Etate Sector Bio-monitoring Report

Recommendations for the Conservation of the Bonobo and Other Key Species in the Salonga National Park, Democratic Republic of Congo.

Report to ICCN and WWF for CARPE/CBFP Phase I

Zoological Society of Milwaukee

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Introduction

The purpose of this report is to present a preliminary analysis and descriptive overview of bio-monitoring research activities conducted by the Zoological Society of Milwaukee (ZSM) in the Etate sector of the Salonga National Park (SNP) from 2004 to the present. We present results of ongoing research applied to the conservation of bonobos (*Pan paniscus*) and elephants (*Loxodonta africana cyclotis*), as they pertain to developing a park management plan for the SNP. Our research involves the study of fundamental ecological factors which influence the distribution and density of bonobos, and how human pressure (hunting activities) may affect bonobo and elephant occurrence. This baseline information is critical to the conservation biology of the species and the subsequent development of conservation strategies for the SNP and the Salonga landscape.

The SNP was created with the purpose of protecting the bonobo and forest elephant. It is the only national park and World Heritage Site where the bonobo is found. A priority for park management, therefore, is to identify, protect, and monitor viable populations of this endemic great ape.

Surveys within the Etate sector pinpoint core areas of bonobo and elephant distribution, as well as identify zones for species protection, develop access routes and corridors for monitoring, and elucidate the effects of human presence (hunting). Knowing where bonobos are and understanding why they occur there are fundamental aspects in the development of a conservation strategy. Population size and density are functions of available habitat and environmental disturbances. To evaluate areas for protection, managers often select locations based on the relative density of a species within a general region. However, density comparisons among sites are misleading unless the proportion of available habitat is also known. We report preliminary findings that identify areas of forest habitat that are important for bonobo nesting. Given the vast size of the SNP and limited personnel to monitor key wildlife species, we show a way by which monitoring bonobo populations can be streamlined because survey effort can be concentrated in areas that have a higher probability of bonobo occurrence.

In 1997, ZSM first documented the presence of a resident bonobo population in the Etate sector (the northwest strip between the Salonga and Yenge Rivers) (Van Krunkelsven *et al*., 2000). From 2000 to 2002, we surveyed nine dispersed sites in the SNP (north and south sector) and found that forest type and human presence affected bonobo densities (Reinartz *et al*., 2006). Using line transect sampling, we found that nest density was highest in study areas composed of mixed mature forest with a Marantaceae understory, second highest in mixed mature forests with a woody understory, and relatively low in old secondary forests with a Marantaceae understory. A significant inverse association existed between bonobo density and signs of human presence.

Little is known about the limits of bonobo distribution. At present, it is unknown whether distribution is continuous or divided into discrete units/subpopulations (assuming continuous habitat). Several pseudo-populations or hot-spots of bonobos have been identified in Salonga (MIKE and ZSM surveys); some authors consider these to be discrete populations (Inogwabini & Ilambu, 2005). However, apart from natural barriers to dispersal, we do not know whether true boundaries exist between these pseudo-populations and what may determine these limits. Etate is a unique study site in that this question can be addressed in the absence of confounding factors such as deforestation and the permanent presence of humans.

The above findings have implications for bonobo conservation in that surveys are needed to identify target areas for protection. Bonobo distribution in the SNP is patchy and difficult to predict. Therefore, without prior general knowledge of bonobo distribution, large scale, one-time surveys result in large variances in nest encounter rates, potentially miss core areas of distribution, and render coarse density estimates (Blake, 2005). Furthermore, such surveys do not adequately sample the amount of available habitat. Population monitoring requires gathering baseline data to develop a model that predicts the likelihood of bonobo occurrence, so that areas can be identified and periodically re-assessed in the most cost-effective manner. Bonobo nesting seems to be almost entirely limited to these formerly identified forest types (Reinartz *et al*., 2006). If these forest types can be located *a priori*, effort that would otherwise sample marginal habitat could be reallocated and concentrated where bonobos are more likely to occur (Buckland et al., 2001).

Based on former findings, we derived the following hypotheses in order to develop an efficient approach to assess bonobo populations:

- The distribution of the Etate bonobo population (as determined by nest distribution) corresponds to the distribution of available nesting habitat unless interrupted by severe hunting pressure.
- Blocks of nest-forest types can be located *a priori*. Blocks of mixed mature forest with a Marantaceae and/or woody understory can be detected using satellite imagery and pre-selected to be targeted by the overall survey design (stratification).
- The likelihood of finding signs of bonobos in pre-selected sample blocks is higher compared to transects placed randomly with respect to forest types. The density estimates derived from pre-selected forest blocks are more accurate with an equivalent sampling effort and sample size.

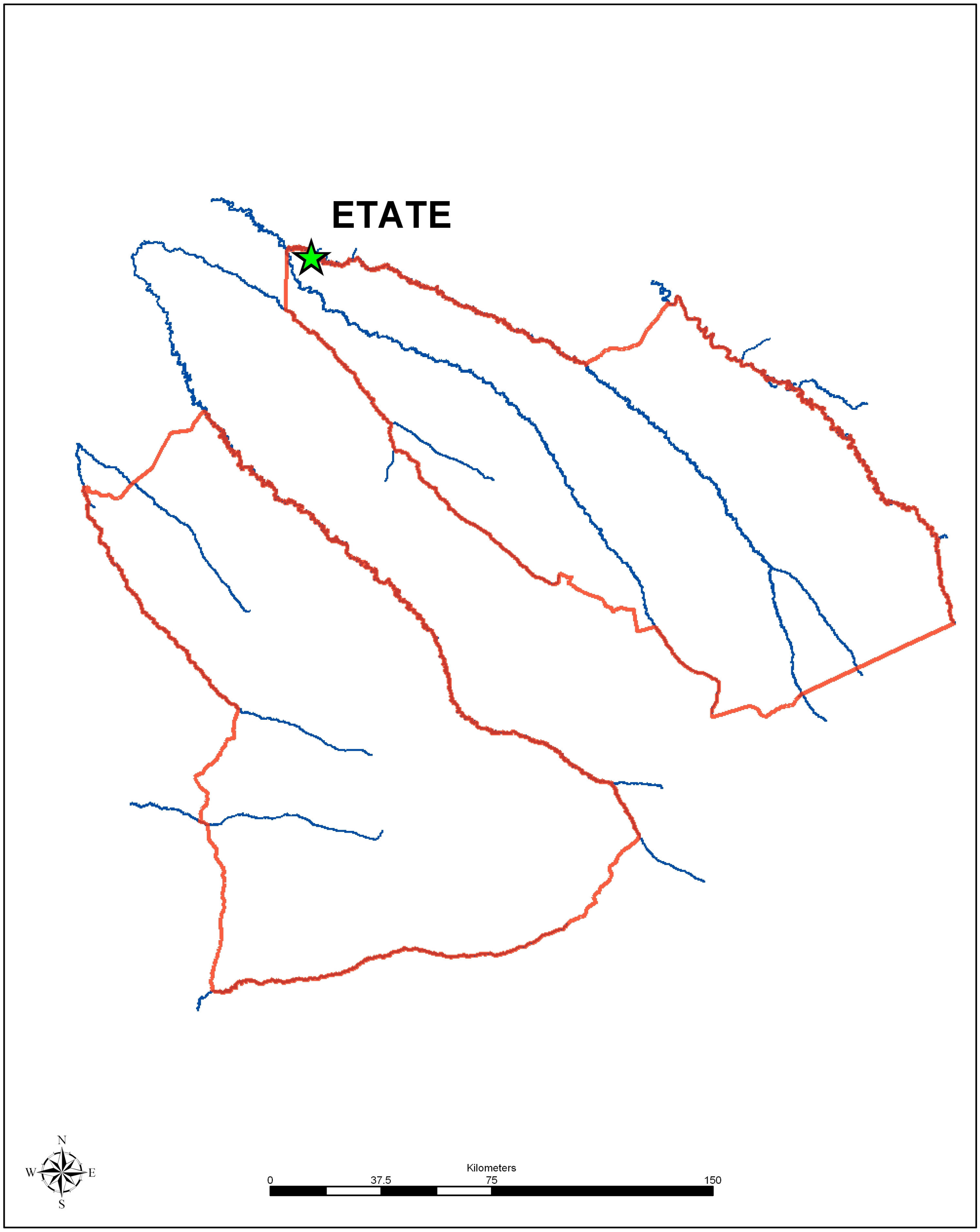
The results of these analyses yield a potential method to streamline survey efforts and design. This pragmatic approach will help direct park management activities and assess the effects of management practices.

Methods

Study Area

The Salonga National Park, located primarily within the Equateur Province, DRC, is Africa's largest tropical forest park, covering a vast area of 36,560 km^2 (D'Huart, 1988; Kempf and Wilson, 1997). The park is divided into northern and southern sectors of approximately equal size, separated by a swath of land roughly 45 km wide. Major rivers lead into and bound most of the Salonga which is a low plateau in the lower latitudes (350m elevation) gradually increasing in elevation southwards (up to 500m) (Evrard, 1968; D'Huart, 1988). The Etate patrol post/ZSM research station is located S01deg 3.255min, E 20deg 48.288min in the northern sector at the northwestern tip between the Salonga and Yenge Rivers (Map 1). The study area is a swath of land located between the Salonga and Yenge Rivers, an area of approximately 155 km^2, from the river junction in the northwest eastward to the latitude of the village of Bofoku Mai.

Map 1: Location of Etate patrol post/ZSM research station.

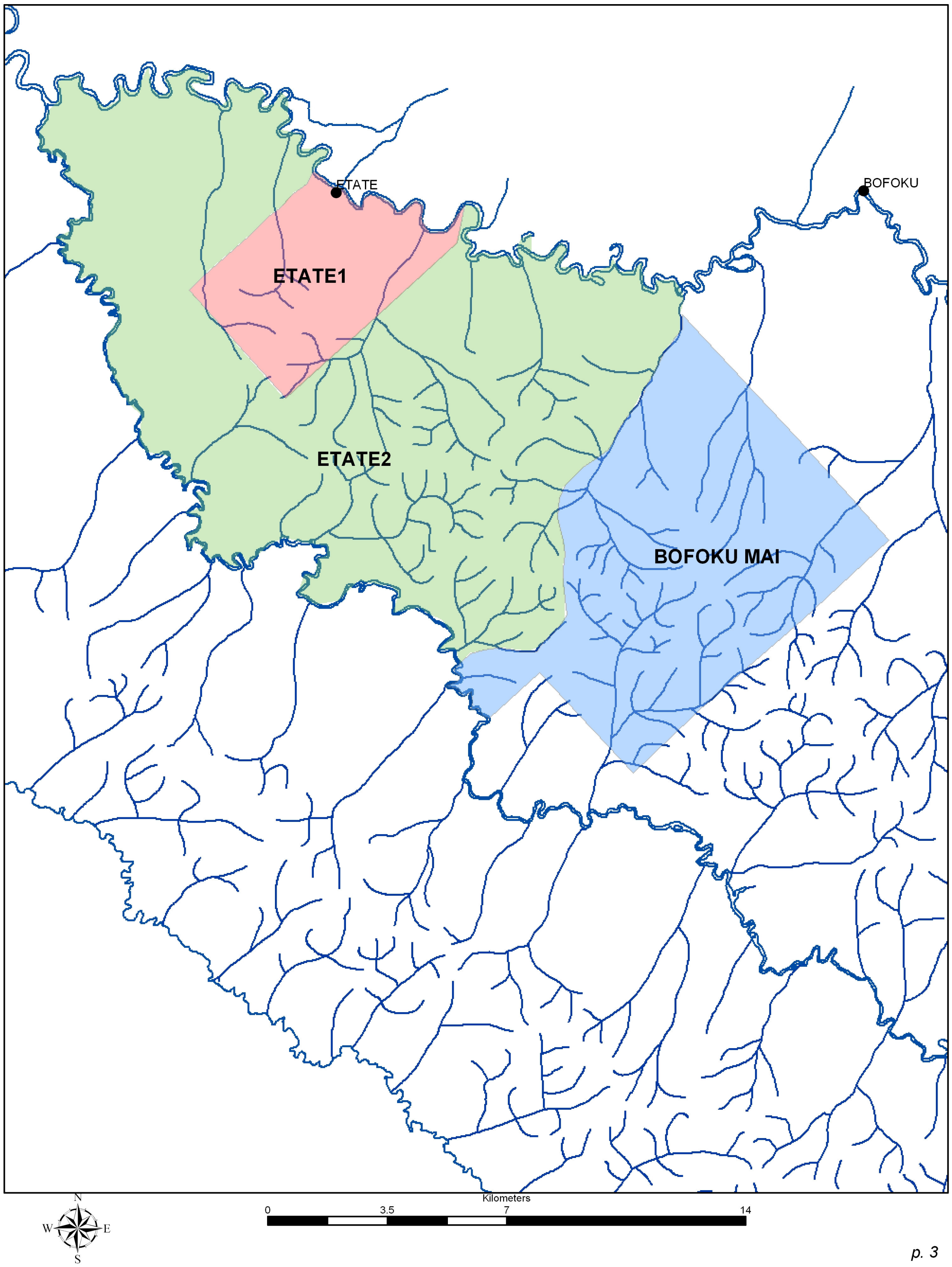


The predominant forest type found on dry land is semi-deciduous (frequently dominated by *Scorodophloeus zenkeri*) occasionally interspersed with mono-dominant stands of the evergreen *Gilbertiodendron dewevrei* on lower slopes (Kortlandt, 1995). Secondary forests of all ages are less frequent in the region of Salonga except in areas recently disturbed or occupied by humans. Areas along rivers are permanently or seasonally inundated and are covered by various stages of successional plant communities adapted to hydromorphic soils (e.g., *Uapaca*, *Pandanus*, *Raphia*, and *Guibourtia*).

The study took place from October 2004 to June 2006. We divided the study area into three sectors based on their increasing distance from the patrol post: Etate 1, Etate 2, and Bofoku Mai (Map 2). Etate 1 is comprised of five randomly located parallel transects of 1.5 to 2.5 km in length (interspersed by approximately 1 km). Randomly located transects were placed without regard to forest type, and were oriented perpendicular to hydrological gradients and to human trails when known (e.g., when trails followed ridge tops). Intentional transects are straight lines cut into pre-selected forest blocks, i.e., transects placed intentionally within what we assumed to be mixed mature forest types on *terra firma*. We pre-selected forest blocks from Landsat TM images based on previous ground-truthing studies and color and texture differences that indicated a greater probability of finding mixed mature forests with either a Marantaceae or woody understory, or a combination of both. Intentional transects were subsequently located in these pre-selected blocks. We sampled both random and intentional transects in the Etate 2 sector (Table 1).

Likewise, we conducted reconnaissance sampling in two ways: by directional recces where we followed paths of least resistance along compass headings without regard to forest types, and by intentional recces, where we followed compass headings in pre-selected forest blocks. We also conducted reconnaissance sampling along human trails connecting river systems and on smaller hunting *pistes*.

Map 2: Sampling sectors with the Etate study area.



Survey Methods

Reconnaissance and Transect Sampling

In general, reconnaissance walks preceded transect sampling and covered greater distances. The survey team covered various distances throughout the study area, using existing footpaths, animal tracks, or off-trail compass headings. Signs of bonobos, other large mammals, and human presence were noted and concomitant notes on forest type were recorded for bonobo and elephant signs. We used a hip-chain (topofil) to measure distances and distances within forest types. The reconnaissance walks provided an overview of forest types and topographic features and aided our interpretation of relative abundance of large mammals and the degree of human activity in the region. To estimate bonobo density, we collected data separately for both random and intentional transects using variable-width line transect sampling (Buckland *et al*., 2001). We sampled transects at Etate 1 three times over the study period; in contrast, we sampled the Etate 2 and Bofoku Mai transects only once.

For both reconnaissance walks and transects, we recorded each bonobo nest site, direct sightings, food remains, display branches, and tracks. We recorded only recent signs of elephants: dung, footprints, and paths. To gauge level of human activity and hunting, we noted recent signs such as snares, traps, footpaths, machete cuts, campsites, shotgun cartridges, and direct sightings. To compare relative abundance between sampling zones, we combined all data from transects and recces to calculate overall encounter rates (number of signs/km) of animal and human signs within each zone.

Density Estimates

We used individual nest counts (including only nests that were visible from the transect) to estimate bonobo nest density following Buckland *et al*. (2001). For calculations of bonobo densities, we utilized terms for the nest construction and decay rates and assumed that (a) weaned bonobos make one nest per night per individual, and (b) nests last on average 99 (±5) days as calculated for the Lomako Forest, Equateur (Fruth pers. comm., in Van Krunkelsven, 2001). Plumptre (2000) has emphasized the inherent error related to converting nest density to individual animal density caused by the variability of nest decay rates. The decay rate of 99 days was the only estimate available to date to estimate the mean life-span of bonobo nests. Acknowledging potential errors in decay rate, we converted the nest density data to nest-builder densities in order to make inter-site comparisons (the same results are obtainable from nest density).

To estimate nest densities, we measured the perpendicular distance of individual nests to the transect line. The computer program DISTANCE (version 4.1, Release 2: Thomas *et al*., 2003) used the frequency distribution of the perpendicular distances to model the probability of detection for nests and to calculate the effective strip width (ESW) for the area sampled. The probability of detection changes with different forest types, so to obtain asymptotically unbiased estimates of bonobo density, we included forest type as a covariate in the model (Buckland *et al*., 2001; Marques and Buckland, 2003; Thomas *et al*., 2003). To avoid pseudo-replication (Hurlbert, 1984), we combined observations for the transects re-sampled at Etate 1 and took the weighted average for these transects (weighted by 1/no. times visited) (Buckland *et al*., 2001; Buckland, pers. comm.).

Forest Description and Sampling
We designated forest classes in accordance with Evrard (1968) and modified from Kortlandt (1995), White and Abernethy (1997), and White and Edwards (2000b). Because forest classification systems vary among authors describing bonobo and great ape habitat (for review, see Kortlandt, 1995), we adopted a forest description method that defines broad discrete categories of forest tree canopy, understory, and hydrological conditions encountered in Salonga. We confined our categories to forests occupying *terra firma* or seasonally inundated soils. We did not sample completely inundated forests due to the logistical difficulty of cutting transects and the evidence that bonobos infrequently nest in inundated forests (Kano, 1983, 1984; Kortlandt, 1995). This approach underestimates elephant occurrence.

The forest tree canopy classes and understory followed Reinartz *et al*., 2006. They consisted of *Mixed mature* (Mm), *Old secondary* (Os), *Young secondary* (Ys), *Monodominant* (Md), and *Open* (O) *forests*. The understory designations included: *woody* (w), *Marantacea* (m), *liana* (l), and *open* (o). Forest types consisted of overstory and understory combinations (e.g., mixed mature/woody: Mmw) further defined by soil conditions and canopy conditions.

Along transects and recces, we measured the distance of forest types encountered. The proportions of representative forest types were calculated using only randomly placed transects and recces across the study area. We also analyzed the proportion of forest types in pre-selected blocks, on intentional transects and recces, and on major footpaths and hunting *pistes* separately. A single classification G-test for goodness of fit (based on assumptions extrinsic to the data: Sokal and Rohlf, 1995) tested whether bonobo nests were distributed uniformly within forest types (pooled across sectors; two-tailed tests). We manually calculated bonobo nest density -- for the area sampled within each forest type -- using the effective strip width (ESW) for each forest type as calculated by DISTANCE to obtain the effective area of the sample. We calculated the density of bonobo nests for the intentional vs. randomly placed transects using DISTANCE (stratified by transect type) in order to test whether transects placed in pre-selected forest blocks, assumed to be mixed mature forests, contained a higher bonobo nest density and produced a lower coefficient of variation than randomly placed transects.

An additional reconnaissance took place at Ikolo (between the Yenge and Loile Rivers) in December 2005. We collected data on four transects and on 5.5 km of reconnaissance to search for signs of bonobos, elephants, and humans.

We conducted training *in situ* with various Etate guards and ZSM personnel. We supplied each literate guard with a GPS. Bio-monitoring training entailed identification of bonobo nest trees (species), forest types, measurements of tree characteristics such as DBH, distance measures (topofil and *decametre*), compass, map reading, and GPS functions.

Results

We constructed 14 random and 19 intentional transects throughout the sampling sectors combined. The sampling effort totaled 34 km and 23.5 km for random and intentional transects, respectively (Table 1). Overall, reconnaissance effort totaled 63.4 km, of which 52.2 km were foot paths and hunting *pistes*.

Bonobo Density Estimates
Over the entire study area, bonobo nest density was 139 nests/km^2, yielding 1.4 adult bonobos/km^2 (Table 1). The Etate 1 sector, composed of only randomly placed transects, was richer in bonobo occurrence and had a higher nest density than Etate 2 and Bofoku Mai sectors (even with intentional and random transects combined). Etate 1 appears to be the core of this bonobo population. Nest density at Etate 1 was estimated at 186 nests/km^2 (1.9 adult bonobos/km^2), whereas Etate 2 and Bofoku Mai had 116 nest/km^2 (1.2 adults/km^2) and 104 nests/km^2 (1.1 adults/km^2), respectively.

Table 1: Transect type, number of nests, and nest density by sampling sector across the study area.

Transect		Region			
		Etate 1	**Etate 2**	**Bofoku Mai**	**Study area**
No. transects (No. Nests)	**Total**	11 (101)	20 (102)	8 (19)	**39 (222)**
	random	11 (101)	8 (65)	1 (0)	20 (166)
	intentional Mmm	0	12 (37)	7 (19)	19 (56)
Effort (No. Km)	**Total**	19.5	31.4	6.6	**57.5**
	random	19.5	14	0.5	34
	intentional Mmm	0	17.4	6.1	23.5
Nest Density (No. nests / km²)	**Total**	**186.0**	**117.0**	**104.0**	**139.0**
	% CV	20.8	22.9	54.7	15.4
	random	**186.0**	**100.0**	--	--
	% CV	20.8	30.0	--	--
	intentional Mmm	--	**141.0**	**104.0**	--
	%CV	--	32.0	54.7	--

Representative Forest Types
We encountered nine forest types (Table 2). Using only randomly placed transects and recces to assess representative forest types, the most frequently encountered types were Mmw, Mmm, and Mml. The proportions of Mmw and Mmm forest types were nearly equal (36.2% and 35.3%, respectively). Os forest types were less common (14.9%) in the overall Etate study area and limited to a few sites of ancient villages. Lianas account for 15% of understory and are typically found in wetter soil conditions. The proportions of all other forest types were less than 10% for each type encountered.

Table 2: Representative proportions of forest types (on random transects and directional recces) across the study area.

Representative samples (30.1km)		Forest type		
		Mm	Os	O
Understory	m	10.61 (35.3%)	1.75 (5.7%)	0.25 (0.8%)
	w	10.88 (36.2%)	1.59 (5.1%)	--
	l	3.36 (10.8%)	1.28 (4.1%)	0.10 (0.3%)
	o	0.31 (1.0%)	--	--

Forest Types in pre-selected forest blocks

We sampled forest type on intentional transects and intentional recces (eliminating foot paths, trails and hunting *pistes*) in pre-selected forest blocks in order to determine the proportion of Mmm vs. Mmw vs. other forest types.

In contrast to representative forest types (random transects), analyses of intentional transects and recces showed that we had sampled 93% of mixed mature forests (compared to 71% on random samples). The proportion of Mmm doubled (68.5%) while the proportions of Mmw and other dropped to 24% and 6.8% respectively (Table 3). Thus, finding a greater proportion of mixed mature forests on intentional transects confirmed our hypothesis that these can be located remotely.

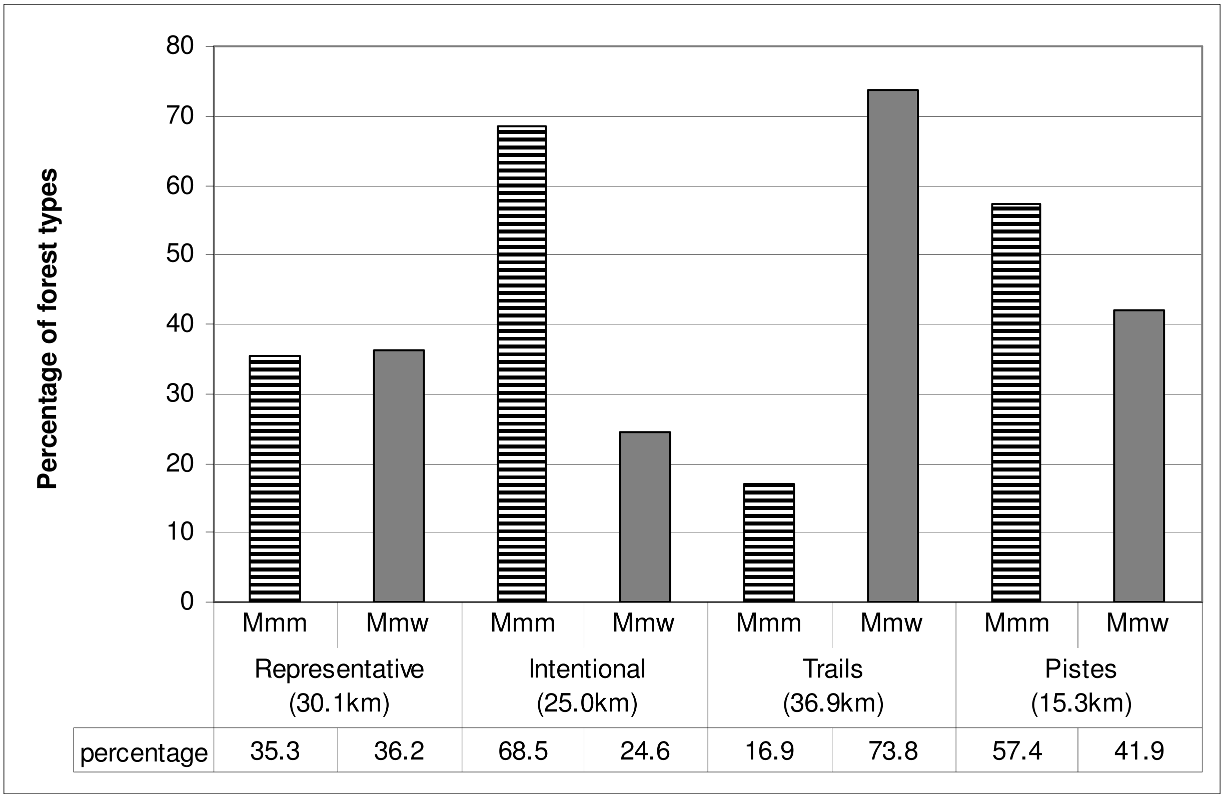
Table 3: Proportions of forest types on intentional transects and recces across the study area.

Intentional samples (25km)		Forest type		
		Mm	Os	O
Understory	m	17.12 (68.5%)	--	--
	w	6.16 (24.6%)	0.16 (0.7%)	--
	l	1.47 (5.9%)	--	0.07 (0.3%)
	o	--	--	--

Forest Types on trails and pistes

Mmw forest dominated major trails that often paralleled small rivers and streams; they appeared to avoid the thick undergrowth of the Mmm forest. Smaller hunting *pistes*, however, did not follow this pattern (Figure 1).

Figure 1: Major forest type proportions on representative samples, intentional samples, trails and *pistes*.



Forest types within sectors

The proportions of forest types varied locally over the study area and were divided into random vs. intentional transects (Table 4). Using random transects only; Etate 1 contained a somewhat higher proportion of Mmm than Etate 2. As no random transects currently exist at Bofoku Mai, representative forest type proportions are not yet known. Using intentional transects, Etate 2 showed a slightly higher proportion of Mmm than Bofoku Mai.

Table 4: Forest type proportions and nest density estimates for intentional and random transects within survey sectors.

	Etate 1		**Etate 2**		**Bofoku Mai**	
	No. nests /km²	**% Mmm forest**	**No. nests /km²**	**% Mmm forest**	**No. nests /km²**	**% Mmm forest**
Random transects	186 (20.8% CV)	41%	100 (30% CV)	33%		
Intentional transects			141 (32% CV)	86%	104 (55%CV)	75%

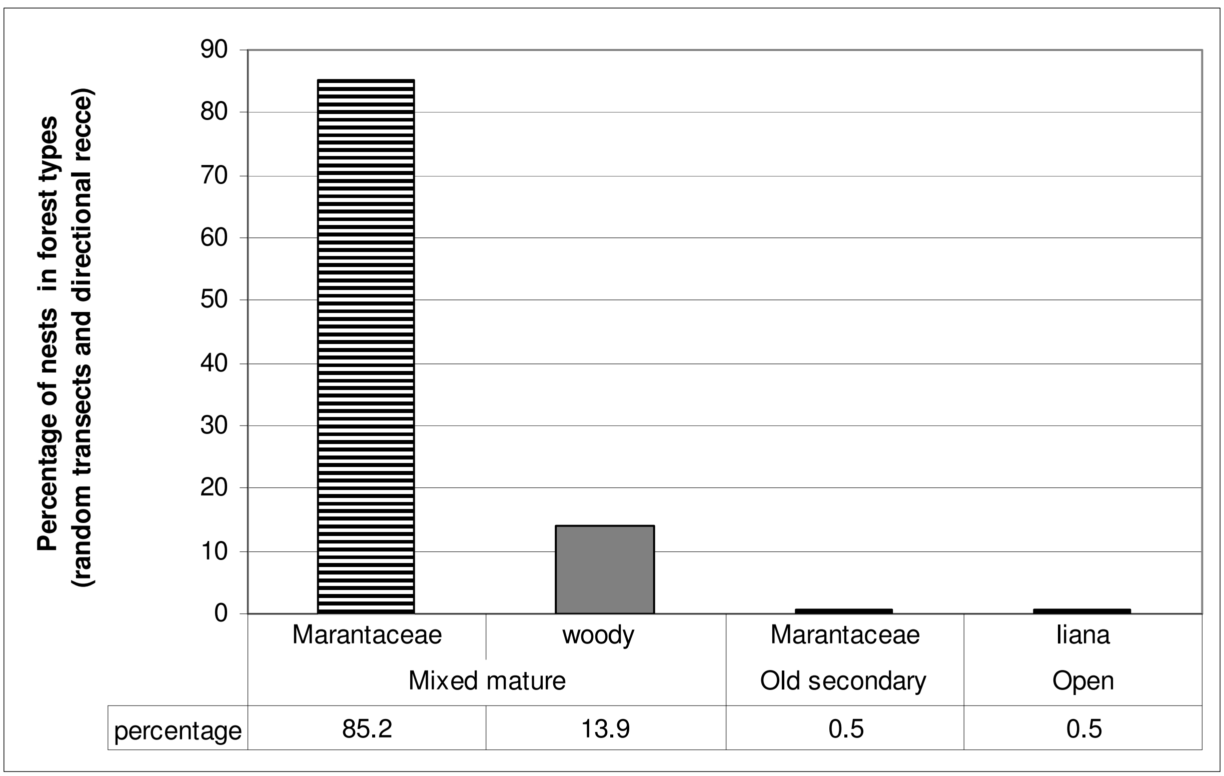
Nest Density in Forest Types

Over all transects in the study area, bonobo nests were not evenly distributed between the two forest types of Mmm and Mmw (X^2 = 29.77, d.f. 1, p << 0.0001); Mmm forests contained a significantly higher proportion of nests (Map 3). In all, 84% of all nests (n=222) were found in Mmm, 15% in Mmw, and 1% in other forest types (Figure 2). Nest density was twice as high in the Mmm (221 nests/km^2) vs. Mmw (113 nests/km^2) (Table 5, corresponding to earlier findings of Reinartz *et al*., 2006).

Table 5: Nest density in Mmm and Mmw forest types.

Forest type	Effort (km)	No. nests	Density (No.nests/km²)
Mmm	29.5	187	221.2
Mmw	12.9	33	112.9
Other	15.1	2	5.2

Figure 2: Percentage of bonobo nests in forest types.



Nest Density by Forest Type by Sample Sector

Etate 1 has the highest nest density of all three study sectors (186 nests/km^2) (Table 4). As compared to Etate 2, and using only random transects, Etate 1 has a slightly higher proportion of Mmm (41% vs. 33% at Etate 2). Etate 2 ranks second in nest density (100 nests/km^2) for random transects, and as expected, the nest density for Etate 2 on intentional transects is higher (141 nests/km^2). The proportion of Mmm on intentional transects at Etate 2 is 86% as compared to 75% at Bofoku Mai. Bofoku Mai intentional transects have a nest density of 104 nest/km^2.

These density estimates, however, had large coefficients of variation (20%-55%), producing a trend but unreliable estimates. For the comparison of the random vs. intentional transects at Etate 2, we expected to find both a higher nest density and a lower coefficient of variation for the intentional transects. While density was higher, the coefficient of variation was approximately the same for both transect types due to small sample size.

Elephant Distribution and Sign Encounter Rates
Etate 1 was devoid of recent elephant signs, although numerous ancient elephant trails existed (mostly overgrown). We encountered signs of elephants most frequently in the Ikolo Sector (between the Yenge and the Loile Rivers) at a rate of 0.9 signs/km (Table 6). In the Etate 2 and Bofoku Mai sectors, elephant signs (n=56) were concentrated near the Yenge River (0.8 signs/km) (Map 3). Most signs consisted of foot prints and paths heading in a northwesterly direction (from Bofoku Mai towards Etate 1 along the Yenge). We found no forest association with elephant occurrence, but small sample size precluded this analysis.

Table 6: Elephant sign encounter rates within Ikolo, Yenge and Salonga zones of the study area.

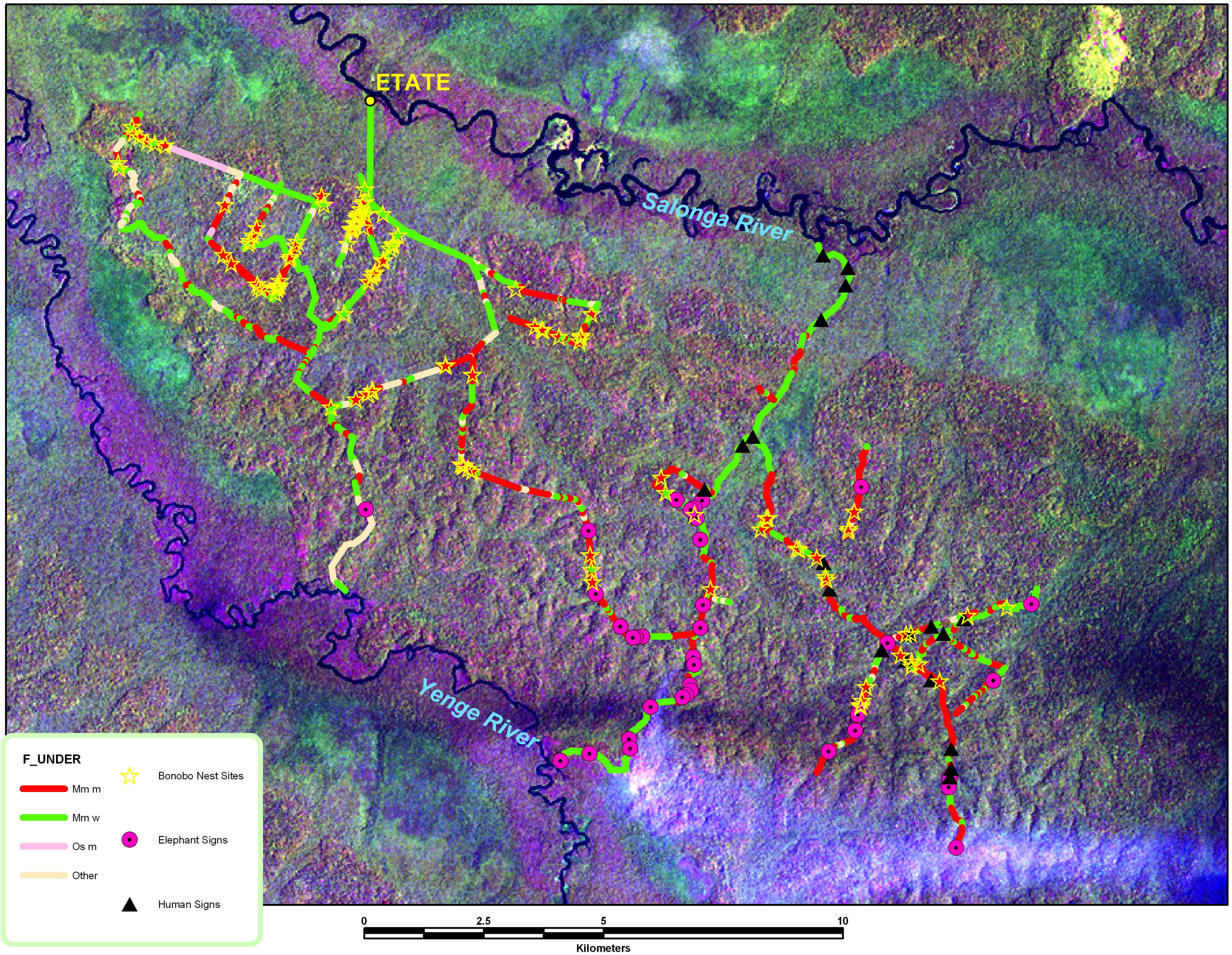
Elephant	Etate & Bofoku Mai sectors		Ikolo sector	Overall
	near Salonga	near Yenge		
No. signs	5.0	51.0	9.0	65.0
Effort (No. km)	54.7	61.7	9.5	125.9
Signs/km²	**0.1**	**0.8**	**0.9**	**0.5**

Human Sign Encounter Rates
Etate 1 and 2 are nearly devoid of illegal human signs (0.02 signs/km; n=1; Table 7). In contrast, in the Bofoku Mai sector, human signs of hunting are numerous (0.6 signs/km, n=32), consisting of permanent camps, temporary campsites, recent trails and machete cuts. Ikolo had the highest human encounter rate of all study sites, 1.6 signs/km (n=11), twice as high as the Etate-Bofoku Mai area (Map 3). The presence of elephants, the lack of regular patrols, and the existence of wide corridors cut in the forest at Ikolo (for Congo Peacock research) undoubtedly encouraged more poaching.

Table 7: Human sign encounter rates within sectors of the survey area.

Human	Etate	Bofoku Mai	Overall	Ikolo
No. signs	1.0	32.0	33.0	11.0
Effort (No. km)	61.1	55.3	116.4	9.5
Signs/km²	**0.02**	**0.58**	**0.28**	**1.16**

Map 3: Distribution of forest types, bonobo nest sites, elephant and human signs in a spaghetti format over the study area.



Training
From 2004 to the present, ZSM trained three SNP guards (*prise en charge* ZSM) to collect bio-monitoring data (Table 8). Because four out of six Etate guards were illiterate, thus limiting their training, we initiated a literacy program in late 2004. Two literate guards (*chef PP* and *adjoint*) successfully mastered the use of Garmin 12 XL GPS, including waypoint marking, GoTo and track functions, and map panning. While training took place during ZSM research activities, the guards used these same skills while conducting patrols (guard-based bio-monitoring). For the remaining Etate guards, bio-monitoring skills were at an elementary level; however, these guards have recently applied their skills successfully on patrols (writing in Lingala). Transects and recces have served as numerous access corridors which are currently used for patrolling and monitoring. These transects have effectively enabled the guards to expand their patrol area from 45km^2 in 2004 to 155km^2 in May 2006 (ZSM, 2006b).

Table 8: Overview of ZSM bio-monitoring training from 2004 to the present.

Biomonitoring Training (days)				
	Name	**Position**	**Biomonitoring**	**of which GPS**
Etate	**Mboyo Bolinga**	Chef PP Etate	**37**	19
	Ndouzo Bokomo	PP Etate	**34**	12
	Edmond Isomana	PP Etate	**35**	0
	Thure Ntoluke	PP Etate	**5**	0
	Alain Botutu	PP Etate	**4**	0
	Tshombe	PP Etate	**2**	0
Other	**Bunda**	Station Mondjoku	**1**	5
	Wema	PP Bofoku Mai	**3**	0
	Jean Baptiste	Station Watsi Kengo	**2**	0
	Botomfie	Conservateur WK	**7**	1
	Guy Tshimanga	Student - NGO staff	**10**	2
TOTAL			**140**	39

Discussion

We have shown that bonobo distribution is continuous throughout the Etate study area and appears thus far to have no limits, although density is lower in sectors that are farther from the core area (Etate1). This study confirms that bonobo nesting in the SNP has a strong association with forest type (Reinartz *et al.*, 2006). Moreover, in the Etate sector, nesting habitat can be located *a priori* with the aid of satellite imagery. The proportions of Mmm and Mmw forests found on intentional samples approximate the percentages of **nests** found on random samples in the Mmm and Mmw forest types. Consequently, with respect to bonobo conservation, bio-monitoring and guard effort can be concentrated in nest forest areas, thereby reducing the need to traverse large areas of marginal habitat.

From the perspective of park management, the Etate bonobo population is not concentrated around the research station as previously assumed, but corresponds to the distribution of contiguous available nesting forest types. We have found neither dramatic habitat changes nor gaps in bonobo occurrence over 155 km^2.

The higher bonobo densities in Etate 1 and 2 coincide with the virtual absence of illegal human activities. Since 2000, regular patrols have occurred in the Etate 1 sector. These law enforcement activities may have contributed to a slight increase in bonobo density (from 1.6 in 2000 to 1.9 in 2006). In the region of Bofoku Mai, patrols have been irregular and hunting signs numerous. However, hunting does not appear to target bonobos because nests are present on large trails leading from the Bofoku Mai port on the Salonga River over to the Yenge River (in contrast to earlier findings, e.g., in Beminyo and Nkinki; Reinartz, pers. obs.). The distribution of hunting signs generally corresponds to elephant distribution (Map 3). The percentage of nest forest types does not change appreciably among the three sectors, and thus the differences in nest density may be attributable to different levels of hunting activity or distance from the community core area.

The number of bonobo nests is significantly higher in the Mmm forest type than in Mmw, even though the two forest types are evenly represented in our study area. Bonobo density in Mmm forest is approximately twice that in Mmw forest. Density estimates of a specified area can be obtained either by random placement of transects across all forest types or by stratifying the survey and more intensively sampling areas where bonobo occurrence is likely. Because bonobo nesting in the SNP is confined largely to Mmm/Mmw forests, randomly placed transects sample a significant proportion of marginal habitat. In stratified surveys, as long as the total area of nesting habitat can be ascertained relative to the total area, the derived density estimate for the total area should be comparable to, and more precise than, the estimate based on randomly placed transects in a non-stratified survey (Buckland *et al*., 2001). Furthermore, concentrating more survey effort in nest forest types makes inter-site comparisons more meaningful. Two survey locations may differ considerably in the area of available nesting habitat, yet without sampling stratification, surveys may yield similar bonobo nest densities, while the bonobos are in fact more concentrated in a smaller area at one site as compared to the other. In failing to *a priori* stratify sampling and not allocating effort to areas of greater density, the actual density within the habitat area remains unknown, and the reasons for any possible differences can not be ascertained.

The preliminary model as discussed applies to the northern latitudes of the SNP, where our previous studies have assessed the proportion of forest types and bonobo nesting habitat. However, at present, we do not know the extent of its application to other locations where bonobo nesting habitat and forest types may differ. We plan to verify our findings in other areas within the Salonga landscape.

Satellite images are essential to locate probable blocks of mixed mature forests. However, a remote sensing study is required to refine the detection of understory and thus calculate the relative area of nest forest types. Furthermore, a study of canopy cover will help refine the type of Mmm; within the Mmm forest type, canopy varies. In low canopy cover, the Marantaceae

(*Haumania*) are usually super-abundant, the trees are sparsely distributed, and thus the number of available nesting trees is limited.

Recommendations for park management:

- Ikolo and Bofoku Mai are experiencing significant levels of hunting pressure. Nearby patrol posts need to be reinforced, and patrols on the Yenge and Loile Rivers should be increased. The Bofoku Mai patrol post should be enfolded into the Etate patrol schedule so that the patrols can coordinate their coverage of the area (ZSM, 2006 a & b).

- It is important to determine the limits of bonobo populations and the characteristics of bonobo distribution. For the Etate-Bofoku Mai sector, ZSM should expand bio-monitoring southeastward between the Yenge and Salonga Rivers in order to ascertain the area and population to be protected. For conservation purposes, the unique study of this aspect of bonobo ecology is needed to understand the distribution of the species.

- In order to devise a cost-effective bio-monitoring system for bonobos, the model, as presented above, should be refined and tested at different locations.

References

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