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2005

Diurnal primate distribution and density in the Sabangau National Park, Central Kalimantan, Indonesia.

MRes Primatology thesis, Roehampton University, UK.

1.0 INTRODUCTION

The island of Borneo is the third largest island in the world with a size of 746,305 km^2 and, administratively, is divided into two autonomous Malaysian states, Sabah and Sarawak, a Brunei Sultanate, and four Indonesian provinces West, Central, East and South Kalimantan. The Indonesian part of Borneo covers the majority of the total land area, three quarters of the island. Borneo, also, has been identified as one of the hottest biodiversity hotspots on earth (Meijaard and Nijman, 2001). Myers *et al*. (2000) define hotspots as "areas featuring exceptional concentrations of endemic species and experiencing loss of habitat." Thus, biological diversity is the foundation for sustainable development (Sugandhy, 1997). Specifically, Borneo sustains 13 species of non-human primates from five different families where 11 are diurnal species, long-tailed macaque (*Macaca fascicularis*), pig-tailed macaque (*Macaca nemestrina*), banded leaf monkey (*Presbytis hosei*), red leaf monkey (*Presbytis rubicunda*), white-fronted leaf monkey (*Presbytis frontata*), proboscis monkey (*Nasalis larvatus*), silvered leaf monkey (*Trachypithecus cristatus*), agile gibbon (*Hylobates agilis*), bornean gibbon (*Hylobates muelleri*), and orang-utan (*Pongo pygmeus*); and two are nocturnal, slow loris (*Niycticebus cougang*) and western tarsier (*Tarsier bancanus*). From these 13 species, five of them are known to be endemic to the island, four of them are colobines and one of them is a gibbon species. However, as the world's economic development continues to increase, biodiversity is being destroyed. This is especially true for developing countries, whose governments promote rapid instead of sustainable development. This problem is particularly pronounced in tropical forests zones, which are the main habitat for most non-human primates driving their populations to decline and ultimately to extinction.

1.1 Ecology and distribution of primates in Borneo

The diversity of primates in Borneo is widespread throughout the island with a wide range of habitat types. However, there is little solid information on primate distribution and density throughout their range in Borneo. In a study by Meijaard and Nijman (2002) the most primate species-rich area was found to be in central East Kalimantan although the study model excluded primates in small forest patches.

Orangutan (Pongo pygmaeus)

The Orangutan is found in Borneo in eight isolated populations in Kalimantan, Sarawak, and Sabah with a total population number ranging from 10,800 to 15,500 individuals (Blouch, 1994). The Bornean orang-utan is known to exist as three sub-species, *P. p. pygmaeus*, *P. p. wurmbii* and *P. p. morio* (Groves, 1999). This ape inhabits a wide range of habitats in primary and secondary forest and is mainly found in lowland dipterocarp, freshwater and peat swamp forest in Borneo. It has been recorded in hill forests up to 1,500 m however there are no orangutan records in mangrove forest (Morrogh-Bernard *et al*., 2003). Orang-utans are mainly frugivorous species and are characterized by having a solitary lifestyle where males compete for access to ovulating females, resulting in polygyny and great sexual dimorphism. Females tend to be sedentary, remaining close to their natal ranges, whereas males emigrate (Rodman, 1979). Orang-utans home ranges seem to vary. However they are relatively large (Mackinnon, 1974). Its conservation status is critically endangered by the World Conservation Union (IUCN) criteria. The main causes for this population decline will be discussed later on.

Bornean Gibbon (Hylobates muelleri)

This frugivorous species is endemic to Borneo occurring throughout the island with the exception of the southwestern part where other species of gibbon (*H.*

agilis) is known to inhabit (Mackinnon, 1977). In general, gibbons have fixed home ranges and tend to be territorial. They make regular loud morning calls. This behavior is believed to help to defend their territories. Hylobates spp. form monogamous pairs when they reach adulthood. Their groups consist only of family members. No birth seasonality has been recorded. This species is found to be sexually dimorphic in their vocal repertoires and females tend to be co-dominant with males, unlike the majority of primate species. This information on gibbons' ecology was gathered by Leighton (1987). Specifically, the Bornean gibbon has been showed to be able to cope with selectively logged forest and undisturbed forest and it lives in hills and lowlands in tropical evergreen forest, peat swamp forest and freshwater swamps (Meijaard and Nijman, 2002).

Agile gibbon (Hylobates agilis)

The agile gibbon is not restricted to Borneo and it occurs with much lower frequency than the Bornean gibbon (*Hylobates muelleri*). This species of gibbon's ecology is similar to the Bornean gibbon described earlier. However, the agile gibbon in found mainly in West, Central and South Kalimanta in tropical wet evergreen forest, peat swamp forest and freshwater swamp (Meijaard and Nijman, 2002).

Red leaf monkey (Presbytis rubicunda)

This primate species in endemic to Borneo and is the most widespread langur species in the island. The red langur lives in lowlands, hills, and mountains up to 2,000 m of altitude (Blouch, 1994). It inhabits a wide range of habitats such as peat swamp forest, tropical wet evergreen forest, tropical mountain evergreen forest and riverine forest (Meijaard and Nijman, 2002). This is a folivorous species as the rest of the colobine primate species so it feeds mainly on young leaves and seeds of trees and lianas (Payne, 1985). Generally, colobines are found in small social groups ranging from 2 to 13 individuals and are polygynous in their mating (Struhsaker and Leland, 1987). They tend to split into subgroups when foraging and the use of alarm calls in frequent by the individuals to alert the rest of the group members from predators or intruders. Home ranges are found to overlap between groups and they move through the forest quadrupedally (Fleagle, 1999)

White-fronted leaf monkey (Presbytis frontata)

This species is endemic to the central and eastern part of Borneo and is confined to tropical wet evergreen forest. There is not much known about its ecology but is thought to be folivorous as the rest of the leaf monkey species (Meijaard and Nijman, 2002; Blouch, 1994).

Bornean leaf monkey (Presbytis hosei)

The Bornean leaf monkey is one of the endemic primate species in Borneo and is confined to the northern part of the island. This species is found in tropical wet evergreen forest and tropical mountain evergreen forest (Meijaard and Nijman, 2002). The species ecology follows the pattern of the rest of the Colobine monkeys.

Banded leaf monkey (Presbytis femoralis)

This species distribution is restricted to tropical wet evergreen forest and is endemic to Borneo (Meijaard and Nijman, 2002). This primate species' ecological characteristics are comparable to those of the rest of the Colobine monkeys.

Silvered leaf monkey (Trachypithecus cristatus)

There are four subspecies of silvered leaf monkey described by Groves (2001), *Trachypithecus cristatus cristatus, Trachypithecus cristatus vigilans, Trachypithecus cristatus koratensis* and *Trachypithecus cristatus caudalis.* This arboreal species of monkey is primarily folivorous and it lives in groups ranging from 9 up to 51 individuals. This primate species has a quadrupedally locomotion (Fleagle, 1999). This species is widespread throughout Borneo but is restricted to a few patches of mangrove forest and riverine forest close to the coast (Mackinnon, 1974).

Proboscis monkey (Nasalis larvatus)

This species is endemic to Borneo and it is recognized to be endangered by the IUCN criteria. Proboscis monkey is found in few patches of mangrove forest, fresh water swamps, riverine forest and peat-swamp forest close to the coast and often inland but mostly in non protected habitat areas (Meijaard and Nijman, 2002). This monkey species are described as folivorous frugivorous species and are sexually dimorphic. They tend to live in group sizes ranging from 3 to 32 individuals however they have two levels of social system (Boonratana, 1999).. One is the formation of uni-male groups and the other is formed by all-male groups (Boonratana, 1999). Adult females are the group leaders and sometimes females are seen to shift from one uni-male group to another. They have single offspring (Boonratana, 1994).

Pig-tailed macaque (Macaca nemestrina)

This macaque species lives in the lowlands and hills of Borneo in areas of peat swamp forest, tropical wet evergreen forest and tropical mountain evergreen forest. The pig-tailed macaque feeds mainly on fruits and small animals; also, they can be seen as pests on grain and fruit crops by the local communities (Blouch, 1994; Meijaard and Nijman, 2002). They are both an arboreal and terrestrial species. The pig-tailed macaque group size ranges from 2-22 individuals with very large home ranges. They have multimale-multifemale social systems and give birth to only one offspring. Macaques are found to show seasonality in births (Melnick and Pearl, 1987).

Long-tailed macaque (Macaca fascicularis)

The long-tailed macaques are also common in the lowlands and hills of Borneo as the pig-tailed macaques but they are found in a wide variety of habitats such as peat swamps, mangrove forest, freshwater swamps, tropical evergreen forest and riverine forest (Meijaard and Nijman, 2002). However, they are primarily observed along rivers and near local villages. They are able to cope well in disturb habitat areas and are often seen as pests by the people at the villages. They are primarily fruit-eaters as the rest of the Cercopithecines' primates. In general, ecological characteristics are assumed to be the same for all the macaque species with small variation depending on the specific areas where the species might be found.

Slow loris (Nycticebus coucang) and the *Western tarsier (Tarsius bancanus)*

These two primate species are the only nocturnal primate species found in Borneo. Lorises have slow-moving, quadrupedal, climbers, type of locomotion where as tarsiers are active and agile having a leaping type of locomotion (Fleagle, 1999). Lorises consume high-energy food that includes fruits, gums, and animal prey. On the contrary, tarsiers' diet consists exclusively of animal prey (Bearder, 1978). In particular, the western tarsier is usually seen to mate in pairs (Bearder, 1978). In Borneo, this species of tarsiers is found mainly in tropical wet evergreen forest (Meijaard and Nijman, 2002).The slow loris is found at low to medium elevations in tropical wet evergreen forest, peat swamp forest and freshwater swamp (Meijaard and Nijman, 2002).

1.2 Ecological problems in Borneo

Over the last few decades there has been a serious decline in primate populations through out South-east Asia. Therefore, several threats to wild primate populations have been identified in these areas and they fall into three general categories. The first and main threat to primates in South-east Asia is habitat destruction followed by hunting and finally by pet-trade.

1.2.1 Threats

Habitat destruction

Habitat loss and habitat degradation in Borneo are principally due to logging (legally and illegally), forest fires and forest clearance for agriculture and settlement. For example, in Central Kalimantan 1 million ha of wetland (mostly peatland) were deforested and drained in between the years of 1996 and 1998 for agriculture and settlement use. This development was called the 'Mega-Rise

Project' but finally, this area, ended up abandoned without being used (Morrogh-Bernard *et al*, 2003).

A common logging practice here is to do it selectively by extracting all commercial timber products and leaving behind the non-timber products. This creates forest fragmentation by making patches and changing the tree composition and structure of the forest. The abundance and size of canopy gaps are increased and the proportion of larger trees is reduced (Felton *et al*, 2003). This is a real problem to many primate species, which are completely arboreal and might result in isolation of primate populations. This in turn will result in a loss of genetic variability due to genetic drift and inbreeding depression making all these populations more vulnerable to extinction (Primack, 1998).

Forests fires are indirectly caused by human disturbance such as the practices mentioned earlier. Natural fires in fragmented forests are harder to stop clearing extensive areas of forest whereas in untouched primary forest the damage is minimal. Johns and Johns (1995) investigated the effect of primate population density to logging by comparing primate densities from the time before logging until 12 to 18 years after logging at the same site. Their results showed a very high mortality rate for infant primates, immediately after the logging operation started. Surveys, in the same area showed recovery in some primate species infant numbers after 6 and 12 years of logging. In addition, findings from this study also indicate that primates' encounter rates increase significantly in old logged forest.

Hunting

On Borneo hunting has been a traditional practice among the local tribes, Dayak and Punan, for many years (Mackinnon, 1986). Nowadays this has become a problem for the decreasing primate species populations due to their accessible access to hunters from the increase of other human activities in the area as the spread of logging roads, and improved river transport to the previously inaccessible interior forest zones. In addition, the employment of new and more sophisticated hunting methods such as the use of shotguns makes it even easier for hunters to increase their prey quantities. Hence, hunting in rural areas is hard to control because of its traditional value as well as due to the fact that in many of these areas wildlife is main source of protein (Mackinnon, 1986).

Trade of non-human primates

Non-human primates are charismatic animal species that tend to be preferred as pets by many human animal lovers. This seems to be widespread mainly throughout western Indonesia. The capture of primates is a common practice for locals (especially in Sumatra, Borneo, and Sulaweesi) in order to trade them to Java, within Indonesia, and to other parts of the world for zoos, safari parks, or human individuals whom do not seem to know or care the negative effects that this unethical market does to wildlife populations. Also, primates are seen as rare animal species and people have the ideology that the possession of these ones is a symbol of status. Therefore, primate trade is a profitable business for locals and it is heavily active in Borneo in spite of government regulations, which protect many of these primate species against trading (Mackinnon, 1986).

1.2.2 Responses of Primates to Threats

The response of a particular primate species to habitat disturbance is the outcome of a complex interaction such as body weight, dietary preferences and life-history parameters. The general hypothesis is that primate species vulnerability to habitat disturbance increases with body weight and decreases with folivory (Johns and Skorupa, 1987). The explanation behind this hypothesis is that bigger animals need more food to fulfil their energy requirements and larger foraging areas; also they tend to be slow breeders so they occur at low densities. Folivorous primate species get to fulfil their energy requirements even when tree species diversity is limited because leaves are still abundant in spite of habitat diversity reduction. Therefore large-bodied frugivorous primate species, such as orangutans, are the class of primates that are expected to be the most vulnerable to habitat disturbance. There are a number of studies that show that orang-utans are indeed affected by selective logging. Orang-utan populations can be decline by 30% in disturbed habitats and ultimately can be driven to extinction (Rijksen, 1978). Felton *et al* (2003) compared orang-utan densities in selectively logged and undisturbed peat swamp forests. Their findings suggest that orang-utan nest density was 21% lower in the disturbed forest compare to the undisturbed one. In a second orang-utan study, in South-east Asia, there were also, findings that this species was significantly reduced in numbers following habitat disturbance but is thought to be able to re-colonise the area after a number of years once is left undisturbed (Wilson and Wilson, 1975; Payne and Davies, 1982). However, surveys indicate that orang-utans are still rare in even old logged forests (Davies, 1986).

In general, frugivorous primate species are found to be more affected than folivorous primate species by habitat disturbance. In a study at Kibale national park Johns and Skorupa (1987) showed that frugivorous primate species averaged 59% lower in densities in a selectively logged forest compared to those in an undisturbed forest. In contrast, the biomass density of folivorous primate species only declined by an average of 39% (Johns and Skorupa, 1987). One exception to these findings are the *Macaca* species which, despite being large frugivorous primates are often opportunistic in nature, helping them to survive better under harsher environmental conditions than those more specialized frugivorous. Some of these species (e.g. *M. fascicularis*) are reported to be even more abundant in disturbed forest than in primary forest (Marsh and Wilson, 1976).

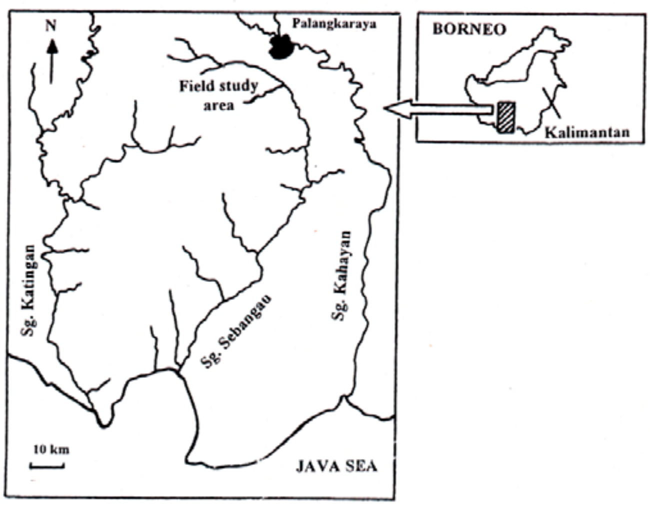
Hylobates spp. and *Presbytis* spp are frugivorous folivorous species that are able to survive in logged forest. In undisturbed forests where fruit diversity is more abundant these species usually prefer to eat fruits but when fruits become unavailable they are able to alternate their fruit dietary preferences to leaves helping them to subsist in logged forest habitats (Berenstain, 1986; Johns, 1986). Also, insectivorous/frugivorous primates as the *Nycticebus coucang* appear to cope well in disturbed forests because they are usually small- bodied primate species and tend to need a less extensive area to survive (Johns and Skorupa, 1987).

There is another important effect of habitat disturbance on primate population species besides the immediate decline of existing animals and that is the decrease in birth rates. Primates tend to stop breeding when their food resources are not abundant. This is a natural response for primates to ensure an individual's survival when there is less available food source. Thus, the major problem with low birth rates is that the effect on primate population densities will not show up immediately in population samples but after time (Johns and Skorupa, 1987).

1.3 Sebangau National Park

Sebangau National Park is situated in Central Kalimantan with an extension area of 6,680 km^2 of peat swamp forest between the Sebangau and Katingan rivers (see attached map in Figure 1.1). This area was recently made National Park on October 16^{th} 2004. The park has different forest types within the peat swamp category and they harbor a great variety of biodiversity. The three main forests are: mixed swamp forest, low pole forest and tall pole forest.

Figure 1.1: Study area



1.3.1 Peatlands

Peat swamp forest is part of one of many Indonesian peatlands. This type of peatland is a further developmental state of freshwater swamp forest. The remains of trees produced in freshwater swamp forest have accumulated over time to form a layer of peat, organic material, giving rise to a new type of swamp forest which, in turn, has been found to have higher diversity of tree species compare to mangrove forest (Sugandhy, 1997).

In general, peatlands are categorized as freshwater wetlands formed under palustrine conditions. Palustrine systems are any inland wetland, which lack flowing water and contain ocean derived salts in concentrations of less than .05% (Sugandhy, 1997).

Indonesia contains the largest area of peat in the tropical zone with an extension area ranging from 160,000 to 270,000 Km^2 including different types of peat in relation to thickness. Thus, most of the peat in Indonesia is concentrated in Sumatra with a total area of 83,000 Km^2 of peat, Kalimantan has 68,000 Km^2 and Irian Jaya 46,000 Km^2 (Sugandhy, 1997) (Rieley *et al.*, 1997). Peatlands are also important watershed areas. They create natural reservoirs, which can absorb and store excess water and reduce flooding in adjacent local areas. Peatland forests, in particularly, are important resources for sustainable forestry with many commercially valuable timber trees. According to Suggandhy (1997) peatland ecosystems can be valued according to their functions, products and attributes. Peatland functions are known for their direct and indirect value. For example, direct functions consist of water flow regulation, protection from natural forces, recreation, education, and production of food and other needs for local communities. The indirect functions are sediment retention, nutrient retention, and micro-climate stabilization. Now, peatland products include provision of water supply to other ecosystems, forest resources (fuelwood, timber, bark, resins, medicines, etc), wildlife resources, agricultural resources and energy resources. Peatlands' attributes are values that can be derived directly from the ecosystem; for example, biological diversity is important as genetic reservoirs for certain plant species. In overall, peatland ecosystems maintain the sustainability of various life forms and contain many invaluable genetic resources for food crops, horticulture, timber, fisheries, livestock, and biotechnological developments (Suggandhy, 1997).

Hence the fauna and flora of this ecosystem has received little or no investigation, however, as the knowledge of the importance of peatlands continues to increase this area is getting more attention from the scientific community. Now the multiple natural resources functions which peatland habitats can provide are being studied and the key roles that they play in the maintenance of biodiversity and the conservation of rare, threatened and endangered species area are being defined (Page *et al*., 1997).

1.3.2 Wildlife diversity

The majority of wildlife species in peatland habitats live in the forested area of peat swamps, home to many rare and endangered species. Sebangau's forest diversity also carries different species diversity dependent on the forest type. In summary, the mixed swamp forest is found on shallow to moderately deep peat ranging from 2 to 6m with lots of under story vegetation but with high biodiversity; in contrast, the low pole forest has deep peat of 6 to 10m but with low biodiversity; and, finally, on the watershed area, the tall interior forest contains the deepest and oldest peat ranging from 8 to 13m and, also, has high biodiversity (Page *et al*., 1997).

Page *et al*. (1997) conducted multiple surveys on mammal, bird and fish species diversity during the years of 1993 to1995 in these three habitat types. During the mammal survey's observation on the different ecosystems mammals were recorder from two transects, 11km and 25km long, which encompassed the full habitat diversity of the area. A total of thirty- five mammal species were recorded. Table 1.1 is a compilation of the different mammal species identified in this study with the specifics on the habitat types were these were observed. Several of these mammal species are recognised as endangered, threatened or vulnerable by the Convention on the International Trade in Endangered Species (CITES) and IUCN (Groombridge, 1993).

Table 1.1: Identified mammal species in peat swamp forest at Sebangau National Park (Page *et al*., 1977)

Common name	**Scientific name**		**Habitat**	
		MSF	LPF	TIF
Primates				
Agile gibbon	*Hylobates agilis*	*		*
Orang-utan	*Pongo pygmaeus*	*	*	*
Long-tailed macaque	*Macaca fascicularis*	*		
Pig-tailed macaque	*Macaca nemestrina*	*	*	*
Red leaf monkey	*Presbytis rubicunda*	*		*
Slow loris	*Nycticebus coucang*	*		*
Western tarsier	*Tarsius bancanus*	*		*
Carnivora				
Sun bear	*Helarctos malayanus*	*	*	*
Bearded pig	*Sus barbatus*	*	*	*
Common tree shrew	*Tupaia glis*	*	*	*
Painted tree shrew	*Tupaia picta*	*		*
Slender tree shrew	*Tupaia gracilis*	*	*	*
Clouded leopard	*Neofelis nebulosa*	*		
Leopard cat	*Prionailurus bengalensis*	*		
Marbled cat	*Pardofelis marmorata*	*		*
Flat-headed cat	*Prionailurus planiceps*	*		
Common palm civet	*Paradoxurus hermaphroditus*	*		*
Malay civet	*Viverra tangalunga*	*		
Small toothed palm civet	*Actogalidia trivirgata*	*		*
Binturong	*Arctitis binturong*			*

<u>Table 1.1:</u> Continuation

Common name	**Scientific name**		**Habitat**	
		MSF	LPF	TIF

Artiodactyla				
Lesser mouse deer	*Tragulus javanicus*		*	*
Sambur deer	*Cervus unicolor*	*		
Rodentia				
Horse-tailed squirrel	*Sundasciurus hippurus*	*		*
Low's squirrel	*Sundasciurus lowi*	*		
Black-eared pygmy squirrel	*Nannosciurus melanotis*	*		*
Plain pygmy squirrel	*Exilisciurus exilis*	*		*
Plantain squirrel	*Callosciurus notatus*	*	*	*
Prevost's squirrel	*Callosciurus prevostii*			*
Black flying squirrel	*Aeromys tephromelas*	*		
Large flying fox	*Pteropus vampyrus*	*		*
Dark-tailed tree rat	*Niviventer cremoriventer*	*		
Grey tree rat	*Lenothrix canus*	*		
Muller's rat	*Sundamys muelleri*	*		*
Plynesian rat	*Rattus exulans*	*		
Red spiny rat	*Maxomys surifer*	*		
Whitehead's rat	*Maxomys whiteheadi*	*		*
Chiroptera				
Dayak roundleaf bat	*Hippseridos dyacorum*	*		

Habitat Type: MSF= Mixed swamp forest **LPF**= Low pole forest **TIF**= Tall interior forest **IUCN Red list Vulnerable**: 1 **IUCN Red list Endangered**: 2 **IUCN Red list Critically Endangered**: 3 **US Federal list Threatened**:4 **US Federal list Endangered**: 5 **CITES Appendix II:** 6 **CITES Appendix I**: 7

In addition to the mammal surveys in the area bird observations were made over the same period of time using the same transects and a total of 150 bird species were identified. Six of these bird species recorded are in the Red Data Book of endangered species (table 1.2) this is almost 50% of the listed bird species for the island of Borneo which are thirteen in total (Page *et al*., 1997).

<u>Table 1.2:</u> Rare and notable bird species at Sebangau (Page *et al*., 1997).

Common name	Scientific name	Habitat			
		MSF	LPF	TIF	RSS
Red Data Book species		*			
Storm's stork	*Ciconia stormi*				*
Lesser adjutant stork	*Leptopulus javanicus*				
Wrinkled hornbill	*Aceros corrugatos*	*		*	
Helmeted hornbill	*Buceros vigil*			*	
Short-toed coucal	*Centropus rectunguis*	*		*	
Wallace's hawk eagle	*Spizaetus nanus*	*	*	*	
Uncommon wetland and swamp forest species					
Grey-breasted babbler	*Malacopteran albogulare*			*	
Hook-billed bulbul	*Setornis criniger*	*		*	
Great-billed heron	*Ardea sumatrana*				*
Black bittern	*Dupetor flavicollis*				*
Cinnamon-headed green pigeon	*Treron fulvicollis*	*			
Striped wren-babbler	*Kenopia striata*	*			
Malaysian blue-flycatcher	*Cyornis turcosus*			*	
Other common or occasional lowland forest species					
Crestless fireback	*Lophura erythrophthalma*			*	
Greater coucal	*Centropus sinensis*	*			
Brown wood-owl	*Strix leptogrammica*			*	
Red-naped trogon	*Harpactes kasumba*	*		*	
Roufous-backed kingfisher	*Ceys rufidorsa*	*		*	
Roufous-collard kingfisher	*Actenoides concretus*	*			
Asian black hornbill	*Anthracoceros malayanus*	*		*	
White-bellied woodpecker	*Dryocopus javensis*	*			
Lesser cuckoo-shrike	*Coracina fimbriata*	*			*
Grey-bellied bulbul	*Pycnonotus cyaniventris*			*	
Rufous-tailed shama	*Trichixos pyrropygus*	*		*	

MSF= Mixed swamp forest **LPF**= Low pole forest **TIF**= Tall interior forest **RSS**= Riverine sedge swamp

Finally, there was a preliminary study of fish using different trapping techniques and a total of 34 species from 16 different families were identified. Seven of these species might be new species or subspecies and 12 species are endemic species to Borneo from which seven were not previously recorded in the Central Kalimantan area (table 1.3) (Page *et al*, 1997).

Table 1.3: Peat swamp fish from the sungai Sebangau catchment (Page *et al.*, 1997)

Family	Species	Habitat

		R	RSS	MSF	LPF	GH
Cyprinidae	*Cyclocheilichthys janthochir*	*				
	Puntius lineatus	*				
	P. rhombocellatus					*
	Rasbora cephalotaenia	*				
	R. dorsiocellata	*				
	R. gracilis	*		*	*	
	R. kalochroma		*	*	*	*
Cobiditae	*Lepidocephanichthys pristes*					*
Bagridae	*Mystus sp.*	*				
Siluridae	*Wallago leeri*	*				
	Kryptopterus cf. macrocephalus	*		*		
Clariidae	*Clarias teijsmanni*	*	*			
Chacidae	*Chaca bankanensis*					*
Hemiramphidae	*Hemiramphon cf, tengah*	*	*	*	*	*
	H. chrysopuntatus	*				
Nandidae	*Nandus nebulosus*	*				
Pristolepididae	*Pristolepis fasciata*	*		*		
	P. grooti	*				
Luciocephalidae	*Luciocephalus pulcher*	*		*	*	*
Helostomatidae	*Helostoma temminckii*	*				
Anabantidae	*Anabas testudineus*		*			
Belontidae	*Belontia hassleti*	*				
	Betta sp.		*		*	
	B. cf. akarensis		*	*		*
	Parosphromenus parvulus	*	*	*		*
	Sphaerichthys acrostoma			*		
	S. selatanensis	*	*	*	*	*
	S. vaillanti			*		
	Trichogaster sp.	*				
Channidae	*Channa lucius*	*	*			*
	C. micropeltes		*			
	C. pleurophthamus	*				
Chaudhuriidae	*Chendol keelini*			*		
Mastacembelidae	*Macrognathus maculatus*	*				

R= River **RSS**= Riverine sedge swamp **MSF**= Mixed swamp forest **LPF**= Low pole fores
GH= Swamp forest close to granite hill

1.4 Aims of the study

Peatlands are one of the most understudied ecosystems in the planet because of several reasons: they occur in remote locations, they have difficult access and there is lack of knowledge about their biodiversity and importance (Page *et al*., 1997). There is very little known about the forest species' composition or structure in this area; although, there have been few studies done most of them emphasized the forest vegetation structure or the very broad animal species composition, which are in deed fundamental knowledge to the area. From these studies five species of diurnal primates were identified at Sebangau: Orang-utan (*Pongo pygmaeus*), agile gibbon (*Hylobates agilis*), red leaf monkey (*Presbytis rubicunda*), pig-tailed macaque (*Macaca nemestrina*) and long-tailed macaque (*Macaca fascicularis*). From these specific primate species there are not many studies being conducted with the exception of orang-utans and gibbons. Therefore there is a lack of significant information about the primate species found in the park. Therefore this research project aims to expand the knowledge on diurnal primate species composition and distribution at Sebangau National Park, a peatland zone, in order to establish a baseline of future primate research and in turn to help to create an effective management plan for the park in order to conserve its biodiversity.

Ecological research is important for conservation because it allows for an insight on the species and the habitat well-being, as well as it provides us with the necessary tools to create effective management plans in order to sustain the habitat and maintain stable populations for the species present and assure its existence. Therefore, in this study ecological data will be presented on diurnal primate species at Sebangau National Park from three different habitat types found within the park.

Surveys were conducted on diurnal primate species and vegetation structure by direct observations and measurements using linear transect methods.

Diurnal primates relative densities will be analysed in these three habitats in relation to the site's vegetation structure and, then, the effect of logging on these primate species will be investigated. Also, density results from this study will be compared to previous density survey studies done in the same sites to test for differences in results produced using different methods. Density estimates are important in conservation in order to distinguish between significant, declining or increasing wildlife populations to effectively manage them to be stable. Hence, the specific aims of the study are:

1) To calculate the relative distribution densities of the diurnal primate species found in three sites at the park: mixed swamp forest, low pole forest and tall interior forest.
2) To compare primate species' composition between these three habitats.
3) To compare general vegetation structure between these three habitats.
4) To collect data on resource utilization.

2.0 METHODS

2.1 Study sites

Three study sites were established in Sebangau National Park where five different forest types have been identified with differences in peat depth, vegetation structure and logging history (Page *et al*.,1999). This study focuses on 3 of these habitats; mixed swamp, low pole and tall interior forests. In these three habitats more than 300 tree species were identified (Shepherd *et al*., 1997).

Mixed swamp forest

This forest has been selectively logged over 20 years and it is characterized by medium to tall and stratified vegetation, with an upper canopy at 35m high followed by other layer ranging from 15 to 25m high and then another one conformed by smaller trees from 7 to 12m high. It has a peat thickness that ranges from 2-6m and high diversity of tree species of timber and non-timber. The most common three species are: *Aglaia rubiginosa, Calophyllum hosei, C. lowii, C. sclerophyllum, Combretocarpus rotundatus, Cratoxylum glaucum, Dactylocladus stenostachys, Dipterocarpus coriaceus, Dyera costulata, Ganua mottleyana, Gonystylus bancanus, Mezzetia leptopoda, Neoscortechinia kingii, Palaquium cochlearifolium, P. leiocarpum, Shorea balangeran, S. teysmanniana and Xylopia fusca* (Shepherd *et al*., 1997).

Low pole forest

This type of forest has a water-table that is permanently high and the forest floor is very uneven therefore there is water throughout the year. Two canopy layers can be distinguish here: the upper layer whish is open and it reaches a maximum height of 20m and the lower layer at a height of 12 to 15m which is almost fully close on peat ranging from 7 to 10m thick. There is not much tree diversity suitable for logging and the terrain is difficult to walk; therefore, there hasn't been any logging operation in this area. The main canopy species are *Combretocarpus rotundatus, Calophyllum fragrans, C. hosei, Campnosperma coriaceum* and *Dactylocladus stenostachys.* The ground floor is infested by pandan and *Nepenthes* spp is abundant (Shepherd *et al*., 1997).

Tall interior forest

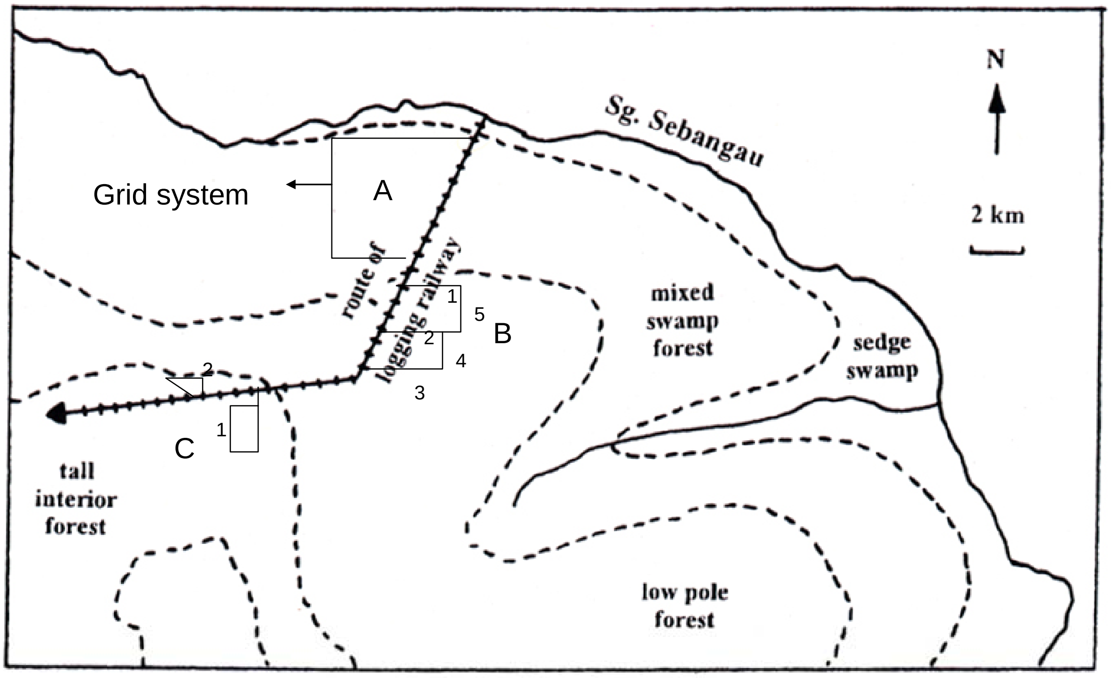
This forest type is found at the highest elevation of the area, therefore is dry throughout the year. It has the greater number of commercial tree species and it has also been subjected to selective logging but not as intensive as the mixed swamp forest, although there are no legal logging operations running nowadays. The tall pole has the highest canopy height with the upper canopy reaching 45m at height. The second canopy layer ranges from 15 to 25m high and the third 8 to 15m. Main species of trees include *Aglaia rubiginosa, Calophyllum hosei, C. lowii,Cratoxylum glaucum, Dactylocladus stenostachys, Dipterocarpus coriaceus, Dyera costulata,Eugenia havelandii, Gonystylus bancanus,Gymnostoma sumatrana, Koompassia malaccensis, Mezzetia leptopoda, Palaquium cochlearifolium, P.*

leiocarpum, Shorea teysmanniana, S. platycarpa, Tristania grandifolia, Vatica mangachopai, Xanthophyllum spp. and *Xylopia* spp. (Shepherd *et al*., 1997).

2.2 Field stations and sampling transects

Field research was carried out in the upper catchment of the Sebangau river located 20 Km southwest of Palangka Raya, the provincial capital of Central Kalimantan. Access to the forest was obtained by using the extraction railway track of the Setia Alam Jaya logging concession, which is no longer running. The mixed swamp forest area is located from the limits of the river flooding up to 6 Km south inland. A 3 by 3 Km grid system has been established southwest from the railway track by previous researchers to collect orangutan behavioural data. This grid system was used to set up 6 transects, on average, 4 km long each. Four transects run, approximately, East to West and 2 North to South. The next research site was set up in the low pole zone starting, roughly, from 6 Km southwest inland from the Sebangao River up to kilometer 10. Here, 5 transects were set up. These transects are, on average, 2.27 Km long and run South-East from the railway track. Three, from these five transects, run West to East and 2 North to South. The third site is located in the tall pole forest, which is the summit of the watershed area running 12 to 23 Km South-West from the river. Two transects were cut here. The first one has a square shape (S, W, N and E) situated roughly on the left side of the rail way going south, then turning west at 1.7 Km, north at 2 Km and east at 3 Km with a total length of 3.53 Km. The second transect starts on the right side of the railway track taking a 320° angle then at .85 Km turns east and at 1.3 Km turns south giving it a triangular shape and a total length of 2 Km. Figure 2.1 illustrates these three study sites with reference on the line transects surveyed in each habitat type.

Figure 2.1: Study sites and sampling transects

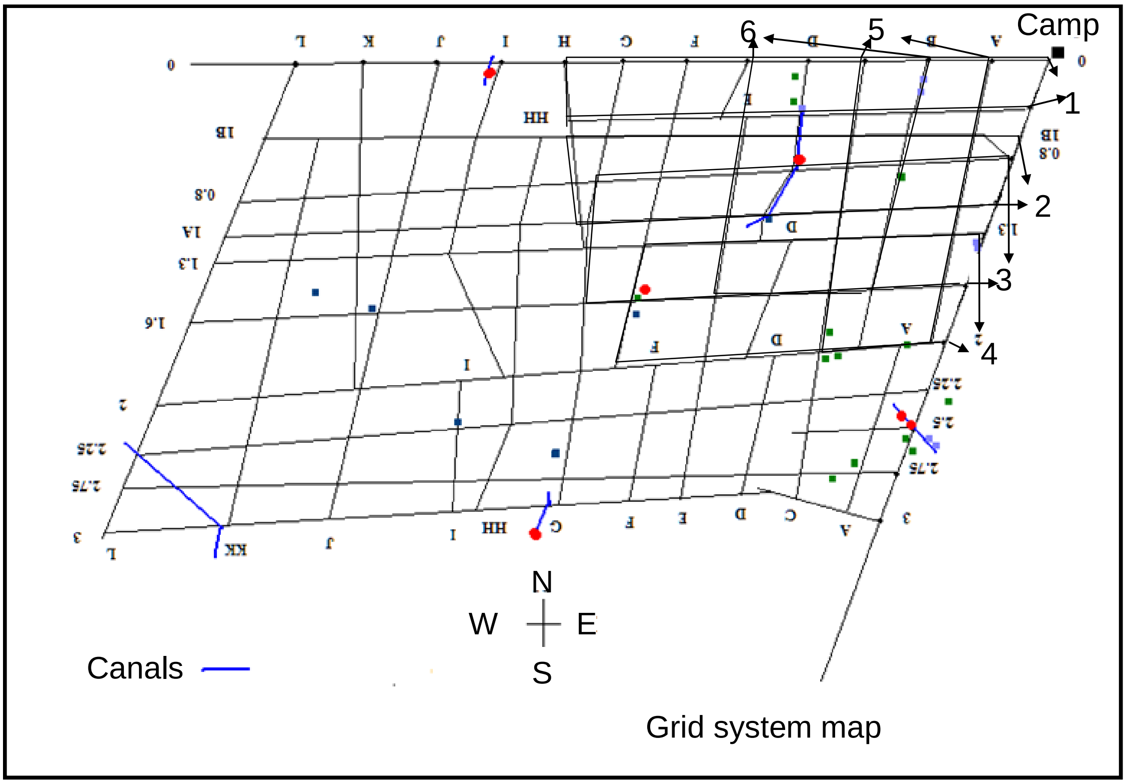


A= Represents the first study site in mixed swamp forest- six transects were used from the grid system previously established (see Figure 2.2).

B= Represents the second study site where five transects were sampled.

C= Represents the third study site where two transects were sampled.

Figure 2.2: Linear transects used from the grid system located at the mixed swamp forest



2.3 Censusing techniques

There are different approaches for censusing biological populations; however, the most frequent used method is distance sampling. There are two main techniques within distance sampling approach for density estimation: line transects and point transects. Depending on the ecology of the species at interest is important to select either one of these two methods. In this study, line transect techniques will be used to estimate density of diurnal primate species. However, two different approaches for calculating density within linear transect methodology will be used. These two techniques varied according to how transect width was estimated and the formula used to calculate population density estimates. In general, the basic theory behind line transect method is to set up a, random or systematic, set of lines for sampling at a site, then measure the perpendicular distances from the line transect to the detected species of interest by travelling the transect. The following statistical assumptions are to be made, in order to estimate accurate densities: 1) Objects on the centre line are always detected. 2) Objects are detected at their initial location. 3) Distances are measure accurately 4) Sightings are independent events (Buckland *et al*., 1993).

In line transect technique, one or multiple straight lines are set up of known length and walked by an observer assuming that no objects within the line will go undetected. The observer will measure the perpendicular distance from transect to the object and then density can be calculated. The species density can then be estimated by calculating the area surveyed i.e. the area visible from the line by estimating the proportion of animals seen at the distances observed.

The first approach for calculating density in distance sampling used in the present study is by fixed-width calculations and it assumes that all animals within a certain distance have been seen. The second approach uses more data and includes animals at distances where only a proportion are likely to have been observed. The second method can be carried out using the DISTANCE software programme.

The fixed width method uses a general density formula, described below, where the width of the transect is being fixed by selecting the most reliable perpendicular distance value measured from the sightings. This assumes that observers have not missed any individual animal sighting in the transect within that distances. One way of getting the width value for the transect is by plotting all perpendicular distances onto a histogram graph. Once the perpendicular distances are plotted the histogram shows a series of bars representing the different frequencies on perpendicular distances, generally, by decreasing in frequency the further the perpendicular distance is from the transect. Therefore, until there is a sudden drop in frequencies, usually when the perpendicular distance is too far out, is when the value just before that sudden drop should be chosen. Also, the width (w) of the transect should be measured separately for every animal species. Density formula used by fixed-width methodology:

$d = n * E(s) / 2wL$ if animals are found in groups

Where:

d= Animals density (animals / Km^2)

n= Sighting number

E(s) = Expected cluster size (mean group size)

w= Reliable perpendicular distance in which you are able to accurately detect individuals from the transect to either side of the transect (left and right)

L= Total length of the transect times the number of times walked on it (Km)

Consequently, densities can be calculated using this general formula. Observations (n) are multiplied by the group mean size [E(s)] then divided by 2 which stands for the two sides (left and right) cover by the transect line and multiplied by the total length (L) cover by the transects (including repetitions within one transect) and by the transect width (w) which is calculated by the perpendicular distances measured.

The second density calculation method allows for a large proportion of objects to go undetected under certain assumptions and, still, calculate accurately density estimates. In general, this form of distance sampling asks one main question: “Giving the detection of *n* objects, how many objects are estimated to be within the sampled area (Buckland *et al.*, 1993)”?

The software programme DISTANCE analyses distance sampling surveys data to estimate density by fitting several possible methods to the data in order to estimate the effective transect strip width using the whole data set of perpendicular distances. DISTANCE selects the model that best fits to the data according to the Akaikes Information Criterion (AIC) (Buckland *et al.*, 2001).

The computer software programme DISTANCE uses the following formula to calculate density (2.1.B.):

$$D = E(n) * f(0) * E(s) / 2L$$

Where:

D= Animals density (individuals / Km^2)

E(n)= Expected number of animals in the surveyed area

f(0)= The probability density function of detected distances from the transect

E(s)= Expected cluster size

L= Total length of transect

2.3.1 Alternative methods to sample primate species not employed by this study

There are direct and indirect ways of collecting data for estimating animal species population densities. The methodology described earlier is through direct observations of the animals. However some primate species are harder to be detected in their natural environment therefore surveying signs of the animal species, such as nests, is a good way for estimating densities. For example, orang-utans are usually surveyed from nest counts using the next equation:

$$d= (C_f * N) / (L * 2w * p * r * t)$$

Where:

d= Orang-utan density (individuals / Km^2)

C_f= Correction factor for N

N= Number of nests observed along the transect

L= Total length of the transect cover (Km)

w= Estimated width of the strip of habitat being surveyed

p= Proportion of nest builders in the population

r= rate at which nests are produced (n/day/individual)

t= decay rate of nests (days)

In this method, nests are surveyed on the same fashion than animals are being sighted in the earlier approach. Perpendicular distances are measured from the nest to the transect however other variables described by the formula are taken into account.

Another indirect approach to sample biological populations commonly used by primatologists, especially for gibbon species, is by auditory sampling where animals' densities are calculated by triangulation. Here, a total of three researchers are needed. Each researcher is stationed in three designated listening posts forming a triangle in one area. Researchers record compass bearings of estimated distances to singing groups for couple of hours during the heaviest singing period of the day (e.g. for gibbons during the morning). Then animal groups can be located by triangulation and this is repeated for the rest of the sites until there is a representative sample of animal groups for the area being censused (Brockelman and Ali, 1987).

2.4 Diurnal primate surveys

Field surveys were carried out during the wet season and the starting of the dry season from the 7^{th} of March to the 4^{th} of August, 2005. Direct primate observations were made along line transects through the three forest types. Perpendicular distances were measured for all observations from the transect to the sighting place. When more than one individual was present, distances were taken from the transect to the center of the group and data on the group size was recorded. Measurements were made using a 50m measuring tape. Data on resource utilization was collected by noting the tree species, the substrate height above ground and the activity of the animals observed (including feeding, resting, traveling and vocalising) at the time of the sighting.

Transects were walked on an average speed of 800 m/hr starting generally at 06:00 am (see Appendix A for details on data collection during transect walks). Two persons were employed to survey the transects. One person remained constant throughout the study while the second person rotated. The second person consisted of trained local field assistants that previously and presently work in a forest environment with different primate species interactions. Field assistance were already able to distinguish between primate species and tree species exploited by the animals. Surveys were conducted repeatedly on each habitat type rotating between field sites within a period of one month changing the starting point for all transects every time, to account for any biases on time of the day, with the exception of the two transects at the tall pole forest because of their shape. However, given the difficult access to the low and tall pole zones surveys were done, here, in a much lower frequency compared to those in the mixed swamp area.

2.5 Vegetation sampling

Vegetation sample plots were set up at 100 m intervals along each transect length on each habitat site. Plots were circular with a 5 m radius starting from the centre of transect. A total of 40 plots were surveyed at each habitat site to compared vegetation structure between habitats. Data on tree species above 10cm of diameter breast height (DBH) was collected from every plot with their respective DBH measurements using a diameter measuring tape called the d-tape. A minimum of 10cm diameter for DBH measurements was chosen so that the resulted tree data could be compatible to other previous vegetation studies done on the area. The type of measuring tape (d-tape) used for all DBH measurements is especially being calibrated from centimetres to calculate tree's diameter by measuring the circumference of the tree. Tree circumferences were measured at 137cm above ground level. There were cases, though, where trees had external roots so in those cases tree circumferences were measure at 137cm above the roots level. Dead trees were not included in these measurements. In addition to DBH tree data, the highest tree height was noted from all plots, the number of fruiting or flowering trees and the percentage of ground cover. Tree heights were estimated by using a pair of range finders. Next, the percentage of ground cover was calculated from a hand-made cylinder device where squares were drawn on top; therefore, by looking through it straight up one is able to count the number of squares covered and non-covered by the vegetation on top. Then, percentage cover is calculated assuming the same ratio.

2.6 Data analysis

2.6.1 Primate surveys

In the present study, diurnal primate densities for the three habitat types, mixed swamp, low pole and tall pole forests, were calculated using two types of methods for analysing distance sampling data to estimate population densities. The first method calculates the transect width using a histogram of visibility (explained earlier) and the second technique utilises the whole data set of perpendicular distances to estimate the width of the transect. This later method was employed by using the software programme DISTANCE 4.0. The main reason for using two approaches in calculating diurnal primate densities in this study is due to small sample sizes for many of the primate species in the different habitats, so there was no certainty that the computer software DISTANCE was able to accurate calculate density for all primate species.

Also, data on three primate species' (*Pongo pigmaeus, Hylobates agilis* and *Presbytis rubicunda*) group sizes was analysed by ANOVA to test for differences within primate species group sizes between habitats where these primate species were documented. The H(0) states that there is no difference between primate species group sizes in the different habitats and vice versa for the H(1). Only these three primate species were taken into account because those were the common primate species between the mixed swamp forest and the tall pole forest.

2.6.2 Vegetation sampling

Differences between the habitats were investigated by looking at the species diversity, tree DBH, maximum tree height and percentage ground cover within the habitats.

In order to measure biodiversity in each forest type both the Shannon-Weiner function index and species richness were calculated for the three habitats. Tree species richness for each habitat was also calculated as the sum of tree species per habitat. The Shannon-Weiner function (Krebs, 1978) was calculated as follows:

$$H = -\sum_{i=1}^{s} (p_i)(\log_2 p_i)$$

Where:

H= the Shannon-Weiner biodiversity index

S= number of species

pi= proportion of each species in the sample

This function combines two components of biodiversity, the number of species and the evenness of allotment of individuals among species (Krebs, 1978). As a general rule, the higher number of species in a community and the more evenly spread among species the greater biodiversity. In the Shannon-Weiner index the minimum value for H is 0 meaning only one species in a community and H increases as the species richness increases and relative abundance becomes more even.

Tree species' DBH data from all three habitats was analysed by analysis of variance (ANOVA) and principal components analysis (PCA), an objective ordination technique useful to check for underlying factors that might be shaping the data, (Shaw, 2003) using SPSS 11.5 for Windows software programme. This was done by gathering all DBH measurements from all habitats for each tree species and forming one big data set. After running a one-sample Kolmogorov-Smirnov test on all DBH data to test if it is normally distributed, log values in case of abnormal distribution were taken. Thus, this raw set of data was, then, condensed by PCA analysis through two resulting PC axes. In PCA analysis, the first principal axis explains the greatest variation within a set of data and the second PC axis shows the second greatest variation within the data. Next, to visualise any underlying trend on habitat type within the tree species DBH measurements, a scatter plot was created from these two PC axes.

An analysis of variance (ANOVA) and a Kruskal-Wallis (KW) test were, then, conducted on the first and second PC axes from the PCA to statistically test for any significant differences in tree species DBH measurements between habitats. Therefore, the null hypothesis (Ho) from the ANOVA analysis run on the first PC axis states that the scores on the axis do not differ between habitats and the alternative hypothesis (H1) states that they do differ. Also, the H(0) from the KW test states that there is no differences between habitats in tree species DBH and the H(1) states that there is a difference. These two types of statistical tests are essentially testing for the same thing but the difference is that one is a parametric test, ANOVA, and the other one is a non-parametric test, KW.

In order to test for differences in mean DBH measurements from each habitat type without separating the data into tree species a third ANOVA analysis was conducted on the means of DBH measurements between habitats. Here, the H(0) states that tree means DBH from each habitat do not differ where as the H(1) states that they do differ. A bar graph was used to ilustrate these results.

Further ANOVA analyses were carried out to compare means of percentage ground cover and maximum tree height between habitats. Data on these two variables were also tested for normal distribution within the variables by one-sample Kolmogorov-Smirnov test and in the case of any abnormalities values were log. ANOVA's H(0) for both variables states that the means of the variable do not differ between habitats and the H(1) states that means are significantly different between habitats. Bar graphs were also drawn here to visualise these results.

2.6.3 Resource utilization

Data on resource utilization was taken by noting the type of tree species on which the animals were resting, eating, etc, as well as the activity. Additionally, the height in meters at which the primate species were found was also estimated and defined, here, as substrate use. After identifying the tree species, used by the observed animals, these were taken from the whole tree species data set of DBH measurements and run through a PCA. The first PC axis was, then, tested for any significant difference in tree species DBH utilised by the animals between habitats by ANOVA and KW test. The H(0) for ANOVA analysis states that there is no significant difference between tree species utilised by primate species in mixed swamp forest compared to tree species used by the animals in the tall pole forest and the H(1) states that they are different. Next, for the KW test, the H(0) states that tree species utilised by primate species between habitats are random. The H(1) states that primate species differ in resource utilization of tree species between habitats. Then, to analyse substrate used by primate species an ANOVA analysis and one-sample Kolmogorov-Smirnov test, to check for normality in distribution, were run. However, only mixed swamp and tall pole forests were taken into account in this ANOVA analysis, because of low sample size in the low pole forest (only data on one tree species). The H(0) states that substrate used by primates does not differ between habitats and the H(1) states that there is a difference in substrate used by primate species between habitats.

Finally, the activity data collected during the primate species sightings in the three different habitats, four different activity patterns were identified, feeding, resting, travelling and vocalization. Then, percentages of these activities were calculated separately for each habitat. Percentages on activity patterns were further assessed by comparing percentages values between mixed swamp forest and tall pole forest. Low pole forest was discarded from this comparison because of lack of data. Afterwards, percentages on activity for specific primate species were also computed. For these last set of calculations data from each habitats was compile to one data set to obtain a more representative sample in activity patters for specific primate species without making a distinction between habitats.

3.0 RESULTS

3.1. Diurnal primate densities

A total of 55 sightings of diurnal primates (n=145 individual animals) from four different species were observed along 151.48 Km of transects in mixed swamp forest. These species were *Pongo pigmaeus, Hylobates agilis, Presbytis rubicunda* and *Macaca nemestrina.* Twenty-nine groups of primate species were observed (n=72 individual animals) in the tall pole forest including *Pongo pigmaeus, Hylobates agilis* and *Presbytis rubicunda*. Hence, only one observation was made in the low pole forest consisting of an adult matured (flanched) male orang-utan (*Pongo pigmaeus*). Densities for all diurnal primates in the tree habitats calculated by the DISTANCE programme and the fixed-width method are being summarised in Table 3.1.

Table 3.1:Diurnal primates' densities in mixed swamp, low pole and tall pole forests at Sebangau National Park, Central Kalimantan.

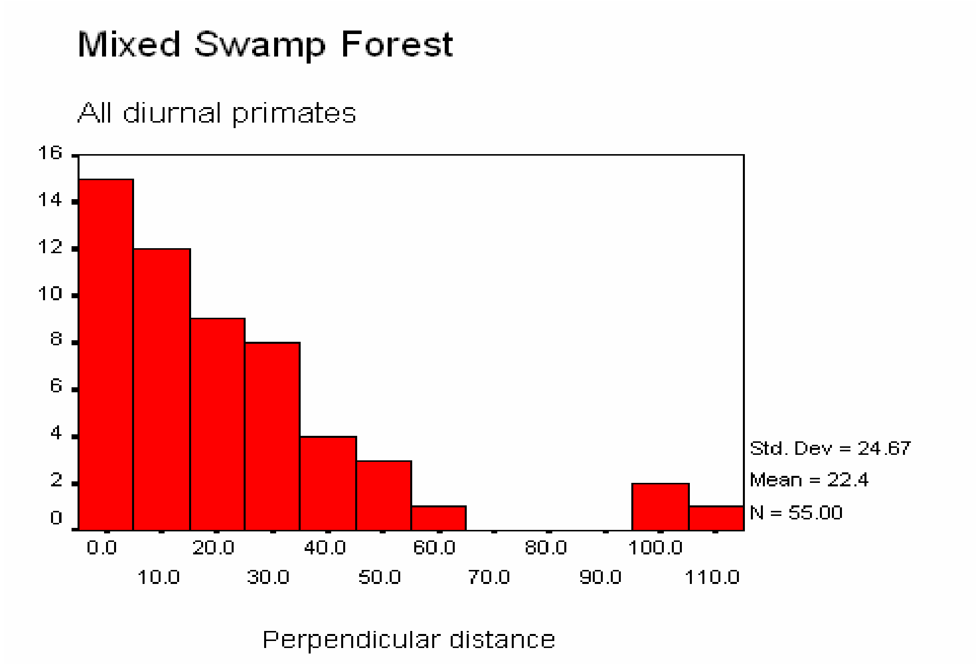
Densities given by the DISTANCE software					
Habitat	**Primate spp.**	**Sightings**	**L (Km)**	**Model**	**Density (individuals/Km2)**
Mixed swamp	*Pongo pygmaeus*	18	151.482	Half-normal/ cosine	2.3
	Hylobatis agilis	18	151.482	Half-normal/ cosine	6.91
	Presbytis rubicunda	15	151.482	Half-normal/ cosine	5.59
	Macaca nemestrina	4	151.482	Half-normal/ cosine	0.33
	Total	55	151.482	Half-normal/ cosine	13.94
Low Pole	*Pongo pygmaeus*	1	34.5	Half-normal/ cosine	1.5
	Total	1	34.5	Half-normal/ cosine	1.5
Tall Pole	*Pongo pygmaeus*	14	27.65	Half-normal/ cosine	6.73
	Hylobatis agilis	9	27.65	Half-normal/ cosine	13.98
	Presbytis rubicunda	6	27.65	Half-normal/ cosine	16.44
	Total	29	27.65	Half-normal/ cosine	32.84

Densities calculated from the fixed width model						
Habitat	**Primate spp.**	**n**	**L (Km)**	**w (Km)**	**E(s)**	**Density (individuals/Km2)**
Mixed swamps	*Pongo pygmaeus*	18	151.48	0.05	1.3	1.5
	Hylobates agilis	18	151.48	0.035	2.2	3.7
	Presbytis rubicunda	15	151.48	0.04	3.8	4.7
	Macaca nemestrina	4	151.48	0.025	6	3.1
	Total	55	151.48	0.03	2.6	15.9
Low pole	*Pongo pygmaeus*	1	34.5	0.009	1	1.5
	Total	1	34.5	0.009	1	1.5
Tall pole	*Pongo pygmaeus*	14	27.6	0.04	1.2	7.7
	Hylobates agilis	9	27.6	0.035	3	13.9
	Presbytis rubicunda	6	27.6	0.03	4.6	16.7
	Total	29	27.6	0.035	2.4	36

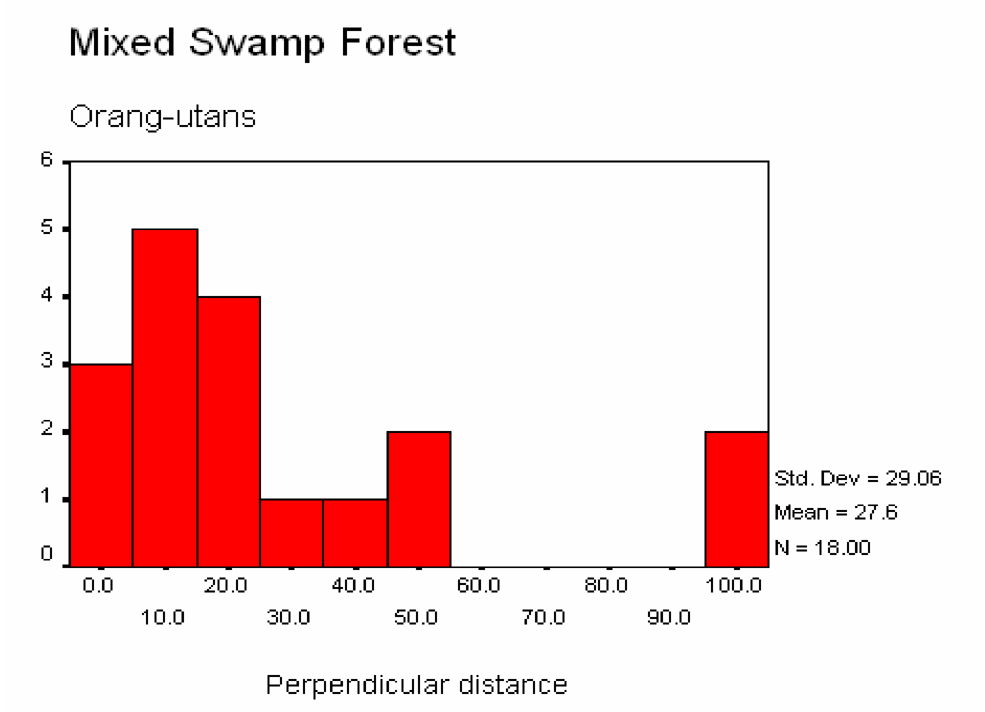
3.1.1 Calculating transect width (w) by the fixed-width method

Transect width (w) by the fixed-width method was evaluated from a series of histograms made for each group of primate species in each habitat (see Figures 3.1-3.4 and 3.6-3.9). For pig-tail macaques in mixed swamp forest, alternatively, *w* was taken from the mean value of perpendicular distances because there were only four sightings and each sighting had a different perpendicular distance (see Figure 3.5). Also, in low pole forest only one value for *w* was available (only one observation was made) so this was taken as a measure for *w*.

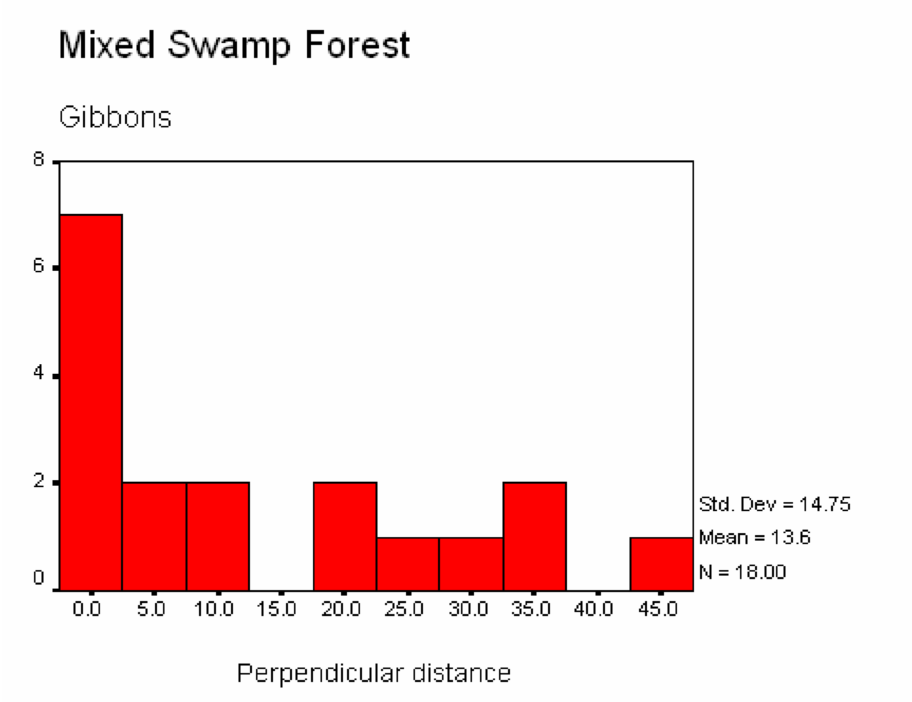
<u>Figure 3.1</u>: Histogram on perpendicular distances of all diurnal primates in mixed swamp forest showing w= 30m



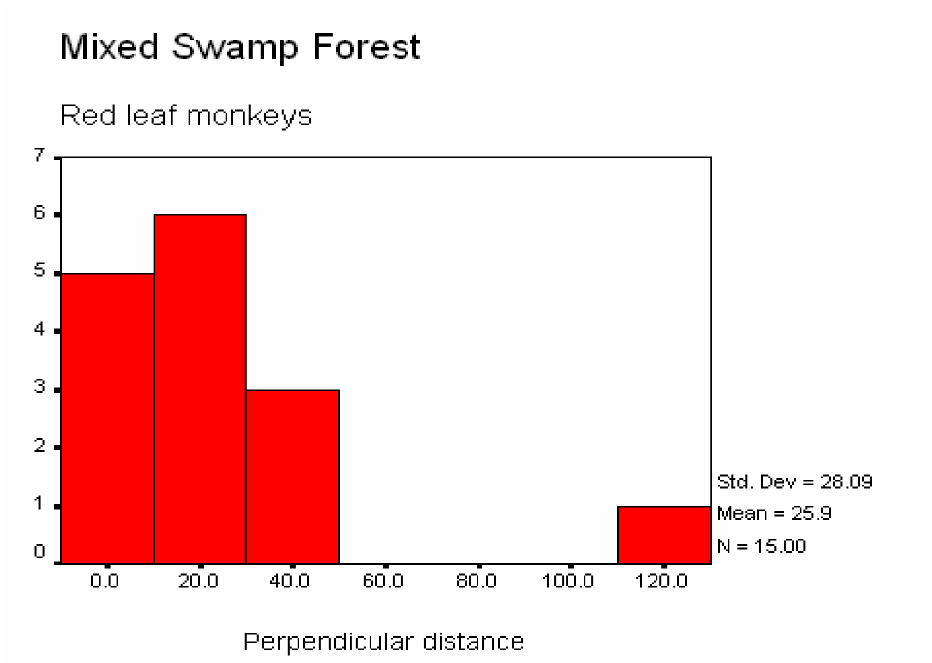
<u>Figure 3.2:</u> Histogram on perpendicular distances of orang-utans in mixed swamp forest showing w=50m



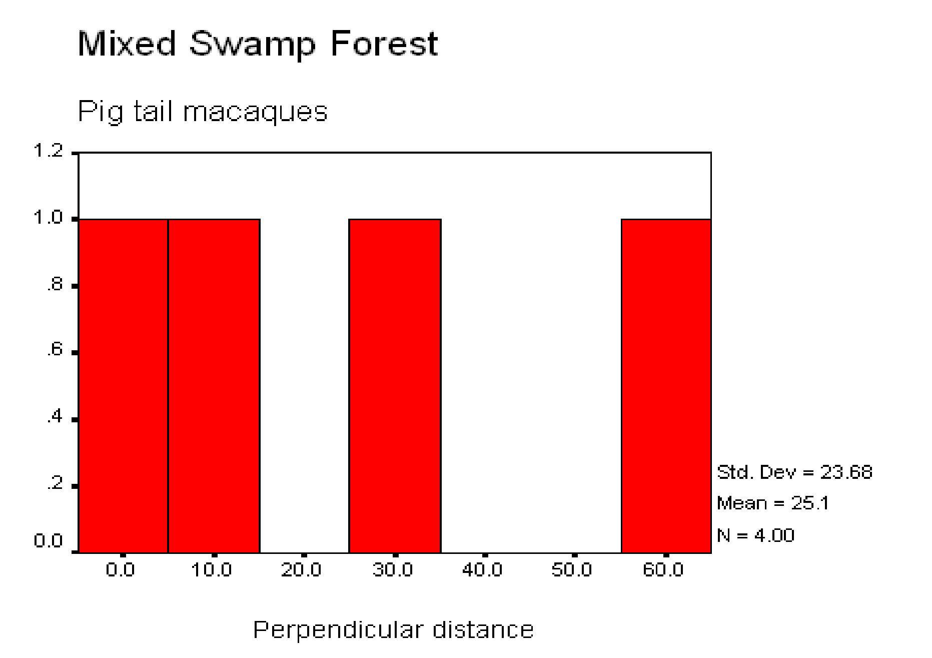
<u>Figure 3.3:</u> Histogram on perpendicular distances of gibbons in mixed swamp forest showing w=35m



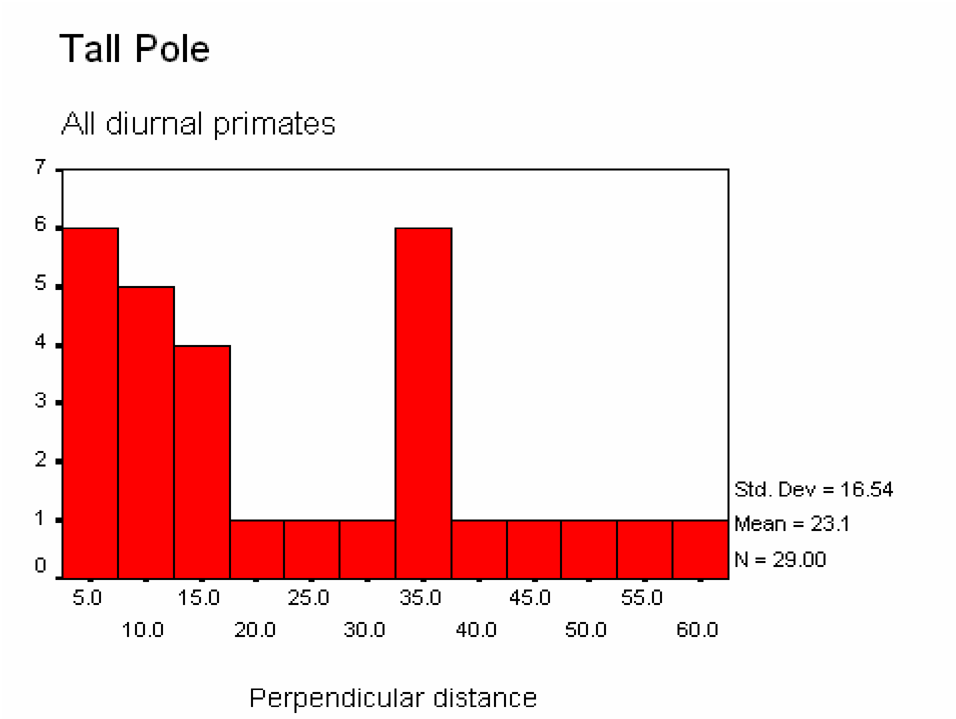
<u>Figure 3.4:</u> Histogram on perpendicular distances of red-leaf monkeys in mixed swamp forest showing w= 40m



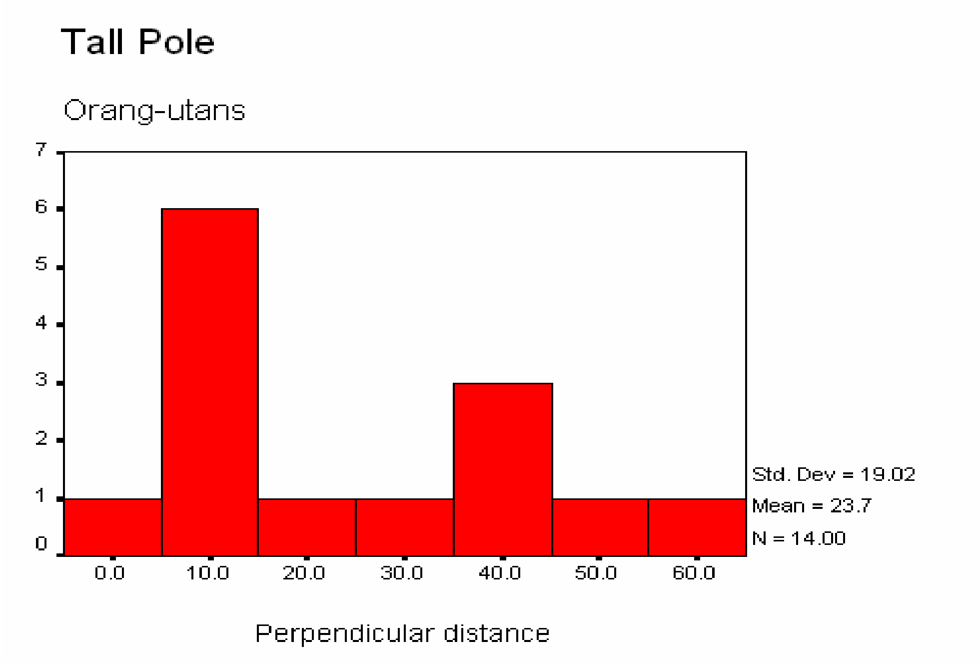
<u>Figure 3.5:</u> Histogram on perpendicular distances of pig-tailed macaques in mixed swamp forest showing a mean w value of 25.1m



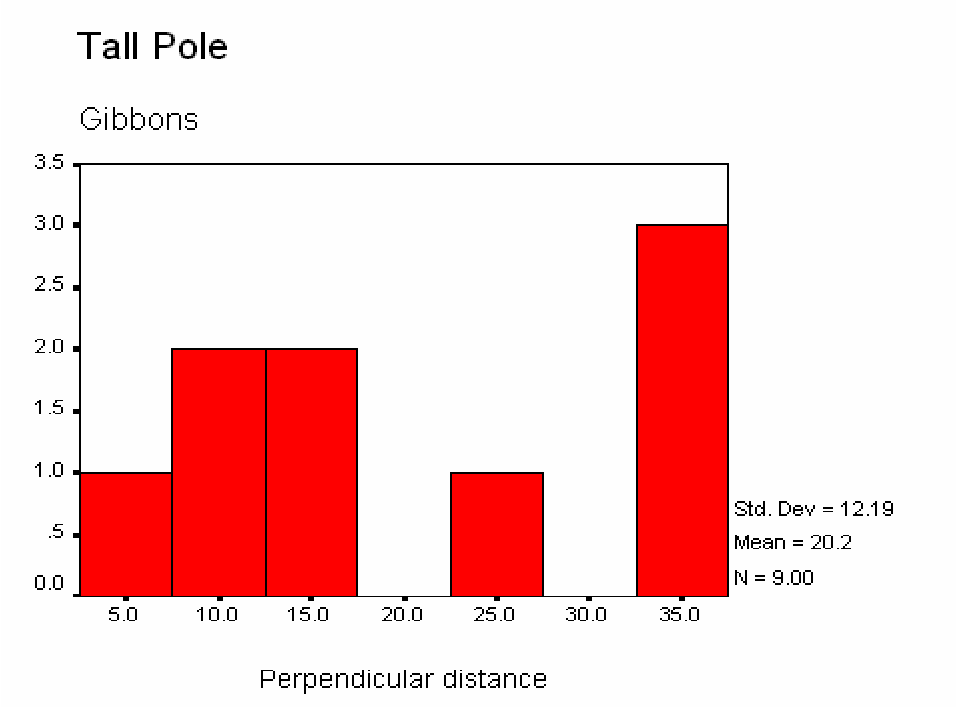
<u>Figure 3.6:</u> Histogram on perpendicular distances of all diurnal primates in tall pole forest showing w=35m



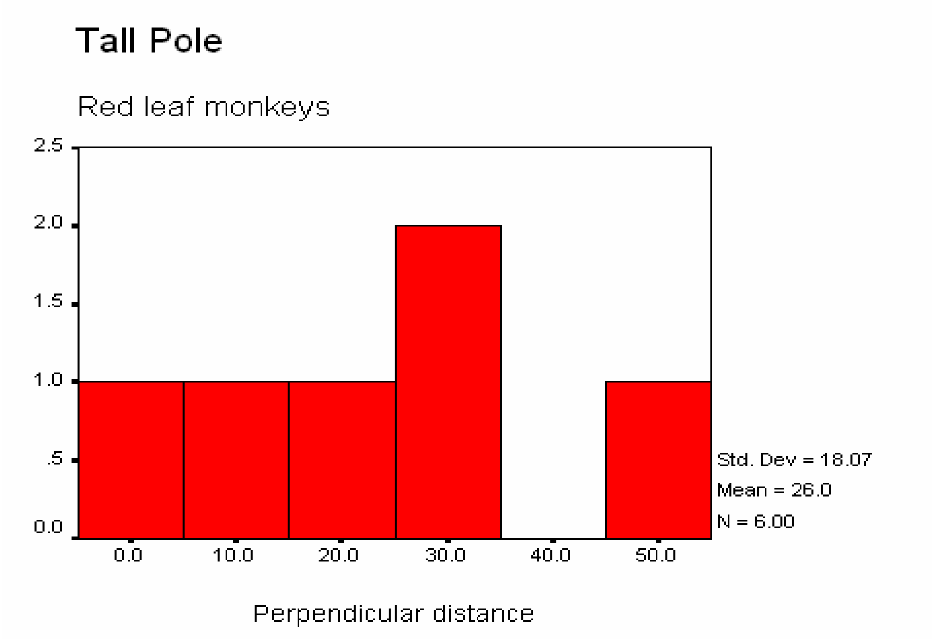
<u>Figure 3.7:</u> Histogram on perpendicular distances of orang-utans in tall pole forest showing w=40m



<u>Figure 3.8:</u> Histogram on perpendicular distances of gibbons in tall pole forest showing w=35



<u>Figure 3.9:</u> Histogram on perpendicular distances of red-leaf monkeys in tall pole forest showing w=30m



3.1.2 Group size analysis

No significant difference was found to exist in primate species' (*Pongo pygmaeus, Hylobates agilis* and *Presbytis rubicunda*) group size between the mixed swamp forest and the tall pole forest. Table 2 shows slightly higher values for primate species' means group size in the tall pole forest compare to the mixed swamp forest. However, ANOVA analyses showed that this difference is not significant, also shown in Table 3.2.

Table 3.2: ANOVA analysis in primate species' group size

Primate species' group size analyses			
	Group size mean (Habitat)		**ANOVA analysis**
Species	Mixed swamp	Tall pole	
Pongo pygmaeus	1.3	1.2	*F(1,30)= .160, p> .001
Hylobates agilis	2.2	3	F(1,25)= 2.74, p>.001
Presbytis rubicunda	3.9	4.7	F(1, 19)=.575, p>.001

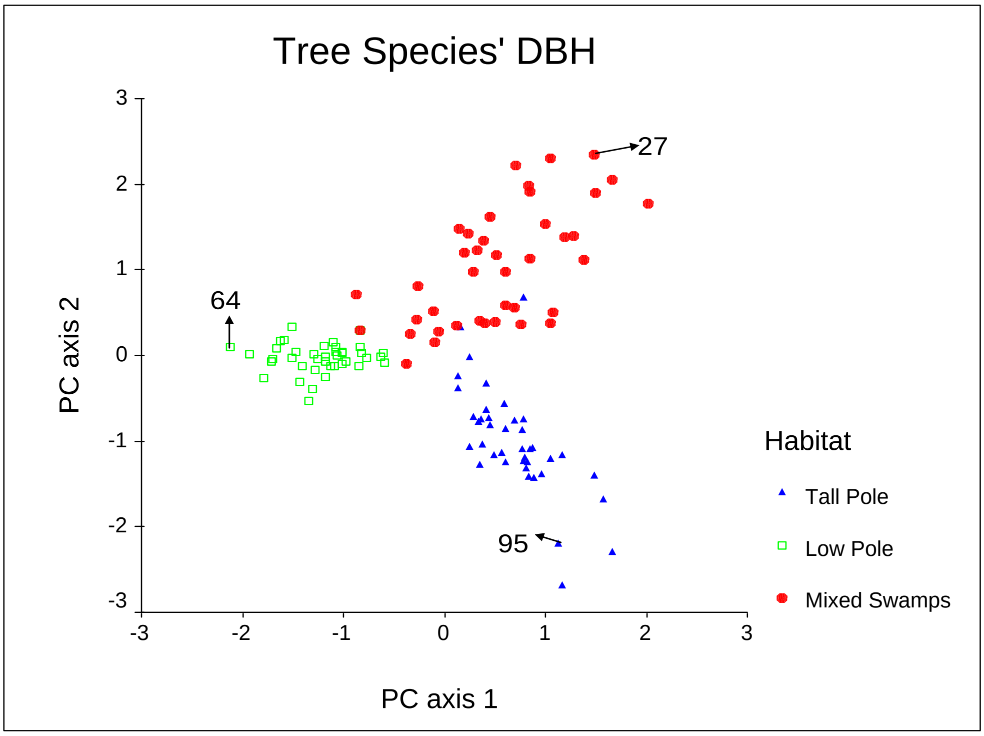
*Logged values
Note: Not sufficient data for *Macaca nemestrina*

3.2 Vegetation analysis

3.2.1 Tree species' DBH analyses

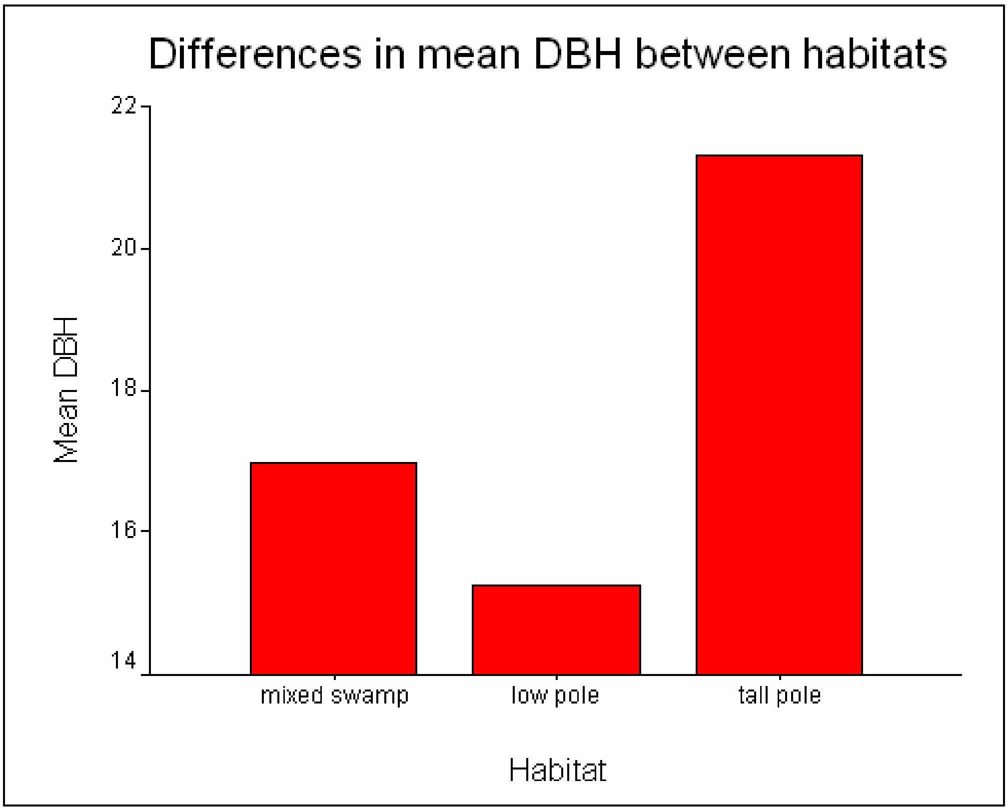
A total of 126 different tree species with a DBH > 10cm were identified in the mixed swamp, low pole and tall pole forests. Tree species DBH data were logged, then from the PCA analysis run on all 126 tree species DBH measurements, a near-perfect separation of tree species between habitats was observed and is clearly shown in Figure 3.10. For example species 27 shown with an arrow in Figure 3.10 is specific to the mixed swamp forest, species 64 to the low pole forest and species 95 to the tall pole forest. The PC axis 1 in Figure 3.10 shows that the greatest difference across habitats is between the low pole forest and the other two habitats (mixed swamp and tall pole forests). Most tree species found in mixed swamp and tall pole areas on PC axis 1 have positive values where as all low pole tree species have negative values along PC axis 1. In contrast, the PC axis 2 shows the variation between mixed swamp forest and tall pole forest. This variation is shown by tree species in mixed swamp forest found on the positive side of the PC axis 2 and the majority of tree species living in the tall pole forest are on the negative side of the axis.

Figure 3.10: Scattered plot of the two resulted PC axes from the tree species DBH data



Both statistical tests, ANOVA and KW, on the first PC axis were highly significant (ANOVA: F (2,117) = 191.908, p< .001; KW: X^2= 78.797, df= 2, p< .001). These means that tree species' DBH in mixed swamp forest and tall pole forests are found to differ from tree species' DBH in low pole forest. Analyses run on the second PC axis were also highly significant (ANOVA: F (2,116)=128.619, p< .001; KW: X^2= 91.681, df= 2, p< .001). Therefore, tree species in mixed swamp forest are, as well, significantly different than tree species in tall pole forest. The third ANOVA analysis also showed that trees' mean DBH between all habitats are significantly different (ANOVA: $F(2, 1387) = 81.27$, $p < .001$). Data on tree species mean DBH for the three habitats was logged for this analysis. These last results are more explicitly shown in Figure 3.11.

Figure 3.11: Bar graph on mean DBH



3.2.2 Habitat diversity assessment

Habitats were found to have different levels of tree species diversity. Specifically, 78 different tree species were found in the mixed swamp forest, 81 in the tall pole forest and 53 in the low pole forest. Hence, although the tall pole forest had the highest tree species richness the mixed swamp forest was found with the highest tree species diversity in accordance to the Shannon-Weiner index (3.79 index value for the mixed swamp forest). The index values for all habitats resulted from the Shannon-Weiner function are shown in Table 3.3.

Table 3.3: Comparing general vegetation structure between habitats

	DBH		Biodiversity	
Habitat	mean	range	spp. richness	Shannon-weiner index
1	16.97	*10-63.4	78	3.79
2	15.244	*10-50.5	53	2.99
3	21.33	*10-100.2	81	3.37

1= mixed swamp 2= low pole 3= tall pole
* 10cm was taken as the minimum tree diameter that was measured

3.2.3 Analyses on vegetation ground cover and tree height

Statistical analyses for ground cover (using logged data) and maximum tree height showed a significant difference between habitats (Ground cover, ANOVA: $F_{(2,113)}=13.818$, $p<.001$; Maximum tree height, ANOVA: $F_{(2,112)}= 53.516$, $p< .001$) therefore H(0)s for both variables were rejected. Figure 3.12 illustrates the difference between percentage ground cover between habitats and Figure 3.13 shows the difference between maximum tree heights between habitats.

Figure 3.12: **Bar graph showing the different means on percentage ground cover for each habitat**

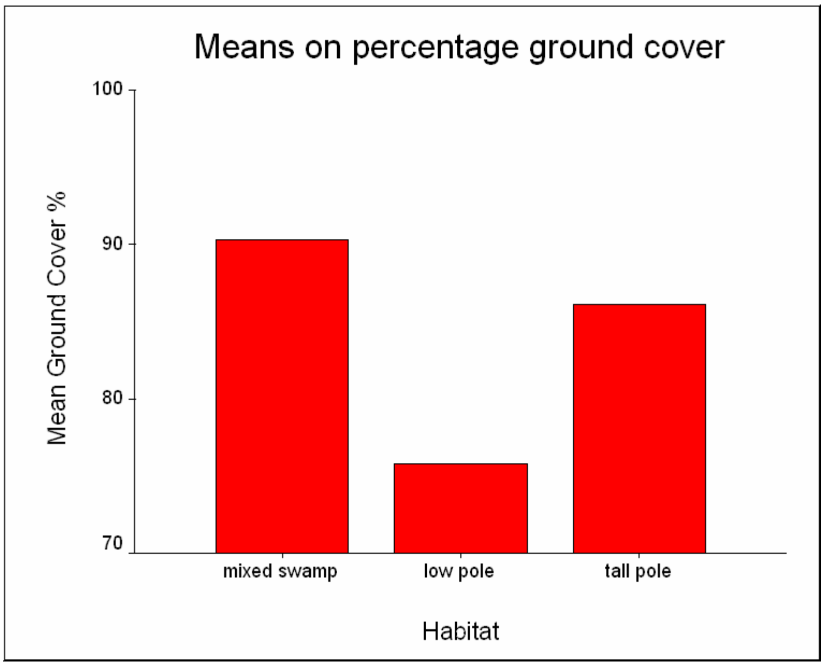
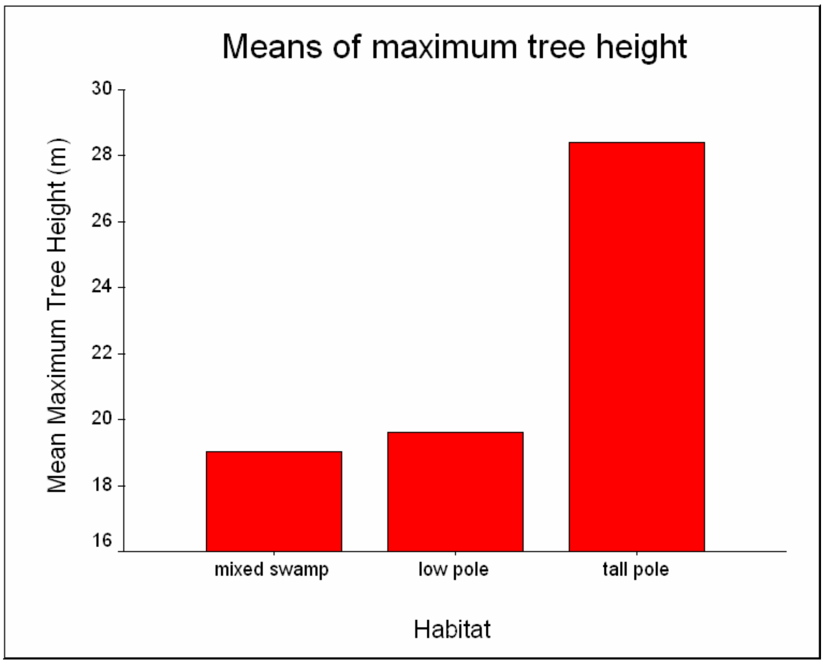


Figure 3.13: **Bar graph showing the different means of maximum tree heights for each habitat**



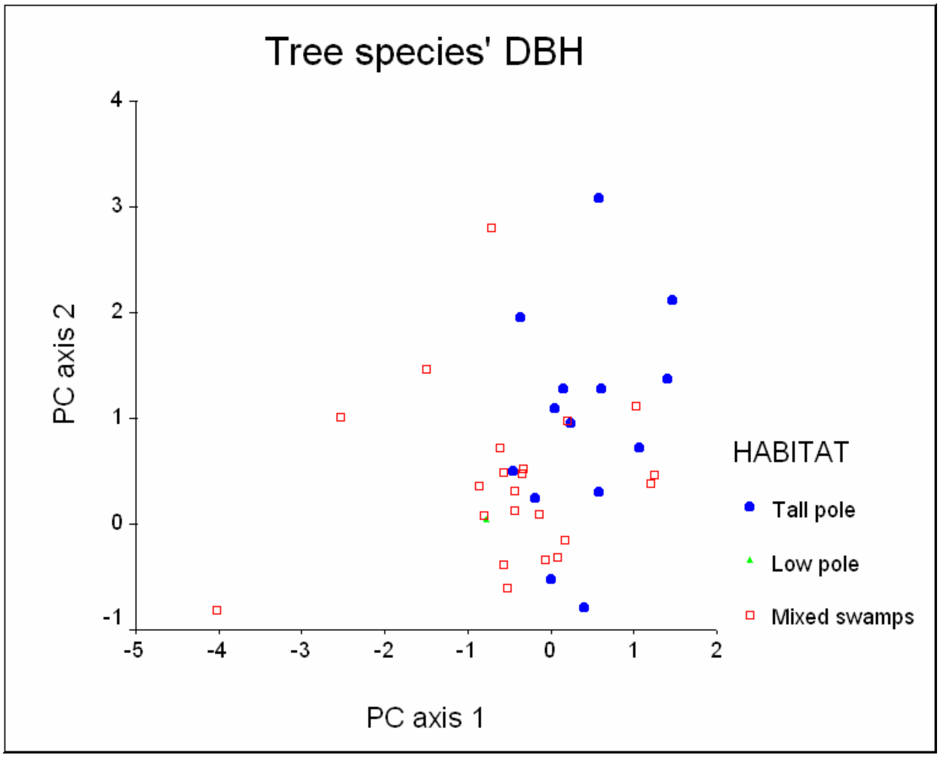
3.3 Analyses on resource utilisation data

3.3.1 Tree species' DBH analyses

In thirty-seven primate species' sightings from a total of 85 sightings between habitats, 21 different tree species were identified and data on substrate used and activity of the animals at the time of the sightings was recorded. Thirteen different tree species were identified in the mixed swamp forest and 9 in the tall pole forest during these 37 sightings.

The PCA analysis of these 21 tree species showed a distinction between the tree species used by primates depending on the habitat type (See Figure 3.14). In Figure 3.14 the scores on the principal axis 1, represent the greatest difference in variation between tree species in the mixed swamp forest from the tall pole forest, these differences were found significant by ANOVA and KW analyses (ANOVA: 3.664> F1, 34: .95, sig. .036; KW: X^2= 9.916, df= 2, sig. .007).

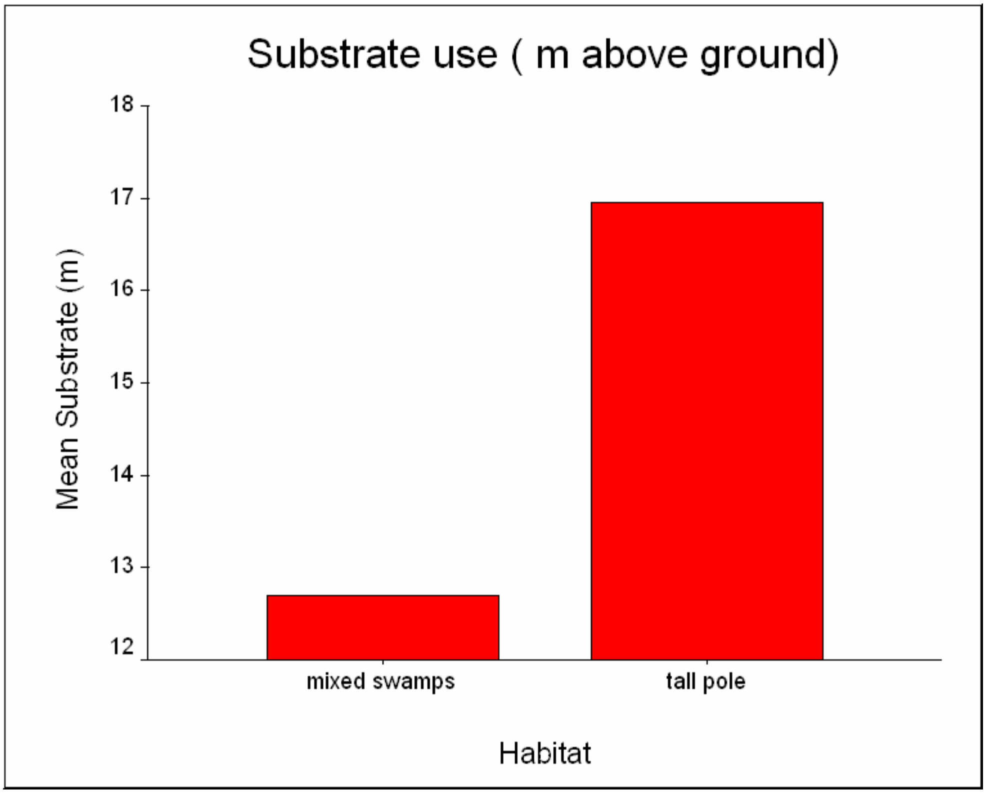
<u>Figure 3.14:</u> Scatter plot from the two PC axes on tree species' DBH measurements from tree species found to be used by diurnal primates



3.3.2 Analysis on substrate use

An ANOVA analysis showed a significant difference in primate species' substrate use between habitats (F (2, 62)= 13.201, p< .001). Therefore, the H(0) in being rejected in this analysis. Figure 3.15 illustrates this significant difference in substrate used by primate species depending on habitat type.

<u>Figure 3.15:</u> Bar graph on substrate use (m above ground)



Also, descriptive statistics on primate species' substrate use between mixed swamp forest and tall pole forest are presented in Table 3.4.

<u>Table 3.4:</u> Descriptive statistics on substrate use

	Substrate use (m above ground)			
	Mixed swamp		Tall pole	
Primate species	mean	range	mean	range
Pongo pygmaeus	13.38	8-22.5	16.56	8-23
Hylobates agilis	13.5	8.5-23	16	8-23
Presbytis rubicunda	12.5	11-13	12.5	13-21
Macaca nemestrina	8	8		

3.3.3 Percentages of primate species activity patterns

On seventy-one diurnal primate sightings from a total of 85 sightings activity data was collected. Fifty-two of these 71 primate sightings were made in the mixed swamp forest, 22 sightings in the tall pole forest and one sighting in the low pole forest. Percentages derived from this data on four different activity patterns, feeding, resting, travelling and vocalising, are display in Table 3.5. More specifically, Table 3.5 compares percentages for primate species' activity patterns between the mixed swamp forest and the tall pole forest and percentages on activity patterns between three primate species, *Hylobates agilis*, *Pongo pigmaeus* and *Presbytis rubicunda*.

Table 3.5: Percentages on activity patterns

Percentage activity shown by habitat and three primate species*					
	Habitat		Species		
Activity	Mixed swamp (n=52)	Tall pole (n=19)	*Hylobates agilis* (n=25)	*Pongo pygmaeus* (n=24)	*Presbytis rubicunda* (n=18)
Feeding	42.3	47.4	24	75	33.3
Resting	13.5	21.1	16	16.7	11.1
Traveling	36.5	21.1	40	8.3	55.6
Vocalising	7.7	10.5	20		

* *Macaca nemestrina* was not included because of low sample size (4 sightings)

4.0 DISCUSSION

Tropical peat swamp forest ecosystems have been heavily undervalued as a habitat for several rare and threatened species, as well as for general biological diversity, which was considered to be lower than that of other terrestrial tropical zones. However, recent studies show that biodiversity in this ecosystem is in fact quite high and that this habitat is important for several primate species especially for orang-utans which are on the border of extinction.

4.1 Calculating density

4.1.1 Estimation of n and E(s) parameters by the fixed-width method

Sighting numbers are recommended to be around 40-60 to accurate calculate true densities at any given site (Buckland *et al.*, 2001) but unfortunately there was not enough time during this project to reach that goal and this number was not reached for any primate species at any habitat type. However, this shouldn't be a problem for calculating relative densities between sites. On the other hand, this could be a problem for calculating cluster size or group size (E(s)), which was taken from the average of every group sighting because perpendicular distances were not taken individually but from the centre of the group. Therefore, group size values in low sample size cases can be overestimated or underestimated if the groups of animals encounter were unusually larger or unusually small rather than normal.

4.1.2 Estimation of w and L parameters by the fixed-width method

Transect length (L) is very straightforward but in order to get accurate density estimates it is important to cover an extensive amount of area. The larger the L the more reliable true densities estimates will be. The problem in this study is that it was almost impossible to travel the same survey distance for all three habitats because of the inaccessibility of the low pole and tall pole areas. Therefore, 151.5 Km were covered in the mixed swamp forest and only 34.5 and 27.7 Km in the low pole and tall pole forests.

The bigger problem comes with the width (w) parameter where having perpendicular distances measured correctly is important. This parameter (w) changes depending on the habitat type and animal species. Some areas are denser than others therefore it affects visibility and different primate species are found in different stratum layers of the forest canopy. Therefore w is measured separately for every species in every habitat. Also, the problem with w could be with low sample size. For example, pig-tail macaques in the mixed swamp forest were only noted 4 times and every time at different perpendicular distances. Therefore, in this case it is hard to tell which distance is the reliable sighting distance for this particular species in this particular habitat. As a result, an average of the perpendicular distances was taken for w. A second problematic case for this parameter in this study is the low pole forest where only one sighting was recorded, so only one value for w was available.

4.1.3 Comparing densities between fixed-width method and the method employed by the DISTANCE software programme

The pattern of primate species' densities within habitats were the same between the density estimates calculated using the fixed-width method and those calculated by the second method using the DISTANCE software programme. However, primate densities given by DISTANCE in the mixed swamp forest were slightly higher compared to the densities calculated by the fixed-width method with the exception of pig-tailed macaques. This might be due to the low sample size of this species, and so the DISTANCE programme might have taken the furthest perpendicular distance as w where in the fixed-width method w was taken by the average of the perpendicular distances. However, diurnal primate density estimates in low pole and tall pole forests were similar from both analyses (see table 3.1).

4.2 Comparing censusing techniques

This study focused on direct sightings of diurnal primates using distance sampling linear transects methodology. Other researchers prefer using indirect methods such as nest counts of animals in order to estimate densities. For example, orang-utan surveys are usually done by nest counts because of the rarity of the species. Researchers believe that the likelihood of encounter for this particular species is low; this is especially true in unhabituated populations. In other species such as gibbons, researchers prefer to survey the vocalizations made by the animals for similar reasons i.e. it is more likely to hear the animal than to see it. However, to survey different primate species at the same time direct sightings were thought, by the author, to be the best way to conduct surveys.

An orang-utan density study (Morrogh-Bernard *et al*., 2003) conducted in the same research field stations as my study was carried out during August 1994 and August 1995 dry seasons. The study used nest counts to estimate orang-utan densities. Linear transects were set up in the mixed swamp, low pole and tall pole forests. Total transects length surveyed from each habitat were the following: 5.25 km in mixed swamp forest, 2.30 Km in low pole forest and 5.48 Km in tall pole forest. Calculations on orang-utan nest counts were made using the DISTANCE software programme by Morrogh-Bernard *et al*. (2003). Density estimates results from this orang-utan nest count study were almost exactly the same as density estimates results calculated by my study using the computer software programme DISTANCE. The only density estimate found to vary between these two studies is from the tall pole forest. Results from both studies are being compared in Table 4.1.

Table 4.1: Results on orang-utan density estimates from two different studies using different approaches

Orang-utan (Pongo pymaeus) densities		
	Nest counts study (Morrogh-Bernard et al, 2003)	Direct sightings study (My study)*
Habitat	Densities (individuals/ Km2)	Densities (individuals/ Km2)
Mixed swamp	2.42	2.5
Low pole	1.15	1.5
Tall pole	2.57	6.73

*Results from software programme DISTANCE only

In my study estimate density of orang-utans in the tall pole forest are double than that of Morrogh-Bernard *et al*.'s study. This variation in density estimates could be caused by different factors. One factor could be that orang-utan density estimates in my study could have been overestimated due to small sample size or biased by seasonality. The proportion of fruiting or flowering trees changes throughout the year. Usually during the wet season there is a higher proportion of fruiting or flowering trees, therefore depending on the time of year the animal encounter rate can increase or decrease depending on the resource availability of the area.

Another factor underlying the differences in density estimates between studies could be that the Morrogh-Bernard *et al.* study covered a less extensive area than my study. As a result their nest surveys may have resulted in an underestimation of orang-utan densities since it did not have a representative sample size. Also, at the time of the nest counts study logging activities were active and orang-utans are known to be affected by this (Ancrenaz *et al*., 2004). Therefore it is likely that there were indeed few orang-utans inhabiting the area at this time. On the contrary, by the time of my study, legal logging activities had ceased to operate since 1996, giving some time for orang-utans to repopulate the area.

Multiple studies support the use of linear transect surveys to estimate primate species density. Fashing and Cords (2000) tested the accuracy of this method by comparing different methods of analyses of linear transects' data to true density estimates. True density estimates were determined by a long-term monitoring study of five primate groups from two primate species (*Colobus guereza* and *Cercopithecus mitis*), then data on home range size and overlap patterns was analysed. For the linear transect method 24 transect lines were surveyed along a 2.88 Km route and perpendicular distances from the transect to the animal's sighting place and from the observer to the animal's sighting place were recorded. Data from the linear transect surveys were analysed by four different methods that varied according to how the transect width was estimated. Therefore they used slightly different formulas. The Whitesides method estimates transect width by calculating the maximum reliable perpendicular distance from the transect to the animal, taking into account the species-specific mean group spread. The second method also calculates maximum reliable perpendicular distance from the transect to the animal. However it does not take mean group spread into account. In contrast to these two methods the third method calculates the maximum reliable distance from the observer to the animal for transect width. The study shows very similar primate density estimates of *Colobus guereza* and *Cercopithecus mitis* between the two general approaches for estimating biological population densities, home-range and linear transects. However, the Whitesides method of analyses of linear transect data which incorporates species-specific mean group spread into its formula for estimating transect width, provided the most accurate primate density estimates. Table 4.2 summarises these results where the Whitesides method showed closer density estimates for the two primate species compared to the other two linear transect methods of analysis.

<u>Table 4.2:</u> Comparing methodologies for calculating density using linear transects for sampling

Density estimates (individuals/ Km2)				
Methods				
	Home-range	Linear transect methods of analyses		
Species	True density	Analysis by Whitesides	Reliable observer to animal distance	Reliable transect to animal distance
Colobus guereza	11.5	11.1	10.6	13.9
Cercopithecus mitis	5	4.2	6.8	10.7

In ape studies the use of linear transect techniques is most frequently implemented by cue sampling, the sampling of the animals' signs such as nests or dung. Cue sampling is used due to the low densities that ape species generally exist at their natural environment. Therefore it would be very time consuming to attempt to estimate densities for apes by direct sightings under these low density conditions, given that large sample sizes are required to gain reliable estimate densities (Buij *et al*., 2003). In these types of survey where density estimation relies on traces left by the animals (nests or dung), additional sources of error are introduced compared to sampling methods that used direct animal sightings. However, by increasing the sample size through the sampling of nests or dung it improves the statistical resolution of the study (Blom *et al*., 2001). Buij *et al*. (2003) described the following possible sources of errors that have to be taken into account while sampling biological populations through cue (nests or dung) counts:

Estimating the proportion of nest builders in the population (p) and the rate at which nests are produced (r) raises minor problems in that these parameters differ between populations. One reason for this is that different populations have different group composition. Populations with fewer adult individuals are likely to have lower p because young infants do not construct nests, whereas for r there is evidence that this parameter may differ depending on the sex ratio because females with babies are found to construct twice as many nests as adult males in a day (Van Schaik *et al*, 1995; Buij *et al*, 1993).

The more crucial problems come with estimating the effective strip width of the transect (w) and the nest decay rate (t), which may result in false density estimates. If *w* is overestimated orang-utan densities are being underestimated. Now, the problem with the decay rate of nests (t) is that this parameter tends to vary a lot depending on the season (temperature, humidity, wind, etc), the type of nest (night nest or day rest nest) and the wood density of the tree species where nests are built. However according to Buij *et al*. (2002) this problem can be controlled by combining two different techniques for obtaining t , the nest monitoring technique and the matrix technique. This is done by calibrating the matrix technique against values obtained using the monitoring technique, and developing a correction factor (Buij *et al*., 2002).

Overall, the use of linear transects in distance sampling for estimating primate species population densities is presently the most frequently used method and is, generally, found to be reliable. Thus, within this methodology there are different approaches for collecting distance sampling data and analysing it. There is no correct method for collecting distance sampling data but there is an appropriate one. Depending on the study needs and the species being studied, it is important to meet the assumptions required by the methodology in use and the animal species ecological parameters in order to get accurate density estimates.

A second primate study has been carried out in Setia Alam research station area in the mixed swamp forest. This study was conducted by Cara Buckley from the 28th of June to the 27th of July 2004 and the study has not yet been published. Buckley surveyed agile gibbons (*Hylobates agilis*) by auditory sampling in mixed swamp forest. Buckley's density estimates were slightly higher than my study estimating 7.4 individulas/Km^2 and a group mean of 3.4 individuals (Buckley pers.

com.). In contrast, my study shows a density of 6.9 individuals/Km^2 and a group mean of 2.2 individuals for gibbons using DISTANCE. The difference between densities, here, may be due to the difference between mean group values. Mean group values in my study for gibbons are lower than Buckley's. In turn, this could have been caused by misses on individual sightings of group members while surveying the transects. However, I was not able to test this hypothesis given that the densities being compared from my study were calculated by the software programme DISTANCE, which do not enable me to change the group size value resulted from the linear transects data.

Generally, primate surveys using different methodology in this ecosystem showed similar density estimates for diurnal primates and it is valid to assume that these estimates are close to true density estimates for at least two primate species, orang-utans and gibbons in the mixed swamp forest. Also, having estimated the other diurnal primate species' density in Sebangau National Park opens the door to new research possibilities in the area by knowing the general primate species diversity composition and structure.

4.3 Comparing primate densities in relation to vegetation structure, resource availability and forest quality between habitats

In Sebangau National Park different diurnal primate densities were found to vary with the different peat swamp forest types. The mixed swamp forest was found to have the highest tree diversity (3.79 Shannon-Weiner biodiversity index) compared to the low pole and tall pole forests; although, the tall pole forest had the highest tree species richness (81 species). The mixed swamp forest was found to harbour the highest diurnal primate species diversity. During primate surveys in the mixed swamp forest, orang-utans, gibbons, red-leaf monkeys and pig-tailed macaques were all sighted. Long-tailed macaques were often seen at camp which was located in the mixed swamp forest, although they were never recorded during transects walks. The tall pole forest, on the other hand, was found to carry the highest densities of diurnal primates even though only three species of primates (orang-utans, gibbons and red leaf monkeys) were recorded. In contrast, the low pole forest was found to have very low primate diversity and in low densities.

Differences in primate densities between habitats are attributed to a combination of several factors such as: vegetation structure, resource availability of the area, forest quality and animals' ecology. All of these factors are in turn defined by other external causes that can be classified into two groups: natural and anthropogenic. These two general causes also interact with each another. For example, natural causes can be as simple as the amount of rainfall in a particular area which helps to shape the vegetation structure and the fruit abundance. Anthropogenic causes, alternatively, are all human activities carried out within an ecosystem. In this case, selective logging could be one important factor affecting the different habitats.

The mixed swamp and tall pole forests had both been exposed to logging activities for 30 years up until 1996, when the logging concession stopped running, whereas the low pole forest hasn't been touched. Although these two habitats were greatly damaged by selective logging they still harbour the greatest biodiversity in the Park. This indicates that these two habitats were always found to be home to a diversity of animal species whilst there is no knowledge on the effects of logging in these biological communities.

There is evidence to suggest that logging activities are indeed a threat to primate species especially to orang-utan populations. Felton *et al*. (2003) compared two different orang-utan (*Pongo pygmaeus*) populations between a selectively logged peat swamp forest and an unlogged forest in West Kalimantan, Indonesia. Felton's results are comparable to other studies where densities in orang-utan populations are found to decline by an average of 21% in selectively logged or hand-logged areas (Rijksen and Meijaard, 1999).

Ecological threats such as habitat disturbance are shown to affect different primate species differently. Thus, primate species that exhibit low ecological flexibility (more specialised animals) have shown to be more affected by disturbed areas (Isaac and Cowlishaw, 2004). Orang-utans, in particular, are large bodied highly arboreal frugivorous species. Their diet consists on average of 62% fruits and in order to fulfil their energy requirements they tend to feed long hours every day (Mackinnon, 1977). Therefore fruit abundance is a key aspect to orang-utans subsistence in a given area. Evidence of this assumption is given by a second orang-utan density study in a logged and unlogged forest in Sumatra (Knop, 2004). Knop (2004) found a positive correlation between orang-utan density and fruit availability. This study also suggests that as long as the fruit resource is not decreased in disturbed forest by logging, it is no longer a serious threat to orang-utan populations. However, the problem with selective logging is that it does not only causes food resource reduction but also fragmentation. Large forest gaps can be a serious problem to primate species, especially those that are highly arboreal. In the case of orang-utans which moved between branches by quadrupedal gait along inter-crown path-ways (Felton *et al*., 2003), large canopy gaps could cause them to travel longer than normal distances in search of appropriate food source.

4.3.1 Habitat vegetation structure and resource availability for diurnal primate species

The mixed swamp forest was found to be dominated by the following tree species written in order of abundance: 1. *Myristicaceae gymnacranther* 2. *Euphorbiaceae neoschortechina kingii* 3. *Lauraceae cryptocarya* 4. *Amonaceae xylopia fusca* 5. *Dipterocarpaceae shorea teysmanniana* 6. *Clusiaceae calophyllum hosei* 7. *Clusiaceae mesua* 8. *Anarcardiaceae campnosperma coriaceum* 9. *Myrtaceae syzygium* 10. *Fagaceae lithocarpus* 11. *Ebenaceae diospyros pseudomalabarica* 12. and *Annonaceae mezzetia leptopoda*. From these 12 different tree species 11 are known to produce fruit eaten by primates, 3 of these 11 tree species produce fruit prefered fruits by the animals. All 13 dominant tree species contain leaves consumed by primate species and 3 of these 13 tree species have eatable cambium (see Appendix C: Data provided by Morrogh-Bernard, 2005).

In the tall pole forest the 12 dominant three species were identified (written in order of abundance): 1. *Sapotaceae palaquium leiocarpum* 2. *Polygalaceae* *xanthophyllum* 3. *Euphorbiaceae neoschortechina kingii* 4. *Fabaceae koompassia malaccensis* 5. *Annonaceae mezzetia leptopoda* 6. *Clusiaceae mesua* 7. *Clusiaceae garcinia* 8. *Annonaceae polyalthia* 9. *Apocynaceae dyera lowii* 10. *Annonaceae xylopia* 11. *Icacinaceae platea* 12. and *Dipterocarpaceae shorea teysmanniana.* Although only 8 of these 12 tree species are known to produce fruit resources for primate species, 6 of these 8 are highly preferred fruits. Also, from these 12 tree species 7 (including tree species that produce fruit) contain leaves consumed by these animals, one has edible cambium and another one contains pith and flower liked by them (Appendix C).

In contrast to these two habitats the low pole forest is dominated only by 8 tree species. It harbours 4 abundant tree species that produced fruit consumed by primates, from which only one is found to be preferred by the animals. Also, the area contains three abundant tree species with leaves harvested by primate species and one tree species with edible cambium and flowers (Appendix C). The most dominant three species were: 1. *Anarcardiaceae campnosperma coriaceum* 2. *Anisophyllaceae combretocarpus rotundatus* 3. *Sapotaceae Palaquium cochlearifolium* 4. *Crypteroniaceae dactylocladus stenostachys* 5. *Dipterocarpaceae shorea teysmanniana* 6. *Clusiaceae mesua* 7. *Mrtaceae tristaniopsis* 8. and *Myrsinaceae rabanea borneensis.*

The different vegetation structure between the three habitat types can explain some of the variation between them in primate densities. Orang-utans and gibbons are highly frugivorous animals and prefer habitats where fruit availability is high as in the mixed swamp and tall pole forests. Also, these two habitats have a higher canopy height and most of the primate species found here are mainly arboreal with the exception of the pig-tailed and long-tailed macaques. These two species are usually found near river edges.

4.3.2 Niche separation in diurnal primate species

GAUSE's theorem assumes that two species can only co-exist if their ecological requirements are sufficiently different to avoid competitive exclusion (Mackinnon, 1977). In support of this theorem, diurnal primate species co-existing in Sebangau National Park appear to differ ecologically in their foraging strategies when food resources overlap or, alternatively, differ in their dietary needs. For example, the two highly frugivorous primate species in Sebangau are gibbons and orang-utans. Although these two species seem to compete for the same food source, mainly fruit, they employ very distinct foraging strategies. Mackinnon (1977) suggested that this is due primarily to differences in body size. Orang-utans on the one hand are very large animals and tend to move slowly through the forest canopy travelling on average 500m a day (Macknnon, 1977) whereas gibbons, on the other hand, are medium size primates and tend to be very agile, moving quickly through the forest vegetation travelling compared to orang-utans much further distances in a day range. These characteristics allow them to exploit the same food sources in a different manner.

Orang-utans spend long periods of time in one area or in one tree where food is abundant; they prefer quantity versus quality of food. On the contrary, gibbons prefer quality food. They travel long distances to get the best and ripest fruit resources available, therefore they need to keep moving in search of these ones. As a result of these two different foraging strategies these two apes are also found to differ in activity patterns (Mackinnon, 1977). Orang-utans maintain a feeding time to travel time ratio of 4.1 according to Mackinnon (1977), and gibbons a 1.1 ratio.

Langurs and macaques are also found to be sympatric. There is evidence to suggest that this is due to differences in food specialisation and the use of vertical vegetation stratum. In a study by Singh *et al*. (2000) the lion-tailed macaque (*Macaca silenus*) and the Nilgiri langur (*Presbytis johnii*) were found to co-exist in areas where the forest was relatively large. This study was conducted in the forests of Western Ghats in southern India. Singh *et al*. analysed the ecological and behavioural data of these two primate species, for the purpose of comparing the two species' niches. Data were collected through scan sampling. Their results concluded that the lion-tailed macaque is mainly a frugivorous and insectivorous species where as the nilgiri langur is primarily folivorous. Also, these two species were found to feed in different layer stratums of the forest vegetation i.e. lion-tailed macaques were found to feed in higher vegetation stratum than the nilgiri langur. Nilgiri langurs seemed to compromise with the lion-tailed macaques when both primate species were feeding near each other, langurs appeared to shift their activity and move to a lower layer canopy stratum. Their feeding schedules were also found to vary between midday and afternoon periods. In the case of langur and macaque species (*Presbytis rubicunda and Macaca nemestrina*) found at Sebanagau National Park, it is safe to assume that these two species behave in similar ways.

These types of niche separation in diurnal primate species might explain density patterns shown by my study. The mixed swamp forest was found to be the most diverse habitat, supporting the highest primate species diversity. Four diurnal primate species were found to co-exist in the area (*Pongo pymaeus, Hylobates agilis, Presbytis rubicunda* and *Macac nemestrina*). The tall pole forest, in contrast, was found to harbour only three diurnal primate species (*Pongo pymaeus, Hylobates agilis* and *Presbytis rubicunda*), but these primate species were found in higher densities. One explanation for this could be that higher densities are due to less competition for food resources between species, allowing the present species to do well.

The mixed swamp forest and the tall pole forest are also known to vary in area size. The mixed swamp forest is found to cover an extensive area of 3, 900 Km^2 and the tall pole forest only of 400 Km^2 (Morrogh-Bernard et al., 2003). This difference in area size could also account for the difference in primate species diversity. Larger forest areas are able to sustain a more diverse group of primate species.

4.4 Implications for conservation

In order to manage different ecosystems efficiently the need to know and understand how these ecosystems function is essential. According to the IUCN (1994) classification system of protected areas, National Parks such Sebangau are natural areas of land designated to protect the ecological integrity of one or more ecosystems for present and future generations. Exploitation or human settlement likely to damage the protected area should be excluded from National Parks. Also, these areas should provide a basis for scientific, educational and recreational use based on foundations that are environmentally and culturally compatible (White and Edwards, 2000).

A well developed management plan is essential to protect the ecosystem or ecosystems of interest. A management plan is defined by White and Edwards (2000) as "a guideline to control the management of protected area resources, the use of the area, and the development of facilities needed to support management and use." Hence, to established these guidelines an extensive amount of research on the area's natural resources and community interaction is needed, as well as research into the factors threatening the natural balance of the ecosystem(s).

Two fundamental research phases were identified by White and Edwards in order to truly succeed in the attempt to manage a protected area. The first phase is mainly descriptive, where research is focused primarily on the ecology of the area. This is essential for newly protected areas which lack information on the areas' animal and plant species present in the ecosystem(s). There are four main biological questions asked by descriptive research which were accounted for in my study in relation to primate species:

1. What animals are found in the area?
2. What type of vegetation is found in the area?
3. Is there a difference in animal species or plant species diversity and abundance between different habitat types within the park?

Answers to these sorts of questions provide a foundation for management strategies. One is able to identify priority animal or plant species and areas to target for conservation within the park. In addition, it is also important to identify the area's ecological threats to later investigate the effects of these threats upon the ecosystem.

The second phase of research investigates more deeply the effects of habitat disturbance on biological populations and biological communities' interactions through experimental studies. Experimental studies seek to explain preliminary observations gathered from the first phase of research. In particular, my study provides basic information on primate species and tree species diversity and abundance of the three main habitats encompassed by the park. The mixed swamp forest and tall pole forest were found to be highly important for diurnal primate species. However, the low pole forest could be an important buffer zone area for primate species, especially for orang-utans which tend to have very large home ranges. Hopefully, my study findings could work as a foundation for future experimental research studies in the area.

4.5 Implications for future research

Research studies are important in protected areas because the more information available on specific biological communities the more effective management strategies can be implemented for species-specific needs. In addition to this a well studied area can gain popularity within the scientific community and contribute to the park financial support for management practices. Particularly, Sebangau has been subjected to multiple research studies, whilst most of them focused on the general vegetation structure of the peat swamp forests. A few studies have been carried out on the ape species inhabiting the area. However, none of these studies have been focused on the rest of the primate species. There is also a lack of information on the effects of selective logging on primate species communities, with the exception of the orang-utan community which has been well documented to be negatively impacted on by selective logging (Morrogh-Bernard, 2003).

Behavioural studies on specific primate species are also needed to understand primate species specific niches which in turn could explain their diversity patterns in the different habitats. Once behavioural data are available for the different primate species found here, these data can then be compared with other primate species communities found elsewhere in undisturbed forest areas, to then test for possible effects of ecological threats on Sebangau's primate species.

It is also important to conduct research that looks for seasonal distributional patterns of primate species. Most studies in Sebangau have been carried out during the dry season because of the difficulty of travelling through the forest during the wet season. This seasonality factor could highly bias a study results. Therefore, I propose that future research should attempt to test for differences in primate species seasonal movement patterns and differences in food resource availability in each habitat type during the wet and dry seasons.

The future of threatened primate species such as orang-utans is dependent upon collective human efforts to preserve these animal species ecosystems. The establishment of protected natural areas are meant to contribute to maintaining the dynamics of biological populations and thus preserving its biodiversity. However, the conservation work to classify priority natural areas as National Parks needs to be supported by efficient management practices. Effective management is carried out only when the area's ecological communities are well studied. Sebangau National Park is a newly established protected area and is known to sustain one of the largest orang-utan populations in the world. Therefore the hopes are for this park to implement an appropriate management plan for this priority species and in turn ensure its subsistence with the rest of the primate species in the park co-existing with this one.

References:

Ancrenaz, M., R. Calaque and I. Lackman-Ancrenaz (2004). "Orangutan Nesting Behavior in Disturbed Forest of Sabah, Malaysia: Implications for Nest Census." INTERNATIONAL JOURNAL OF PRIMATOLOGY 25, 5: 983-1000.

Anwaruddin, C. (2003). "The Pig-Tailed Macaque *Macaca Nemestrina* in India-Status and Conservation." PRIMATE CONSERVATION 19: 91-98.

Bateman, G. (1984). Primates. New York and Toronto, Torstar books.

Blom, A., A. Almasi, I. M. A. Heitkonig, J. B. kpanou and H. H. T. Prins (2001). "A Survey of the Apes in the Dzanga-Ndoki National Park, Central Africa Republic: A Comparison between the Census and Survey Methods of Estimationg the Gorilla (*Gorilla Gorilla Gorilla*) and Chimpanzee (*Pan Troglodytes*) Nest Group Density." East African Wild Life Society 39: 98-105.

Boonratana, R. (1994). "The Ecology and Behaviour of the Proboscis Monkey (Nasalis Larvatus) in Lower Kinabatanga, Sabah." Asian Primates 4, 1: 13-14.

Brockelman, W. Y. and R. Ali (1987). Methods of Surveying and Sampling Forest Primate Populations. New York, USA.

Buckland, S., D. R. Anderson, K. P. Burnham and J. L. Laake (1993). Distance Sampling: Estimating Abundance of Biological Populations. London, UK.

Buij, R., I. Singleton, E. Krakauer and C. van Schaik (2003). "Rapid Assessment of Orangutan Density." BIOLOGICAL CONSERVATION, 114(1): 103-113.

Chapman, C., S. Balcomb, T. Gillespie, J. Skorupa and T. Struhsaker (2000). "Long-Term Effects of Logging on African Primate Communities: A 28-Year Comparison from Kibale National Park, Uganda." CONSERVATION BIOLOGY, 14(1): 207-217.

Davies, A. and I. Baillie (1988). "Soil-Eating by Red Leaf Monkeys (Presbytis Rubicunda) in Sabah, Northern Borneo." BIOTROPICA, 20(3): 252-258.

Delgado RAJr and C. van Schaik (2000). "The Behavioral Ecology and Conservation of the Orangutan (Pongo Pygmaeus): A Tale of Two Islands." EVOLUTIONARY ANTHROPOLOGY, 9(5): 201-218.

Fashing, P. J. and M. Cords (2000). "Diurnal Primate Densities and Biomass in the Kakamega Forest: An Evaluation of Census Methods and a Caomparison with Other Forest." American Journa of Primatology 50: 139-152.

Felton, A., L. Engstrom, A. Felton and C. Knott (2003). "Orangutan Population Density, Forest Structure and Fruit Availability in Hand-Logged and Unlogged Peat Swamp Forests in West Kalimantan, Indonesia." BIOLOGICAL CONSERVATION, 114(1): 91-101.

Fleagle, J. G. (1999). Primate Adaptation and Evolution. California and London, Academic press.

Grieser Johns, A. and B. Grieser Johns (1995). "Tropical Forest Primates and Logging: Longterm Coexistence?" ORYX, 29(3): 205-211.

Groves, C. P. (1999). The Taxonomy of Orang-Utans. C. In: Yeager. New York, Columbian University**:** 27-30.
Groves, C. P. (2001). Primate Taxonomy. Washington, DC, Smithsonian Institute Press.
Hill, C., F. Osborn and A. Plumptre (2002). Human-Wildlife Conflict. New York, Wildlife Conserv Soc.
Isaac, N. J. B. and G. Cowlishaw (2004). "How Species Respond to Multiple Extinction Threats." The Royal Society 271: 1135-1141.
IUCN (1994). Guidelines for Protected Area Management Categories. IUNC, Gland & Cambridge.
Johns, A. (1986). "Effects of Selective Logging on the Behavioral Ecology of West Malaysian Primates." ECOLOGY, 67(3): 684-694.
Johns, A. (1987). "Long-Term Responses of a West Malaysian Primate Community to Selective Logging." INTERNATIONAL JOURNAL OF PRIMATOLOGY, 8(5): 511.
Johns, A. and J. Skorupa (1987). "Responses of Rain-Forest Primates to Habitat Disturbance: A Review." INTERNATIONAL JOURNAL OF PRIMATOLOGY, 8(2): 157-191.
Knop, E., P. Ward and S. Wich (2004). "A Comparison of Orang-Utan Density in a Logged and Unlogged Forest on Sumatra." BIOLOGICAL CONSERVATION, 120(2): 183-188.
Krebs, C. J. (1978). Species Diversity. Ecology the Experimental Analysis of Distribution and Abundance. J. k. Smith. New York, Hagerstown, San Francisco, London, Harper and row**:** 449-487.
Leighton, D. R. (1987). Gibbons: Territoriality and Monogamy. Primate Societies. T. Struhsaker. Chicago and London, The Univesity of Chicago Press**:** 135-144.
MacKinnon, J. (1974). "The Behaviour and Ecology of Wild Orang-Utans (Pongo Pygmaeus)." ANIMAL BEHAVIOUR, 22: 3-74.
MacKinnon, J. (1977). "A Comparative Ecology of Asian Apes." PRIMATES, 18: 747-772.
MacKinnon, J. (1984). The Distribution and Status of Gibbons in Indonesia. The Lesser Apes: Evolutionary and Behavioural Biology. N. Creel. Edinburgh, Edinburgh University Press**:** 16-18.
MacKinnon, J. and K. MacKinnon (1974). Animals of Asia: The Ecology of the Oriental Region. New York, Holt, Rinehart and Winston.
Mackinnon, J. and I. Suwelo (1984). "Species Conservation Priorities in the Tropical Forests of Indonesia." OCCASIONAL PAPERS OF THE IUCN SPECIES SURVIVAL COMMISSION (SSC), (1): 27-39.
MacKinnon, K. (1986a). "The Conservation Status of Indonesian Primates." PRIMATE EYE, (29, suppl.): 30-35.
MacKinnon, K. (1986b). "Conservation Status of Indonesian Primates." PRIMATE REPORT, (14): 163.
MacKinnon, K. (1986c). The Conservation Status of Nonhuman Primates in Indonesia. Primates: The Road to Self-Sustaining Populations. K. Benirschke. New York, Springer-Verlag**:** 99-126.

MacKinnon, K. (1987). "Conservation Status of Primates in Malesia, with Special Reference to Indonesia." PRIMATE CONSERVATION, (8): 175-183.
MacKinnon, K. (1997). The Ecological Foundations of Biodiversity Protection. Last Stand: Protected Areas and the Defense of Tropical Biodivesity. J. Johnson. New York, Oxford Univ Press: 36-63.
MacKinnon, K., G. Hatta, H. Halim and A. Mangalik (1997). The Ecology of Kalimantan. Oxford, Oxford Univ Press.
Mbora, D. and D. Meikle (2004). "Forest Fragmentation and the Distribution, Abundance and Conservation of the Tana River Red Colobus (Procolobus Rufomitratus)." BIOLOGICAL CONSERVATION, 118(1): 67-77.
Meijaard, E. and V. Nijman (2003). "Primate Hotspots on Borneo: Predictive Value for General Biodiversity and the Effects of Taxonomy." CONSERVATION BIOLOGY 17, 3: 725-732.
Melnick, D. J. and M. C. Pearl (1987). Cercopithenes in Multimale Groups: Genetic Variation Diversity and Population. Primate Societies. T. T. Struhsaker. Chicago and London, The University of Chicago Press.
Morrogh-Bernard, H., S. Husson, S. Page and J. Rieley (2003). "Population Status of the Bornean Orang-Utan (Pongo Pygmaeus) in the Sebangau Peat Swamp Forest, Central Kalimantan, Indonesia." BIOLOGICAL CONSERVATION, 110(1): 141-152.
Page, S. E., J. O. Rieley, K. Doody, S. Hodgson, S. Husson, P. Jenkins, H. Morrogh-Bernard, S. Otway and S. Wilshaw (1997). Biodiversity of Tropical Peat Swamp Forest: A Case Study of Animal Diversity in the Sungai Sebangau Catchment of Central Kalimantan, Indonesia. Tropical Peatlands. J. O. Rieley and S. E. Page. Cardigan, Samara publishing limited.
Page, S. E., J. O. Rieley, O. W. Shotyk and D. Weiss (1999). "Interdependence of Peat and Vegetation in a Tropical Peat Swamp Forest." The royal society 354: 1885-1897.
Payne, J., C. M. Francis and K. Phillips (1985). Mammals of Borneo. The Sabah Society, Kuala Lumpur.
Plumptre, A. (2000). "Monitoring Mammal Populations with Line Transect Techniques in African Forests." JOURNAL OF APPLIED ECOLOGY, 37(2): 356-368.
Plumptre, A. (2003). Recommendations for Censusing Chimpanzee Populations in Forests. West African Chimpanzees: Status Survey and Conservation Action Plan. B. TM. Gland, Switzerland, IUCN - World Conservation Union: 179-182.
Plumptre, A. and A. Johns (2001). Changes in Primate Communities Following Logging Disturbance. The Cutting Edge: Conserving Wildlife in Logged Tropical Forest. R. JG. New York, Columbia Univ Press: 71-92.
Plumptre, A. and V. Reynolds (1994). "The Effect of Selective Logging on the Primate Populations in the Budongo Forest Reserve, Uganda." JOURNAL OF APPLIED ECOLOGY, 31(4): 631-641.
Primack, R. B. (1998). Essentials of Conservation Biology. Massachusetts U.S.A, Sinauer Associates.

Rieley, J. O., S. E. Page, S. H. Limin and S. Winarti (1997). The Peatland Resource of Indonesia and the Kalimantan Peat Swamp Forest Research Project. Tropical Peatlands. J. O. Rieley and S. E. Page. Cardigan, Samara publishing limited.

Rijksen, H. D. and E. Meijaard (1999). Our Vanishing Relative: The Status of Wild Orang-Utans at the Close of the Twentieth Century. Leiden, Backhays.

Rodman, P. S. (1979). The Great Apes. California, Benjamin/ Cummings.

Rodman, P. S. (1988). Diversity and Consistency in Ecology and Behavior. Orang-Utan Biology. J. H. Schwartz. New York, Oxford University Press**:** 31-51.

Ross, C., A. Srivastava and R. Pirta (1993). "Human Influences on the Population Density of Hanuman Langurs Presbytis Entellus and Rhesus Macaques Macaca Mulatta in Shimla, India." BIOLOGICAL CONSERVATION, 65(2): 159-163.

Russon, A., A. Erman and R. Dennis (2001). "The Population and Distribution of Orangutans (Pongo Pygmaeus Pygmaeus) in and around the Danau Sentarum Wildlife Reserve, West Kalimantan, Indonesia." BIOLOGICAL CONSERVATION, 97(1): 21-28.

Shaw, P. J. A. (2003). Multivariate Statistics for the Environmental Sciences. London, Hodder Arnold.

Shepherd, P. A., J. O. Rieley and S. E. Page (1997). The Relationship between Forest Vegetation and Peat Characteristics in the Upper Catchment of Sungai Sebangau, Central Kalimantan. Tropical Peatlands. J. O. Rieley and S. E. Page. Cardigan, Samara publishing limited.

Singh, M. R., M. E. Singh, M. Ananda Kumar, H. N. Kumara, A. K. Sharma and H. S. Sushma (2000). "Niche Separation in Sympatric Lion-Tailed Macaque (*Macaca Silenus*) and Nilgiri Langur (*Presbytis Johnii*) in an Indian Tropical Rain Forest." PRIMATE REPORT 58: 83-95.

Struhsaker, T. T. and L. Leland (1987). Colobines: Infanticide by Adult Males. Primate Societies. T. T. struhsaker. Chicago and London, The University of Chicago Press**:** 83-97.

Sugandhy, A. (1997). Conservation and Sustainable Use of Tropical Peatland in Indonesia, within the National Strategy for Environmental Management of Wetland Ecosystems. Tropical Peatlands. J. O. Rieley and S. E. Page. Cardigan, Samara publishing limited.

Umapathy, G., M. Singh and S. Mohnot (2003). "Status and Distribution of Macaca Fascicularis Umbrosa in the Nicobar Islands, India." INTERNATIONAL JOURNAL OF PRIMATOLOGY, 24(2): 281-293.

White, L. and A. Edwards (2000). Conservation Research in the African Rain Forest: A Technical Handbook. New York, The Wildlife Conservation Society.

Wich, S., R. Buij and C. van Schaik (2004). "Determinants of Orangutan Density in the Dryland Forests of the Leuser Ecosystem." PRIMATES, 45(3): 177-182.

(MacKinnon 1974; MacKinnon and MacKinnon 1974; MacKinnon 1977; Krebs 1978; Rodman 1979; Bateman 1984; MacKinnon 1984; Mackinnon and Suwelo 1984; Payne *et al.* 1985; Johns 1986; MacKinnon 1986a; MacKinnon 1986c, 1986b; Brockelman and Ali 1987; Johns 1987; Johns and Skorupa 1987; Leighton 1987; MacKinnon 1987; Melnick and Pearl 1987; Struhsaker and Leland 1987; Davies and Baillie 1988; Rodman 1988; Buckland *et al.* 1993; Ross *et al.* 1993; Boonratana 1994; IUCN 1994; Plumptre and Reynolds 1994; Grieser Johns and Grieser Johns 1995; MacKinnon 1997; MacKinnon *et al.* 1997; Primack 1998; Fleagle 1999; Groves 1999; Rijksen and Meijaard 1999; Chapman *et al.* 2000; Delgado RAJr and van Schaik 2000; Fashing and Cords 2000; Plumptre 2000; Singh *et al.* 2000; White and Edwards 2000; Blom *et al.* 2001; Groves 2001; Plumptre and Johns 2001; Russon *et al.* 2001; Hill *et al.* 2002; Anwaruddin 2003; Buij *et al.* 2003; Felton *et al.* 2003; Meijaard and Nijman 2003; Morrogh-Bernard *et al.* 2003; Plumptre 2003; Shaw 2003; Umapathy *et al.* 2003; Ancrenaz *et al.* 2004; Isaac and Cowlishaw 2004; Knop *et al.* 2004; Mbora and Meikle 2004; Wich *et al.* 2004)