3	11.5	5.1	9.5	2.5	0.5	0.0	0.0	0.0	0.0	
GN2-4	34	198	31.5	1.09	527509–182473	528195–182835	23.8	9.8	4.3	19.8	6.3	1.5	2.5	2.5	2.5	2.5	
GN2-5	25	146	33.9	0.79	526530–183476	526421–na	19.3	9.3	4.9	11.8	5.0	2.0	0.8	0.8	0.8	0.8	
GN2-6	7	41	29.2	0.22	526343–181919	526292–180978	27.0	10.5	3.3	17.5	6.0	1.0	0.8	0.8	0.8	0.8	
Mean	21	121	37.6	0.66			24.0	10.9	3.5	17.3	6.8	1.2	1.0	1.0	1.0	1.0	
Baai	14	402	7.7	2.02	565190–129262	na	4.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
MR	10	200	55.6	0.50	531198–12028C	na	10.0	1.0	1.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	
MR																	
Mean	12	301	31.6	1.40			7.0	1.5	0.5	1.3	0.0	0.0	0.0	0.0	0.0	0.0	

*The total number of orangutan nests, point estimate and coefficient of variation (CV) of nests/km², estimated orangutan density (individuals/km²), and UTM (WGS84) coordinates of the start and endpoint at each midline are given. At MR and Baai both raw data and density estimates scaled up to account of the fact that transects at these sites were walked only once (indicated by “•”) are given. The stem density of trees in three diameter classes and lianas and figs in two diameter classes are also provided, na, not available.

surveys based on direct sightings. Therefore, we conclude that differences in nest density reflect real habitat differences in the density of orangutans that can be supported (i.e., karst forests have lower orangutan carrying capacities compared to lowland forests).

The different habitat-specific population densities of karst and lowland forest were not correlated with differences in any of our simple ecological measures (e.g., fig abundance, liana density, or tree size distributions), although we have no means of assessing the relative availability of food at the time when the surveys were conducted. It is likely that more fundamental differences between the habitat types are responsible for the difference in orangutan abundance. For example, karst forests have roughly one-third of the floristic diversity present in lowland Dipterocarp forests [MacKinnon et al., 1996; Proctor et al., 1983]. Therefore the availability of orangutan food trees in karst forest is likely to be much lower than that in lowland forests. Thus, differences in food availability may underlie differences in habitat-specific orangutan densities, although this hypothesis has yet to be directly tested.

Perhaps more puzzling is the result that orangutan nest densities are higher in highly disturbed karst forest (Baai and MR) than in relatively undisturbed karst forest (GN). Although results have varied substantially among studies, logging generally appears to have negative effects on orangutan density [e.g., Johnson et al., 2005; Morrogh-Bernard et al., 2003; Rijksen & Meijaard, 1999; Singleton et al., 2004]. In the case of the karst forests we surveyed, logging (and burning) appeared to have the opposite effect. The most likely explanation is that the orangutans in the disturbed karst areas were feeding in nearby plantations and therefore were able to subsist at far higher densities than the habitat could otherwise support. Observations of nests in plantations near Baai support this hypothesis. It is also possible that fast-growing pioneer species (e.g., *Macaranga* spp.) in disturbed areas provided, perhaps temporarily, more food for the orangutans than was present prior to disturbance. More detailed surveys of orangutan food availability would address this issue.

Whether orangutans can survive solely in karst forest or need to forage in other habitats is at present unknown and deserves further study. In addition, it is unknown whether karst forests are of sufficient quality to allow orangutans to reproduce. Nevertheless, it is clear that karst forests are suboptimal habitats for orangutans, and should be considered as such by conservationists and managers interested in protecting orangutan populations. However, it should be noted that orangutans that occupy marginal habitats such as these may harbor interesting genetic or ecological variations that are not found in other orangutan populations.

The forests of East Kalimantan hold the last populations of *Pongo pygmaeus morio* in Indonesia. Our surveys indicate that the karst forests that dominate the Sangkulirang peninsula and other parts of this province are essentially non-habitat for orangutans. Therefore, although karst forests are of substantial conservation importance because of their high levels of endemism, they should not be the focus of programs targeted at preserving habitat for Asia's only great ape. Instead, efforts should focus on preservation of the lowland and swamp forests that are known to support high orangutan densities.

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