



# **ORANGUTAN NESTING PREFERENCES IN A DISTURBED TROPICAL DEEP-PEAT SWAMP FOREST, CENTRAL KALIMANTAN, INDONESIA.**

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## **Abstract**

The primary aim of the study was to identify tree and habitat preferences essentially important in orangutan nesting behaviour within a disturbed swamp forest habitat. The main objective being to identify the desires and needs of the population with regard to nesting areas and to shed new light on the understudied area of orangutan nesting behaviour.

The study was carried out on a previously unstudied wild population of southern race Bornean orangutans (*Pongo pygmaeus wurmbii*) in the newly designated Sabangau National Park of Central Kalimantan, Indonesia. The hypothesis under investigation was that orangutans possess distinct nesting preferences, which vary according to the sex and maturity of the nest builder. Preferences were predicted to be based on individual tree and site attributes, whereby orangutans purposefully seek the best available habitat for nesting. Recently habituated, wild orangutans were followed from nest to nest over a six-month period; architectural and structural variables of nest trees and nesting sites were recorded. 74 nests from twenty-one individuals were investigated, with additional data from OuTrop nest density surveys increasing available data to 279 nest trees. Nesting behaviour was found to be species specific with distinct preferences discovered for each age / sex class, enabling multivariate analysis to predict the age / sex class of a nest builder by following a set of simple rules based on deep-ended variables identified in one-way analysis.

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## Preface

Field work was carried out in partnership with Simon Husson and Helen Morrogh-Bernard, Directors of the Orangutan Tropical Peatland Project (OuTrop). Research was carried out independently under OuTrop guidance, although some data sharing occurred between projects in a collaborative capacity. The results of the present study are of importance to OuTrop's comprehensive baseline behavioural ecology study taking place in the Sabangau National Park.

Software used for the prediction of nest membership, was kindly provided by Dr. G. D. Smith of the School of Computing Science at the University of East Anglia.

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## 1 Introduction

In the Malayan language orangutan (strictly ‘orang-hutan’) or ‘man of the forest’, reflects the anthropomorphist character and remarkable intelligence of these unique animals. Orangutans are distinctive among the great apes; they are highly sexually dimorphic and truly arboreal, existing on an omnivorous diet and rarely visiting the ground.

Orangutans belong to the taxonomic family Pongidae, they are classified alongside the other great apes; the African bonobo (*Pan paniscus*), the chimpanzee (*Pan troglodytes*), the gorilla (*Pan gorilla*), and man (*Homo sapien*); they are our closest living relatives.

In 1999, the orangutan was reclassified from two sub-species into two distinct species, *Pongo pygmaeus* in Borneo and *Pongo abelii* in Sumatra (Groves, 2003; IUCN Classification<sup>1</sup>), however due to their ability to reproduce they are not intrinsically isolated, as most distinct species (Markham 1985, Xu, X.F. and Arnason, U. 1996). Work by Groves (2001) has escalated taxonomic debates, suggesting that the Borneo species actually occurs as three separate sub-species across the island; the western *P. p. pygmaeus*, (north of the Kapuas river), the southern *P.p wurmbii* (south of the Kapuas river and Central Kalimantan) and the eastern *P.p.morio* (East Kalimantan and Sabah). This diagnosis is mostly accepted by field workers today, yet despite experts predicting the loss of both species within two decades (Population and Habitat Viability Assessment Workshop (PHVA) finding, 2004), controversy still surrounds the taxonomy of orangutans with suggestions that reclassification is a conservation strategy rather than a scientific reality (Muir 1998).

This study focuses on the nesting behavioural ecology of the southern race of Borneo orangutan, *Pongo pygmaeus wurmbii* found in the lowland swamps and dipterocarp forests of Central and Southern Kalimantan. Although currently containing the largest number of individuals of any sub-species, the surviving 25,000 individuals (Husson,

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<sup>1</sup> The World Conservation Union (IUCN) classifies the Sumatran orangutan (*Pongo abelii*) as ‘critically endangered’, or “facing an extremely high risk of extinction in the wild in the immediate future” and the Bornean orangutan (*Pongo pygmaeus*) as ‘endangered’; or “facing a very high risk of extinction in the wild in the near future” (Baillie and Groombridge, 1996).

report to the PHVA, 2004) are extensively fragmented across their range (Meijaard, report to the PHVA, 2004).

Surveys carried out in 2002 across Kalimantan show that the total amount of available orangutan habitat has decreased by over 141,500km<sup>2</sup> since the early 1990s (Meijaard, report to the PHVA, 2004). Tropical deforestation rates in Indonesia are amongst the highest in the world (Meijaard and Dennis, 2003). In 2003, figures released by the Indonesian Ministry of Forestry reported the rate of forest loss in the country was 3.8 million hectares per year; the worst in the world (Forest Watch Indonesia, 2002). A 35% decrease in orangutan numbers has occurred over the past ten years (van Schaik, report to the PHVA, 2004) and at the current rate of deforestation, there will be no lowland orangutan habitat left in Kalimantan, outside of protected areas by 2010 (Orangutan Foundation UK, 2005).

## **2 Study Aims**

### **2.1 Primary Aims and Objectives**

It has been said that efforts for conserving the orangutan should focus on identifying optimum habitat; demanding insight into those ecological factors desired, or required by the species in question (van Schaik *et al.*, 1995). In the case of the orangutan, the health of populations relies heavily on the presence of suitable nesting sites (Rijksen *et al.*, 1999).

The primary objectives of this study are, to:

- ❖ Identify tree and habitat preferences essentially important in orangutan nesting behaviour in a disturbed swamp forest.
- ❖ Cast new light on the understudied area of orangutan nesting behaviour.
- ❖ Identify the needs and desires of the population, with regard to recognising optimum nesting sites within the habitat.
- ❖ Suggest a set of variables which may predict the age / sex class of a nest builder where their identity is unknown.
- ❖ Inform forest managers of the findings of this study to facilitate the protection of this important orangutan stronghold.
- ❖ Inform anthropological studies so that the results may be extrapolated and compared with those of the great apes in explanations of hominid evolution.

### **2.2 Hypothesis**

The hypothesis under investigation was that orangutans have specific structural and architectural tree and site preferences for nesting, which vary between the age / sex cohorts of the population.

### **2.3 Predictions**

The hypothesis assumes that orangutans behave similarly to other great apes. The less-vulnerable members of the population, sub-adult and flanged males, were therefore predicted to behave as guardians of the forest, dominating resources, with vulnerable members displaced to inferior habitat.

Nests, or sleeping platforms as they are sometimes called, require the durability to support the weight of a fully-grown sleeping orangutan for an entire night, often in windy and wet conditions. With an average body mass of 78kg for fully grown adult males and 36kg for adult females (Delgado and van Schaik, 2000), it was assumed that large, sturdy trees would be preferred over small trees with insubstantial branches. It was also assumed to be advantageous to choose species with large leaves; orangutans are known to use large leaves or bundles of leaves as makeshift umbrellas in heavy rain and also to use leaf bundles as blankets and pillows in the nest (MacKinnon, 1974; Rijksen 1978; van Schaik 2003; Russon, *et. al.*, in press; S. Wich, Pers. Comm.; personal observation).

The architectural units of nesting trees were predicted to be a key factor in determining nest tree choice, densely branched trees avoided in favour of more open, rhythmically branched trees; which would provide lateral branches useful for a large platform base. The health or amount of cover provided by the nest tree was included to investigate whether concealment was significant in the avoidance of competition and predators, the degree of interconnectivity of nest tree canopies would reveal whether open look-out towers or obscured hide-outs were preferred.

Investigation of nest sites was expected to reveal distinct clusters of nests within the study area, where similar cohorts would refuge together. It was also anticipated that disturbance levels and forest quality would affect the nesting behaviour of the population, whereby orangutans seek the best available habitat and avoid areas of local conflict or instability. It was hoped that through careful analysis of nesting preferences, formulation of a model for the prediction of nest builder age / sex identity would be possible.

### **3 Nesting Behaviour and Ecology**

#### **3.1 Nest Building**

In common with the other great apes orangutans build a new nest every night and sometimes during the day, although these 'day nests' tend to be less durable and used for short resting bouts. The function of the 'night nest' is purely as a place of rest and sleep, not for breeding or as a home base. Due to their specific function, nests are distinguishable from the more permanent nests, or homes of other mammals, birds and reptiles (Heidiger, 1977; Sugardjito, 1983).

Nissen's (1931) study on chimpanzees, delivered the earliest report on nests and nesting behaviour in the great apes. However, it was not until the late 1950s and 1960s that research into the great apes took off and the importance of nesting habits emerged. Comparatively uniform within the great apes variations in nesting behaviour are mainly contributed to ecological or environmental differences such as seasonality, predator pressure and available vegetation (Baldwin *et al.*, 1981).

For the orangutan, Schaller (1961) first described nests and nesting; his work later followed by Yoshida (1964), Harrison (1969), MacKinnon (1974) and Rijksen (1978). Gorillas differ slightly from other apes as they frequently nest on the ground however females and adolescents may construct tree nests (Casimir, 1979; I. Redmond, Pers. Comm.).

Nests vary according to the site, availability of nest building materials and the animals experience with those materials (Collias and Collias, 1964; Fruth and Hohmann, 1996). They are constructed by initially forming a solid foundation by bending, breaking or inter-weaving branches inwards to a central point and then using smaller branches and twigs, which may be bent over the rim in a circular pattern (MacKinnon, 1974; Fruth and Hohmann, 1996).

#### **3.2 Ontogeny**

Nest building is the most pervasive form of material skill in the apes (Fruth and Hohmann, 1996). Studies have shown that it is a behaviour passed on from mother to

infant over weaning years. Goodall (1968) estimates that an infant chimpanzee will have witnessed their mother construct over 2000 nests during infancy, with chimps as young as 8 months old beginning to practice nest construction during play. Ontogeny is similar in all species, with orangutans and gorillas constructing nests slightly earlier than chimps and bonobos, at around 3-4 years, who will wean at around 5 years (Baldwin *et. al.*, 1981).

### **3.3 Reuse of Nests**

Nest reuse refers to ‘abandoned’ nests which are used again either by the same individual or another, the nest is often re-padded and the construction may be added to, or redone. Reuse is reported from all species with different frequencies<sup>2</sup>; Orangutans reuse nests most often, although this varies among and between populations. Orangutans in Sabah and Sumatra frequently reuse and rebuild old nests (MacKinnon, 1974, van Schaik *et al.* 1995; Ancrenaz, 2004), while in Kalimantan they only rarely do so (Galdikas, 1982; MacKinnon, 1974; Personal observation). Conjecture suggests this reluctance to reuse an old nest may be an anti- predator strategy (Sugardjito, 1983) or due to the possible presence of parasites in the nest (H. Morrogh-Bernard,. Pers. Comm).

An alternative explanation for the incidence of nest reuse may be environmental. Basabose and Yamagiwa (2002) found that nest reuse by chimpanzees in the Democratic Republic of Congo, was dependant on habitat and the availability of suitable nest material, drier habitats also had a higher incidence of reuse.

### **3.4 Nest Building - A Tool?**

Nest building as a behavioural trait has been open to much debate. Traditionally, it has been treated separately from tool use (Beck, 1980; Tuttle, 1986). However, recent

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<sup>2</sup> Nest reuse is described in chimpanzees by Baldwin *et al.*, 1981; Fruth and Hohmann, 1994; Basabose and Yamagiwa, 2002); in gorillas by Casimir, 1979; Remis 1993; Tutin *et al.*, 1995; Basabose and Yamagiwa, 2002 and in bonobos by Kano, 1983; Fruth and Hohmann, 1993).



research on culture by van Schaik *et al.* (2003) and by Russon *et al.*, (in press) has demonstrated that nest building technique and complexity, varies both amongst and between populations, suggesting that the trait varies culturally and therefore qualifies as a tool using behaviour. Van Schaik defines a cultural variant as; “behaviours present in at least one site at customary or habitual levels and absent elsewhere without clear ecological differences”. Included in this are building a rain or sun cover; an ‘umbrella’, for the nest, bunk nests or the construction of simple pillows and blankets to make sleep more comfortable.

Within a population, not all individuals will produce nests, and those that do produce them at different rates. Adult females with infants and sub-adult males produce the most nests, while females without infants and flanged males produce fewer. Studies in Sumatra have shown that non-nest builders represent 10% of the population (van Schaik, 1995). This may be slightly lower in Borneo where logging and hunting are more of a risk to populations. On the whole this figure is representative of unweaned infants still highly dependant on their mother, these individuals share nests until they are old enough to learn and repeatedly practice the art of nest building themselves (Groves and Sabater Pi, 1985) which usually occurs between the ages of 5-8 years (Galdikas and Wood, 1990).]

Nests are thought to reflect the cultural complexity of a population, the innovativeness of a nest demonstrating the mechanisms of socially based learning within a population. Van Schaik *et al.* (2003) suggested that nests may give away so much information on their builder that they may be akin to ‘membership badges’ of the population.

### **3.5 Implications of Nest Building**

The reasons postulated for the purposeful development of a sleeping place vary. Baldwin and Sabater Pi (1981) suggested that the move of large bodied primates to sleep lying down as opposed to sleeping upright on a branch, was the beginning of a highly skilled and complex behaviour. The impetus to adaptation being the desire for a better quality of sleep and to make life more comfortable (Baldwin and Sabater Pi, 1981). Fruth and Hohmann (1996) have suggested an alternative explanation for the appearance of nests, based on a strategy arising in response to the protection of food resources, especially

important at the time when monkey species diversified. They offered the idea of the ‘feeding-nest’, arising as a result of arboreal feeding on fruits growing distally on branches. Usually the largest and tastiest fruits grow at the far reaches of what are often, flimsy branches. These branches may be inaccessible, but feeding apes bend and break branches towards their bodies, positioning themselves so that they sit on the broken platform closer to the proximal parts of the tree, leaving their hands free to pick at the fruit (Wrangham, 1975; Rijksen, 1978). It may be that this feeding spot was the beginning of what we see today as the sleeping platform.

### **3.6 Food Trees as Nest Trees**

In support of the adapted feeding-nest proposal, the relationship of the nest site to food resources is of great interest in the study of nest development and hominid evolution studies. Relationships have been demonstrated between nest location and feeding trees in all of the great apes; in orangutans (Schaller, 1961; MacKinnon, 1974; Rijksen, 1978; Sugardjito, 1983); chimpanzees (Goodall, 1962; Chapman and Wrangham, 1993; Fruth and Hohmann, 1994; Tutin *et al.*, 1995; Basabose and Yamagiwa, 2002); bonobos (Kano, 1983; Fruth and Hohmann, 1993); and gorillas (Casimir, 1979; Remis, 1993; Tutin and Fernandez, 1994; Basabose and Yamagiwa, 2002).

Observations in bonobos suggest that nesting in or next to a feeding tree, sometimes ‘marks’ the food as the property of the nest builder and deters other group members from approaching (Fruth and Hohmann, 1993). The same may also be said for chimpanzees and gorillas (Basabose and Yamagiwa, 2002), who have been shown to nest in food sources to dominate the resource over competitors.

Sugardjito (1983) studied the Sumatran orangutan (*Pongo pygmaeus abelii*) over a two-year period measuring their tendency to nest inside, or outside of, the last feeding tree. His findings that apes usually nested close to their last feeding tree also found inter-cohort differences when the tree was a fruit tree (as opposed to leaves or invertebrates), and that the vulnerable age / sex classes never nested in fruiting trees. Possible explanations for this behaviour are discussed in Section 3.8.

### **3.7 Nest Site Selection**

Great apes clearly select the site in which they sleep, but our understanding of how orangutans make that selection remains unquantified. Generally, nests are constructed at or just before dusk and will be occupied from nightfall until just before dawn. Nest construction follows immediately after, or shortly after the last feeding bout of the day; it therefore follows that the individual makes some kind of assessment of the area around them before going to sleep. Exactly what they are assessing is what this study hopes to uncover.

Despite the semi-solitary nature of orangutans, nests tend to be spatially clumped (MacKinnon, 1974; Rijksen, 1978; Sugardjito, 1983; van Schaik *et al.* 1995; Ancrenaz, 2004). Research into nest site selection has shown that environmental factors such as predator avoidance, human hunting pressure, climatic conditions and habitat type all influence where a nest is located. This is also the case with gorillas (Casimir, 1979; Remis, 1993; Schaller, 1963; Tutin *et al.*, 1995), bonobos (Fruth and Hohmann, 1993; Kano, 1983, 1992), chimpanzees (Baldwin *et al.*, 1981; Goodall, 1962; Wrangham, 1975) and orangutans (MacKinnon, 1974; Sugardjito, 1983). However, as the orangutans of Central Kalimantan are largely unaffected by direct predation pressures of large hunters, it is most likely that climatic and habitat conditions are the main factors influencing the nest site selection process in this area.

### **3.8 Factors Influencing Nest Tree Choice**

Our understanding of how the great apes choose the tree in which to build their nest is largely incomplete conjecture. Clearly, there are more factors involved in nest site selection than the presence of another animal, sufficient branch support and the leaf edibility of the species involved.

Work on chimpanzees, bonobos and gorillas across Africa, suggests that a likely factor in nest location choice is the abundance of food sources in the area (Fruth and Hohmann, 1994, Goodall, 1962, Kano, 1992, Basabose and Yamagiwa, 2002). In the tall dipterocarp forests of northern Sumatra, van Schaik *et al.*, (1995) found that nests of orangutans were focused around feeding trees; not in them. As with the chimpanzees and bonobos,

research on orangutans has revealed that they rarely build a night nest in a tree offering ripe fruit; instead they will stay close enough to reoccupy the tree early the next morning (Rijksen, 1978, Sugardjito, 1983). In support of this, Rijksen (1978) and Setiawan *et al.* (1996) have suggested that one possible reason for the reluctance of most apes to build their nests in attractive places such as fruit trees, could be the risk of agonistic encounters. Rijksen (1978) noted that; “the risk for agonistic encounters with conspecifics of higher social status seems evident, but there may also be a risk of agonistic encounters with other species, in particular man, who regards several of the preferred fruit tree species of the orangutans as private property and may kill competitors.”

Studies from Tshibati in the Democratic Republic of Congo have found that food competition between gorillas and chimpanzees plays an important role in their nest site selection, especially during periods of low fruiting (Basabose and Yamagiwa, 2002). Orangutans in Borneo however, lack the competition from other large-bodied mammals, their main opposition being other orangutans; who as semi-solitary beings are usually mutually avoiding. Gibbons and macaques, who utilize many of the same feeding trees as the orangutans have a large size disadvantage and are not seen as a threat by orangutans, who will often co-feed in the same trees as them unperturbed (H. Morrogh-Bernard, Pers. Comm.).

### **3.9 Factors Influencing Nest Location**

One factor influencing nest site choice proposed by several authors (Harrison, 1969; Kurt, 1971; MacKinnon, 1974; Rijksen, 1978) is the presence of vegetation breaks or slopes, which may afford a good look out position from the nest. It has been suggested that an observation vantage point may be of benefit for the detection of conspecifics or predators and to avoid agonistic encounters with birds, bats or other food competitors. Like the orangutan, nesting chimpanzees and gorillas tend to be high in the canopy. However, dissimilarly orangutans nest alone (with the exception of nursing mothers) and are generally not alert in the nest. The high nests of the chimpanzees and gorillas are thought to be an anti-nocturnal-predator strategy (Kawai and Mizuhara, 1959; Casimir,

1979; Baldwin *et al.*, 1981) whereas the orangutan anti-predator strategy is more that of concealment; and for this stratagem a high nest is not necessarily an advantage.

Another factor deemed highly significant in the selection of nest sites by orangutans is anthropogenic or natural disturbance. Work by Basabose and Yamagiwa (2002) on chimpanzees found an overwhelming preference to build nests in undisturbed primary forests over disturbed secondary areas. Studies on orangutans also show this to be the case. Research shows that individual orangutans avoid logged forest and may move out of areas exposed to disturbance, returning once the disturbance has ceased (Rao and van Schaik, 1997; MacKinnon, 1974). Studies on orangutan population density and distribution conclude that selectively logged forest supports only a half to one third of the number of animals found in equivalent pristine forests (Rijksen, 1978; Davies and Payne, 1982; Payne, 1987; van Schaik and Azwar, 1991; Rao and van Schaik, 1997; Morrogh-Bernard *et al.*, in press). Levels of disturbance and resultant forest structure also influence the spatial use of a habitat and therefore the density of orangutans (Hern 2001, unpublished).

### **3.10 Justification of the Study**

Previous research on nesting behaviour has been inconclusive in identifying exactly what orangutans look for when choosing a nest tree. Preliminary work on orangutan nests focused on the construction of the nest with detailed descriptions and techniques dominating research efforts (Mobius, 1893; Bernstein, 1969 and Jantschke, 1972).

Early lines of investigation assumed that one tree was as good as another for building a nest; they did not credit the orangutan with the capacity or the desire to choose a particular place for sleeping. Early field research was of course crude, with Schaller (1961) suggesting that sufficient branch support was enough to satisfy the requirements of a nesting ape.

As research progressed, the complexity of the orangutan mind began to emerge, the first suggestion that orangutans may distinguish between trees (in choosing where to build their nest) proposed that the edibility of leaves may influence the decision in whether to nest in one tree over another (MacKinnon 1974). As an explanatory reason however, this

falls down since feeding usually ceases once the nest is completed and resumes once the nest is left the following morning.

To date, only nesting study on the orangutan has emerged with an appreciation of the complexities of choice involved in nest building. Sugardjito (1983) was the main inspiration in prompting new questions and lines of investigation. His work focused on the Sumatran orangutan (*Pongo abelii*) and was conducted in the dipterocarp hill forests of North Sumatra. It was Sugardjito's impression that animals within a population differ in their selectiveness with respect to choosing nest sites. His research, discovered the relationship between food trees and nests and identified different behaviours within the population (See Section 3.6). Sugardjito's findings are relevant in connection with the question of whether orangutans are subject to the selective pressures of predation, despite their arboreality and their large body size (Sugardjito, 1983).

In 1992, Djojosedharmo and van Schaik published the results of a study on orangutan distribution in Sumatra that supported the work of Sugardjito, they concluded that the best ecological predictor of the decline in nest density, and therefore the presence of orangutans, was the abundance of key food resources.

Despite these reports and those findings from the African apes, detail on orangutan nesting behaviour remains vague with many questions unsolved. I believe that past studies have failed to realize the depth of choice orangutans make in nesting because the inherent characteristics of the nest tree and its immediate location have not been examined closely enough. It is also apparent that those studies which do focus on orangutan nesting exist only from the accessible, dry slope forests of Sumatra and Sabah and work from the flat, low-lying swamp forests of Kalimantan is highly incomplete and poorly documented. Conclusions from other studies may therefore not be relevant in such a vastly different habitat. Nonetheless, past studies provide a good starting point for the present work and with this in mind I have investigated a number of factors based on individual tree and site attributes which are liable to environmental variation. The project aims to describe orangutan nesting behaviour so that there can be no doubt as to why orangutans living in low-lying swamp forests choose to build their sleeping platforms in the trees and areas that they do.

## **4 The Location**

### **4.1 The Sabangau National Park**

Research was carried out in the Sabangau Ecosystem of Central Kalimantan, Indonesian Borneo, see Figure 4-1., formally granted full National Park status in November 2004. The Greater Sabangau Region covers an extensive area encompassing four major river catchments. The Sabangau river represents the core area, located between the Katingan and the Kahayan rivers (Figure 4-1), with a forested area covering over 6000km<sup>2</sup>. The area is a tropical deep-peat swamp forest representing a highly fragile and threatened habitat subjected to intense anthropogenic disturbances; it also contains the third largest remaining contiguous habitat of the Bornean orangutan (Meijaard and Dennis, 2003). The Orangutan Tropical Peatland Project (OuTrop) is performing preliminary assessment of the population and its behavioural-ecology. The present work forms an important component on the nesting behavior of the population within this larger multi-disciplinary study.

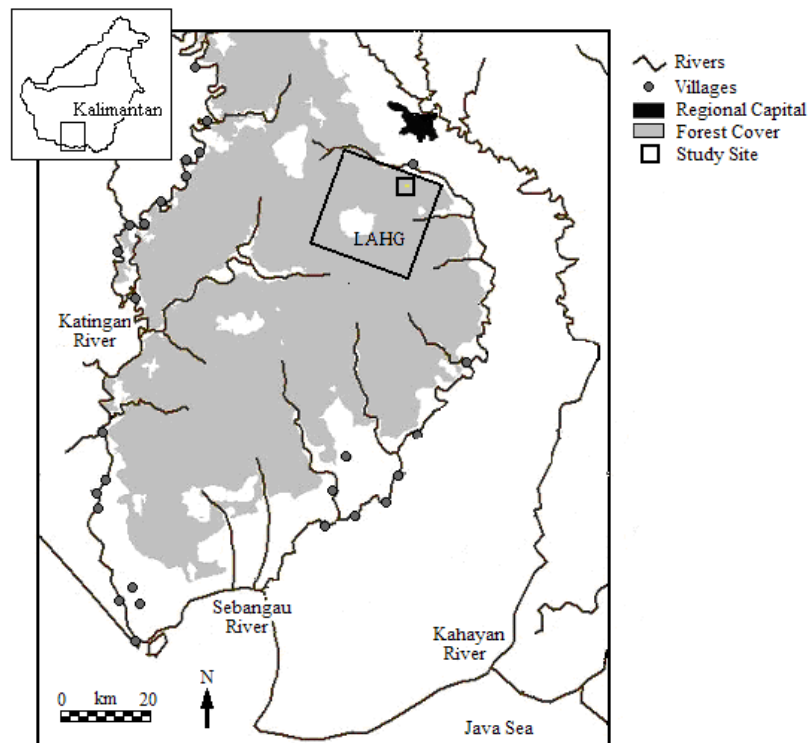
Population density surveys in the area by Morrogh-Bernard *et al.* (2003) found the highest densities of orangutans in the mixed-swamp forest of the Sabangau; with 1.8 individuals/km<sup>2</sup> in the study area (up to transect 1.25km into the study area, see Figure 4-2) (Husson, S.L., unpublished). Extrapolating these figures for the whole landscape unit has put the population in the range of 5671 (+/- 955) to 8951 (+/-1509) individuals (Morrogh-Bernard *et al.*, 2003). It has been suggested that possibly 37% of the total Bornean orangutan population live in the Sabangau; making this the largest remaining contiguous orangutan population anywhere in the world (Morrogh-Bernard *et al.* 2003).

### **4.2 The Natural Laboratory**

Field research was carried out during the period March - August 2004. The research camp, known as the Natural Laboratory for the Study of Peat Swamp Forest (NLSPSF) was founded in 1997, formerly a government timber concession; today it is under management of the Centre of International Cooperation in Management of Tropical

Peatland (CIMTROP), University of Palankaraya, Central Kalimantan and is the base camp for the Orangutan Tropical Peatland Project (OuTrop).

The laboratory encompasses an area of 500km<sup>2</sup> with a core study area of 9km<sup>2</sup> complete with forest base camp. It is located 20km south-west of the provincial capital town of Palankaraya, 1km from the west bank of the Sabangau River (2o 19'S, 114o 00'E) in an area of mixed swamp forest habitat bordering the riverine swamp along the river.

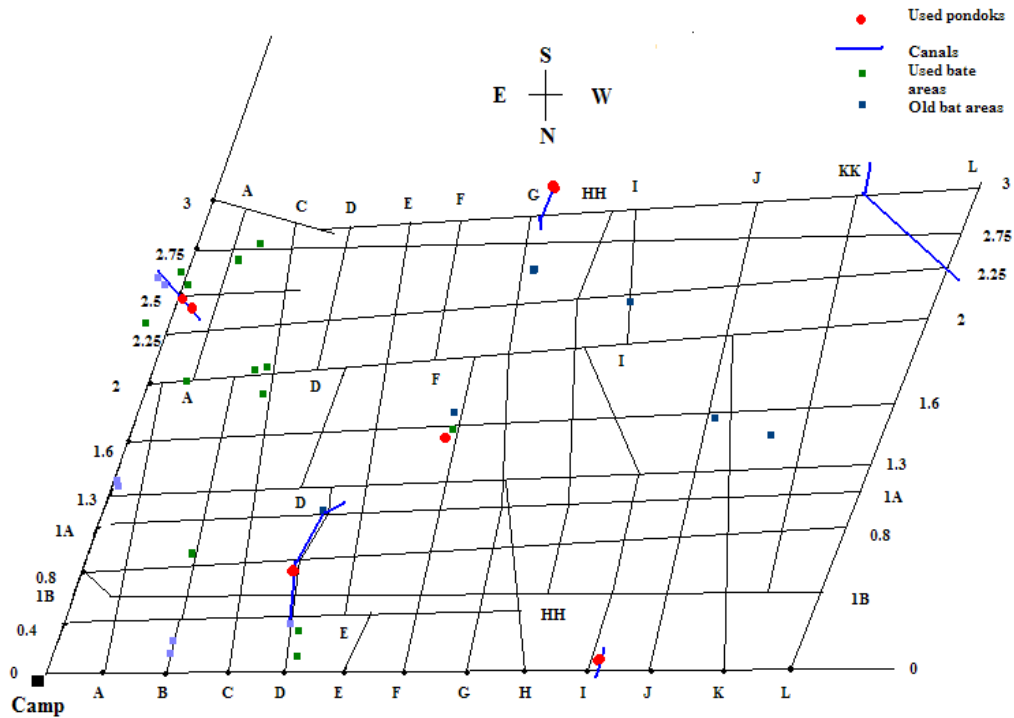


**Figure 4-1:** The location of The NLSPSF in the Sabangau National Park, Central Kalimantan, Indonesia, the core 9km<sup>2</sup> study site shown as the smaller square set inside the larger 500km<sup>2</sup> laboratory. Also shown is the regional capital town of Palankaraya and the nearby village of Kering Bankiri. **Inset;** Location map of the Sabangau area in Borneo. (Courtesy of OuTrop, 2004).

The Sabangau river catchment covers some 9200km<sup>2</sup> in the heart of Central Kalimantan, representing a large part of the 22000km<sup>2</sup> of tropical peat swamp forest in the province. The study grid, has a north-south, east-west trail system cut to facilitate easy access to the forest, spaced at 250m intervals and marked with coloured flags, the trail system is shown in Figure 4-2.



During the study at the Natural Laboratory, new trails were cut to the north of base camp, to allow easier access to the riverine swamp, extending the grid system by a further 1km north to the river (not yet plotted onto maps).



**Figure 4-2:** The grid system at the Natural Laboratory. Base camp is located at the north-eastern tip of the grid. In the wet season only 2km<sup>2</sup> of the grid (T2/TH) is accessible from base camp. The location of canals, bat collection areas and pondoks used by forest workers are also shown.

The Setia Alam Jaya company, from which the base camp takes its name, operated in the mixed swamp for 25 years until 1997. Their logging activities focused on removing highly commercial timber species such as Ramin (*Gonystylus bancanus*) and Meranti (*Shorea spp.*), extracted using a narrow gauge railway. The railway runs from the river bank, through the base camp and for a further 1km into the forest where it is replaced by a boardwalk, extending a further 3km. The track persists today and now forms the western boundary of the grid system providing relatively quick and easy access to the study area for both researchers and local forest exploiters, see Figure 4-3.

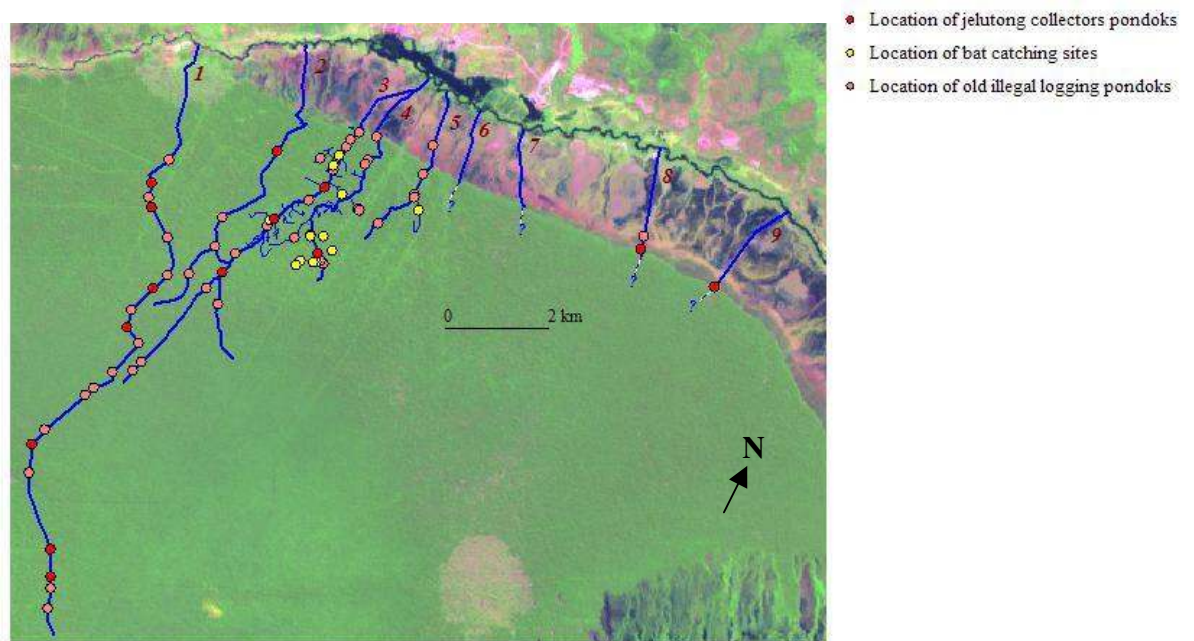


Photo: ©2004

**Figure 4-3:** The Disused Loggers Railway, which now marks the western boundary of the Natural Laboratory study grid system and the entrance to the forest.

Nearby villagers use the railway for access to the forest, mainly to collect the sap of the Jelutong tree (*Dyera costulata*); used in the production of chewing gum. Other disturbance in the area is a result of bat collectors who make clearings and erect towers with large collecting nets around known fruiting trees. The consequences of opening up the forest canopy can be catastrophic causing a high incidence of wind-fallen trees and degradation of the peat in the area.

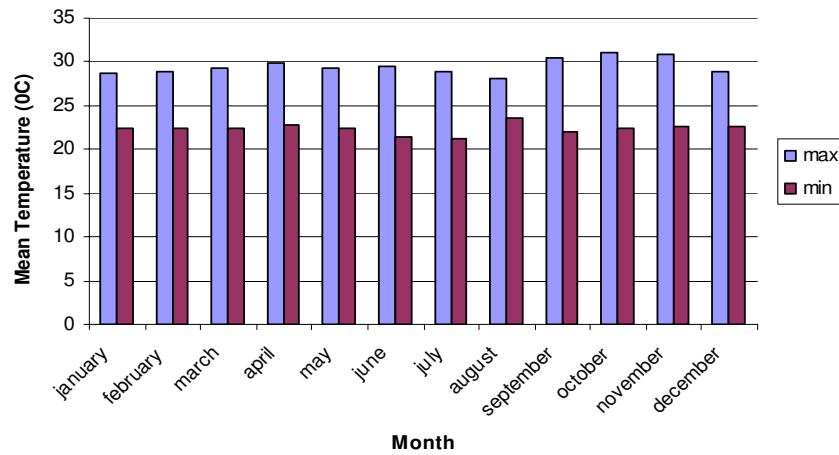
Since the concession ended in 1997 illegal logging activities in the area are a problem, lacking the technical and financial backing of a concession, workers extract timber via a network of small canals which permeate the study area, shown in Figure 4-4.



**Figure 4-4:** The Sabangau river with major canals (blue lines), pondoks and bat collection sites marked for the whole area.

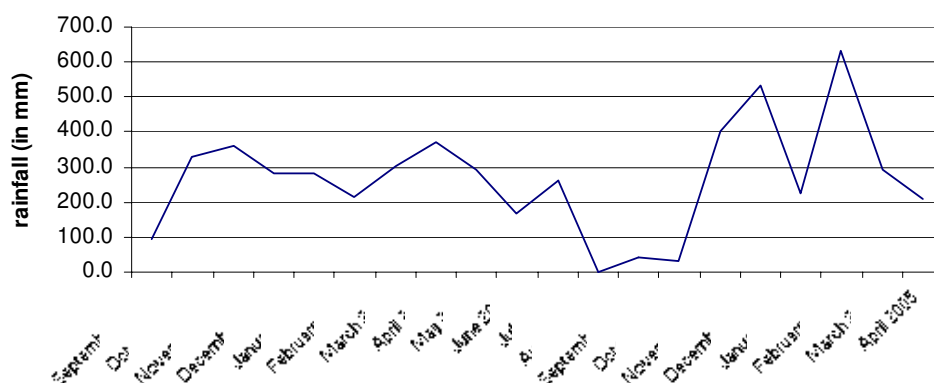
### 4.3 Climate

Located less than 100 miles from the equator, the Sabangau is subject to a truly hot, wet tropical climate. Humidity is high year round and temperatures vary diurnally rather than seasonally with a maximum temperature recorded of 36<sup>0</sup>C and a minimum of 18<sup>0</sup>C over a 6-month period. As climatic factors greatly influence the abundance and diversity of arboreal species, prevailing climatic conditions are routinely recorded at the NLSPSF by OuTrop. Figure 4-5 shows the mean maximum and minimum monthly temperatures recorded at the Natural Laboratory over a 12-month period in 2004.



**Figure 4-5:** Mean Monthly Temperatures recorded at the Natural Laboratory, Central Kalimantan, Indonesia, January – December 2004.

Temperatures remain fairly stable throughout the year although rainfall is highly variable, the wet season occurring from November to April. Figure 4-6 shows the daily rainfall at the station over an 18-month period, the wet season is evident from November to March in this time-frame, with a shorter monsoon in April before the dry season takes full hold; the dry spell during the 6-month research period lasted 18 days from mid-June to July 2004.



**Figure 4-6:** Total Rainfall recorded over an 18-month period at the Natural Laboratory, September 2003 – April 2005.

## **5 Objectives and Methods**

### **5.1 Hypothesis**

**H<sub>1</sub>**; Orangutans have specific tree and habitat preferences for nesting based on architectural and structural attributes, which are variable according to the age and sex of the nest builder.

### **5.2 Summary of Objectives**

#### **Objective 1. Identify preferences of nesting orangutans.**

- Identify preferred structural and architectural characteristics of trees used for nesting.
- Identify preferred nest types.
- Identify the relationship of feeding trees to nest trees and compare with data already known from other similar sites.
- Identify differences in nest, tree and site preferences of orangutans at different stages of maturity and sex.
- Suggest characteristics which will allow prediction of the age / sex class identity of nest builders.

#### **Objective 2. Identify nest cluster areas.**

- Identify nest sites used by the resident population.
- Identify characteristics and the quality of preferred nesting sites of each age / sex class.

#### **Objective 3. Assess the quality of available nest sites within the study area and identify anthropogenic influences.**

- Identify the influence of disturbance on the distribution of nesting areas.
- Provide information to CIMTROP, University of Palankaraya and National Park management staff, on the nesting preferences of the resident orangutan population so that best possible management practices may be employed to conserve the area.

## **5.3 General Methodology**

### **5.3.1 The Age / Sex Classes**

Effective conservation of orangutans and their habitat requires efforts to focus on identifying optimum habitats and the determinants that make these areas crucial to the health of the population (van Schaik *et al.*, 1995). The attributes of trees and nest sites chosen by orangutans to build a secure nest and the factors that these choices are based on are paramount to determining optimum orangutan habitat. It is equally important to establish if and how these choices vary among the population; i.e. between the age-sex cohorts. For the purpose of this study, age-sex classes were based on those defined by MacKinnon (1974). Animals recognized, habituated and studied under OuTrop were divided into five classes defined as; flanged adult males, unflanged or sub-adult males, adult nulliparous females, adult females with infants and adolescents, examples are given in Figure 5-1.

### **5.3.2 Following Wild Orangutans**

The Orangutan Network sets out standard guidelines for studying wild orangutan populations<sup>3</sup>. The study was conducted in accordance with these guidelines and nests were procured from follows of wild habituated orangutans in collaboration with the OuTrop behavioural ecology study.

Follows occurred from nest to nest or from successful searches to nest. On cessation of activity, location was recorded using a Garmin GPS unit (global positioning system), accurate to 10 metres. The site was marked and left so that nesting animals were not disturbed and nests could be relocated for data collection. As far as possible, nests were revisited within a week of construction.

Individuals were followed for a maximum of eight or nine days, however animals were frequently lost, due to bad weather, running away on the ground or leaving the study grid. OuTrop recorded and marked all orangutan food trees by species, with aluminium tags bearing unique numbers, thus enabling relocation of last and first visited fruit trees.

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<sup>3</sup> The Orangutan Network. [www.orangutanetwork.net](http://www.orangutanetwork.net) Guidelines for Researchers 2004





*A*

*B*



*C*

*D*



*E*

**Figure 5-1:** Designated age-sex classes of Bornean Orangutans studied for their nesting habits (Based on MacKinnon, 1974). A Flanged Adult Male. B. Sub-adult male. C Adult female with infant. D Nulliparous Adult Female. E Adolescent. (Photo A-B © 2004. Photo C – E Courtesy H. Morrogh-Bernard).

Quantitative data was measured by myself and one or two assistants, all qualitative data was measured and collected by myself to ensure consistency and eliminate bias.

The nesting behaviour of twenty one wild orangutans, recently habituated by OuTrop; consisting of 4 flanged males, 9 sub-adult males, 3 adult females with infants and 4 adolescents was recorded over 6-months, no nulliparous adult females were encountered or habituated, thus excluding them from this study.

## **5.4 Parameters under Investigation – Objective 1**

### **5.4.1 Tree Size and Stability**

Tree size was assessed using DBH (diameter in centimetres at breast height at 1.3 meters from ground level) and height (in metres). Tree stability was assessed from the type of root system; either rooted (Rt) with no visible roots; stilted (St); buttressed (Bt) or rooted with breathing roots (Rt w Pn) (pneumatophores or knee roots). Where stilts or buttresses were present DBH was measured at 1.3 metres above the point that they ended.

Tree and nest heights were measured using a clinometer. Visual estimations were also recorded to minimize error, as slight underestimates may occur with this equipment. Clinometer operators and estimations were limited to four highly trained individuals for all of the trees assessed in this study.

### **5.4.2 Species**

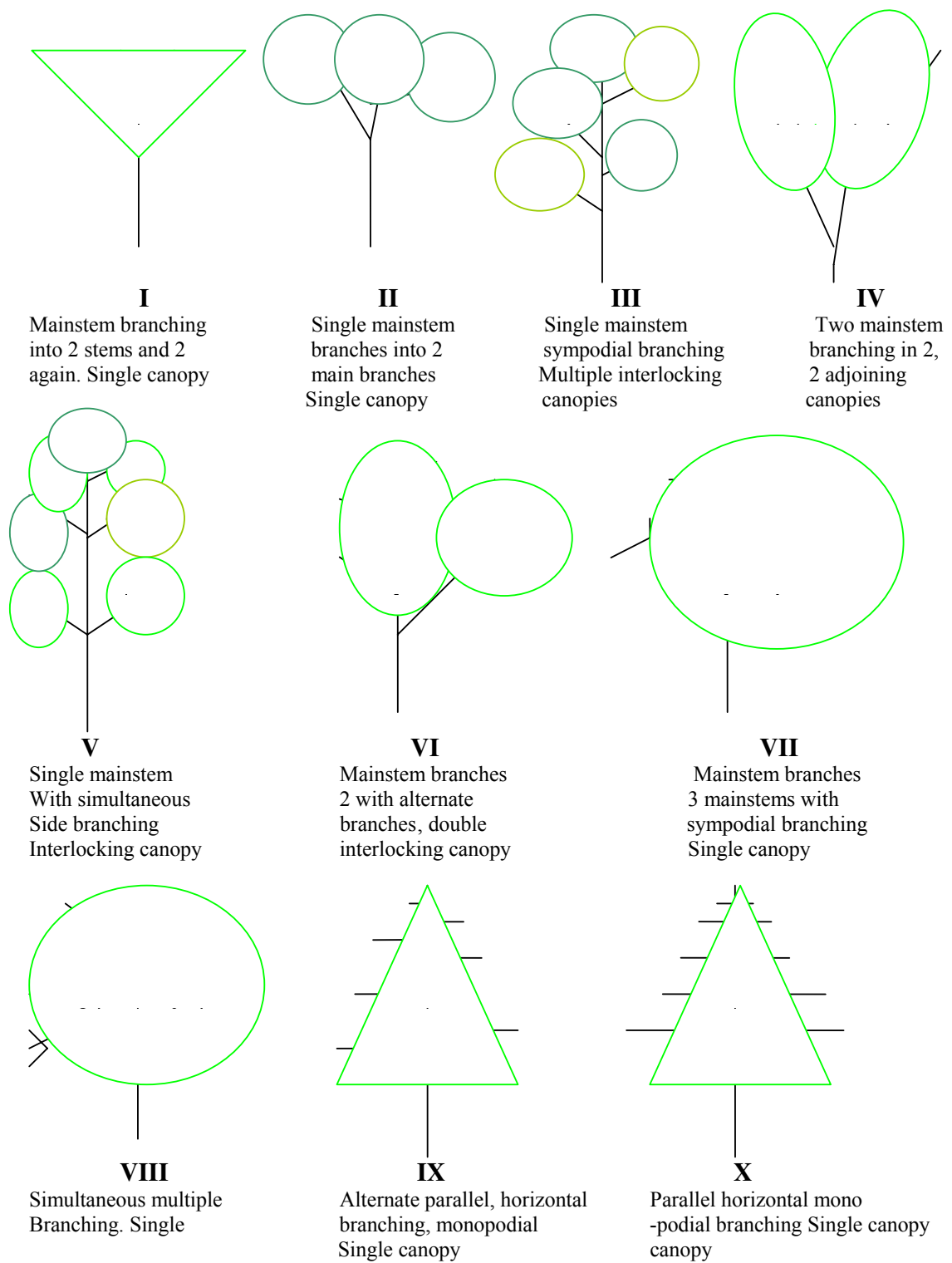
Nest trees were identified as far as possible to species level. Where possible, identification occurred in situ; on the basis of bark, inner slash characteristics, leaf shape and arrangement and fruit, if present. Additional samples were taken to the herbarium at CIMTROP, University of Palankaraya for identification. A list of all the species of tree used for nesting is given in Appendix A1.



### **5.4.3 Architectural Unit**

The architectural unit describes the particular branching pattern of a tree at a particular space and time. By means of their architecture, trees divide their volume into micro-climatological and nutrient conditions. These smaller volumes contain organisms according to their specific ecological requirements. The more varied the architecture of a tree, the more diverse are its niches, and the richer are its floral and faunal species (Oldeman, 1989).

It was expected, that orangutans would opt for trees with simple architectural units; which would attract fewer organisms, minimizing disturbance once in the nest. Using architectural models first proposed by Halle and Oldeman (1970) and rapid assessment of the study site, a system of classification was devised, the system consisting of ten architectural ‘types’ is shown in Figure 5-2. All architectural unit assessments were made by myself to minimize bias and ensure consistency.



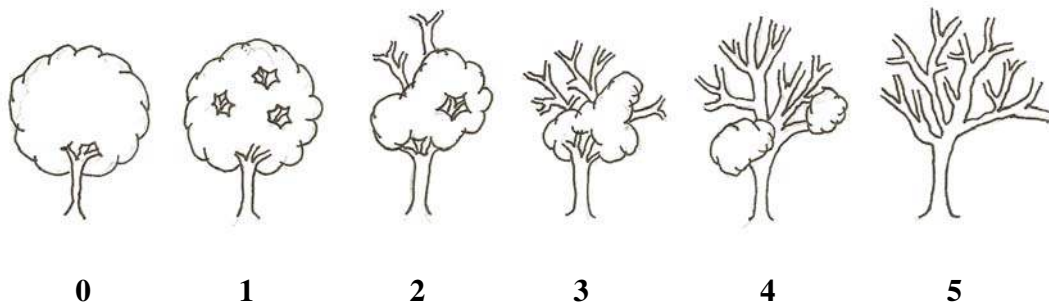
**Figure 5-2:** System of classification of architectural units used to assess nest trees in the mixed swamp of the Sabangau National Park. Based on Halle and Oldeman (1970).

#### 5.4.4 Canopy Health and Interconnectivity

Evaluation of the canopy health of nest trees employed an index, reflecting total leaf or canopy<sup>4</sup> cover. Canopy health was scored on a scale of 0-5; 0 representing 80-100% leaf cover, 1 being 60-80% and 5 representing 0-20% leaf cover. The assessment is used by OuTrop and is shown in Figure 5-3. All data was collected by myself to eliminate inter-observer bias and ensure consistency.

Interconnectivity of each tree canopy was assessed on the same basis. An index of 5 indicating that the tree was 100% connected to other canopies around it; in other words the branches were closed. Where trees had an index of 1, this was representative of a completely open canopy where 0% of the canopy interconnected.

Connectivity and cover were assessed using a homemade piece of equipment, consisting of the top section of a litre-capacity plastic bottle with wire attached to the open-end forming small, even-sized squares. The spout of the bottle was held to the eye and the squares directed up towards the canopy. Standing at a distance of 1 metre from the base of the tree, the total number of squares covered or not covered by leaves, could then be counted to produce a percentage.



**Figure 5-3:** System of indices for the assessment of canopy health of trees in the mixed swamp forest. Where 0=100% leaf cover, 1=80% cover, 2=60%. 3=40%, 4=20%, 5=0% leaf cover.

<sup>4</sup> 'Canopy' is defined as the leaf cover of an individual tree, where multiple canopies are implied, the term 'Forest Canopy' is used.

#### **5.4.5 Feeding Trees**

In light of work by Sugardjito (1983), Rijksen (1978) and MacKinnon (1974), investigation included the distance of the last feeding tree to the nest. This parameter was included not to repeat the work of others, but to identify if the findings from the fruit-rich hill habitats of Sumatra and Malaysia remain relevant to the low-lying swamps of Kalimantan.

Lowland swamps are unaccustomed to prolific year-round fruiting and as logged forest food patches are smaller and more spatially clumped (Johns 1988), this parameter may not be so relevant to the present population; competition will be less intensive and may vary seasonally to a larger extent.

Distances to the first fruit feeding bout on leaving the nest in the morning were also included in the present study. This is a new parameter previously overlooked by research; included to identify any fore-thought of nesting orangutans, who may be pre-empting a good feeding bout on leaving the nest.

It is important to clarify that feeding bouts vary from a quick snack on the move, to prolonged bouts of several hours in duration. For the purpose of this investigation, only feeding bouts on fruit, lasting over 5 minutes were included. Feeding on leaves and invertebrates were not included as bouts of leaf-feeding are usually short-lived browses. The number of species of leaves which orangutans will consume is still not fully documented and so it was assumed that leaf feeding constitutes a subsidiary dietary component, unaffected nest site location. Feeding bouts on invertebrates were also excluded, as their abundance in forests is widespread and not a deciding influence on nest location.

In addition to the distance to these first and last feeding trees, fruit tree crop sizes recorded by OuTrop, were also included in data collection. It was hypothesized that orangutans may vary in the distance traveled from the last food tree to the nest and from the nest to the first food tree. Variations predicted to exist between vulnerable and non-vulnerable age / sex classes, whereby less-vulnerable animals would stay closer to plentiful resources than those which are more vulnerable.

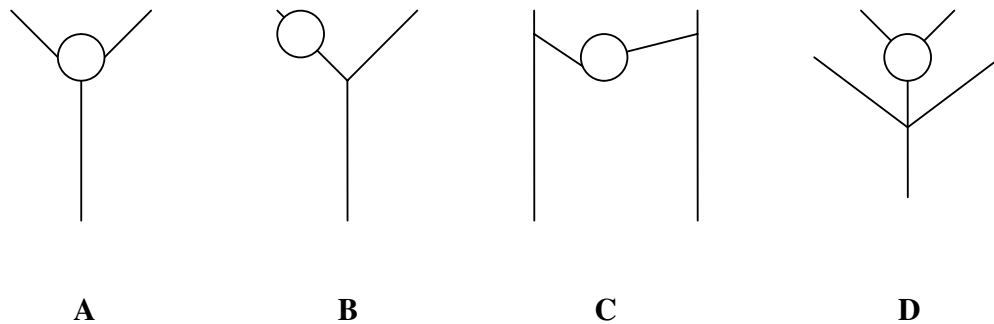
Data was collected by highly trained assistants regularly tested in distance estimates in this habitat type to eliminate biases. Crop size was assessed on a percentage cover scale;

4 representing 75-100% fruit cover, 3 being 50-75%, 2 was 25-50% and a crop size of 1 represented branches with 0-25% fruit cover.

#### 5.4.6 Nest Position and Complexity

Potential nest positions are standardized by the Orangutan Network<sup>5</sup> to allow inter-site comparison. There are 4 possible positions, shown in Figure 5-4, listed A-D. Position ‘A’ is a nest in the bough of the main-stem, ‘B’ nests are constructed on a main side-branch. Position ‘C’ denotes a ‘tree-tied’ or integrated nest; where more than one tree is tied in to support the nest platform. Only trees supporting the nest from below were included in the analysis as ‘nest-supporting trees,’ trees tied into the nest from above, for use as a pillow for example, were not counted. ‘D’ nests are those built at the top of the tree, usually above the canopy<sup>6</sup>.

Data on nest construction times was collected from OuTrop to investigate possible differences and hence complexity of nests of the age / sex classes.



**Figure 5-4:** Nest Position Index; Whereby nest position ‘A’ represents a nest in the bough of the tree; ‘B’ nests are located on a branch limb extending out from the main bole; ‘C’ represents an integrated nest and ‘D’ nests are positioned at the apex of the trees branches.

<sup>5</sup> The Orangutan Network. [www.orangutannetwork.net](http://www.orangutannetwork.net) Guidelines for Researchers 2004

<sup>6</sup> ‘Canopy’ is defined as the leaf cover of an individual tree, where multiple canopies are implied, the term ‘Forest Canopy’ is used.

#### **5.4.7 Resurvey Nests**

At the half way stage of fieldwork, preliminary data analysis showed a strong preference for a particular species; *Campnosperma coriaceum*, used in 25% of all nest constructions, across and between ages / sexes. It was subsequently assumed that nesting may be more highly species dependant than was previously predicted. To investigate further, nest trees located under OuTrop population surveys were measured and assessed to clarify the early indication of species preference.

Visit to a second research site, the Mawas Reserve in Central Kalimantan revealed a common observation of orangutans carrying *Campnosperma spp.* leaves to the nest (Russon *et al.*, inpress; Morrogh-Bernard, H. and Wich, S. Pers Comm.); which may, or may not be constructed in *Campnosperma spp.* It was also noted that *Campnosperma spp.* leaves were often used for blankets and pillows across the cohorts, the large, waxy leaflets providing large surface areas and soft cushioning. In light of the potential importance of this species to the study, resurvey data was collected to dramatically increase the sample size. This data referred to as ‘resurvey nests’ distinguishes it from nests where the identity of the nest builder was known; referred to as ‘follow nests’. Architectural units of nest trees were also recorded; predicted as another possible deep-ended variable; however as the identity of nest builders were unknown for resurvey nests other parameters were excluded from analysis.

#### **5.4.8 Baseline Tree Survey**

Trees inside six randomly distributed plots in the study area, which have undergone various degrees of anthropogenic disturbance and representative of the overall area, were examined to provide a comparative data set to nest trees and to therefore identify preferences of orangutans in selecting nest sites.

The plots measured 300m x 5m, with all trees over 6cm DBH tagged. OuTrop possessed data on tree sizes, height and species identification although no data on architecture, health, stability, interconnectivity or disturbance had been collected; these parameters were therefore taken as a part of this study using the methods already described. An index

of tree density was calculated as this is thought to be significant for an indication of overall habitat quality.

### **5.5 Parameter under Investigation – Objective 2**

Studies have shown that factors such as hunting, climate and habitat type exert an influence on nest site selection in orangutans (MacKinnon, 1974; Sugardjito, 1983). However, the orangutans of the Sabangau are largely unaffected by direct hunting from man and other large predators. The climatic conditions at the study site are favourable to the resident population as nests are found throughout the area (Husson, S., unpublished findings) and so focus was on existing habitat conditions to determine the fine scale use of the area for nesting. Through identifying preferred nesting sites within the study area, this section aims to;

- Map individual nests of the resident orangutan population.
- Identify clumping patterns in the nests of the resident population.
- Identify and justify the characteristics of the preferred nesting sites of each age / sex class within the population.

#### **5.5.1 GPS**

Follow nests were marked using a Garmin GPS unit, accurate to around 10 metres. A map was then produced of nest locations made by individuals over a 6-month period. These maps will identify both nest-clusters and areas avoided in the study area. Justification for the areas identified here is the subject of Section 5.6.

### **5.6 Parameter under Investigation – Objective 3**

In Sumatra, Rao and van Schaik (1997) studied the behavioural ecology of orangutans in logged and unlogged forests, they found that orangutans spent longer resting in logged forest but nests were built mainly in undisturbed areas.

As an ex-government logging concession, the study site has been (and continues to be) disturbed to varying degrees, with the more heavily logged areas closest to the eastern edge of the study grid next to the railway. A study by Hearn (2001) at the NLSPSF on orangutan habitat associations in relation to forest structure and disturbance, found that although orangutans may change the small-scale use of their range in response to logging activities, within the NLSPSF nests will always be associated with disturbed areas to varying degrees. His work found that nests were more densely distributed in open areas, which may contradict findings of Rao and van Schaik (1997), but which may support those hypotheses predicting that nests are built close to look-outs (Harrison, 1969; Kurt, 1971; MacKinnon, 1974; Rijksen, 1978). On identification of preferred nest sites this objective aims to:

- Assess the quality of the habitat chosen by nesting orangutans.
- Identify the influence of anthropogenic disturbance on the distribution of nesting areas in the area.
- Provide information to CIMTROP, University of Palankaraya and National Park management staff, on the nesting preferences of the resident orangutan population so that best possible management practices may be employed to conserve the area.

### **5.6.1 Habitat Quality**

Habitat structure is known to greatly influence the activity patterns of arboreal species. Expanding on previous work, which has found that forest structure, may influence nest-site location and that levels of disturbance influence orangutan habitat usage, affecting their overall population density (Hearn, unpublished), this study will explore the habitat quality utilized by nesting orangutans in the mixed deep-peat swamp forest of the Sabangau.

The forest quality around nests was assessed using the standardized OuTrop classification system (Table 1). Forest surrounding nest trees within a 20m radius were classified according to the overall height of the forest canopy and the amount of cover provided (as a percentage). Table 1 shows the seven classes, ranging from ‘good forest quality’ or a



state 1; a maximum height of 21-35m with 75-100% canopy cover, to that of a ‘cleared, or open forest’; a state 4, where no trees over 1 metre in height are present. Signs of disturbance, such as cut stumps, canals, logging skids or bat towers were also noted if they occurred within 5 metres of the nest tree.

**Table 1:** Classification system for the assessment of habitat quality at individual sites.

	<b>Forest Quality Index</b>							
	<b>1 Good</b>	<b>2a Less Complete More closed</b>	<b>2b Less Complete and Open</b>	<b>3 Good but Open</b>	<b>3 2/b Young less Complete</b>	<b>3a Young Open</b>	<b>3b Young Improving</b>	<b>4 Cleared</b>
<b>Tree Height (metres)</b>	21-35	21-35	21-35	16-20	16-20	11-15	2-10	≤1
<b>Canopy Cover (%)</b>	75- 100	50-75	25-50	>50	<50	<50	>50	0

All observers were fully trained and regularly tested for their ability to assess forest quality as this was found to be a very objective parameter. Bias was minimized as all forest quality assessments were made by myself and subsequently compared to those made by OuTrop observers to ensure consistency of efforts.

## 5.7 Method of Analysis

Analysis of the results was approached on a step by step approach. Looking at each objective in turn data was analysed first on a field by field basis (Section 6.3-6.5) and then using multivariate techniques (Section 6.7). Data on trees obtained from the baseline

survey were used as a comparison to follow nest data. Jacobs Preference Index (Jacobs, 1974) was employed to identify preferences and avoidance in the nesting behaviour of the population. For the architecture and species parameters, sample size was increased using resurvey nest tree data. Differences between the age / sex classes were assessed using one-way analyses of variance.

Multivariate analysis using canonical discriminant functions was performed to identify clustering in the data, and rule induction (G. Smith, Pers. Comm.) was used to formulate a set of simple rules which may be used for the prediction of age / sex classes when the identity of a nest builder is unknown.

Figures and analysis were produced using the software Microsoft SPSS for Windows version 12.0. and Microsoft Office Excel 2003. A statistics report is provided in Table 2, Page 34.

## **6 Results**

### **6.1 Introduction**

The hypothesis that orangutans have distinct structural and architectural tree and habitat preferences for nesting was predicted to vary according to the age and sex of the nest builder to the extent that nest builder identity may be predicted through assessment of certain parameters. During six months of field investigation (March to August 2004), over 1500 trees and 250 nests were assessed using over 20 parameters. The identity of the nest builder was known for 29% of these nests, the remainder assessed from population density resurveys, increasing available sample size for species and architecture. Identification of preferences was achieved by comparing observed nest trees with a baseline sample of trees available in the habitat using Jacob's Preference Index (Jacobs, 1974).

Over 6-months a total of 74 follow nests were assessed, which represented the sleeping places of 21 wild orangutans and 114 separate trees of 16 families, 26 genera and 21 species. Of the nests measured, 23 were constructed by adult females with infants, 20 were constructed by adolescents (all female); 12 were made by unflanged, sub-adult males and 19 nests were constructed by flanged adult males. Data was absent for nulliparous adult females as no individuals were encountered or habituated during the research period.

In some cases, data for nests or trees was incomplete; mainly pertaining to GPS position, distances or crop sizes of feeding trees or species. Table 2 provides a summary statistics report of data collected to attain the objectives set out in Section 5.2, including minimum and maximum values collected, mean and standard deviations, the data type (numerical or categorical) and the number of records existing for each field.

**Table 2:** Statistics summary table of data collected to attain the 4 main objectives set out in Section 5.2.

The table provides minimum and maximum values collected for each field, with mean and standard deviations, the amount of data points collected for each field and the data type (CAT = categorical or NUM = numerical). N= 24 fields and 114 records.

#	Name	Min.	Max.	Mean	Std Dev	Unique	Missing	Type
1	Sex	-	-	-	-	2	0	CATL
2	Age_Class	-	-	-	-	4	0	CAT
3	GPS	-	-	-	-	67 *	8	CATL
4	NEST_TREE_SPECIES	-	-	-	-	40 *	11	CAT
5	ARCHITECTURE	-	-	-	-	9 *	3	CAT
6	Nest_Tree_Height	5.12	34.79	14.9125	7.24152	94 *	3	NUM
7	DBH	2.4	41.5	15.2386	9.45245	96	0	NUM
8	BD	3.5	47	17.0333	10.5154	97	0	NUM
9	ROOT_TYPE	-	-	-	-	10	0	CAT
10	CANOPY_HEALTH	0	5	1.7807	1.33613	6	0	NUM
11	SURROUNDING_CANOPY	0	5	3.90351	1.31101	6	0	NUM
12	DISTANCE_LAST_FOOD_TREE	0	420	53.8344	80.5713	31 *	12	NUM
13	CROP_SIZE_LFT	1	4	2.97333	1.13106	5 *	39	NUM
14	Distance_CLASS_LFT	-	-	-	-	17 *	12	CAT
15	DISTANCE_FIRST_FOOD_TREE	0	160	40.075	42.3455	24 *	34	NUM
16	Crop_size_FFT	1	40	3.29508	4.89678	6 *	53	NUM
17	Distance_CLASS_FFT	-	-	-	-	20 *	33	CAT
18	WEATHER	-	-	-	-	9	0	CAT
19	NEST_POSITION	-	-	-	-	8	0	CAT
20	NEST_TYPE	-	-	-	-	2	0	CAT
21	Total_NEST_BUILDING_TIME	0	17	6.77778	2.99345	13 *	15	NUM
22	Supporting_trees	1	13	3.07018	3.71275	6	0	NUM
23	Nest_Height	5.12	29.45	12.4436	6.07753	74 *	3	NUM
24	FOREST_QUALITY	-	-	-	-	6	0	CAT

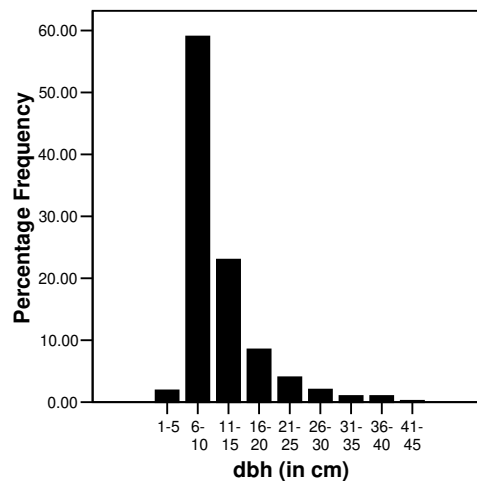
NOTE: An asterisk in the 'unique' column indicates that one of the unique entries represents a missing value

## 6.2 Habitat Survey Results

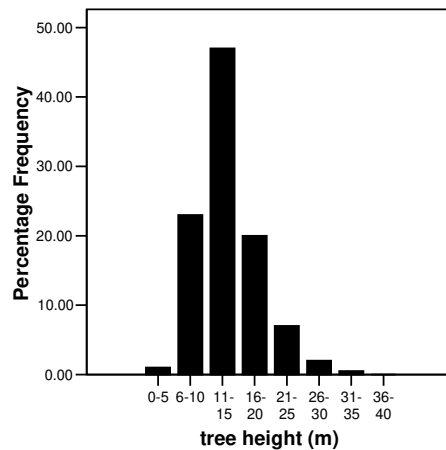
The Natural Laboratory study site was selectively logged under concession until 1997. From 4 botanical plots measuring 300m x 5m, randomly located in the mixed deep-peat swamp forest 555 trees (DBH  $\geq 10$ cm) were identified as representing 83 species from 31 families and 52 genera.

Most of the trees were small, pole stage trees. Sampling produced a mean DBH of trees in the study area of 11.28cm (+/-SD 0.69) Figure 6-1 shows the distribution of the DBH values of trees in the mixed swamp forest.

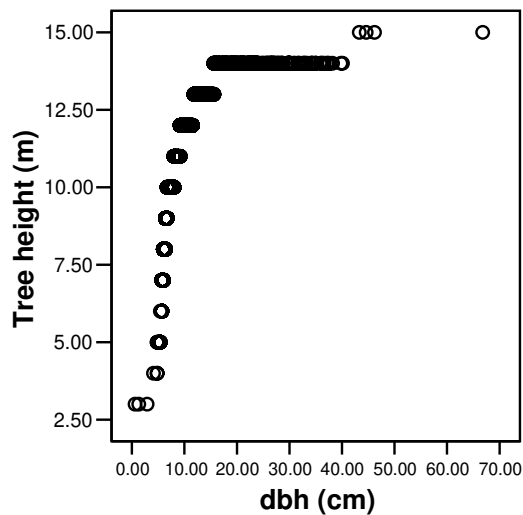
Mean canopy height of the trees in the study area was 13.86m (+/-SD 4.64m) (Figure 6-2), with just one specimen found measuring more than 36m in height. The forest has a distinct stratification of three main layers; an herbaceous understorey below 6m; a mid-level canopy at around 10 – 15m and an upper canopy reaching from 21-35m. A density of 3650 trees / ha was extrapolated with a mean basal area of 172.98cm<sup>2</sup> (SD +/- 276.61cm<sup>2</sup>). Figure 6-3 shows the S-shaped positive correlation found between the height and DBH of trees in the mixed swamp. It shows how DBH remains small in trees up to a height of 14.5m, after which DBH increases sharply and height plateaus.



**Figure 6-1:** Distribution of tree DBH (in cm) shown in terms of percentage frequency, recorded from the deep-peat mixed swamp forest in the Sabangau (n = 1421).



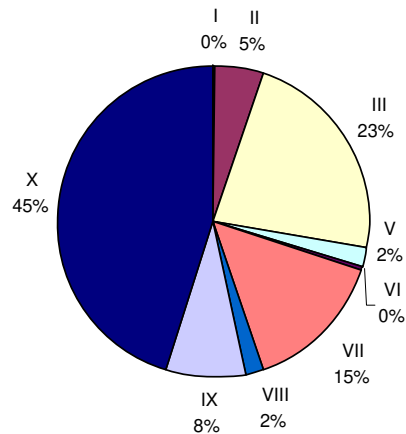
**Figure 6-2:** Distribution of tree heights (in metres) shown in terms of percentage frequency, recorded from the deep-peat mixed swamp forest in the Sabangau (n = 1421).



**Figure 6-3:** Correlation of tree height (in metres) to DBH (in centimeters) of trees in the mixed swamp forest of the Sabangau ( height n = 1421, DBH n = 1421).

The architectural structure of 578 trees in the habitat were recorded, the proportional representation of each class is shown in Figure 6-4. Type X architecture, with monopodial axes, extending horizontally from the trunk, was by far the most common architecture of mixed swamp trees, representing 45% of all trees assessed. Type III, with an alternate continuous branching pattern extending upwards from the mainstem, represented almost a quarter of all trees in the swamp while types I, VI and VIII were

rare, accounting for just 0.7% of 578 trees assessed. Despite examples observed in the forest in devising the architectural units, none of the trees surveyed were found with type IV architecture, defined as trees with a mainstem branching into two independent canopies.



**Figure 6-4:** Proportional representation of the architectural units of trees surveyed in the mixed swamp forest in the Sabangau (n = 578).

### 6.3 Objective 1 Analysis – Nest Tree Preferences

The following section will rigorously test the hypothesis that nesting orangutans have specific tree and habitat preferences based on architectural and structural attributes.

It has been predicted that:

- Orangutans will demonstrate specific structural and architectural tree preferences when selecting nest sites.
- Different age / sex classes of orangutan will have different preferences for nest trees and sites
- Disturbance levels in the forest will affect nesting choices, whereby orangutans seek out the best available habitat for nesting.

‘Structural’ characteristics are defined as those inherent qualities constituting the nest tree; such as height, DBH and stability. In order to investigate this question the following

parameters were measured; Tree height, DBH, root type and canopy health. Architectural characteristics' define the blueprint of the nest tree and include the distinctive brachiating pattern of the branches (architectural unit); the species and the families that these represent and the presence of sticky exudate.

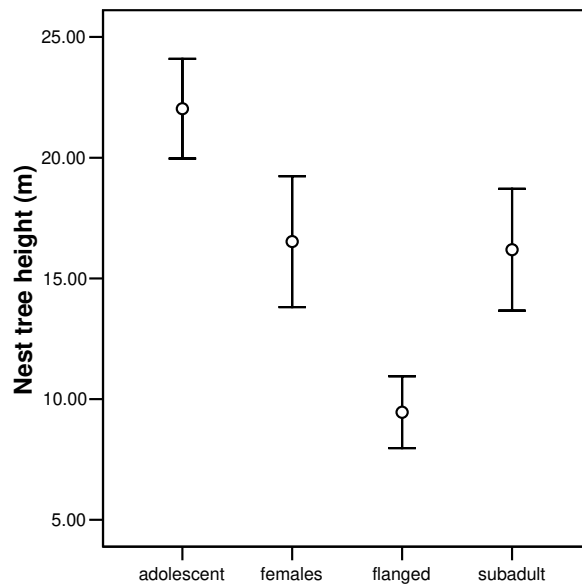
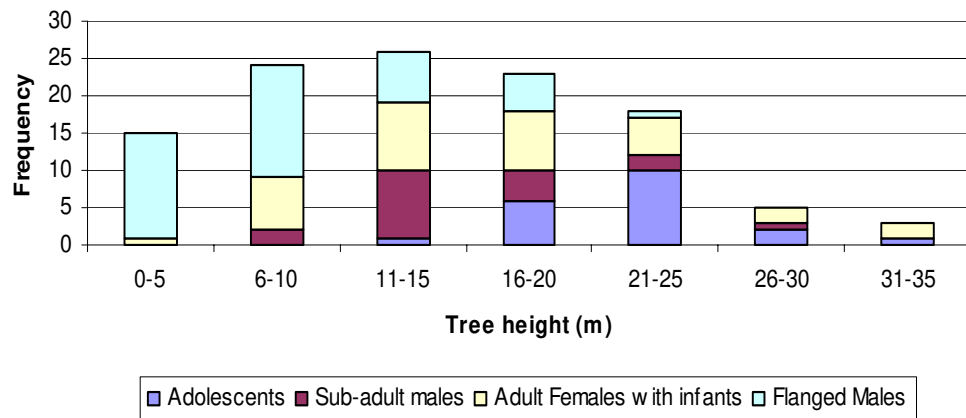
### **6.3.1 Nest Tree Height**

The heights of 114 nest-supporting trees were recorded from 74 nests (20 nests were integrations; that is they used more than one tree to support the nest). Based on previous work (MacKinnon, 1974; Rijksen, 1978; Sugardjito, 1983) it was anticipated that distinct preferences would be found with regard to the tree heights chosen by the orangutans for nest building. It was predicted that vulnerable age / sex classes (adolescents and adult females with infants) would nest in taller trees and less vulnerable animals (flanged and sub-adult males) would nest lower in forest.

The results, shown in Figure 6-5a. found an interesting distribution in the data, with a clear arrangement of the cohorts. Mean nest tree height for the population was 14.86m (SD +/-7.26m). In terms of the age /sex classes adolescents preferred a mean tree height of 22.03m (SD +/-4.41m); sub-adult males preferred a mean tree height of 16.12m (SD +/-5.23m); adult females showed a preference of 16.52m (SD +/-7.52m) and the flanged adult males used a mean height of 9.46m (SD +/-4.71m). Figure 6-5b. includes 95% confidence intervals of these mean values.

Figure 6-2 found the upper forest canopy layer of the mixed swamp was 21-35m in height, results of the heights of preferred nest trees shown in Figure 6-5 found that adolescent animals preferred trees reaching the upper limits of the forest, nesting between 16-25m in 80% of nesting events. Sub-adult males nested in the mid-forest layers, between 11-20m, in 68% of cases, placing them in the densest layer of the forest, 52% of adult female with infant nests were also in this layer. Flanged adult males nested in trees of the lower forest layer below 10m, in 68% of cases.





**Figure 6-5: Top a)** Distribution of the data of nest tree heights, showing preferred tree heights of each age / sex class (n = 114) and **Bottom b)** Mean nest tree heights of the age / sex classes (adolescents n = 20, females n = 32, flanged n = 43, sub-adults n = 19). Circles indicate the mean value of each class and lines emitting from these indicate 95% confidence intervals.

Preliminary results support the prediction that the vulnerable members of the population prefer larger nest trees than less-vulnerable members. Assuming that the variation in observed tree heights is the same as the variation in tree heights taken from the age / sex classes; analysis finds that tree heights of at least two of the age / sex classes are different

with a very high level of significance ( ANOVA test,  $F_{3,108} = 24.095$ ,  $P < 0.0001$ ) with a 95% confidence limit. Table 3 shows the results of the analysis of variance.

**Table 3:** Results of a one-way analysis of variance on the heights (metres) of nest trees used by the age / sex classes of orangutan in the Sabangau mixed swamp forest (n = 114).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2541.763	3	847.254	26.581	.000
Within Groups	3538.053	111	31.874		
Total	6079.816	114			

Although highly conclusive, no indication is given of which age / sex classes differ. A post hoc Tukey HSD Test (Appendix B.1) found that the heights of nest trees are significantly different between all of the classes; except for those of sub-adult males and females with infants, who did not use trees significantly different in height.

Flanged males used significantly smaller trees than all of the other classes ( $p = < 0.0001$  with 95% confidence). Sub-adult males and adult females both preferred trees which were significantly smaller than the adolescents ( $p = < 0.01$  and  $p = < 0.005$  respectively) but were not significantly different to one another ( $p = 0.997$ ).

### 6.3.2 DBH

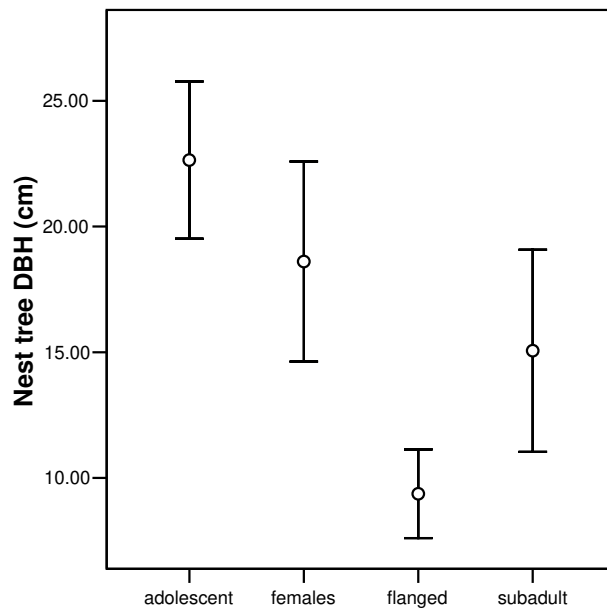
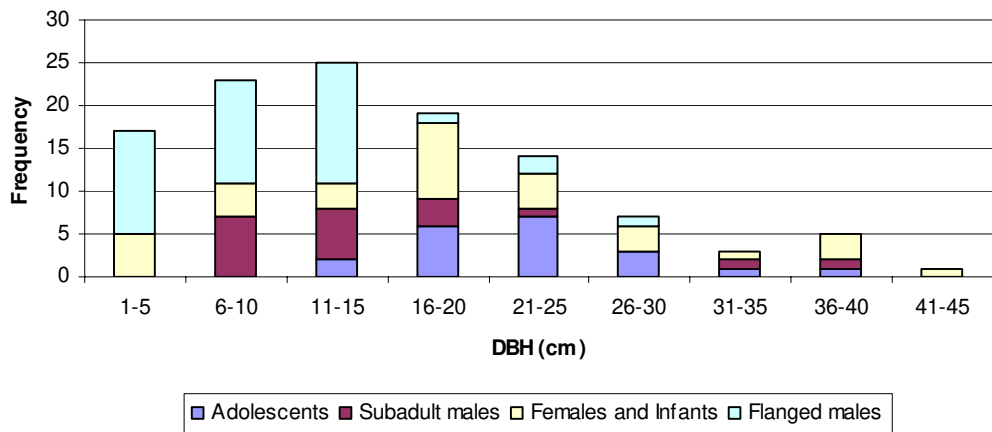
The diameter at breast height (DBH) was recorded for 113 supporting nest trees. As DBH is correlated with height (Figure 6-3) it was predicted that the population would show distinct preferences, which would vary between the age / sex classes. Basal areas of nest trees were also recorded, although have been excluded from analysis due to the strong correlation with DBH.

Figure 6-6a shows the distribution of the DBH (in cm) values of nest trees, and the mean DBH of nest trees of each age / sex cohort; the overall mean DBH of nest trees was 15.24cm (SD+/-9.50cm).

Small trees ( $\leq 15$ cm DBH) (Figure 6-6) accounted for the majority of nest trees and the age / sex classes did differ in their preferred tree size. The mean DBH of adolescent nest trees was 22.64cm, (SD  $\pm 6.6.8$ cm) (see Figure 6-6b) with 65% of all nests constructed in trees of 16-25cm. Sub-adult male nest trees were mean DBH 15.06cm (SD  $\pm 8.33$ cm) with 68% in small to mid-sized trees, 6-15cm. Female nest trees varied the most, with mean 18.61cm DBH (SD  $\pm 11.03$ cm). 38% of female with infant nests fell between 16-25cm DBH. Flanged males nested in trees with mean DBH 9.37cm (SD  $\pm 5.73$ cm), choosing small trees ( $\leq 15$ cm DBH) in 90% of nesting events.

Preliminary analysis shows that the age / sex cohorts varied in their usage of different sized trees. The less-vulnerable animals using smaller sized DBH trees, being younger trees, than vulnerable adolescents who tended to use larger and therefore older, more established trees (see Figure 6-3). The size of nest trees of the females with infants and sub-adult males varied to a larger extent.

Statistical analysis using an analysis of variance test (Table 4) found that the DBH values of nest trees used by the different cohorts differed with a very high level of statistical significance, where  $F_{3, 110} = 14.879$ ,  $p < 0.0001$ . (Homogenous subsets are shown in Appendix B.2.).



**Figure 6-6: Top a).** Distribution of the data of nest tree DBH (in cm), shown as frequency of use by each age / sex class (n = 114) and **Bottom b).** Mean DBH values of nest trees, shown as a circle used by each age / sex class; 95% confidence intervals are indicated by the emitting lines, (adolescents n = 20, females n = 32, flanged n = 43, sub-adults n = 19).

**Table 4:** Results of a one-way analysis of variance on the DBH (cm) of nest trees used by the age / sex classes of orangutan in the Sabangau mixed swamp forest (n = 113).

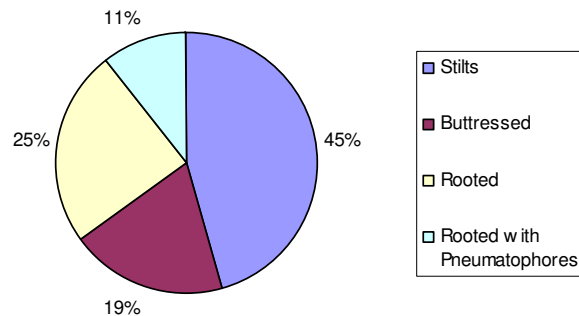
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2940.206	3	980.069	14.879	.000
Within Groups	7245.564	110	65.869		
Total	10185.770	113			

A Tukey test for multiple comparison (Appendix B.2) found that the largest difference in nest tree DBH existed between adolescents who used trees with a larger DBH than the flanged males ( $p = < 0.0001$ ), adolescent nest trees also possessed larger, although to a lesser degree, DBHs than sub-adult male nest trees ( $p = < 0.05$ ). Flanged male nest trees had a smaller DBH, with a very high level of significance, to all of the other cohort nest trees, ( $p = < 0.0001$ ), except for those of the sub-adult males, who chose nest trees with a DBH of a similar size.

### 6.3.3 Stability of Nest Trees

The type of roots possessed by the 114 nest supporting trees were recorded to provide an indication of the relative stability of the tree. Analysis is based on the assumption that stilted and buttressed trees are the most stable root systems for trees in a swamp environment and trees with straight rooted trunks or those possessing breathing roots (pneumatophores or knee roots) provide less stable bases and are therefore more prone to movement and wind-throw.

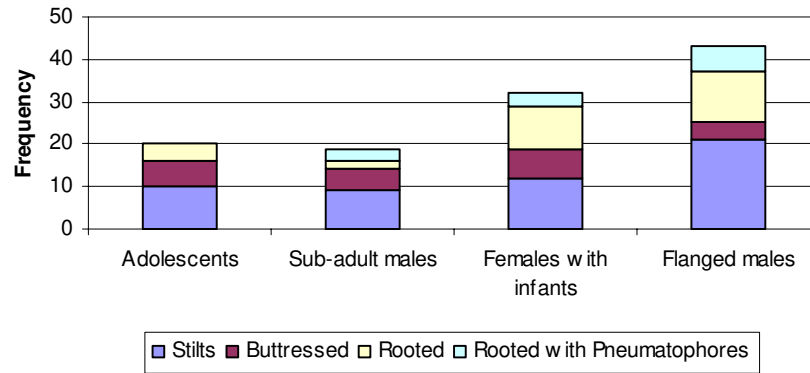
It was assumed that roots are important to the structural assembly of a nest tree and that orangutans avoid unstable trees in the forest. The results in Figure 6-7 found that trees with stilted roots represented 45% of nest trees and buttressed trees represented 19%, trees with straight 'rooted' trunks represented 25% and the remaining 11% of nest trees possessed visible breathing roots.



**Figure 6-7:** Types of root systems of nest trees shown as a percentage (n = 114).

Figure 6-8 shows the frequency each root system accounted for a nest tree of each age / sex class. Adolescents did not use trees possessing breathing roots and females used these trees in only 9% of their nests. Trees with breathing roots represented 16% of sub-adult male and 14% of flanged male nest trees. Stilted nest trees were prolific in all age / sex classes, accounting for 50% of adolescent nest trees, 47% of the sub-adult males, 38% of the adult females and 49% of flanged male nests.

Buttressed trees represented 30% of adolescent nest trees, 26% of the sub-adult males, 22% of female and infant nests and just 9% of the flanged male nest trees. Trees with straight rooted trunks were preferred over buttress roots by the adult females (31% of nest trees) and the flanged males (28% of nest trees), while the sub-adult males used these trees least, with just 11% of nest trees reported with no visible roots and 20% recorded in the adolescents.



**Figure 6-8:** The frequency with which each root system occurred as a nest tree of each age / sex class (adolescents = 20, sub-adult males = 19, females with infants n = 32, flanged males n = 43).

To identify if the results are due to preferences or are a reflection of the types of trees available in the forest, Jacob's Preference Indices,  $D$ , (Jacobs, 1974) were calculated. The index compares the proportions of each observed value with the proportion actually available in the forest, given that

$$D = (r - p) / (r + p - 2rp),$$

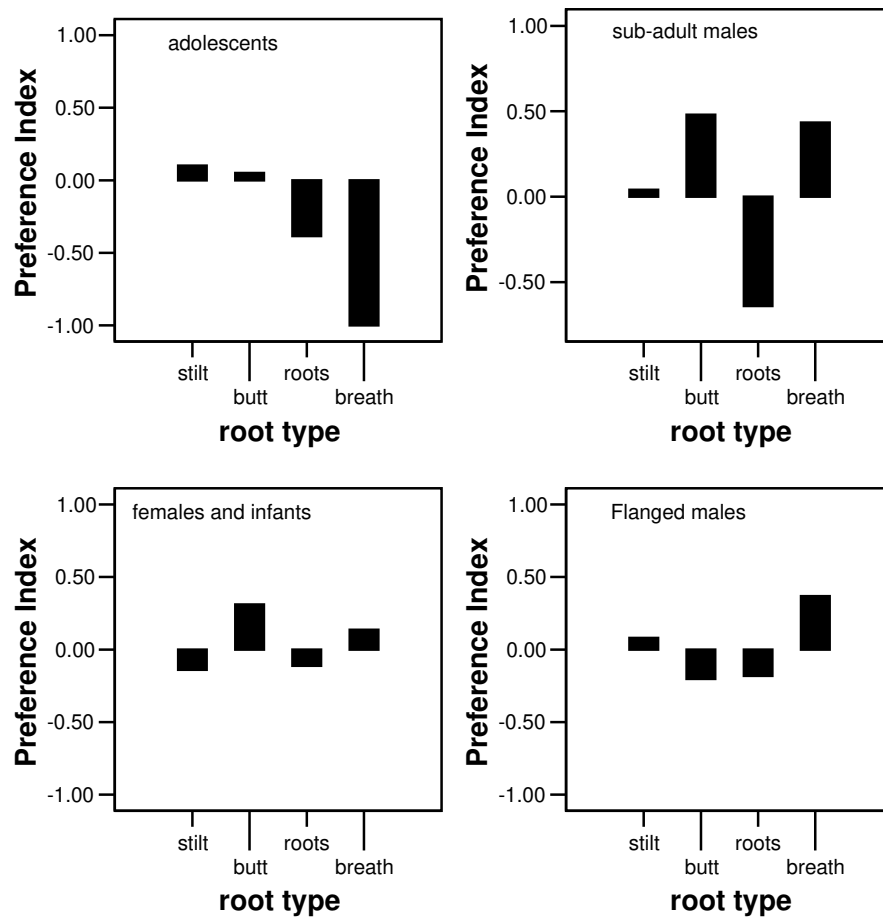
Where  $r$  is the proportion of a given value occurring in the sample and  $p$  is the proportion of the study site covered by that value. The index provides an indication of proportional use, and produces a value ranging from -1; indicating total avoidance, to +1; indicating preferential use. Where an index of  $D = 0$  is found the variable is used in proportion to its availability.

The results, shown in Figure 6-9, for adolescent trees found they largely avoided rooted trees ( $D = -0.39$ ) and completely avoided trees with breathing roots ( $D = -1$ ). However, the result with regard to stilted and buttressed trees was the result of the abundance of these root types within the forest ( $D = 0.1$  and  $0.05$  respectively).

Sub-adult males avoided trees with straight rooted trunks, ( $D = -0.64$ ) and their apparent preference for stilted trees was due to their abundance ( $D = 0.04$ ). Sub-adult males had a preference for buttressed trees ( $D = +0.5$ ), used in 26% of nesting events.

Adult females demonstrated the strongest preference for buttressed trees, albeit slightly weak ( $D = +0.3$ ), they made this choice for 30% of their nest trees, 38% of nesting occurrences in stilted trees was due to the abundance of these trees in the swamp (-0.14); the index actually shows a weak tendency to avoid stilted roots.

A preference for trees with breathing roots, ( $D = +0.37$ ) was found in the flanged males and as with the other classes, stilted trees were used as a result of their abundance in the forest ( $D = 0.08$ ); as were buttressed ( $D = -0.20$ ) and rooted trees ( $D = 0.18$ ).



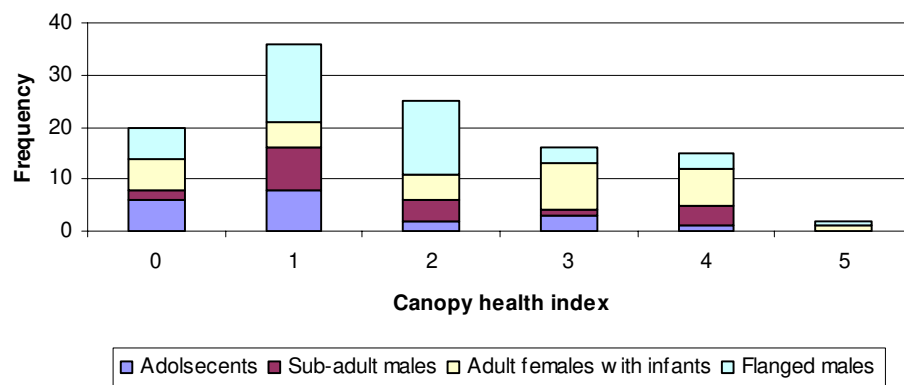
**Figure 6-9:** Jacob's Preference Indices for the root systems of nest trees used within the mixed swamp forest by each age / sex class (adolescents = 20, sub-adult males = 19, females with infants n = 32, flanged males n = 43). Where -1 = indicates total avoidance; +1 = indicates preferential use and 0 = proportional use.



### 6.3.4 Canopy Health

Based of previous work on nesting (MacKinnon, 1974; Rijksen, 1978; van Schaik *et al.* 1995; van Schaik *et al.* 2003), it was predicted that orangutans would nest in healthy trees with an abundance of leaves in order to construct comfortable nests. The leaf cover or health of nest trees was assessed on a percentage cover and awarded an index (Figure 5-3). The results of 114 nest trees (Figure 6-10), found that 18% of nest trees had 100% leaf cover (index = 0); 32% of nest trees possessed 80% leaf cover, (index = 1); 22% of nest trees had 60% leaf cover, (index = 2); and only 2% of nests had 0% leaf cover<sup>7</sup>.

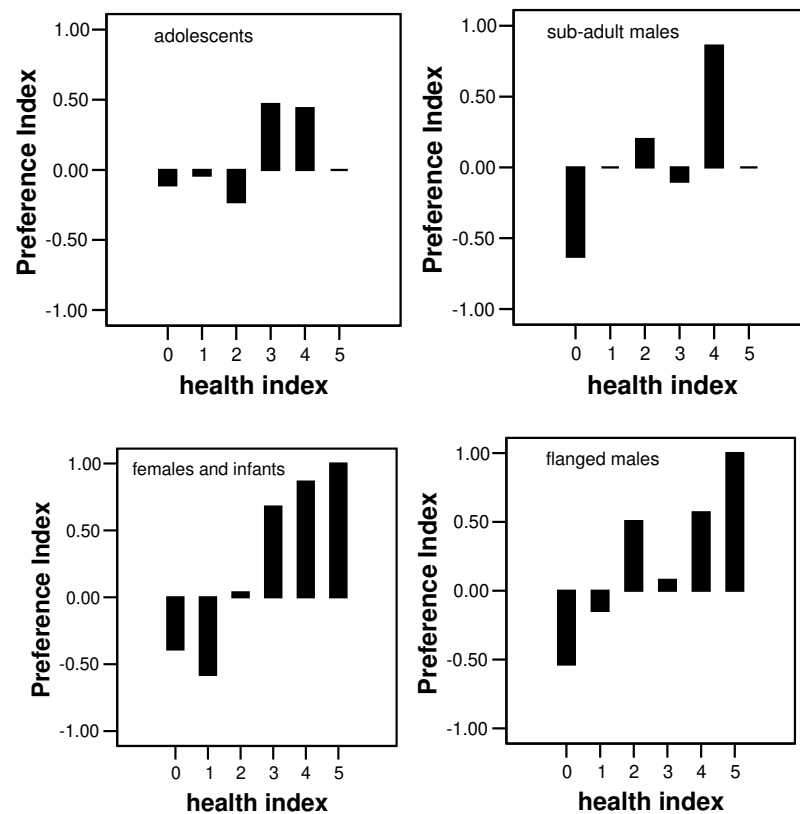
The findings for the age / sex classes, were that adolescents chose predominantly healthy specimens; 70% of nests had an index of 0-1. Adult females with infants were expected to display a similar result, however a highly varied result was found with over 50% of their nest trees in poor health (index = 3-5). Sub-adult males used trees of good health, most with 60-80% cover (index = 1-2), although trees with an index 4 were chosen in 21% of their nesting events. Flanged males show the strongest consistency; 70% of nest trees with an index 1-2 and only 16% in poor health (index = 3-5).



**Figure 6-10:** Canopy health indices of nest trees shown in terms of the percentage frequency each age / sex class nested in each index (adolescents = 20, sub-adult males = 19, females with infants n = 32, flanged males n = 43). Where 0 = 100% leaf cover, 1 = 80%, 2= 60%, 3 = 40%, 4 = 20% and 5 = 0% leaf cover.

<sup>7</sup> It is noteworthy that these trees were not dead but in a state of degraded health.

Jacob's Preference Indices (Figure 6-11) found adolescents preferred to nest in trees of a poor health, with 20-40% cover ( $D = 0.44$  and  $0.47$ ). Trees in this state of health account for only 8% of the forest, yet adolescents used these trees in 20% of nesting events. With regard to the healthy trees, adolescents used these in accordance with their abundance in the forest, tending slightly to avoid them ( $D = -0.11$  for 100% cover;  $-0.04$  for 80% cover;  $-0.23$  for 60% cover).



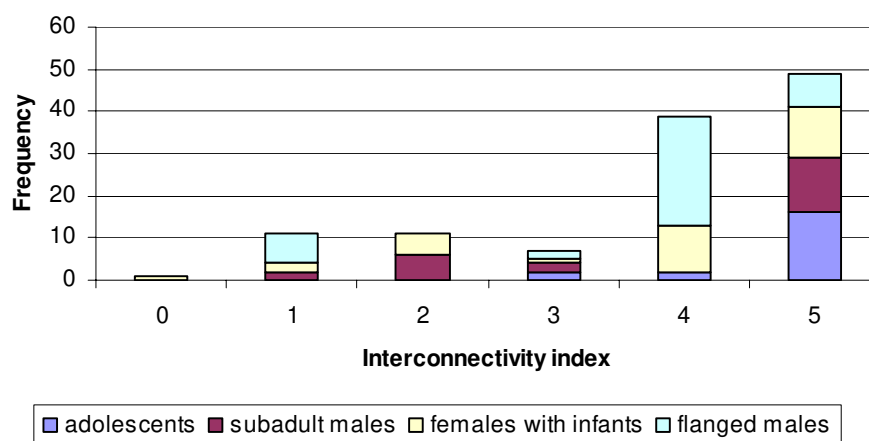
**Figure 6-11:** Jacob's Preference Indices for nest tree canopy health within the mixed swamp forest for the age / sex classes (adolescents  $n = 20$ , sub-adult males  $n = 19$ , females with infants  $n = 33$ , flanged males  $n = 42$ ). A health index of 0 = 100% leaf cover, 1 = 80%, 2 = 60%, 3 = 40%, 4 = 20%, 5 = 0% cover. Where -1 = indicates total avoidance; +1= indicates preferential use and 0 = proportional use.

Sub-adult males had a strong preference for trees with 0% leaf cover ( $D = +0.86$ ) also tending to avoid healthy trees with 100% leaf cover ( $D = -0.63$ ). Trees where leaves covered 40-80% of their branches (used for 47% of nest trees), were used in proportion to their availability.

Females also displayed their strongest preference for trees with 0- 20% cover ( $D = 1$  and  $0.87$ ). As the amount of leaf cover increased their use of these trees decreased ( $D = 0.68$  at 40% cover) and turned to avoidance of trees with over 80% leaf cover ( $D = -0.58$ ). Trees with 60% cover (index = 2) were used in proportion to their abundance in the forest. Flanged males also show this relationship. As leaf cover decreased, tree use was more a result of preference, than the convenient use of available resources. As the females, flanged males preferred trees with 0% leaf cover ( $D = 1$ ) and avoided trees, where leaf cover approached completeness ( $D = -0.54$ ).

### 6.3.5 Canopy Interconnectivity

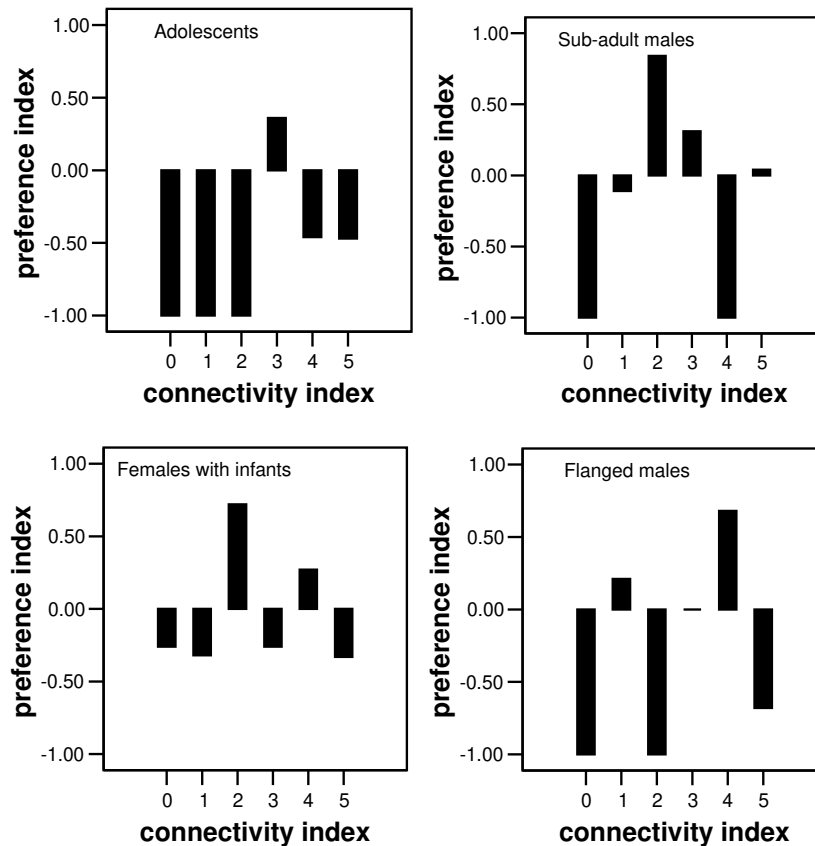
Previous work on orangutan nests have suggested that nests may be built close to look-outs (Harrison, 1969; Kurt, 1971; MacKinnon, 1974; Rijksen, 1978). However, as orangutans are largely unalert whilst inside the nest and the study area is known to have few predators but lots of disturbance, it was predicted that orangutans may be nesting in the more camouflaged areas available, where a high degree of interconnectivity exists between tree canopies. It was assumed that vulnerable animals may prefer more concealed nests and the less vulnerable animals may nest in more open areas. Figure 6-12 gives the frequency of interconnectivity indices of 114 supporting nest trees.



**Figure 6-12:** Frequencies of canopy interconnectivity indices for the nest trees of each age / sex class (adolescents = 20, sub-adult males = 19, females with infants n = 32, flanged males n = 43). Where 0 = 100% interconnectivity, 1 = 80%, 2 = 60%, 3 = 40%, 4 = 20% and 5 = 0% interconnectivity.

The results found that nest trees with 0-20% connectivity (an index of 4-5), were used in 88% of cases and a completely closed canopy was used in < 1% of cases. There were no incidences of adolescents using nest trees with more than 60% interconnectivity, while 80% of their nest trees had 0% interconnectivity. Sub-adult males used trees with an index of 5 (0% interconnectivity) in 57% of cases.

Adult females used poorly interconnected trees (index 4 - 5) in 72% of cases and closed canopies in only 3% of cases (index 1; 100% interconnectivity). Flanged males used open canopied trees in 80% of nesting events (0-20%) and never nested in trees with totally connected canopies. Jacob's Preference Indices were calculated for the age / sex groups, the results are shown in Figure 6-13.

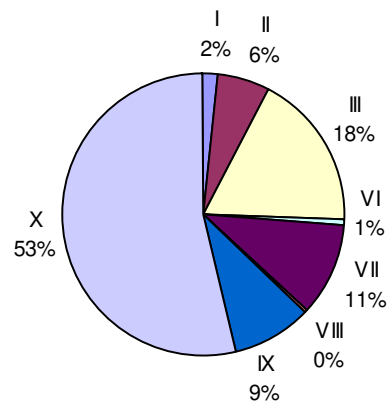


**Figure 6-13:** Jacob's Preference Indices for canopy connectivity of nest trees for adolescents (n=20), sub-adult males (n=23), females with infants (n=32) and flanged males (n=43). Where 0 = 100% interconnectivity, 1 = 80%, 2 = 60%, 3 = 40%, 4 = 20% and 5 = 0% interconnectivity. Where -1 = indicates total avoidance; +1 = indicates preferential use and 0 = proportional use.

Adolescents had no specific preference for degree of canopy interconnectivity; although they did avoid trees with complete interconnected canopies. 40% interconnected trees were a weak preference ( $D = 0.36$ ); but this is most likely the result of the profusion of these canopies in the forest and a small sample size. The weaker avoidance indices for the higher connectivity indices, indicates that adolescents preferred more open canopies. Sub-adult males preferred trees with semi-exposed canopies of around 60% interconnectivity. They avoided canopies 100% and 20% interconnected, indicating that they do not like to sleep where they are completely covered or completely exposed. Females with infants show a similar result to sub-adult males although they were less selective; most indices found weak preference for 60% interconnectivity. A weak preference ( $D = 0.27$ ) also existed for more open canopies (20% interconnectivity) and, as Figure 6-13 shows; the other nest trees appear to have been chosen as a result of their abundance in the forest with no real preferences apparent. Flanged males preferred nest trees with some leaf cover (20%,  $D = 0.68$ ) and actively avoided trees with fully leaf-locked branches ( $D = -1$  at 100% and 60%). There is also evidence that the flanged males avoided completely open canopies ( $D = -0.68$  at 0%).

### **6.3.6 Architecture**

The prediction that orangutans have architectural tree preferences for nesting required classification of nest tree branching patterns (Figure 5-2). 293 nest trees were assessed from the population (including resurvey and follow data) and the percentage of nest trees of each unit are shown in Figure 6-14. The most commonly occurring architecture in nest trees was a type X, representing 53% of nest trees. Architectural units III constituted 18% all nest trees and type VII represented 11%. None had an architecture IV or V.

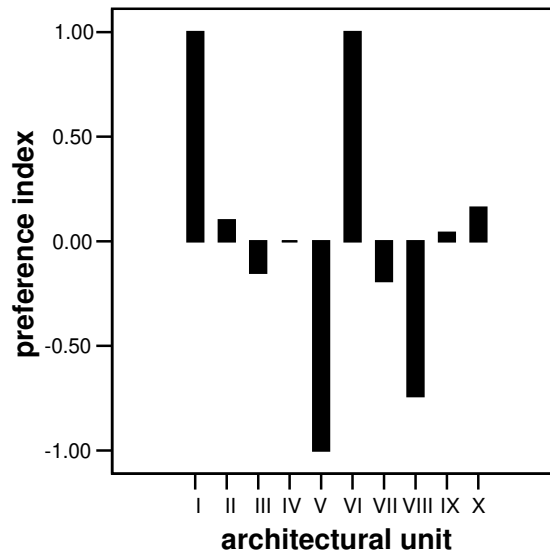


**Figure 6-14:** The architectural units of nest trees expressed as a percentage (n = 293).

Data was compared using Jacob's Preference Indices with the proportions of each architectural type commonly available in the forest (Figure 6-4), results are shown in Figure 6-15.

The indices found that two architectural units were used disproportionately to their availability in the forest; types I and VI ( $D = 1$ ), indicating that their use was preferential as opposed to proportional. Despite type X representing 54% of nest trees, it also accounted for over 45% of trees in the forest; its use by nest builders was thus found to be only slightly preferential.

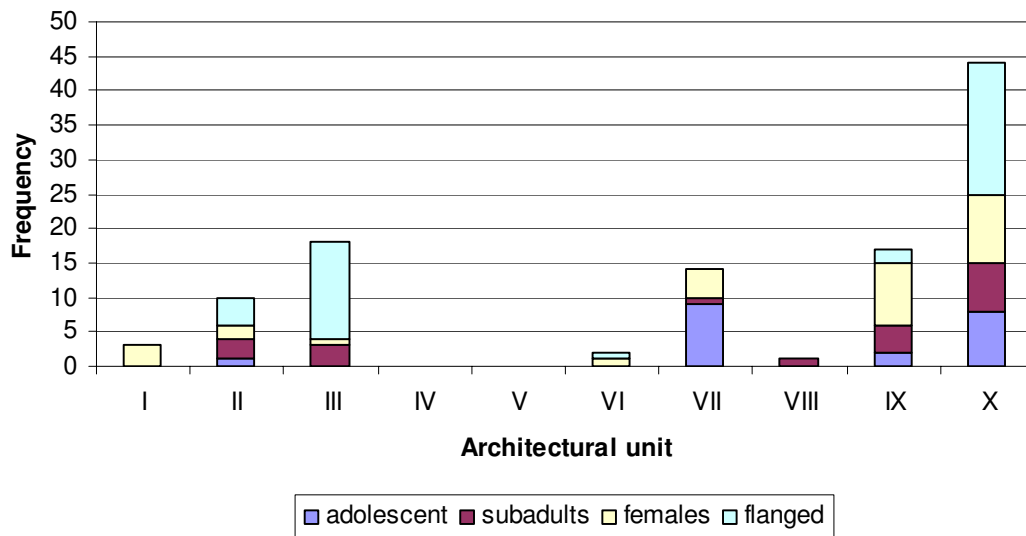
Despite representing 2% of all forest trees, type V was completely avoided by the population for nest building. Type VIII architecture was also avoided by nest builders; used for less than 1% of all nests but accounting for 15% of trees in the forest. The remaining indices indicate proportional use by the population.



**Figure 6-15:** Jacob's Preference Indices for architectural units of nest trees (n = 293). Where -1 = indicates total avoidance; +1= indicates preferential use and 0 = proportional use

Trees where the nest builder was known (n = 109) were analysed to identify architectural preferences of the age / sex classes. The results are shown in Figure 6-16 as the frequency each class used each architecture. Again, types II, IX and X were used in common by all of the age / sex classes. Adolescents used mainly VII and X; accounting for 85% of their nest trees.

Sub-adult males were the only group to use trees with type VIII architecture, although these accounted for only 5% of trees, they mainly used type; X in 37% of trees and type IX in 21%. 16% of sub-adult male nests were made in trees with type II or III architecture and flanged males nested in a type X tree in 48% of nesting events and a type III in 35% of events.



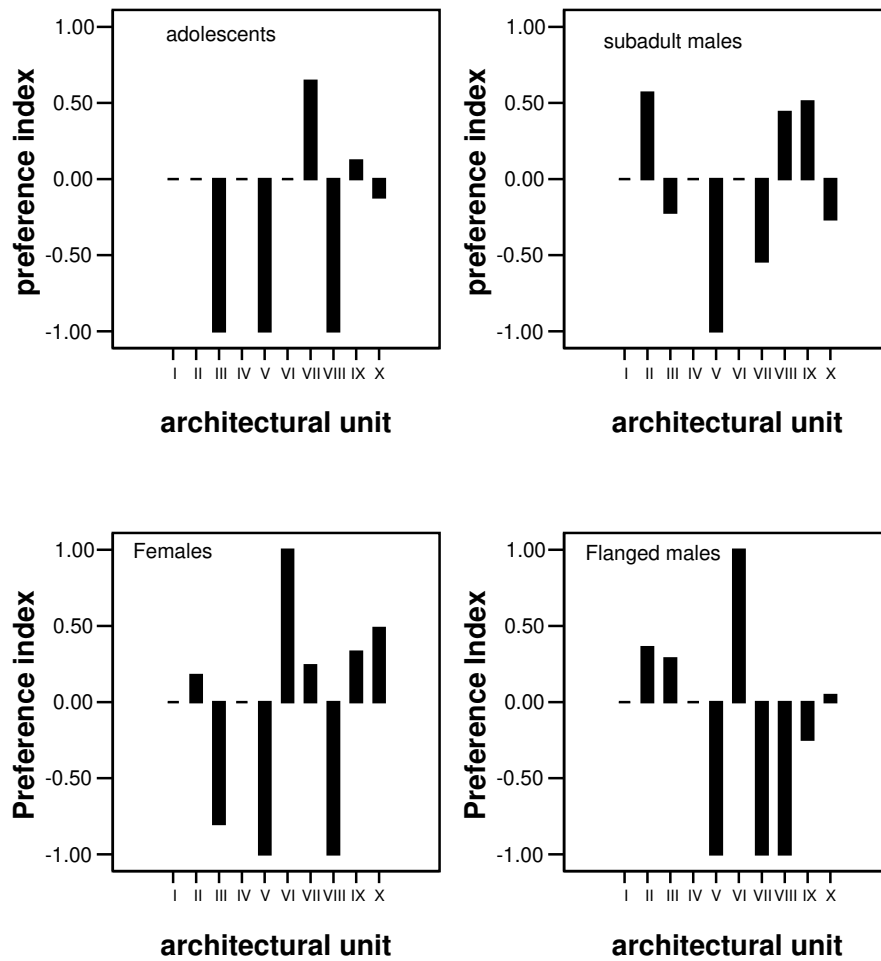
**Figure 6-16:** Architectural units of the nest trees used by the age / sex classes, expressed in terms of the percentage frequency of each type was used by each cohort (adolescents n=20, sub-adult males n = 19, females with infants n = 30, flanged males n = 40). Figure 5-2 shows the architectural unit classification system.

Females with infants were the least selective with a wider variety of architectures used as nest trees. 34% were type X and 30% were type IX. The females were the only group to build their nests in type I architecture; although this represented just 10% of their 30 nest trees assessed.

The results of Jacob's Preference analysis (Figure 6-17) show that the majority of architectural units were used as a result of their abundance in the habitat. However, each class does display a strong preference for at least one type of architecture. Of note, is a type VII architecture ( $D = 0.7$ ) used for 45% of adolescent nest trees. Sub-adult males showed preference for types II and IX and were also interestingly the only group to not only use trees of a type VIII architecture, but to prefer them ( $D = 0.44$ ) over type III ( $D = -0.22$ ) and X ( $D = -0.26$ ); both used as a matter of preference (albeit weakly) by the flanged males (III,  $D = 0.29$ ; X,  $D = 0.05$ ) and the adult females (III,  $D = 0.25$ ; X,  $D = 0.49$ ).

Females also preferred type VI architecture ( $D = 1$ ), type IX ( $D = 0.33$ ) and type VII ( $D = 0.24$ ). Flanged males distinctly preferred nest trees with a type VI ( $D = 1$ ), also choosing





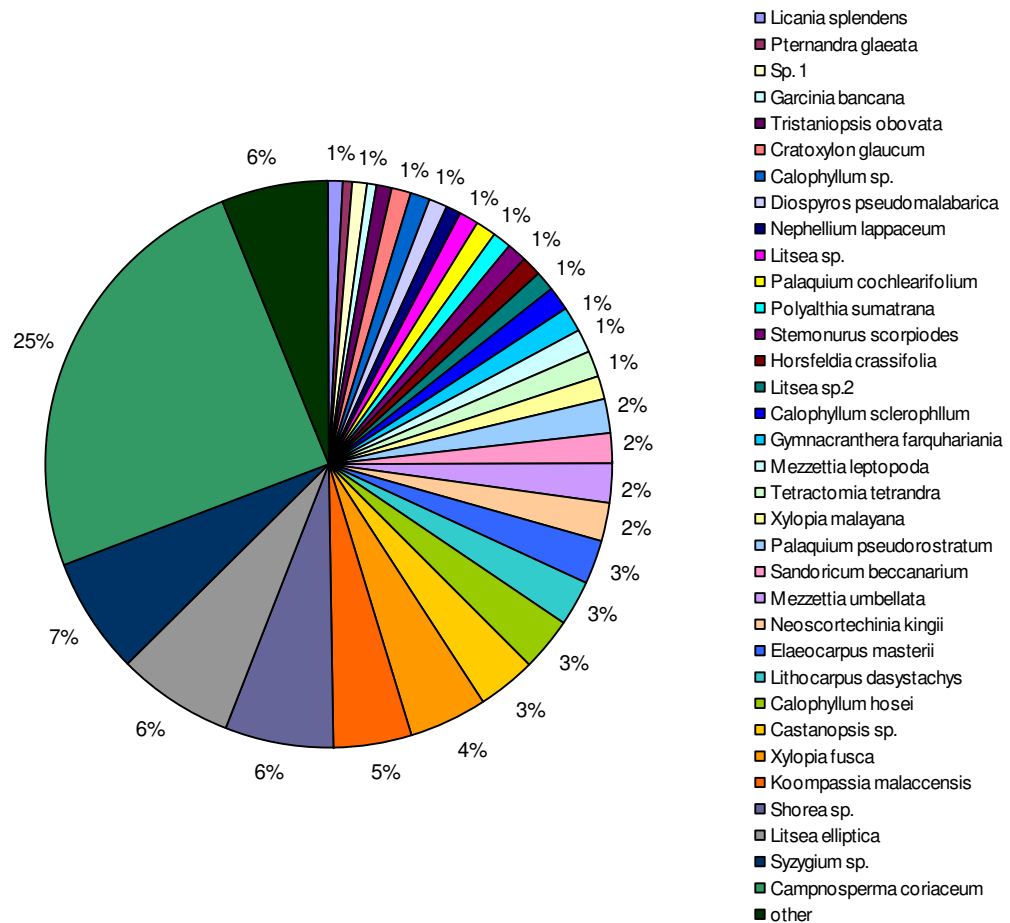
**Figure 6-17:** Jacob's Preference Indices for nest tree architecture within the mixed swamp forest for the age / sex classes (adolescents  $n = 20$ , sub-adult males  $n = 19$ , females with infants  $n = 30$ , flanged males  $n = 40$ ). Figure 4.4.4.1 shows the architectural unit classification system. -1 = indicates total avoidance; +1= indicates preferential use and 0 = proportional use.

type II ( $D = 0.36$ ) and III ( $D = 0.29$ ); they completely avoided trees of types V, VII and VIII (all  $D = -1$ ).

All individuals in the age / sex classes avoided trees with an architecture of type V (all  $D = -1$ ) and although none used type IV either, this result was due to the low abundance of these trees in the forest. Nest trees with a type I architecture were used by all groups in proportion to the availability of these trees.

### 6.3.7 Nest Tree Species

If the orangutans of the Sabangau are similar to other great apes, they were expected to have species preferences for nest trees. 101 of the 114 trees used for nesting were confirmed to belong to 29 species, representing 17 families and 24 genera. A species list of nest trees is provided in Appendix A1, Appendix A2 provides all known species in the Sabangau National Park available for nesting (local names from the Palankaraya area and common Indonesian names are included). Figure 6-18 shows the percentage of nest trees which each species accounted for.

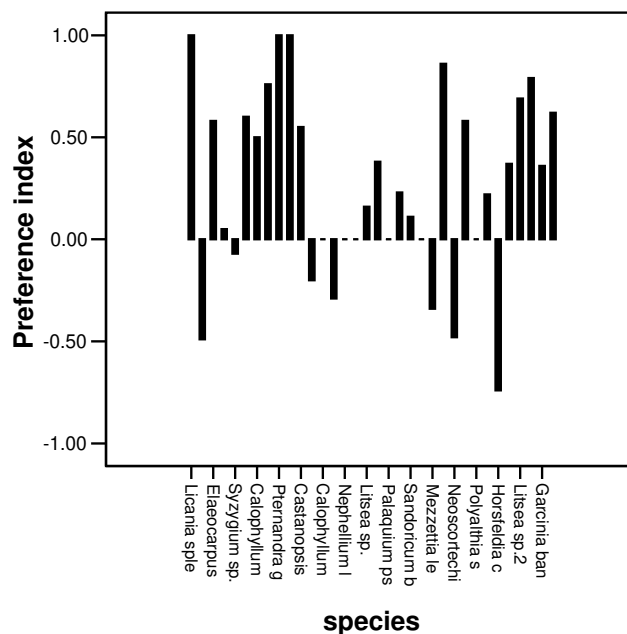


**Figure 6-18:** Species of nest trees, shown as a percentage of the total (n = 279). ‘Others’ represents 17 species, each used in just one nest construction, the species listed were used at least twice for nest building.

*Camposperma coriaceum*, was the most popular species, used in 25% of nest constructions. *Syzygium sp.*, accounted for 7% of all nest trees and *Litsea elliptica* and *Shorea sp.* each accounted for 6% of nest trees. *Koompassia malaccensis* and *Xylopia fusca* were also used more than other species, representing 5% and 4% of trees respectively. The results of Jacob's Preference, shown in Figure 6-19, found definite preferences for particular species in nesting orangutans.

Of 34 species included in the analysis, three instances where  $D = 1$ ; do not conclude strong preferences as they were used for just two nesting incidences each and were not represented in the habitat sample; an example of how Jacob's Preference Index may be misleading (See Section 7).

Six species were used in direct proportion to their availability in the forest, ( $D = 0$ ) and six were used as a result of their abundance in the forest. Of the remaining 19 species preferred for nesting, the strongest preferences are shown for; *Mezzettia umbellata* ( $D = +0.86$ ), *Camposperma coriaceum* ( $D = +0.79$ ) and *Koompassia malaccensis* ( $D = +0.76$ ).



**Figure 6-19:** Jacob's Preference indices for species of nest tree (n = 262, not including species only used once for nest building). -1 = indicates total avoidance; +1= indicates preferential use and 0 = proportional use.

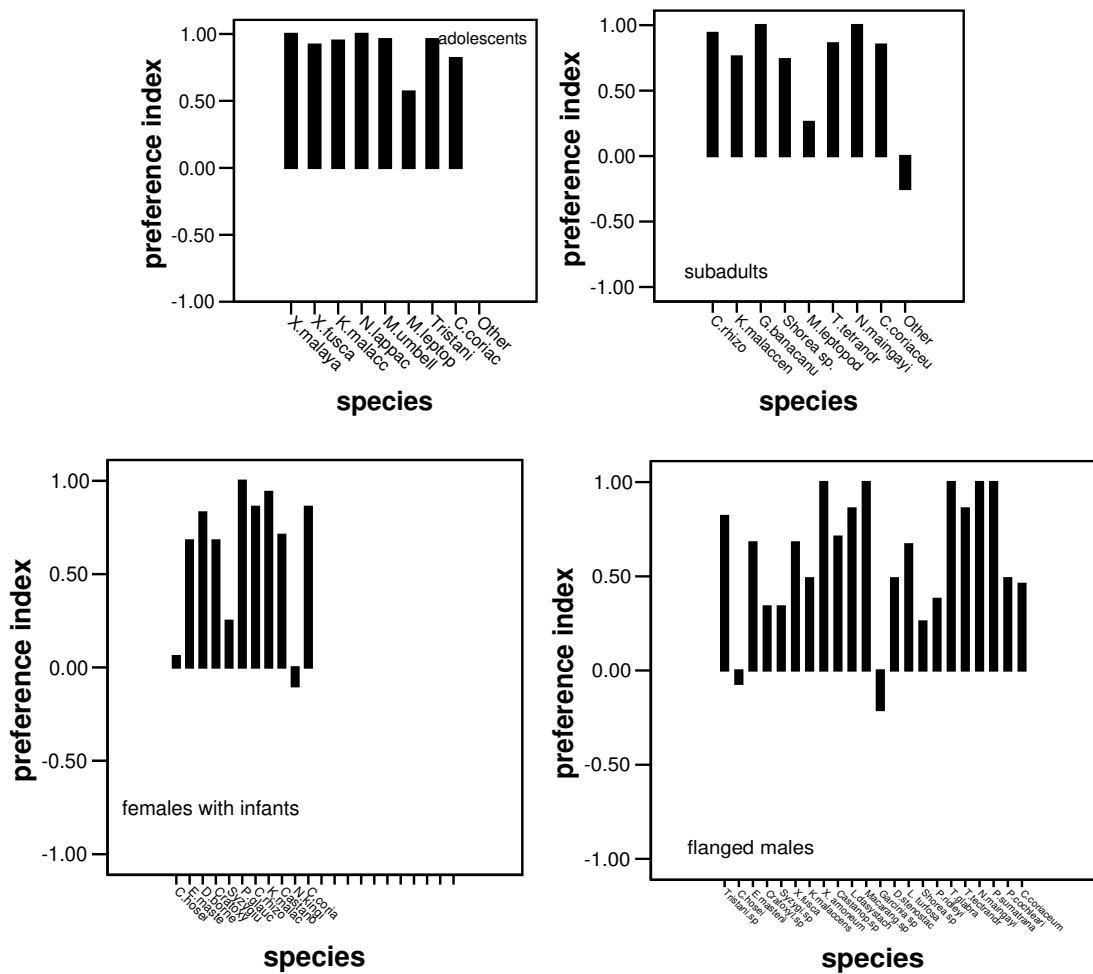
Analysis of the age / sex classes revealed marked species preferences within each group. Figure 6-20 shows the results. For adolescents, where  $n = 20$  and the number of species used was 8, all were used as a matter of preference. *Koompassia malaccensis*, was used far more than its abundance in the forest would suggest ( $D = 1$ ), indicating that adolescents seek these trees for nest building. *Tristaniopsis* sp. ( $D = +0.96$ ) was also a strong preference as was *Xylopia fusca* ( $D = +0.95$ ). The weakest index was found for *Mezzetia leptopoda* which was sought for nesting but the lower index ( $D = +0.57$ ) indicates that this was a more common species, used less than it could have been.

Sub-adult males had strong preferences for seven species, of which *Koompassia malaccensis* ( $D = +0.76$ ) and *Camptosperma coriaceum* ( $D = +0.85$ ) were in common with the adolescents. The data for the sub-adult males includes nine species used for 18 nests, their preferred nest tree species was *Camptosperma coriaceum* ( $D = 0.85$ ). For the species *Calophyllum rhizophorum* ( $D = 0.94$ ) and *Tetractomia tetrandra* ( $D = 0.86$ ) these were again used as a result of their high proportions in the sample; due to a small sample size and their low proportion in the habitat survey. *Nephellium maingayi* and *Garcinia bancanus* indices; both  $= +1$ , are also misleading as they indicate that these species were sought for nesting; however they were rare in the forest and were each used just once as a nest tree. Sub-adult males used only one species in proportion to its abundance, a *Syzygium* ( $D = -0.25$ ).

22 trees used by adult females with infants were identified as 11 species. The analysis found that ten of these species were used as a matter of preference and two; *Neoscortechinia kingii* and *Calophyllum hosei* were used in proportion to their abundance in the forest. The biggest species preferences of this group was *Koompassia malaccensis*, where  $D = +0.94$  and *Camptosperma coriaceum*. The indices for *Xylopia malayana* where a  $D = +1$  index was calculated and *Calophyllum rhizophorum*  $D = +0.86$ , is another result of small sample size and species rarity.

The flanged male nests recorded incorporated a greater number of species into the analysis;  $n = 41$  and number of species was 22. The results again may be affected by small sample size as strong preferences are indicated for many of the species used just once by the flanged males.  $D = 1$  was calculated for; *Xanthophyllum amoenum*; *Macaranga* sp.; *Tetrameristra glabra* and *Polyalthia sumatrana*, again used in just one or

two trees, and so these were not species of preference. Two species were used in proportion to availability; *Calophyllum hoesi* and *Garcinia* sp. Of note in the flanged males is *Nephellium maingayi* ( $D = 1$ ); *Camposperma coriaceum* ( $D = 0.46$ ) and *Syzygium* sp. ( $D = 0.34$ ) which were used more than would be expected, compared to their abundance in the forest.



**Figure 6-20:** Jacob's Preference Indices for nest tree species used by each of the age / sex classes (adolescents  $n = 20$ , sub-adult males  $n = 18$ , females with infants  $n = 24$ , flanged males  $n = 39$ ). -1 = indicates total avoidance; +1= indicates preferential use and 0= proportional use.

### 6.3.8 Exudates

Bark slashes, revealing the inner bark and any exudates were taken from each nest tree. The prediction was that orangutans would avoid trees with sticky exudates for nesting. The results found that 94% of nest trees were free from sticky exudate, or sap. Across the forest, 83% of trees were sap-free. Jacob's Preference Index produced a positive result ( $D = +0.52$ ); indicating that preference for trees without sticky sap was the cause of the findings.

The results are reiterated in the age / sex groups. Adult females show the strongest preference for sapless<sup>8</sup> trees ( $D = +0.74$ ) and adolescents and sub-adult males both demonstrated the same preference for trees without sticky sap ( $D = +0.6$ ). A different result was observed in flanged males, who used trees with and without sap in proportion to their availability; although avoidance of sap ( $D = -0.35$ ) was stronger than their preference for sapless trees ( $D = -0.06$ ).

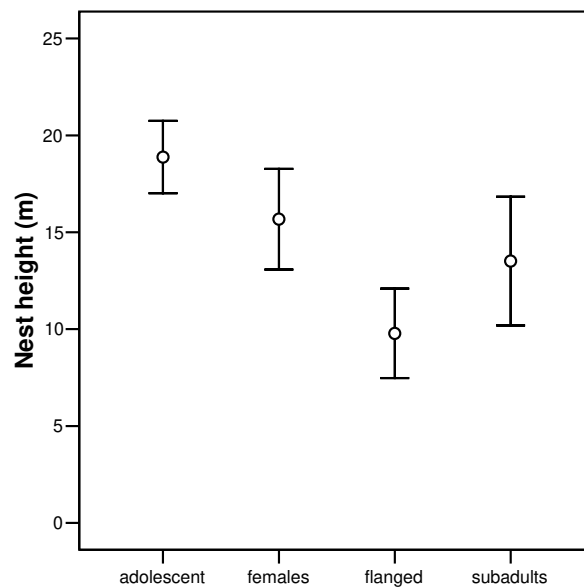
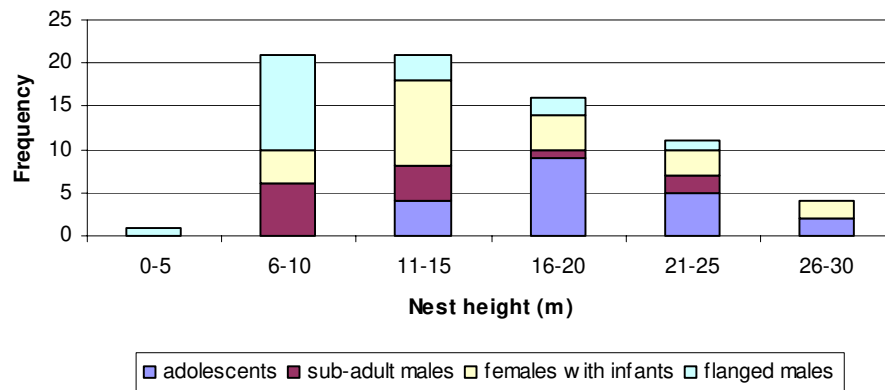
### 6.3.9 Nest Height

Sections 6.3.9- 6.3.14 are purely concerned with the nesting behaviour of the population. For the purpose of analysis, nest type is defined as the size of the nest, whether the nest is new or has been reused, the position of the nest within the tree and the complexity of the nest; assessed by the time spent on construction. The hypothesis predicted that each age / sex class would have a recognizable nest type, so that nest builder identity may be predicted using a key set of parameters.

The heights of 73 nests, constructed by 21 individuals were measured with a mean height of 14.74m (SD +/-5.99m) recorded for the population. The distribution of nest heights in the forest is shown in Figure 6-21a. 47% were built less than 10m above the forest

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<sup>8</sup> Sapless in this case refers to species not exuding sticky sap, it is not intended to implicate species with non-sticky saps such as some species of Mryristicaceae or Burseraceae.



**Figure 6-21: Top a).** Distribution of nest heights (metres) of each age / sex class. **Bottom b).** The mean values of nest heights (in metres) of the age / sex classes (adolescents  $n = 20$ ; sub-adult males  $n = 13$ ; females with infants  $n = 22$ ; flanged males  $n = 18$ ). Circles indicate the mean nest height value; emitting lines indicate the 95% confidence intervals.

floor, 28% of which were constructed by flanged males. Figure 6-21b shows the mean nest heights of the population with 95% confidence intervals. Mean flanged male nest height was 9.94m (SD  $\pm$ 4.64m). Sub-adult males also preferred to nest in the lower forest levels, at a mean height of 13.51m (SD  $\pm$ 5.22m) with 53% of their nests built at 6-10m. Females with infants nested lower than expected, preferring an intermediate

height of 15.67m on average (SD +/-6m). 72% of female nests were constructed between 6 and 15m from the ground, the remaining 28% made above this threshold.

As predicted, adolescents nested higher than any other age / sex class; at a mean height of 18.88m (SD +/-3.99m), 45% of these occurring 16-20m above the ground and 4% built in the upper canopy, over 26m; 2% each produced by the adolescents and the females.

Table 5 shows the results of an analysis of variance, which found differences in the data with a very high level of statistical significance ( $F_{3, 69} = 10.750$ ,  $p < 0.0001$ ), with 95% confidence limits.

**Table 5:** ANOVA test for the significance of differences observed in the nest heights (m) of the age / sex classes (n = 73).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	885.242	3	295.081	11.635	.000
Within Groups	1775.261	70	25.361		
Total	2660.503	73			

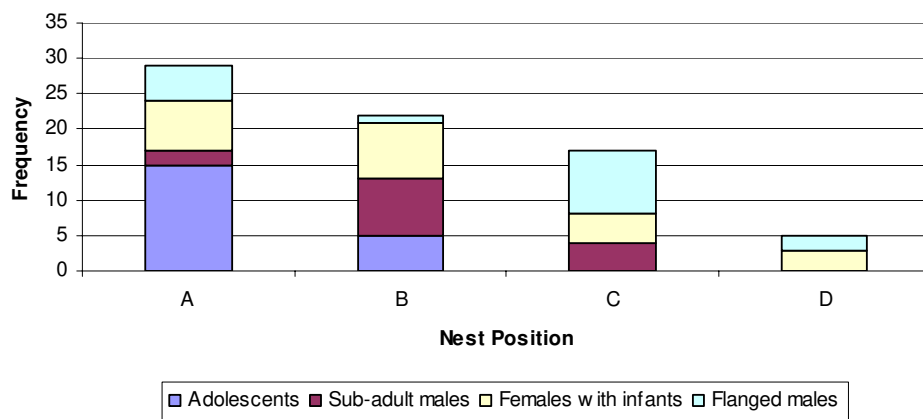
A Tukey test (Appendix B3) found the largest difference in nest height was with the flanged males, who nested much lower than the other members of the population.

Within the vulnerable classes; adolescents and adult females; nest heights were not statistically significantly different to one another ( $p = 0.169$ ) and within the less-vulnerable classes; the sub-adults and flanged males; nest heights were not statistically different ( $p = 0.158$ ). However, between these groups, flanged male nests were lower, with a very high level of significance to adolescents ( $p = < 0.0001$ ) and lower with high significance to adult females with infant nests ( $p = < 0.01$ ). The sub-adult males nested significantly lower than the adolescents ( $p = < 0.05$ ) however, no significant difference was found between them and the adult females ( $p = 0.628$ ).



### 6.3.10 Nest Position

Nest positions were classified into 4 positions as set out in Figure 5-4. It was predicted that the population may vary in their preference for nest position. Figure 6-22 demonstrates the frequency which each of the four positions were used by the age / sex cohorts. 40% of 73 nests assessed were in position 'A', of which 52% were made by adolescents and 24% by adult females. Only 7% of these nests were made by sub-adult males and 17% by flanged males.



**Figure 6-22:** Nest positions of the age / sex classes expressed in terms of the frequency each position was observed (adolescents n = 20, sub-adult males n = 13, females with infants n = 22, flanged males n = 18).

29% of all nests were nests in position 'B', of which 38% were constructed by adult females with infants and 33% by sub-adult males. 24% were made by adolescents and 5% by flanged males. Tree-tied or integrated nests in position 'C', accounted for 24% of all nests. 53% of these were constructed by flanged males and 23.5% each were prepared by females and sub-adult males. Position 'D' nests were the least common, accounting for just 7% of nests. 'D' nests were only constructed by adult females and flanged males, who constructed these nests in 14% and 12% of their nesting events respectively.

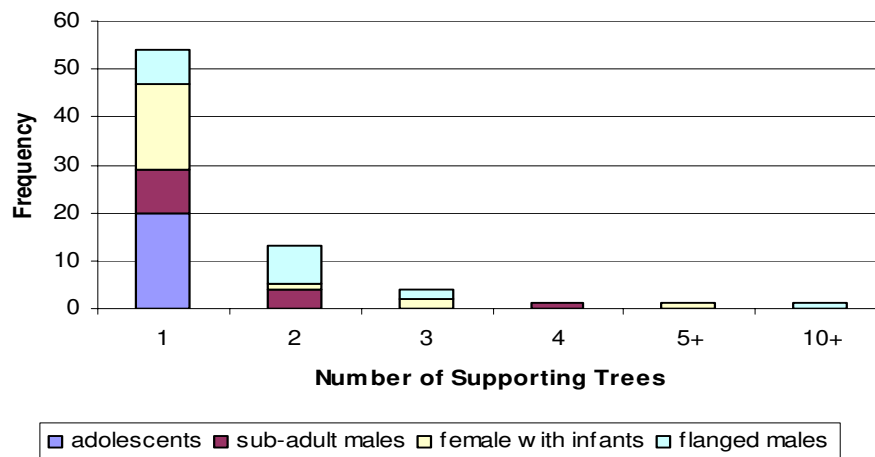
Using the Chi-squared statistic, the significance of the differences observed in the nest positions used by each age / sex class, were compared to expected frequencies.  $\chi^2_3 =$

31.01,  $p = <0.0001$ , nest position did therefore vary, with a high level of statistical significance, between the age / sex classes.

### 6.3.11 Supporting Trees

Nest position 'C' implies an integrated nest, (Section 6.3.10) but it gives no indication of the number of trees supporting a nest and therefore its complexity. Figure 6-23 shows the number of trees used in supporting the nests of each age / sex group.

74% of the 73 nests assessed used one supporting tree, 16% used 2 trees and 5% used 3 trees. There was one incidence of a nest using 13 trees for support; produced by one of the flanged males.



**Figure 6-23:** The number of supporting trees frequently used in nest construction (adolescents  $n = 20$ , sub-adult males  $n = 13$ , females with infants  $n = 22$ , flanged males  $n = 17$ ).

There was no incidence of an adolescent using an integrated nest and females and sub-adult males only used integrated nests four times each, representing 14% and 31% of total nesting events. Flanged males used integrations in 58% of their nesting events, an example is shown in Figure 6-24.

Statistical analysis found that there was no real difference in the number of supporting trees used by the age / sex classes, (ANOVA test)  $F_{3,70} = 2.361$ ,  $p = > 0.05$ . The result is shown in Table 6.

**Table 6:** Results of a one-way ANOVA on the number of supporting trees used in the nest construction by the four age / sex classes (n= 73).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16.213	3	5.404	2.361	.079
Within Groups	160.233	70	2.289		
Total	176.446	73			

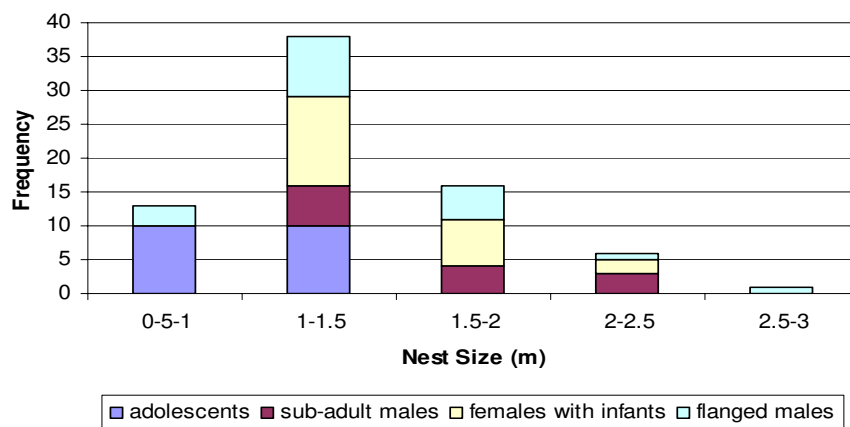


**Figure 6-24:** An example of an integrated nest, made by a flanged male in the mixed swamp forest of the Sabangau National Park. © 2004.

### 6.3.12 Nest Size

Nest size was predicted to vary among the population; adolescents were expected to build the smallest nests and flanged males the largest; in proportion to their body masses. It was predicted that nest size may be a causative factor in the choice of structural and architectural tree characteristics. Figure 6-25 shows the results of 74 nests.

All of the age / sex classes produced nests of 1-1.5m diameter. 61% of adult female and 46% of sub-adult male and 50% of adolescent nests measured 1-1.5m. Adolescents produced the smallest nests (all below 1.5m diameter), flanged males had the largest variation in nest size, producing the largest nests ranging from 0.5m to 3m in diameter. Females with infants and sub-adult males produced similar sized nests, from 1m to 2.5m diameter.



**Figure 6-25:** Nest sizes, given for diameter in metres produced by the age / sex classes (adolescents n = 20, sub-adult males n = 13, females with infants n = 22, flanged males n = 19).

Table 7 shows the results of a one-way ANOVA test which found a very highly significant difference in the nest sizes of the cohorts as  $F_{3, 71} = 9.278$ ,  $p = < 0.0001$ . A Tukey test (Appendix B.4) found that adolescent nests were significantly smaller than sub-adult male nests and females with infants nests ( $p = < 0.0001$ ). Adolescent nests were also smaller, with a high degree of significance to flanged male nests ( $p = < 0.005$ ).

Sub-adult male, flanged male and female nests did not differ significantly in size to one another.

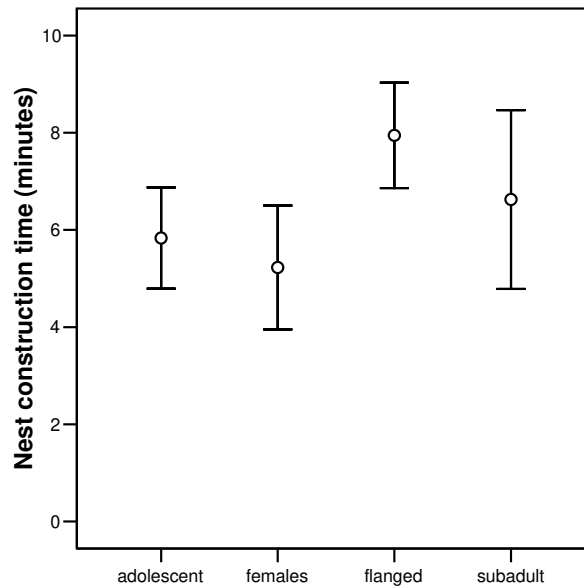
**Table 7:** One-way analysis of variance on the nest sizes of the age / sex groups (n = 74).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16.393	3	5.464	9.278	.000
Within Groups	41.229	70	.589		
Total	57.622	73			

### 6.3.13 Construction Time

The time taken to construct a nest is thought to reflect its complexity. It was predicted that adolescents, with less nest building experience would build quick, less complex nests and the more experienced nest builders, flanged males and mothers teaching young infants would build the most complex nests.

Construction times were available for 66 nests. The mean time taken by the population to complete a nest was six and a half minutes (SD +/- 2.61 minutes). Figure 6-26 shows the average time taken (in minutes) by each age / sex class to construct their sleeping platforms, confidence intervals of each mean are included; although the data ranged from 2 minutes to 17 minutes, both extremities were recorded from the same adult female with an infant.



**Figure 6-26:** Mean nest construction times (in minutes) of each age / sex class (n = 18, sub-adult males n = 8, females with infants n = 22, flanged males n = 18). Circles indicate the mean nest height value; emitting lines indicate the 95% confidence intervals.

Flanged males spent longer on average, constructing their nests than any of the other classes at 7.94 minutes (SD +/- 2.18mins.). Sub-adult males spent 6.63 minutes on average (SD +/- 2.20mins.); adolescents spent 5.83 minutes (SD +/- 2.09mins.) and females with infants were the fastest nest builders, spending just 5.23 minutes building their nests on average (SD +/- 2.88mins.).

The significance of these times differences was tested using a one-way ANOVA, which found a highly significant difference in the nest construction times of the age / sex groups, where  $F_{3,62} = 4.482$  and  $p = <0.01$  (Table 8).

**Table 8:** Results of a one-way ANOVA test on the time (in minutes) taken to construct a nest

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	78.756	3	26.252	4.482	.007
Within Groups	363.183	62	5.858		
Total	441.939	65			

A Tukey test (Appendix B.5) found that females built nests much quicker than the flanged males with a high level of significant difference ( $p = < 0.01$ ). There were no significant differences in the nest construction times between any of the other classes. The hypothesis that more experienced nest builders such as the adult females spend longer building more complex nests was not proven. The discovery that flanged males spent the longest amount of time building their nest indicates that they do produce the most complex nests and females with infants produce the least complex.

#### **6.3.14 Reuse of Nests**

Previous work on orangutan populations found that the apes in Kalimantan only rarely reuse nests (Galdikas, 1982; MacKinnon, 1974), it was therefore expected that a low incidence of reuse would occur in the Sabangau.

Of the 74 nests investigated just one incidence of reuse was recorded. The nest was made by an adolescent and reused by another adolescent, producing a frequency estimate of 1.4% for the population.

### **6.4 Objective 2 Analysis – Nest Site Preferences**

Nest site selection in orangutans is thought to be influenced by a variety of environmental factors including predator avoidance and habitat type (MacKinnon, 1974; Rijksen, 1978; Sugardjito, 1983). An investigation into the environmental factors influencing nest site selection recorded the distance to and the crop size of the last food tree visited before nesting and the distance to and the crop size of the first food tree visited in the morning of waking from the nest. Investigation into predator avoidance is implied in Objective 3, looking at anthropomorphic disturbance in the forest. Natural predators were excluded from the study due to the limitations on the size of the study. As a new research base information on natural predators in the area is also lacking. Recommendation is made for surveys to take place in order to identify the presence of clouded leopard and other known predators of orangutans.

#### **6.4.1 Distance of the Last Feeding Tree**

The last feeding tree is defined by ‘the last significant fruit feeding bout lasting no less than five minutes, prior to nesting’. Based on the work of Sugardjito (1983), food resources were predicted to be dominated by flanged males, the less-vulnerable animals nesting further away. Flanged males were also predicted to display the highest incidence of nesting in the resource, as seen in chimpanzees and gorillas (Fruth and Hohmann, 1993; Basabose and Yamagiwa, 2002).

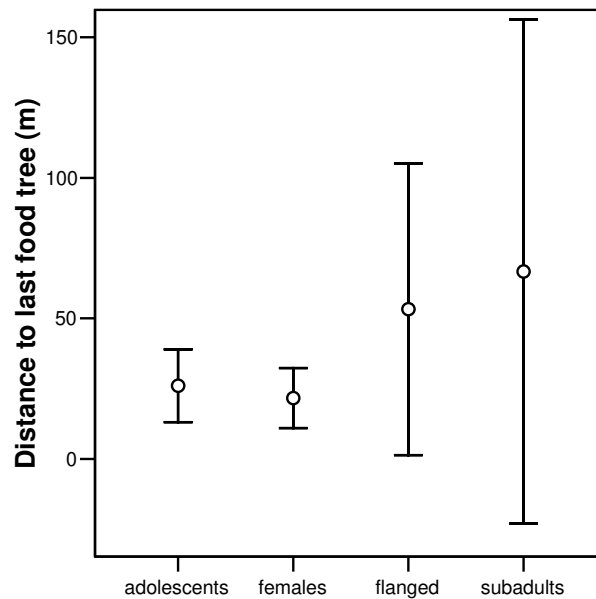
The results of 67 distances found that 4% of nests were made in the last food tree, one was made by a flanged male, however another flanged male nest was built over 400 metres away ( $n = 68$ ). Figure 6-27 displays the mean distance at which each age / sex class nested from the last food trees (95% confidence intervals are included).

The results found highly variable distances. Females with infants nested closest at 21.63m (SD  $\pm$  23.46m) frequently nesting less than 30m away from their last food trees (29% of cases), 5% of nests were in the food tree. Adolescents, expected to nest the furthest away from their last feeding trees, also frequently nested close, with 11% of their nesting events occurring in the last food tree and a mean distance recorded of 26.05m (SD  $\pm$  27.70m).

Flanged males also nested close to food trees, (frequently between 1-25 metres away), although there were also incidences of nests made over 50 metres away, and one over 400 metres away. There was just one incidence of a flanged male sleeping in their last food tree; overall the mean distance they traveled to the nest was 53.27m (SD  $\pm$  104.30m).

Sub-adult males nested furthest away from the last food tree, averaging 66.67m (SD  $\pm$  116.64m). Although this is highly variable, as the confidence interval shows (Figure 6-27). They did frequently nest (78% incidence) less than 30 metres from the food trees. None of the sub-adult males nested inside their last food tree.





**Figure 6-27:** Mean distances traveled by the population from the nest to the last feeding trees, Circles indicate mean values and extending lines indicate 95% confidence intervals of the means (adolescents n = 20, sub-adult males n = 9, females with infants n = 21, flanged males n = 18).

Despite the vulnerable animals appearing to nest closer to the last food trees, a one-way ANOVA test proved insignificant ( $F_{3,64} = 1.338$ ,  $p = > 0.1$ ). The results are shown in Table 9 and the test for homogeneity of the variances is given in Appendix B.6. The prediction that food trees are dominated by the less vulnerable animals in the population is not proven and as expected (See Section 5.4.5) this study does not support the result shown by Sugardjito (1983) from Sumatra.

**Table 9:** One-way analysis of variance on the distances of the last feeding trees of the age / sex classes (n = 67).

	Sum Squares	of df	Mean Square	F	Sig.
Between Groups	20035.623	3	6678.541	1.338	.270
Within Groups	319359.192	64	4989.987		
Total	339394.815	67			

#### **6.4.2 Crop Size of the Last Feeding Tree**

The crop sizes of the last food trees were investigated to highlight any relationship between fruit abundance and nest site.

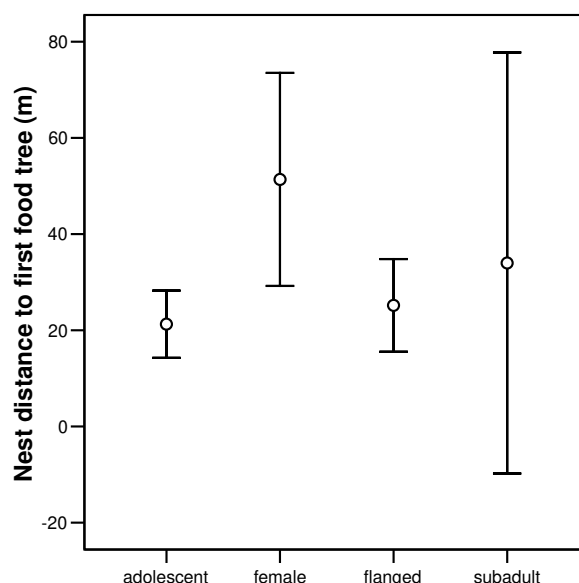
The prediction was made that shorter distances would be traveled to a nest site when the last food tree bears a large crop, however analysis was not possible under the present study due to insufficient sample size ( $n = 57$ ) and a high incidence of tied data.

#### **6.4.3 First Feeding Tree**

Although studies have been made on the distance of nests from their last food trees, no study has investigated the location of the nest in relation to the first food tree visited on leaving the nest. Assuming the benefit of fore-sight in the population, it was predicted that the population may locate nests close to trees which they plan to feed in the following morning. As with the last food tree, it was predicted that vulnerable animals would nest further away from these trees than the more dominant groups who may nest in close proximity in a defensive capacity.

Data was available from 58 nests. Mean distance to the first food tree across the population was 33.31m (SD  $\pm$  32.73m) ( $n = 58$ ). This mean is 3.9 metres smaller than that obtained for the last food tree ( $n = 68$ ). A  $z$  test found that there was no significant difference in the distances to the last and the first food trees ( $z = 0.41$ , and  $p = > 0.05$ ).

3% of nests were in trees fed in the following morning and the furthest distances traveled to a food tree the following day was 160 metres, made by an adult female with an infant. Looking at the age / sex classes, the results were variable; Figure 6-28 shows the mean distance each class traveled to their first food tree (including 95% confidence intervals). Females with infants nested furthest away from the first food tree, traveling 51.37 metres (SD  $\pm$  45.94m), although their nests ranged from 10-160 metres away. The sample for sub-adult males was limited to just five examples, however these ranged from 10-95 metres; an average distance of 34 metres (SD  $\pm$  35.25m). Flanged males nested 25.19 metres away (SD  $\pm$  18.06m) and adolescents nested closest, traveling just 21.28m (SD  $\pm$  14.05m) to their first food tree. Adolescents were also the only group to feed in their nest tree in the morning, representing 11% of their nesting events.



**Figure 6-28:** Mean distances traveled from the nest to the first feeding tree. Circles indicate the mean distance for each age / sex group and emitting lines indicate 95% confidence intervals (adolescents  $n = 18$ , sub-adult males  $n = 5$ , females with infants  $n = 19$ , flanged males  $n = 16$ ).

Table 10 shows the results of an ANOVA test, showing that there were significant differences between the age / sex classes with regard to the distances nests were built from their first feeding trees, ( $F_{3, 54} = 3.466$ ,  $p = < 0.05$ ). Further analysis using the Tukey Test (Appendix B.7) found that statistically, adolescents nested significantly closer to their first feeding trees than the sub-adult males ( $p = < 0.05$ ) and females with infants nested further away from their first feeding trees than the flanged males, with a high degree of statistical significance ( $p = < 0.01$ ). Despite the indications of Figure 6-28 no significant difference existed between the adolescents and the flanged males.

The results contradict the general prediction that vulnerable animals nest further away from first food trees than those of a less vulnerable position; although females with infants nested the furthest away, adolescents actually nested closest. The hypothesis concerning domination of the resources by the flanged males can thus be partially rejected in favour of some other explanation, discussed in Section 7.

**Table 10:** One-way analysis of variance on the distances of the first feeding trees of the age / sex classes (n = 58).

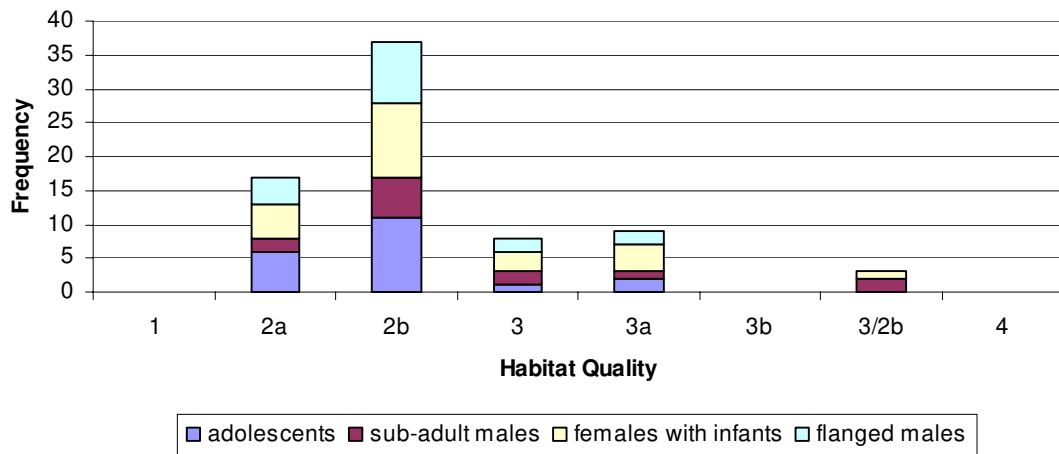
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	9859.944	3	3286.648	3.466	.022
Within Groups	51210.470	54	948.342		
Total	61070.414	57			

#### 6.4.4 Crop Size of First Feeding Tree

The crop sizes of the first feeding trees were recorded to discover whether the amount of food available on the first feeding tree influenced nest location. It was predicted that distance of the vulnerable animals from the nest would increase as crop size and available fruit increased and that distance would be less in the less-vulnerable animals. However, poor sample size (n = 50) and multiple tied data meant that regression analysis was not possible. It is recommended that further study is made on this parameter.

#### 6.4.5 Nest Site Quality

The state of the forest in the immediate vicinity of 74 nest sites was assessed using the OuTrop Habitat Quality Index (see Table 1). Figure 6-29 shows the results of the habitat quality indices at each age / sex class nest site. The noticeable result for this parameter was that the quality of forest used by each of the age / sex classes appears uniform. Less complete, open forest (2b) accounted for 50% of all nest sites and less complete, more-closed forest (2a) accounted for 23% of nest sites. None of the nest sites were classified as ‘good forest’ (1), ‘young improving’ (3b) or ‘cleared forest’ (4). ‘Young’ open (3a) and ‘good but open’ (3) forest were each used in 11% and 12% of sites, respectively. Based on this data alone and the results of the previous sections 6.3.1, 6.3.4 and 6.3.5, the results of site habitat quality appear to reflect the state of the forest, rather than preferences. As the OuTrop project is still carrying out baseline habitat surveys on the area, data are not yet available to perform any real analysis on the present result.



**Figure 6-29:** The observed frequencies which each age / sex class nested in each type of Habitat. See Figure for definitions of habitat quality indices. (Adolescents n = 20, sub-adult males n = 13, females with infants n = 24, flanged males n = 17)

Once that data exists however, Jacob's Preference Indices may be calculated. Until that time, these results conclude that less complete, open forest is the preferred forest state for nesting orangutans in the study area, although this probably reflects the recovery that this forest is currently undergoing following 25 years of selective logging.

### 6.5 Objective 3 Analysis - Habitat Preferences

The influence of disturbance on the behaviour of orangutans has been widely documented and the influence of anthropomorphic factors such as hunting pressure and logging are known to influence habitat use (MacKinnon, 1974; Rijksen and Meijaard 1999; Russon *et al.*, 2001; Morrogh-Bernard *et al.*, 2003). Anthropomorphic disturbance throughout the study area such as bat collection towers, illegal logging, drainage canals, the railway, logging skids and cleared areas are noted on various maps of the area (Figure 4-2 and Figure 4-4) Using the software GPS Utility, waypoints of recorded nests were used to produce a map of nesting sites in the study area. Figure 6-30 shows these locations of

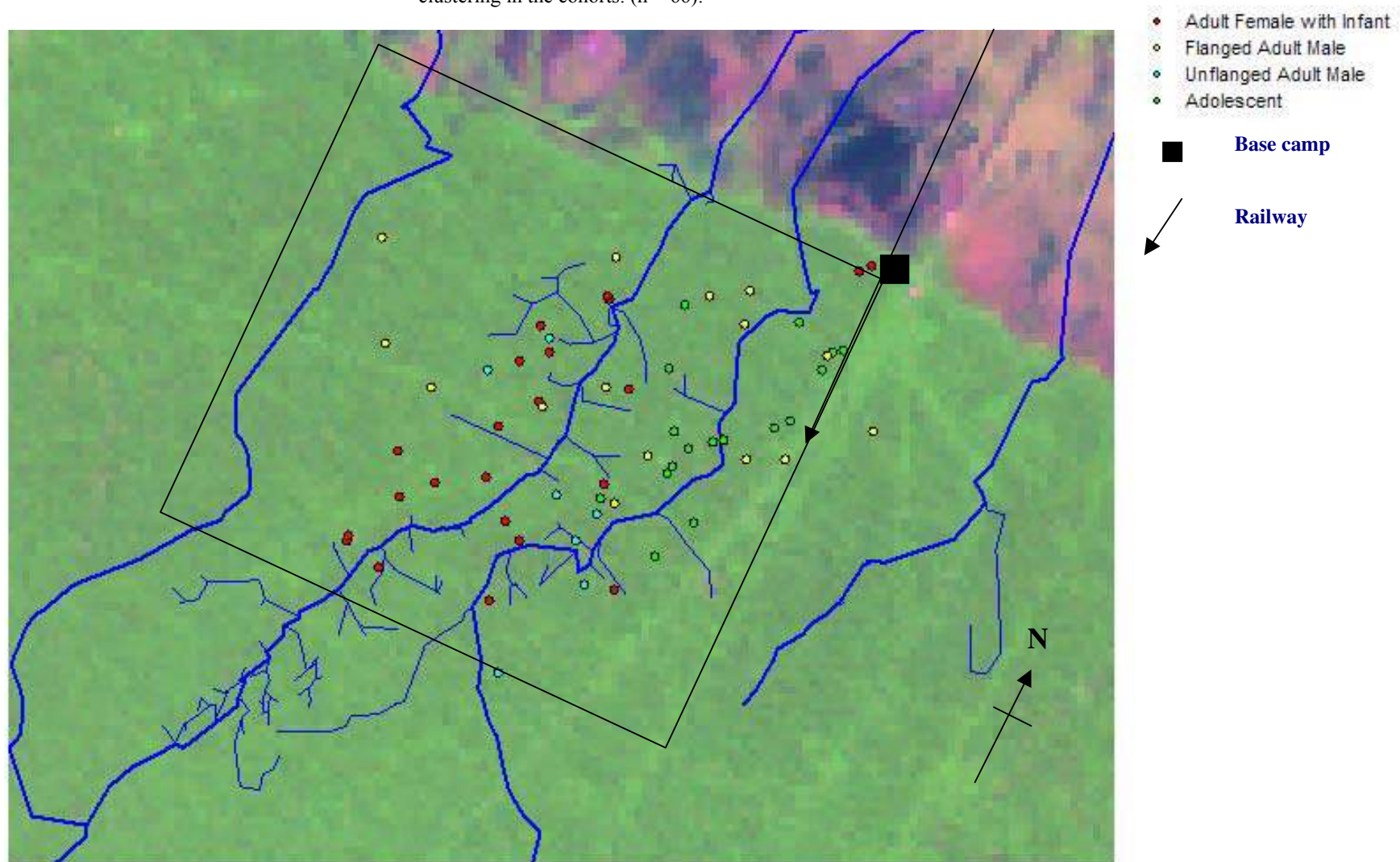
nest sites in the study area grid. The map identifies clear clustering units for each age / sex class.

As noted by Hearn (2001, unpublished) the use of the mixed swamp habitat by the resident orangutan population will always be influenced by past and present disturbance. The canals which permeate the forest imbed disturbance in the nesting behaviour of the population, as gateways to the forest, the canals are associated with numerous kinds of anthropogenic disturbance, including log extraction and access for local villagers earning a living from the forest.

Figure 6-30 shows how the two main canals infiltrating the study grid provide geographic landmarks by which nesting clusters may be analysed. The nests of the 3 adult females with infants are mainly clustered around one of the canals, although there were nesting events closer to the riverine swamp (the purplish area on the Figure 6-30). The adolescent nests seem to have been in the area assumed to be the most disturbed. Remembering the ex-logging concession which previously operated 150m either side of the railway line (See Section 4.2) the adolescent cluster is distributed entirely in this area by the first canal, which is what was predicted; vulnerable animals would be displaced into habitat of a lower quality. The nests of the sub-adult males are distributed along a centralised north-west axis between the adult females and infants and the adolescents over a wider area, and the patrolling flanged males show nests throughout the area, which is to be expected. It would appear from the map that the prediction that less-vulnerable animals dominate the best habitat is proven. The vulnerable adolescents and females do appear to be confined to the areas closest to the areas of highest disturbance (flagged by the canals and the railway) while the more dominant males appear to have a freer range throughout the area. It is unfortunate that the fifth age / sex class could not be included in the present study, so that identification of lone female nests would be possible, further study is again required.

The fine-scale effects of disturbance on the nesting behaviour of the resident population is out of the scope of the present study. The present work is intended as a baseline guide for other work, which should focus on the vulnerable members of the population; particularly in view of future plans for the Sabangau area, which aims to fill the canals preventing further drainage of the swamp.

**Figure 6-30:** Location of nest sites identified from GPS points obtained from nest to nest follows within the study area. The study area is within the limits of the black line. The railway and large canals are also shown. Age / sex classes are colour-coded to identify nest clustering in the cohorts. (n = 66).



## **6.6 Summary of Results**

Table 11 provides a summary of the results found from one-way field analyses of Sections 6.3 and 6.4.

## **6.7 Multivariate Analysis**

### **6.7.1 Discriminant Function Coefficients**

The aim of the multivariate analysis was, using the results of the one-way analyses, to formulate a model which could successfully predict the age / sex class identity of a nest builder for any given nest. In order to perform a multivariate analysis it was first necessary to convert all data to numerical code values, as shown in Table 12.

Discriminant analysis was only able to use only those variables of sufficient data, fields containing multiple missing entries were not included as the coverage and accuracy of the analysis was adversely affected. Those variables which were able to be included are shown in Appendix B.8. Final analysis included 102 of the 114 records. Canonical discriminant function coefficients of the four most relevant parameters are shown in Appendix B.8ii. The territorial map arising as a result of the discriminant functions is shown in Figure 6-31, with the centroids of each age / sex class visible as four distinct areas. Table 13 shows the result of the analysis for predicting group membership, following the territorial mapping.

Three functions were required to successfully identify group centroids in the data. With these limits in place 69.6% of 99 records were successfully classified into the correct age / sex class (see Table 13). Membership prediction of adolescent nests was the most successful, with 80% of nests correctly predicted as being built by adolescents. Prediction of flanged male nests was also highly successful, with 78.6% of nests correctly classified. Some confusion was apparent in the classification of flanged male nests, as 11.9% of nests were predicted to have been built by adolescents.



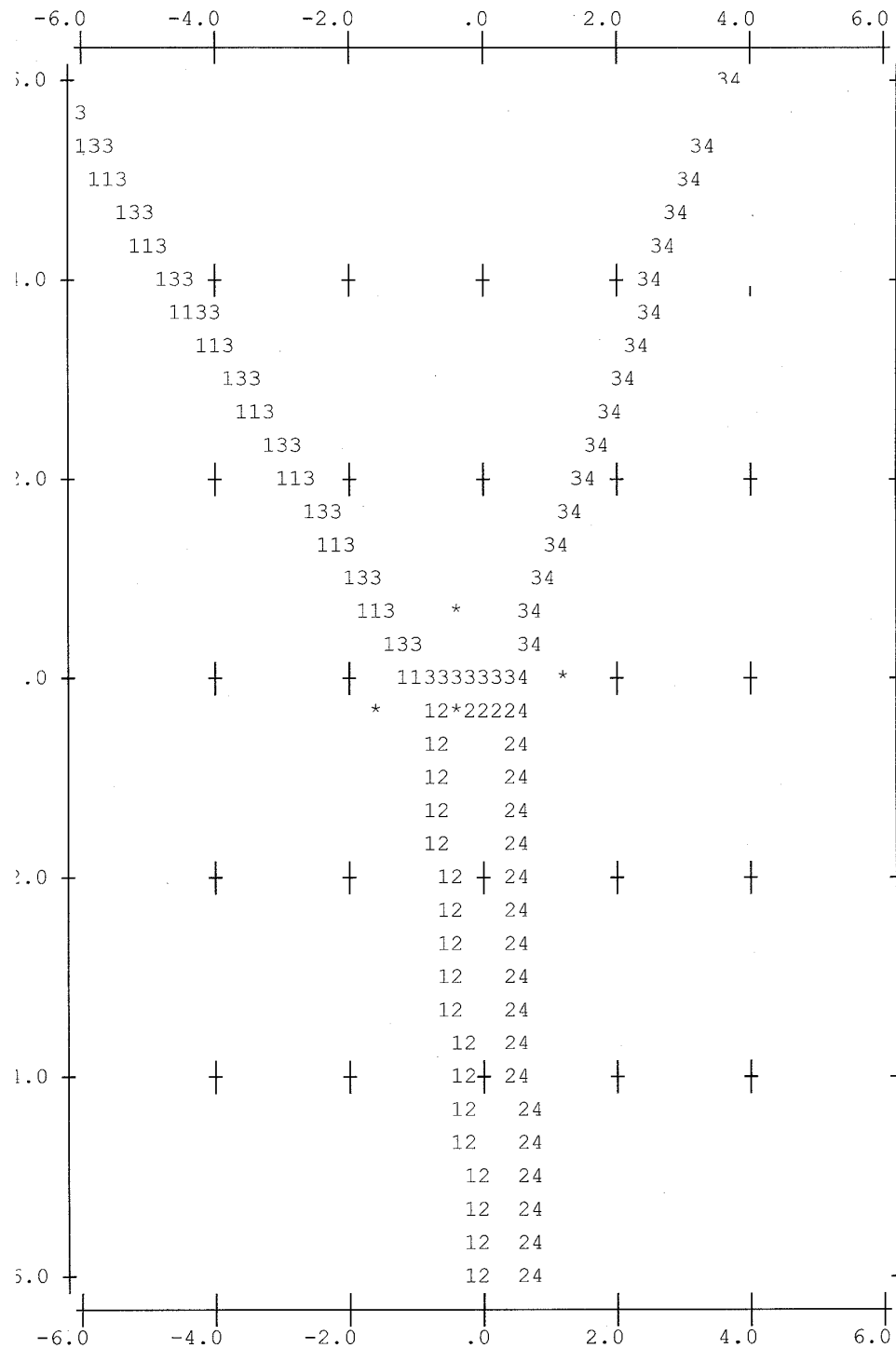
**Table 11:** Summary of results on the nesting preferences of orangutans (*Pongo pygmaeus wurmbii*) in the Sabangau National Park, an area of disturbed tropical deep-peat swamp forest in Central Kalimantan, Indonesia.

		Tree Preferences							Site Preferences				Nest Preferences			
		Tree height (m)	DBH (cm)	Roots	Canopy Health (%)	Architecture	Species	Family	Forest Quality	Interconnectivity (%)	Distance Last Food Tree (m)	Distance First Food Tree (m)	Nest Position	Construction Time (mins.)	Nest Size (m)	Nest Height (m)
Vulnerable animals	Adolescents	22.03	22.64	St	0	VII	Koompassia malaccensis	Fabaceae	2b	80	26.05	21.28	A	6	0.5-1	18.88
	Females with infants	16.52	18.61	Bt	0	VI	Koompassia malaccensis	Fabaceae	2b	60	21.63	51.37	B	5	1-1.5	15.67
Less vulnerable animals	Sub-adult males	16.12	15.06	Bt	0	IX	C. coriaceum	Anacardiaceae	2b	60	66.67	34.0	B	7	1-1.5	13.51
	Flanged males	9.46	9.37	Rt w Pn	0	III	Syzygium sp.	Anacardiaceae	2b	20	53.27	25.19	C	8	1.5-2	9.94
	Overall population	14.86	15.24	Bt	0	X	C. coriaceum	Anacardiaceae	2b	60	37.21	33.31	n/a	6.5	n/a	14.71

**Table 12:** Numerical Data Codes for Multivariate Analysis.

<b>Age / sex</b>		<b>Forest Quality</b>	
Adolescent	1	2a	1
Sub-adult male	2	2b	2
Female with infant	3	3	3
Flanged male	4	3a	4
		3 2/b	5
<b>Sap</b>		<b>Species</b>	
Yes	1	Camptosperma Coriaceum	1
No	0	Xylopia fusca	2
<b>Roots</b>		Koompassia malaccensis	3
Stilts	1	Mezzettia leptopoda	4
Buttresses	2	Mezzettia umbellaa	5
Rooted	3	Xylopia malayana	6
Rooted with breathing roots	4	Shorea sp.	7
<b>Height or DBH or Distance class</b>		Elaeocarpus masterii	8
0-5	1	Tetractomia tetrandra	9
6-10	2	Nephellium lappaceum	10
11-15	3	Tristaniopsis obovata	11
16-20	4	Macaranga sp.	12
21-25	5	Garcinia sp.	13
26-30	6	Cratoxylon glaucum	14
31-35	7	Diospyros borneensis	15
36-40	8	Calophyllum sclerophyllum	16
41-45	9	Calophyllum hosei	17
46-50	10	Neoschortechinia kingii	18
51-100	11	Syzygium sp.	19
101-150	12	Lithocarpus conocarpus	20
151-200	13	Nephellium maingayi	21
201-300	14	Tetramerista glabra	22
301-500	15	Polyalthia sp.	23
500+	16	Lithocarpus dasystachys	24
<b>Weather at time of construction</b>		Knema intermedia	25
Dry	0	Garcinia bancana	26
Light rain	1	Litsea elliptica	27
Heavy rain	2	Palaquium sp.	28
Light wind	3	Dactylocladus stenostachys	29
Strong wind	4	Litsea sp.	30
<b>Tree Family</b>			
Anacardiaceae	1	Annonaceae	2
Fabaceae	3	Myrtaceae	4
Sapindaceae	5	Fagaceae	6
Dipterocarpaceae	7	Euphorbiaceae	8
Clusiaceae	9	Rutaceae	10
Ebenaceae	11	Hypericaceae	12
Tetrameristaceae	13	Lauraceae	14
Sapotaceae	15	Crypteroniaceae	16

**Figure 6-31:** Territorial map produced as a result of canonical discriminant function analysis, identifying group centroid points from the data representing the identity of each age / sex class.



\* indicates centroid cluster point

**Table 13:** Results of age / sex class classification following discriminant function analysis on selected variables (n = 99).

		ageclass	Predicted Group Membership				Total
			1	2	3	4	
Original	Count	1	16	1	3	0	20
		2	1	11	4	2	18
		3	5	3	11	3	22
		4	5	2	2	33	42
	%	1	80.0	5.0	15.0	.0	100.0
		2	5.6	61.1	22.2	11.1	100.0
		3	22.7	13.6	50.0	13.6	100.0
		4	11.9	4.8	4.8	78.6	100.0

a 69.6% of original grouped cases correctly classified.

Prediction of nest membership for the sub-adult males and females with infants was less accurate, although still significant, with 50% success for females nests and 61.1% success for sub-adult male nests. Adult female nests were most commonly confused as adolescents (22.7% of nests), with equal incorrect classification as either a sub-adult male or a flanged male nest. The nests of sub-adult males were most commonly confused as belonging to adult females. This is an interesting result and was expected as a large proportion of follow nest data was obtained from a sub-adult male / female with infant consortship, which obviously affected the nesting behaviour of the individuals involved. This explains the confusion in Table 13, and may be easily overcome by subsequent studies using larger samples and ignoring nests made during consorts.

### 6.7.2 Rules for Predicting Nest Membership

As the multivariate analysis was successful in predicting age / sex class identity of nest builders, a process known as ‘rule induction’ (Smith, GD, unpublished report) was used to formulate a set of simple rules, by which the nest builders age / sex class may be predicted for any observed nest in the field.

Rule induction describes a range of techniques used to extract patterns in the form of rules. In this case they are classification rules of the form:

**IF** (*condition*) **THEN** *class*                      or                       $\alpha \Rightarrow \beta$ .

Where, *condition* is either a single condition on one of the predicting attributes (eg, nest height below 10m), or a conjunction of single conditions (eg, nest height below 10m **AND**  $\geq 6$  supporting trees). Any record in the dataset that satisfies the condition is then classified by the rule as belonging to *class*. Here,  $\alpha$  is referred to as the **antecedent** of the rule, and  $\beta$  as the **consequent** of the rule. Obviously, there are many rules that could be induced from the data. The question asked was; what is the best rule to predict nest membership of a specific class?

The data,  $D$ , has 114 records. Assuming that each record in  $D$  has  $n$  attributes (features),  $F_i$ , and that each  $F_i$  is defined over domain  $DM_i$ . For example,  $F_1$  may be a binary-valued attribute (0 = new nest, 1 = reused nest) so  $DM_1 = \{0,1\}$ . We are asked to discover a rule of the form  $\alpha \Rightarrow \beta$  that appears to hold for some records in  $D$ . Let  $r$  denote a record in  $D$ .

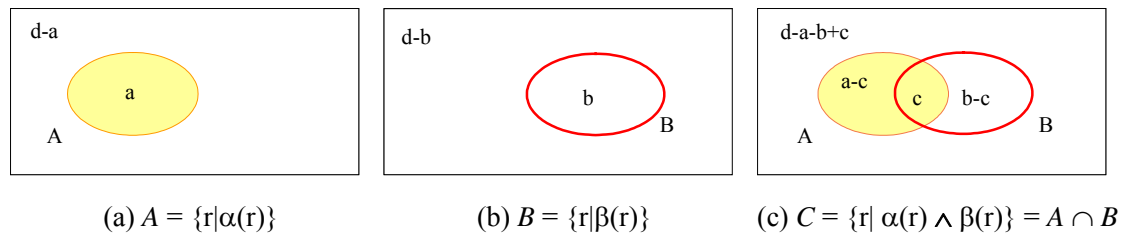
Associated with any rule  $\alpha \Rightarrow \beta$  are three sets of records:

v       $A = \{r | \alpha(r)\}$  is the set of records matching the condition and hence classified as belonging to a particular class. Let  $a = |A|$ .

v       $B = \{r | \beta(r)\}$  is the set of records that actually belong in this class. This is fixed for each class/data set. Let  $b = |B|$ .

v       $C = \{r | \alpha(r) \text{ AND } \beta(r)\} = A \cap B$ . Thus  $C$  is the set of records that are accurately classified by the rule. Let  $c = |C|$ .

These sets are better understood with reference to Figure 6-32.



**Figure 6-32:** In rule induction, the three sets of records associated with a single rule  $\alpha \Rightarrow \beta$ .

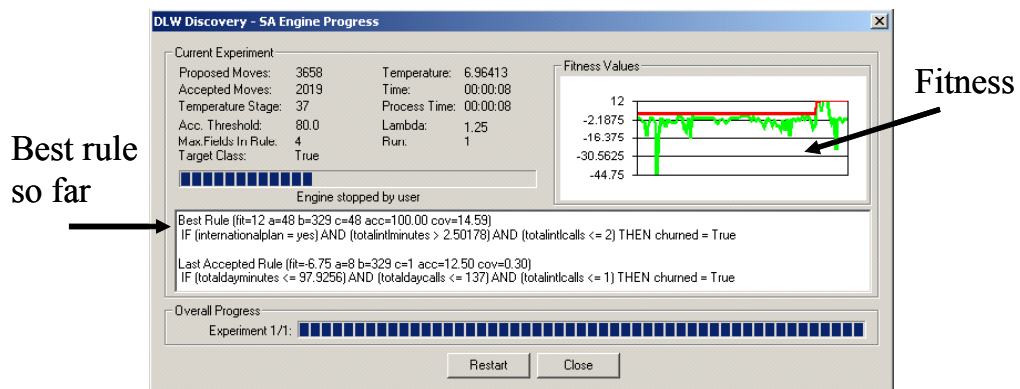
Set  $B$  represents the target class. The set  $A$  denotes those records matching the condition part of the rule and hence predicted to belong to this class, whether correct or not. The set  $C$  represents those records matching the condition part of the rule and correctly predicted by the rule. 2 quality measures relate to any rule:

✓ **Accuracy** is a measure of how often the rule is correct. Measured by the number of records correctly predicted, expressed as a proportion of the number of records matching the condition part, i.e.  $\text{accuracy} = c/a$ . (Also referred to as **confidence**.)

✓ **Coverage** is a measure of the proportion of the data that is correctly predicted, i.e.  $\text{coverage} = c/b$ .

Ideally, a rule with 100% accuracy and 100% coverage, i.e.  $A = B = C$  is desirable. However, in reality, accuracy and coverage are competing objectives. By introducing more conditions into  $\alpha$  to increase the accuracy, the rule becomes more specific, covering fewer records. Hence coverage decreases. In the same vein, very general rules can have good coverage but less accuracy (Smith, G.D., unpublished report).

Members of the Department of Computing Studies Research group at the University of East Anglia developed a system to search for optimal rules based on a fitness function  $f = \lambda c - a$ . It is the main discovery engine of the software Witness Miner. Figure 6-32 shows a screenshot of the Witness Miner discovery process at work.



**Figure 6-33:** The Witness Miner rule discovery engine based on simulated annealing (courtesy G.Smith, School of Computing, University of East Anglia).

### 6.7.2.1 Rules for Adolescent Nests

See Table 12 for numerical variable codes.

1. **IF** (Treefamilycode <= 5)  
    **AND** (surroundhealth > 2)  
    **AND** (nestheightcode > 3)  
    **THEN** ageclass = 1  
    a = 23.6667, b = 20, c = 16  
  
    Accuracy = 67.61, Coverage = 80.00.

2. **IF** (speciescode <= 15)  
    **AND** (Treefamilycode <= 11)  
    **AND** (treeheightcode > 4)  
    **AND** (nestheightcode <= 4)  
    **THEN** ageclass = 1  
    a = 7, b = 20, c = 7  
  
    Accuracy = 100.00, Coverage = 35.00.

Using rule 1, of 20 adolescent nests available, 16 nests were correctly classified, giving 80% coverage and almost 68% accurate classification. Rule 2 although achieving 100% accuracy, only 7 of the 20 nests are included.

### 6.7.2.2 Rule for Adult Female with Infant Nests

1. **IF** (lftdistcode <= 10)  
    **AND** (supportingtrees <= 11)  
    **AND** (nestheightcode > 1)  
    **THEN** ageclass = 3  
    a = 87, b = 32, c = 29.3333  
  
    Accuracy = 33.72, Coverage = 91.67.

Just one acceptable rule was deduced for predicting adult female with infant nest membership. However, the 92% coverage provides a very acceptable level of accuracy, well above the default 25%.

### 6.7.2.3 Rules for Sub-adult Male Nests

1. **IF** (speciescode <= 24)  
    **AND** (dbhcode <= 9)  
    **AND** (basaldiam <= 15)  
    **AND** (surroundhealth > 4)  
    **AND** (nestposition > 1)  
    **AND** (supportingtrees <= 12)  
**THEN** ageclass = 2  
a = 8, b = 19, c = 8

Accuracy = 100.00, Coverage = 42.11.

2. **IF** (dbhcode <= 4)  
    **AND** (surroundhealth > 4)  
    **AND** (nestposition > 1)  
**THEN** ageclass = 2  
a = 14, b = 19, c = 10

Accuracy = 71.43, Coverage = 52.63.

3. **IF** (Treefamilycode <= 11)  
    **AND** (basaldiam > 8)  
    **AND** (surroundhealth > 1)  
    **AND** (nestposition > 1)  
**THEN** ageclass = 2  
a = 40.75, b = 19, c = 16.75

Accuracy = 41.10, Coverage = 88.16.

The three rules above contribute, with varying levels of accuracy and coverage, to the classification of sub-adult male nests. Rule 1 reports 100% accuracy in predicting nest membership; although coverage is less than half. Coverage was increased to just over 50% by compromising accuracy (71% in Rule 2) and increased further (88% in Rule 3) by lowering acceptable accuracy even further, although 41% accuracy is an acceptable level. All three rules have been included as an illustration of what is possible with the data collected, in the field these rules may be used in conjunction with each other to predict any nest membership. Accuracy and coverage would be improved with a larger sample size, discussed in Section 7.



#### 6.7.2.4 Rules for Flanged Male Nests

1. **IF** (Treefamilycode <= 17)  
**AND** (treeheightcode <= 2)  
**THEN** ageclass = 4  
a = 37, b = 43, c = 30  
  
Accuracy = 81.08, Coverage = 69.77.
2. **IF** (treeheightcode <= 2)  
**THEN** ageclass = 4  
a = 40, b = 43, c = 30  
  
Accuracy = 75.00, Coverage = 69.77.
3. **IF** (speciescode > 5)  
**AND** (treeheightcode <= 2)  
**THEN** ageclass = 4  
a = 32, b = 43, c = 27  
  
Accuracy = 84.38, Coverage = 62.79.

Rules for predicting flanged male nests are implicitly simple, with high levels of accuracy and coverage. All three rules rely on the height of the nest tree as the main indicator of membership, Rules 1 and 3 also including species of the nest tree or the family of the nest tree. An interesting point, reinforcing the analysis of Section 6.3.7 where species preferences were identified. The implications of these findings are discussed in Section 7.

## 7 Discussion

Van Schaik *et al.* (2003) suggested that nests may give away so much information on their builder that they may be akin to ‘membership badges’ of the population, however, until now no method has managed to define these membership badges. This study is the first of its kind to suggest a successful model for the prediction of a nest builders identity based on tree and habitat preferences.

### *Structural Nest Tree Preferences*

Evidence of specific architectural and structural nest tree preferences were found in the resident orangutan population of the mixed swamp forest of the Sabangau National Park. Variation in these preferences between the age / sex classes was also found with high levels of statistical significance. Nesting orangutans have changeable preferences; different sexes at different stages of maturity have capricious needs and desires which reflect their status in the population and the availability of materials in the habitat.

Adolescents represent the most vulnerable animals in the population; their preference for nesting higher than other members of the population reflecting their susceptibility to potential danger, flanged males at the top of the dominance ratings, nest significantly lower than the rest of the population. This finding supports that found by Sugardjito (1983) from Sumatra, and shadows the behaviour of the African apes; of which the mountain gorilla (*Gorilla gorilla beringei*) demonstrates the best example of convergence; where males nest on the ground and guard females and adolescents, who nest above the silverback (Fruth and Hohmann, 1996, Redmond, I., Pers. Comm).

The highly significant differences found between the nest trees of the age / sex classes in the present study reveals definite hierarchical positions within the population which forms the basis of membership prediction. Vulnerable animals demonstrated strong preferences for large trees (over 15cm DBH, and 12.5m high) suggesting that tree choice may be based primarily on the height required for individuals’ needs (assuming need is the avoidance of hazard or confrontation). Female Bornean orangutans are known to be potentially at risk from males, particularly sub-adults, who will often attempt to force copulation (Galdikas, 1985; personal observation) and may pose a risk to infants. Nesting

higher than more dominant animals therefore minimizes conspecific contact, however the results of the present study for females and sub-adult males found no significant difference in the size of trees chosen for nesting. The assumption that females would be avoiding this group is therefore contradicted. Explanation is offered by way of an intense period of forced copulations observed during the period of field work. One adult female traveling with a weaning infant was harassed over a period of weeks by several sub-adult males, during which time repeated attempts at copulation were observed, causing the female and her infant signs of distress and visibly corrupted behaviour. Throughout this period of coercion, nests produced by the female were largely ignored by the present study, however on occasion when she was observed to travel and feed as normal, her nests were included. The findings of the analysis may be evidence that her behaviour was not in fact back to 'normal' and that her nesting behaviour continued to be affected by the sub-adult males shadowing her.

The nests of flanged males were largely integrated, using smaller 'less-stable' trees, with breathing roots. Integrated nests with 'less stable' trees were also produced, to a lesser degree by sub-adults and females. It is suggested that trees with breathing roots, used in integrated nest construction may provide a secure but flexible base in the peat; the interweaving above and below ground networks maintaining a stronger, flexible hold in the ground; it appears that the structural characteristics of nest trees used by the different cohorts, suit the projects for which they are undertaken. The higher single-tree nests favoured by the adolescents, and the females, achieve optimum stability with stronger, more durable, deeper roots.

The population preferred trees with poor leaf cover. Females with infants and flanged males actively avoided closed canopy trees in favour of those more open. Adolescents preferred semi-covered canopies, which may support the theories of MacKinnon (1974), Harrison (1969) and Rijksen (1978) who suggest that nest trees are chosen which offer good 'look-out' positions. The avoidance of completely closed, or 'healthy' canopies, despite the protection afforded by these trees, may be a result of the higher diversity of life supported in such branches and the disturbance which these other organisms provide. Nesting orangutans appear to relish the peacefulness afforded by a tree in which they are the sole occupant.

### *Architectural Nest Tree Preferences*

Preference for the architectural arrangement of nest trees was found to exist; although it was not a defining character of potential nest trees. Trees with monopodial or alternate and continuous branching patterns were preferred over those with continuous-rhythmic or sympodial branching.

Figure 6-15 highlighted an interesting point with regard to the Jacob's Preference Indices calculated for architecture and species. Type I architecture shows a  $D = +1$  result, implying that the population actively sought trees with this architecture. In fact the raw data shows that type I architecture was used in just 1% of nest trees, and as none of the trees surveyed in the habitat plots were found with a type I architecture, the calculation awards a  $D = +1$ ; which, when drawing conclusions regarding preferences, leads to a biased answer. It can not be concluded that the population sought out type I architecture for nest building. It is more likely that this result was due to chance. The same can be said for type VI architecture, which represented just 7% of 291 nests. Those results which may be concluded as relevant are weaker but the fact that so many of the nests used these trees does raise the question of whether this can really be completely due to chance. Architecture X, accounted for over half of all nests and types II and IX (although used for fewer constructions) are also weak preferences. It is concluded that the monopodial architectures which these trees provide, with distally arranged, open crowns, provide the ideal architectural nest building platform. If Fruth and Hohmann's (1996) idea of the proto-feeding-nest is to be believed, the progressive development of nest building behaviour would require an architectural arrangement permitting such behaviour and the open arrangement of type X would allow this. The avoidance of types V and VII is also justified by this argument as their oblique, busy, continuous and sympodial branching patterns would not lend themselves well to the intricate manoeuvres of a platform-building ape.

Architectural preferences of the age / sex classes varied, each class demonstrating their own preferences for particular architectural unit arrangements to meet their individual requirements. Adolescents preferred type VII trees, with open, alternate, lateral branches. Type III, was avoided, probably due to the density of the canopies arising from a closed branch arrangement.

Females with infants demonstrated distinct preference for type VI, another alternate system of architecture, which may provide slightly more cover than types X or IX (dependant on the health of the specimen). In common with adolescents, nesting mothers also avoided type III trees.

Flanged males, on the other hand preferred the alternate branching arrangement of type III trees, probably of a more practical use for integrating trees. The profusion of continuous branches possibly provides more opportunity for inter-weaving and multiple canopies providing profusions of leaves for padding and lining the nest. Sub-adult males however preferred type IX trees, very similar in arrangement to type X except for the alternating horizontal branches, which would permit the inward bending of distally-covered branches.

### *Species Preferences*

With regard to nest tree species, Sabangau orangutans behaved in line with findings of studies on chimpanzees (Baldwin *et al.*, 1981) and bonobos (Kano, 1983) and chose nest trees according to species. *Camnosperma coriaceum* accounted for a quarter of all nest trees and was chosen by all age / sex classes. This species, of the family Anacardiaceae is typically described as a medium to large sized tree, of a medium girth (< 20cm DBH) with a somewhat open, spreading canopy, no sticky exudate is produced; a characteristic preferred by 94% of the population and the trunk is mainly stilted (although specimens may possess buttresses), the parallel, monopodial branches have distally positioned large, waxy leaves (Anderson, 1972).

Trees of the genus *Syzygium* (formerly *Eugenia*), were also preferred for nesting by the population, accounting for 7% of nest trees. *Syzygium* is a member of the family Myrtaceae; generally small trees, common in peat swamp forests (Anderson, 1972). Specimens are generally a type III or X architecture and they are characteristically a dense hard wood with papery bark lacking exudates, known for their strength and lack of durability.

*Litsea elliptica* of the family Lauraceae is another medium-sized tree, commonly described as a colonizing species of exploited areas (Anderson, 1972). All *L. elliptica* specimens possessed type X architecture with stilts or small buttresses. In terms of

forestry, Lauraceae are light hardwoods of varying density and are not durable when growing in swamps (Anderson, 1972).

*Koompassia malaccensis*, of the family Fabaceae (formerly Leguminosae) accounted for 5% of nests in the forest. These trees are true giants, capable of reaching over 50m in height and over 3m in girth, although in the mixed swamp they reached just over 30m and 40cm DBH, representing one of the largest trees in the forest. *Koompassia malaccensis* possesses type VII architecture; their tall straight boles giving way to large alternating branches with an open, distally-arranged canopy.

*Shorea sp.* accounted for 6% of all nest trees, consistently a third preference among the cohorts. These Dipterocarpaceae are medium to giant-sized trees, although in the mixed swamp none exceeded 30 metres. Economically, these trees are highly valued (most illegal logging evidence in the study area was based around *Shorea sp.*). Swamp growing *Shorea sp.* are dense hard woods, with no sticky exudates.

*Xylopia fusca* was another preferred nesting species. It is a member of the Annonaceae family and in many ways these small to medium-sized trees possess similar properties to *Camposperma coriaceum* with parallel monopodial branching, distally-arranged open canopies and stilted trunks. Annonaceae specimens also preferred by the population for nesting included *Mezzettia umbellata*, *M. leptopoda* and *Polyalthia sumatrana*; all abundant in mixed swamp forests and said to be completely non-durable (Anderson, 1972). Despite this, Annonaceae was the most commonly used Family of trees, their characteristics concluded to be the best suited to the needs of nesting orangutans. As a commercial commodity Annonaceae trees are not highly sought after, the wood being rather coarse and soft; good news for the orangutans.

Selectivity of species was most pronounced in the adolescents who used just 8 species for 20 nest constructions; *C. coriaceum* accounted for 30% of all adolescent nests, 22% were made in each of *Xylopia fusca* and *Koompassia malaccensis*. Sub-adult males selected 9 species for the 18 nests assessed, *C. coriaceum* again the preferred species, representing over 30% of nest trees. *Shorea sp.* was the second preferred species of the sub-adults, with 17% of nests in these trees. Females with infants selected 11 species for nest building; again they used two main species for nest building, *C. coriaceum*, used in 37% of events and *K. malaccensis* used in 18%.

Flanged male nesting behaviour was slightly different to the other groups, the number of species they employed in their nest building exceeded 20, with *C. coriaceum* accounting for 10% of nest trees and *Syzygium* sp. accounting for 15%. Because of their sheer size, flanged males require well-supported, robust nests. This means that they produce mainly integrated tree-tied nests, and choose a selection of trees with different properties. The same pattern has been observed in adult male bonobos (Kano, 1983; Fruth and Hohmann, 1994).

At most flanged male nesting sites it was not possible to judge any one main tree supporting an integrated nest. Nests varied from two to as many as thirteen supporting trees; and in many cases the properties of these trees were indistinguishable. It was for this reason that all supporting trees were included in the analysis rather than guessing at a main supporting tree which the animal may or may not have chosen. The use of multiple integrations for nest building has also been reported in the bonobos (Kano, 1983) and also in female and sub-adult mountain gorillas (I. Redmond, Pers. Comm.) who may construct large, mattress-type nests in the herbaceous layers of the forest. In the chimpanzees, the use of multiple integrations are said to be an exception, rather than the rule (Goodall, 1962).

It appears that flanged males especially, choose species in particular, with qualities which lend them to being easily bent, which are not heavily laden with leaves, and which do not exude copious amounts of latex-like sap when they are broken. This technique allows them to use saplings which could not otherwise be used in nest building.

### *Nest Preferences*

With regard to the position of the nests of different members of the population, the flanged males as already discussed preferred integrated nests and adolescents only ever made nests supported by a single tree. This may be due to the fact that they are lighter in body mass and do not require the support of additional trees, or it may be that they do not possess the skill to produce the more complex integrated structures. If nest building is a cultural variant, then the lack of skill in adolescents supports this supposition. Sub-adult males represent the least fastidious nest builders in the population their choice of nest position highly variable; although most were built out on branch limbs. The behaviour of

the females with infants was affected by the sub-adult males and the high incidence of integrated nests observed is most probably a result of their nesting lower than they normally would; the lack of trees large enough to support them forcing the production of integrations.

Ignoring the adult females nests made under duress, they, and the sub-adult males both preferred position 'B' nests, which may be a strategy to minimize disturbance. Position B nests are the most concealed, while nests in position 'A' are more visible. Nests in position 'D' may leave the occupant open to disturbance and more exposed to environmental factors. There may also be some psychological safety benefit to the nest occupant from nesting in the body of the tree (position 'B'), rather than the exposed crown (position D). 'C' position nests, usually sit on the top of the trees that have been brought together, which for the dominant animals does not pose any problems, but for those of a more vulnerable position may appear less secure and too open. As mentioned above, in the case of the adult females producing 'C' nests this may have been a case of making the best of what was available when the sub-adult males harassing her prevented her normal nesting behaviour. An alternative explanation of course, is that she was behaving as a female gorilla with a sub-adult male and may have felt at ease with her persuer nesting lower than she normally would. This may have been an acceptable explanation had I not witnessed her distress at the situation first hand. Consequently it is concluded that her integrated nests were an anomaly, produced opportunistically as she tried to conceal herself in the shrubbery from he persuers.

The sizes and complexities of nests were not found to differ as much as was predicted. Nest size therefore could not be relied on for the prediction of nest membership. With regard to nest construction times, flanged males spent the longest, a reflection of the complexity of their integration nests. Sub-adult males also spent longer to construct nests than the adolescents, who surprisingly took longer than the adult females with infants, who may take longer building nests while weaning their infant. Statistically it was only the females and flanged adult males who showed any significant difference in the time spent between the age / sex classes.

The conclusion may be drawn that flanged males construct the most complex nests, implying that they are the best skilled in their use of tools. An alternative explanation for



these construction times concerns vulnerability to predators and conspecifics. If vulnerable animals are minimizing time spent on construction this also minimises the amount of time they are occupied and not aware of other surroundings, completing a nest and occupying it quickly is more beneficial, especially as nest building occurs at dusk when animals may be more at risk (MacKinnon, 1974; Rijksen, 1978). Less-vulnerable animals can afford to be unaware as they are less susceptible to predators and conspecifics, they are less threatened and more confident, they do not hide in the nest like adolescents and females and so spending longer on a more complex, and perhaps more comfortable nest would be their prerogative.

Nest reuse as predicted by Galdikas (1982) and MacKinnon (1974) was also extremely rare in the Sabangau with an incidence of just 1.4%. This may be an adaptive strategy of the population to avoid habitual predators, such as the clouded leopard and reticulated pythons (Rijksen, 1978), although without baseline predation surveys in the area this is speculation.

#### *Nest Site Preferences*

Nest site selection is thought to be influenced by environmental factors including predator avoidance and habitat type (MacKinnon, 1974; Sugardjito, 1983; Boesch, 1991). MacKinnon (1974) suggested that situating nests adjacent to forest gaps may enable orangutans to increase predator detection.

In contradiction to work in Sumatra (Sugardjito, 1983), less vulnerable animals were nested closer to their last food trees than vulnerable animals. There was also a much higher incidence of these animals nesting in their food trees and just one incident of a flanged male sleeping in his last food tree. Statistically the findings of the present work did not find significant differences in the distances the cohorts nested from food trees. Although in contradiction to Sugardjito (1983), similar findings exist for chimpanzees and bonobos, who rarely build their nests in fruiting trees (Goodall, 1962; Fruth and Hohmann, 1993). The dry hill forests in Sumatra where Sugardjito conducted his study are fruit-rich environments, with plentiful fleshy-pulped fruit available year-round. However, as discussed in Section 3.6, the mixed swamp forest of the present study is known for its variable fruit production. The findings of nest distance to feeding trees are

likely to vary seasonally and species chosen for nesting may also vary seasonally as they come in and out of fruit. Further investigation to increase the available sample size over a longer time frame is recommended to confirm these findings as insufficient data was available to the present study. Correlations between crop size and distance to nest could also not be completed due to inadequate sample sizes, however it is expected that smaller distances would be traveled where larger crop sizes are available and if less-vulnerable animals do dominate fruiting trees then they would then be expected to be found nesting closer to them, further work is required for conclusion to be made.

### *Disturbance*

Russon *et al.* (2001) found that disturbed and sometimes seriously degraded areas yielded high densities of nests. Previous work predicted that orangutans may build their nests close to look-outs, or gaps in the canopy (Harrison, 1969; Kurt, 1971; MacKinnon, 1974; Rijksen, 1978), however as orangutans are largely unalert whilst inside the nest, this study predicted that the Sabangau orangutans may be nesting in more camouflaged, less-disturbed areas, where a high degree of interconnectivity existed between the tree canopies. In fact what was found supports the prediction of the previous workers. The population preferred sites which were open with trees possessing low degrees of interconnectivity. The preferential differences within the population vary subtly. Adolescent nest trees tended to be semi-open, with around 40% cover, females with infants preferred even more open canopies of around 20% cover. The sub-adult males chose the most concealed sites, preferring 60% cover and the flanged males chose to nest in very open areas of 0-20% cover. Figure 6-30 demonstrates how the more open canopies used by vulnerable members of the population occur in the most disturbed areas of the forest around the canals and railway. It may therefore be that rather than preferring more exposed areas, as 'nest look-outs' the vulnerable animals were pushed into these areas by the more dominant animals, who may be dominating the less disturbed areas. The health of the surrounding forest, or the interconnectivity of nest trees was found to be quite an important parameter in the identification of nest membership, particularly the sub-adult male nests.

Apparent preferences for openness were also indicated by the forest quality assessment, where the population appeared to choose areas where total canopy cover was <50%; forest obviously subjected to disturbing factors. Open areas chosen by the patrolling flanged males would therefore be a result of using forest representing that which is the best available. Due to the inconclusive nature of the habitat quality preferences, this parameter cannot be included in the prediction of nest membership. However, for the present study at least, Figure 6-30 will be supportive in the prediction process.

At some time in the future this study recommends an in depth assessment of the range of forest qualities available in the study area, in order to draw further conclusions as to whether this choice of habitat was indeed made by the population, or whether the population is forced to make use of what is available in the area.

#### *Prediction of Nest Membership*

The present study is the first of its kind to be successful in formulating a model for the prediction of a nest builder age and sex identity. Studies have tried and failed in the past (E. Fox, unpublished), I believe because they have failed to look closely enough at individual preferences apparent in the populations. Although not 100% accurate, with increased data sets future study will improve on the present findings. The present findings are still highly relevant and accuracy and coverage of the data is of a high standard considering the quantity of data available. Whether the rules set out are relevant to field workers with other populations and in other habitats remains to be investigated. Parameters found to be of primary importance in the identification of nest membership were; for adolescent nests, tree height (and DBH to a secondary degree) and species. For adult female with infants; nest height and the number of nest-supporting trees. Sub-adult male nests are best identified by the interconnectivity of the nest tree canopy, DBH, and the nest position, and flanged male nests are easily identified by the tree or nest height, and the species used in construction.

#### *Concluding Remarks*

The present work has presented vitally important information on the nesting habits and preferences of orangutans living in the disturbed lowland peat swamp forests of

Kalimantan. The model for predicting nest builder age / sex class identity is a breakthrough, tried and failed by previous workers it will hopefully serve to advance cultural studies of the great apes

Due to the limitations on the present work, it is recommended data continue to be collected on the Sabangau population so that classification methods for predicting nest membership may be further advanced.

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## Appendix A

### A.1 Species used as Nest Trees.

Family	Species
Anacardiaceae	Camptosperma coriaceum
Anisophyllaceae	Combretocarpus rotundus
Annonaceae	Mezzettia leptopoda
Annonaceae	Mezzettia umbellata
Annonaceae	Polyalthia sumatrana
Annonaceae	Sp. 1
Annonaceae	Xylopia fusca
Annonaceae	Xylopia malayana
Apocynaceae	Dyera lowii
Burseraceae	Santiria laevigata
Chrysobalanaceae	Licania splendens
Clusiaceae	Calophyllum hosei
Clusiaceae	Calophyllum sclerophyllum
Clusiaceae	Calophyllum sp.
Clusiaceae	Garcinia sp.
Clusiaceae	Garcinia bancana
Crypteroniaceae	Dactylocladus stenostachys
Dipterocarpaceae	Cotylebium lanceolatum
Dipterocarpaceae	Shorea sp.
Ebenaceae	Diospyros pseudomalabarica
Ebenaceae	Diospyros borneensis
Elaeocarpaceae	Elaeocarpus masterii
Euphorbiaceae	Neoscortechinia kingii
Euphorbiaceae	Macaranga sp.
Euphorbiaceae	Neoscortechinia sp. 1
Fabaceae	Koompassia malaccensis
Fagaceae	Castanopsis sp.
Fagaceae	Lithocarpus dasystachys
Hypericaceae	Cratoxylon glaucum
Icacinaeae	Stemonurus scorpiodes
Icacinaeae	Stemonurus scorpiodes
Lauraceae	Litsea elliptica
Lauraceae	Litsea sp.
Lauraceae	Litsea sp.2
Melastomataceae	Pternandra glaeata
Meliaceae	Aglaia rubiginosa
Meliaceae	Sandoricum beccanarium
Myristicaceae	Gymnacranthera farquhariana
Myristicaceae	Horsfeldia crassifolia
Myrtaceae	Syzygium sp.
Myrtaceae	Tristanopsis obovata
Rutaceae	Tetractomia tetrandra
Sapindaceae	Nephellium lappaceum
Sapindaceae	Nephellium sp.

Sapotaceae	Madhuca mottleyana
Sapotaceae	Palaquium cochlearifolium
Sapotaceae	Palaquium pseudorostratum
Sapotaceae	Palaquium sp.
Sapotaceae	Palaquium sp.1
Tetrameristicaceae	Tetramerista glabra
Thymeleaeceae	Gonystylus bancanus

Appendix A.2 Floral List for the Sabangau National Park

Family	Genus	Species	Type	Local Name	Indonesian name
Anacardiaceae	Bouea	oppositifolia	T	Tamehas ?	
Anacardiaceae	Campnosperma	coriaceum	T	Terontang	
Anacardiaceae	Campnosperma	squamatum	T	Nyating	
Anisophyllaceae	Combretocarpus	rotundatus	T	Tumih	Tanah Tanah
Annonaceae	Artobotrys	suaveolins	Liana	Bajakah Balayan	
Annonaceae	Artobotrys	cf. roseus	Liana	Kalalawit Hitam	
Annonaceae	Fissistigma	sp. 1	Liana		
Annonaceae	Mezzetia	leptopoda / parviflora	T	Keripak	Pisang Pisang
Annonaceae	Mezzetia	umbellata	T	Kambalitan Hitam	Pisang Pisang
Annonaceae	Polyalthia	hypoleuca	T	Rewoi	Alulup
Annonaceae	Polyalthia	sp. 1	T	Kayu Bulan	
Annonaceae	Xylopi	coriifolia	T	Nonang	
Annonaceae	Xylopi	cf. malayana	T	Tagula	
Annonaceae	Xylopi	fusca	T	Rahanjang	Jangkang
Annonaceae	sp. 1		T	Kerandau	
Apocynaceae	Alyxia	sp. 1	Liana	Kelanis	
Apocynaceae	Dyera	lowii	T	Jelutong	Pantong
Apocynaceae	Willughbeia	sp. 1	Liana	Bajakah Dango	
Aquifoliaceae	Ilex	cymosa	T		
Aquifoliaceae	Ilex	hypoglauca	T	Sumpung	
Araceae	Raphidophora	sp. 1	Liana		
Araliaceae	Schleffera	sp. 1	T		
Araliaceae	Schleffera	sp. 2	vine	Sapahurung	
Arecaceae	Calamus	sp. 1	Climber	Uey Liling	Rotan
Asclepiadaraceae	Astrostemma	spartioides	Epi	Anggrek Rangau	
Asclepiadaraceae	Dischidia	cf. latifolia	Epi		
Asclepiadaraceae	Dischidia	sp. 1	Epi		
Asclepiadaraceae	Dischidia	sp. 2	Epi	Bajakah Tapuser	
Asclepiadaraceae	Hoya	sp. 1	Epi		

Family	Genus	Species	Type	Local Name	Indonesian name
Burseraceae	Canarium	sp. 1	T	Geronggang Putih	
Burseraceae	Santiria	cf. laevigata	T	Irat	Kayu Sapat
Burseraceae	Santiria	sp. 1	T	Gerronggang Putih	? Teras Bamban
Burseraceae	Santiria	sp. 2	T	Geronggang Putih	
Burseraceae	Santiria	cf. griffithi	T	Teras Bamban	
Celesteraceae	Lophopetalum	sp. 1	T		Kayu Prupuk??
Chrysobalanaceae	Licania	splendens	T	Bintan	? Milas merah
Clusiaceae	Callophyllum	cf. fragrans	T	Kapurnaga Kalakei	
Clusiaceae	Callophyllum	hosei	T	Jinjit	Bintangor
Clusiaceae	Callophyllum	cf. lanigerum	T	Mahadingan	
Clusiaceae	Callophyllum	sclerophyllum	T	Kapurnaga	Penaga Jangkar
Clusiaceae	Callophyllum	soulattri	T	Takal	
Clusiaceae	Callophyllum	sp. 1	T		
Clusiaceae	Callophyllum	sp. 2	T	Mahadingan	
Clusiaceae	Callophyllum	sp. 3	T	Kapurnaga Kalakei	Kapurnaga Laut
Clusiaceae	Callophyllum	sp. 4	T	Kapurnaga Kalakei	
Clusiaceae	Callophyllum	sp. 5	T	Kapurnaga Kalakei	Kapurnaga Laut
Clusiaceae	Garcinia	bancana	T	Manggis	Manggis Hutan
Clusiaceae	Garcinia	sp. 1	T	Aci	? Manggis Coklat
Clusiaceae	Garcinia	sp. 2	T		
Clusiaceae	Garcinia	sp. 3	T	Gantalan	
Clusiaceae	Garcinia	sp. 4 parvifolia	T	Gandis	
Clusiaceae	Garcinia	sp. 5	T	Manggis	
Clusiaceae	Garcinia	sp. 6 cf. cuspidata	T	Gandis	
Clusiaceae	Garcinia	sp. 7	T	Gandis	
Clusiaceae	Garcinia	sp.8 cf. hombroniana	T		
Clusiaceae	Garcinia	sp. 9	T	Gandis	
Clusiaceae	Garcinia	sp. 10	T		
Clusiaceae	Mesua	sp. 1	T	Tabaras	Pasir Pasir
Combretaceae	Combretum	sp. 1	Liana	Bajakah Tampelas ?	
Commelineaceae	Commelina	sp. 1	Vine	Tewu kaak	

Family	Genus	Species	Type	Local Name	Indonesian name
Crypteroniaceae	Dactylocladus	stenostachys	T	Mertibu	Mentibu
Dipterocarpaceae	cf. Anisoptera		T	Keruing Sabun	
Dipterocarpaceae	Cotylebium	cf. lanceolatum	T	Rasak Daun Kecil	
Dipterocarpaceae	Cotylebium	melanoxylon	T		
Dipterocarpaceae	Dipterocarpus	borneensis	T	Keruing	Keruing Bunga (11312)
Dipterocarpaceae	Shorea	balangeran	T	Kahui	Balangeran
Dipterocarpaceae	Shorea	teysmanniana	T	Meranti Sumut	Meranti Bunga
Dipterocarpaceae	Shorea	uliginosa	T	Meranti Batu	
Dipterocarpaceae	Shorea	sp. 1	T		
Dipterocarpaceae	Vatica	sp. 1	T	Rasak Napu	Rasak Daun Besar
Ebenaceae	Diospyros	confertiflora	T	Arang	
Ebenaceae	Diospyros	cf. evena	T	Gulung Haduk	Lamijo
Ebenaceae	Diospyros	lanceifolia	T	Arang	
Ebenaceae	Diospyros	pseudomalabarica	T	Aring Pahe	Malam Malam
Ebenaceae	Diospyros	siamang	T	Ehang	
Ebenaceae	Diospyros	sp. 1	T	Kayu Arang Apui	
Ebenaceae	Diospyros	sp. 7	T		
Elaeocarpaceae	Elaeocarpus	acmocarpus	T	Patanak	
Elaeocarpaceae	Elaeocarpus	cf. griffithi	T	Rarumpuit	? Pahreneng
Elaeocarpaceae	Elaeocarpus	mastersii	T	Mangkinang	Sangheh
Elaeocarpaceae	Elaeocarpus	sp. 1	T		Pasir Payau
Elaeocarpaceae	Elaeocarpus	sp. 2	T		
Elaeocarpaceae	Elaeocarpus	sp. 3	T		
Elaeocarpaceae	Elaeocarpus	sp. 4	T		Ampaning Nyatu
Euphorbiaceae	Antidesma	coriaceum	T	Dawat	
Euphorbiaceae	Antidesma	cf. cuspidatum	T	Tanundang	Matan Undang
Euphorbiaceae	Baccaurea	bracteata	T	Rambai Hutan	
Euphorbiaceae	Baccaurea	sp. 1	T	Kayu Tulang	Kopi Kopi Merah
Euphorbiaceae	Blumeodendron	kurzii / tokbrai	T	Kenari	
Euphorbiaceae	Cephalomappa	sp. 1	T	Kerandau	

Family	Genus	Species	Type	Local Name	Indonesian name
Euphorbiaceae	Macaranga	sp. 1	T	Mahang Sumut	
Euphorbiaceae	Glochidion	cf. glomerulatum	T	Buah Bintang	
Euphorbiaceae	Neoscortechinia	kingii	T	Pupu Palanduk	Nangka Nangka
Euphorbiaceae	Pimelodendron	griffithianum	T		
Euphorbiaceae	sp. 2		Vine		
Euphorbiaceae	sp. 3		T	Maha Ramin	
Euphorbiaceae	sp. 4		T	? Teras Bamban	
Fabaceae	Adenanthera	pavonina	T		
Fabaceae	Archidendron	clyperia	T	Kacing Nyaring	
Fabaceae	Dalbergia	sp. 1	Liana		
Fabaceae	Dialium	sp. 1	T	Kala Pimping Napu	Prupuk Keras
Fabaceae	Koompassia	malaccensis	T	Kempas	
Fabaceae	Leucomphalos	callicarpus	Liana		
Fabaceae	Ormosia	sp. 1	T		
Fagaceae	Castanopsis	foxworthyii / jaherii	T	Takurak	(Pampaning?)
Fagaceae	Lithocarpus	conocarpus	T	Pampaning Bayang Besar	Laja Besar
Fagaceae	Lithocarpus	sp. 1 cf. dasystachys	T	Pampaning Bayang Kecil	Laja Kecil
Fagaceae	Lithocarpus	sp. 2	T	Pampaning Rantai	Laja Besar
Fagaceae	Lithocarpus	sp. 3	T	Pampaning Bitik	
Fagaceae	Lithocarpus	sp. 4	T	Pampaning Suling	
Gesneraceae	sp. 1		Vine		
Gnetaceae	Gnetum	sp.1	Liana	Bajakah Luaa	
Hypericaceae	Cratoxylon	arborescens	T	Geronggang	
Hypericaceae	Cratoxylon	glaucum	T	Geronggang	Geronggang Merah
Icacinaceae	Platea	sp. 1	T	Kambalitan	? Pasir payau
Icacinaceae	Platea	sp. 2	T	Lampesu	
Icacinaceae	Stemonorus	malaccensis	T		
Icacinaceae	Stemonorus	cf. scorpiodes	T	Tabaras	Pasir Pasir
Lauraceae	Actinodaphne	sp. 1	T		
Lauraceae	Alseodaphne	coriacea	T	Gemur	

Family	Genus	Species	Type	Local Name	Indonesian name
Lauraceae	Cinnamomum	sp. 1	T	Sintok	
Lauraceae	Cryptocarya	sp. 1	T	Medang	
Lauraceae	Litsea	cf. elliptica	T	Medang (Species Medang)	
Lauraceae	Litsea	cf. rufo-fusca	T	Tampang	
Lauraceae	Litsea	sp. 1	T	Medang	
Lauraceae	Litsea	sp. 2	T	Tampang	
Lauraceae	Nothaphoebe	sp. 1	T	? Medang	
Lauraceae	Phoebe	cf. grandis	T	Tabitik	
Lecythidaceae	Barringtonia	longisepala	T	Putat	
Linaceae	Ctenolophon	parvifolius	T	Kayu Cahang	
Loganiaceae	Fragraea	accuminatisma	T		
Loganiaceae	Fragraea	sp. 1	Liana	Kalamuhe	
Loranthaceae	Dendrophloe	sp. 1	Liana		
Magnoliaceae	Magnolia	bintulensis	T	Asam Asam	Medang Limo
Melastomataceae	Melastoma	malabathricum	Shrub		
Melastomataceae	Melastoma	sp. 1	Shrub		
Melastomataceae	Memecylon	sp. 1	T		Jambu Jambu
Melastomataceae	Memecylon	sp. 2	T	Milas	
Melastomataceae	Pternandra	cf. coerulescens / galeata	T	Kemuning yg bergaris tiga	
Meliaceae	Aglaia	rubiginosa	T	Kajalaki	Para Para
Meliaceae	Aglaia	sp. 1	T	Banguang Napu	
Meliaceae	Sandoricum	beccanarium	T	Papong	Ketapi Hutan
Menispermaceae	Fibraurea	tinctoria	Liana	Kalamuhe	
Moraceae	Ficus	cf. spathulifolia	Fig	Lunuk Punai	
Moraceae	Ficus	cf. stupenda	Fig	Lunuk Tingang	
Moraceae	Ficus	sp. 1	Fig	Lunuk	
Moraceae	Ficus	sp. 2	Fig	Lunuk Bunyer	
Moraceae	Ficus	sp. 5	Fig	Lunuk Buhis	
Moraceae	Ficus	sp. 6	Fig	Lunuk Sambon	
Moraceae	Ficus	sp. 7	Fig	Lunuk Tabuan	

Family	Genus	Species	Type	Local Name	Indonesian name
Moraceae	Ficus	sp. 8	Fig	Lunuk	
Moraceae	Ficus	sp. 9	Fig	Lunuk	
Moraceae	Parartocarpus	venenosus	T	Tapakan	Lilin Lilin
Myristicaceae	Gymnacranthera	farquhariania	T	Mendarahan daun kecil	Maha darah
Myristicaceae	Horsfieldia	crassifolia	T	Mendarahan daun besar	Maha darah
Myristicaceae	Knema	intermedia	T	Bahandang	Kerandau Merah
Myristicaceae	Myristica	lowiana	T	Mahadarah Hitam	
Myrsinaceae	Ardisia	cf. sanguinolenta	T	Kalanduyung himba	
Myrsinaceae	cf. Rapanea	borneensis	T	Mertibu	
Myrtaceae	Eugenia	spicata	T	Kayu Lalas	Galam Tikus
Myrtaceae	Syzygium	clavatum	T		
Myrtaceae	Syzygium	havilandii	T	Tatumbu	Jambu Jambu
Myrtaceae	Syzygium	cf. valevenosum	T	Kayu Lalas Daun Besar	
Myrtaceae	Syzygium	sp. 1 cf. garcinifolia	T	Jambu Burung	Jambu Jambu
Myrtaceae	Syzygium	sp. 2	T	Kemuning Putih	
Myrtaceae	Syzygium	sp. 3 cf. nigricans	T	Jambu Burung Kecil	
Myrtaceae	Syzygium	sp. 4	T	Jambu Burung Kecil	
Myrtaceae	Syzygium	sp. 5 cf. E.spicata	T	Kayu Lalas	Galam Tikus
Myrtaceae	Syzygium	sp. 6 cf. campanulatum	T	Tampohot Batang	
Myrtaceae	Syzygium	sp. 7	T	Milas	
Myrtaceae	Syzygium	sp. 8	T	Jambu Burung	
Myrtaceae	Syzygium	sp. 9 cf. lineatum	T		Jambu Jambu
Myrtaceae	Syzygium	sp. 10	T	Jambu Burung	Jambu Jambu
Myrtaceae	Syzygium	sp. 11	T	Jambu Burung Kecil	
Myrtaceae	Syzygium	sp. 12	T		
Myrtaceae	Syzygium	sp. 13	T	Tampohot Himba	
Myrtaceae	Syzygium	sp. 14	T	Milas	
Myrtaceae	Tristaniopsis	obovata	T	Blawan	
Myrtaceae	Tristaniopsis	whiteana	T	Blawan	
Myrtaceae	Tristaniopsis	sp. 1 cf. bakhuizenia	T	Blawan Buhis	Blawan Kalasi
Myrtaceae	Tristaniopsis	sp. 2	T	Blawan Merah	



Family	Genus	Species	Type	Local Name	Indonesian name
Myrtaceae	Tristaniopsis	sp. 3 cf. merguensis	T	Blawan Putih	
Myrtaceae	Tristaniopsis	sp. 4	T	Blawan Punai	
Nepenthaceae	Nepenthes	ampullaria	Climber	Ketupat Hinut	Kantong Samar
Nepenthaceae	Nepenthes	gracilis	Climber	Ketupat Hinut	Kantong Samar
Nepenthaceae	Nepenthes	rafflesiana	Climber	Ketupat Hinut	Kantong Samar
Ochnaceae	Euthemis	leucarpa	Shrub		
Ochnaceae	Euthemis	sp. 1	Shrub		
Ochnaceae	sp. 1		T		
Oleaceae	Chionanthus	sp. 1	T		
Orchidaceae	Eria	sp. 1	Epi	Anggrek Bawang	
Palmae	Pinanga	sp. 1	Shrub	Pinang Jouy	
Pandanaceae	Freycinetia	sp. 1	Climber	Akar Gerising	
Pandanaceae	Freycinetia	sp. 2	Climber	Panamar Pari	
Pandanaceae	Pandanus	sp. 1	Shrub	Sambalaun	Pandan
Pittosporaceae	Pittosporum	sp. 1	T	Prupuk Tulang (20351)	Prupuk Napu (12129)
Podocarpaceae	Dacrydium	pectinateum	T	Alau	
Polygalaceae	Xanthophyllum	cf. ellipticum	T	Pohon Kemuning	
Polygalaceae	Xanthophyllum	sp. 1	T	Ketapi Ketapi	
Rhamnaceae	Zyzyphus	angustifolius	Liana	Karinat	
Rhizophoreaceae	Gynotroches	sp. 1	T	? Kelumun	
Rhizophoreaceae	Carillia	brachiata	T	Gandis	
Rubiaceae	Canthium	sp. 1	T	Kopi Kopi	
Rubiaceae	Gardenia	tubifera	T	Saluang Belum	
Rubiaceae	Ixora	havilandii	T		
Rubiaceae	Jackiopsis	ornata	T		
Rubiaceae	Lucinea	sp. 1	Liana	Bajakah Tabari	
Rubiaceae	Musaendopsis	beccarianum	T		
Rubiaceae	Timonius	sp. 1	Shrub		
Rubiaceae	Timonius	sp. 2	Shrub		
Rubiaceae	Uncaria	sp. 1	Liana	Kalalawit Bahandang	Kalalawit Merah

Family	Genus	Species	Type	Local Name	Indonesian name
Rubiaceae	sp. 1		Vine		
Rutaceae	Tetractomia	tetrandra	T	Rambangun	Prupuk putih
Sapindaceae	cf. Cubilia	cubili	T	Kahasuhuy	
Sapindaceae	Dimocarpus	sp. 1	T	Kajalaki	
Sapindaceae	Nephellium	lappaceum	T	Manamun	Rambutan Hutan
Sapindaceae	Nephellium	maingayi	T	Kelumun Buhis	
Sapindaceae	Nephellium	sp. 1	T	Kaaja	
Sapindaceae	Xerospermum	laevigatum / noronhianum	T	Kelumun Bakei	Kelumun Biasa
Sapotaceae	Madhuca	mottleyana	T	Katiau	
Sapotaceae	Madhuca	cf. pierri	T	Nyatoth Undus	
Sapotaceae	Palaquium	cochlearifolium	T	Nyatoth Gagag	
Sapotaceae	Palaquium	leiocarpum	T	Hangkang	
Sapotaceae	Palaquium	pseudorostratum	T	Nyatoth Bawoi	Nyatoth Babi
Sapotaceae	Palaquium	ridleyii	T	Nyatoth Burung	
Sapotaceae	Palaquium	sp. 1	T	Nyatoth Burung	
Sapotaceae	Palaquium	sp. 2	T	Nyatoth Burung	
Sapotaceae	Palaquium	sp. 3	T	Nyatoth Burung	
Sapotaceae	Palaquium	sp. 4	T	Nyatoth Burung	
Sapotaceae	Pouteria	sp. 1	T	Nyatoth Planduk	
Sapotaceae	Pouteria	sp. 2	T		
Simaroubaceae	Quassia	borneensis	T	Kayu Takang	? Prupuk keras
Sterculiaceae	Sterculia	rhoidifolia	T	Loting	
Sterculiaceae	Sterculia	sp. 1	T	Galaga	
Sterculiaceae	Sterculia	sp. 2	T	Muara bungkang	
Tetrameristaceae	Tetramerista	glabra	T	Ponak	Kayu Asem
Theaceae	Ternstroemia	hosei	T		
Theaceae	Ternstroemia	magnifica	T	Tabunter	
Thymeleaeaceae	Gonystylus	bancanus	T	Ramin	
Thymeleaeaceae	sp. 1		T		
Tiliaceae	Microcos (Grewia)	sp. 1	T	Brania himba	

Family	Genus	Species	Type	Local Name	Indonesian name
Verbenaceae	Clerodendron	sp. 1	T	Sopang	
Vitaceae	Ampelocissus	rubiginosa	Liana	Bajakah Katipei Pari	
Vitaceae	Ampelocissus	sp. 1	Liana	Bajakah Oyang	
Zingiberaceae	Alpinia	sp. 1	Shrub	Suli Batu	
Zingiberaceae	Zingiber	sp. 1	Shrub	Suli Tulang	
Unknown	Palaquium ?		T	Sangkuak	
Unknown			T	Kala Pimping Galaget	
Unknown			T	Rumbang	
Unknown	Syzygium ?		T	Hampuak Galaget	
Unknown			T	Takang 2	
Unknown	Liana sp. 6		Liana	Kelemuhe sp. 2	
Unknown	Liana sp. 7		Liana		
Unknown	Liana sp. 8		Liana		
Unknown	Liana sp. 9		Liana		
Unknown	Liana sp. 11		Liana	Bajakah Tolosong	

Prepared by Erna Shinta, Helen Morrogh-Bernard, Simon Husson and Zery Yeen.2005.

## Appendix B

### B.1 Nest Tree Height Analysis

#### Tukey Test for Multiple Comparison of Nest Tree Heights.

(I) agesexcls	(J) agesexcls	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	5.83958(*)	1.80868	.009	1.1219	10.5573
	3	5.50362(*)	1.60928	.005	1.3060	9.7012
	4	12.80459(*)	1.52254	.000	8.8332	16.7760
2	1	-5.83958(*)	1.80868	.009	-10.5573	-1.1219
	3	-.33595	1.63514	.997	-4.6010	3.9291
	4	6.96501(*)	1.54984	.000	2.9224	11.0076
3	1	-5.50362(*)	1.60928	.005	-9.7012	-1.3060
	2	.33595	1.63514	.997	-3.9291	4.6010
	4	7.30097(*)	1.31167	.000	3.8796	10.7223
4	1	-12.80459(*)	1.52254	.000	-16.7760	-8.8332
	2	-6.96501(*)	1.54984	.000	-11.0076	-2.9224
	3	-7.30097(*)	1.31167	.000	-10.7223	-3.8796

\* The mean difference is significant at the .05 level.

#### Homogenous Subsets for Nest Tree Height.

Tukey HSD

agesexcls	N	Subset for alpha = .05		
		1	2	3
4	44	9.2234		
2	19		16.1884	
3	32		16.5244	
1	20			22.0280
Sig.		1.000	.997	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 25.541.

b. The group sizes are unequal. The harmonic mean of the group sizes is used.

Type I error levels are not guaranteed.

## B.2 Nest Tree DBH Analysis

### Tukey Test for Multiple Comparison of Nest Tree DBH Values.

(I) class	(J) class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	7.58211(*)	2.60004	.022	.7993	14.3649
	3	4.03375	2.31340	.306	-2.0013	10.0688
	4	13.27023(*)	2.19665	.000	7.5397	19.0007
2	1	-7.58211(*)	2.60004	.022	-14.3649	-.7993
	3	-3.54836	2.35057	.435	-9.6804	2.5837
	4	5.68813	2.23576	.059	-.1444	11.5206
3	1	-4.03375	2.31340	.306	-10.0688	2.0013
	2	3.54836	2.35057	.435	-2.5837	9.6804
	4	9.23648(*)	1.89479	.000	4.2935	14.1795
4	1	-13.27023(*)	2.19665	.000	-19.0007	-7.5397
	2	-5.68813	2.23576	.059	-11.5206	.1444
	3	-9.23648(*)	1.89479	.000	-14.1795	-4.2935

\* The mean difference is significant at the .05 level.

### Homogenous Subsets for Nest Tree DBH.

Tukey HSD

class	N	Subset for alpha = .05		
		1	2	3
4	43	9.3698		
2	19	15.0579	15.0579	
3	32		18.6062	18.6062
1	20			22.6400
Sig.		.065	.406	.292

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 25.455.

b. The group sizes are unequal. The harmonic mean of the group sizes is used.

Type I error levels are not guaranteed.

### B.3 Nest Height Analysis

#### Tukey Test for Multiple Comparison of Nest Heights.

(I) class	(J) class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	5.36833(*)	1.83887	.024	.5287	10.2079
	3	3.20652	1.53970	.169	-.8457	7.2588
	4	9.29684(*)	1.61333	.000	5.0508	13.5429
2	1	-5.36833(*)	1.83887	.024	-10.2079	-.5287
	3	-2.16181	1.79334	.625	-6.8816	2.5580
	4	3.92851	1.85693	.158	-.9586	8.8156
3	1	-3.20652	1.53970	.169	-7.2588	.8457
	2	2.16181	1.79334	.625	-2.5580	6.8816
	4	6.09032(*)	1.56123	.001	1.9814	10.1992
4	1	-9.29684(*)	1.61333	.000	-13.5429	-5.0508
	2	-3.92851	1.85693	.158	-8.8156	.9586
	3	-6.09032(*)	1.56123	.001	-10.1992	-1.9814

\* The mean difference is significant at the .05 level.

#### Homogenous Subsets for Nest Heights.

class	N	Subset for alpha = .05		
		1	2	3
4	19	9.5832		
2	12	13.5117	13.5117	
3	23		15.6735	15.6735
1	20			18.8800
Sig.		.107	.587	.246

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 17.434.

b. The group sizes are unequal. The harmonic mean of the group sizes is used.

Type I error levels are not guaranteed.

## B.4 Nest Size Analysis

### Tukey Test for Multiple Comparison of Nest Sizes.

(I) class	(J) class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
0	7	.868(*)	.246	.004	.22	1.52
	8	-.401	.276	.472	-1.13	.33
	9	-.132	.240	.947	-.76	.50
7	0	-.868(*)	.246	.004	-1.52	-.22
	8	-1.269(*)	.273	.000	-1.99	-.55
	9	-1.000(*)	.237	.000	-1.62	-.38
8	0	.401	.276	.472	-.33	1.13
	7	1.269(*)	.273	.000	.55	1.99
	9	.269	.268	.748	-.44	.98
9	0	.132	.240	.947	-.50	.76
	7	1.000(*)	.237	.000	.38	1.62
	8	-.269	.268	.748	-.98	.44

\* The mean difference is significant at the .05 level.

### Homogenous sets for Nest Size.

class	N	Subset for alpha = .05	
		1	2
7	20	1.50	
0	19		2.37
9	22		2.50
8	13		2.77
Sig.		1.000	.410

Means for groups in homogeneous subsets are displayed.

A. Uses Harmonic Mean Sample Size = 17.777.

b. The group sizes are unequal. The harmonic mean of the group sizes is used.

Type I error levels are not guaranteed.

## B.5 Nest Construction Time Analysis

### Tukey Test for Multiple Comparison of Nest Construction Times.

(I) class	(J) class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-.792	1.028	.868	-3.51	1.92
	3	.606	.769	.860	-1.42	2.64
	4	-2.111	.807	.053	-4.24	.02
2	1	.792	1.028	.868	-1.92	3.51
	3	1.398	.999	.505	-1.24	4.04
	4	-1.319	1.028	.577	-4.03	1.40
3	1	-.606	.769	.860	-2.64	1.42
	2	-1.398	.999	.505	-4.04	1.24
	4	-2.717(*)	.769	.004	-4.75	-.69
4	1	2.111	.807	.053	-.02	4.24
	2	1.319	1.028	.577	-1.40	4.03
	3	2.717(*)	.769	.004	.69	4.75

\* The mean difference is significant at the .05 level.

### Homogenous sets for Nest Construction Times.

class	N	Subset for alpha = .05	
		1	2
3	22	5.23	
1	18	5.83	5.83
2	8	6.63	6.63
4	18		7.94
Sig.		.421	.103

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 14.206.

b. The group sizes are unequal. The harmonic mean of the group sizes is used.

Type I error levels are not guaranteed.



## B.6 Distance to the Last Feeding Tree Analysis

### Tukey Test for Multiple Comparison of Distances to Last Feeding Trees.

(I) class	(J) class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-40.61667	28.35388	.484	-115.4096	34.1763
	3	4.41619	22.07075	.997	-53.8029	62.6353
	4	-27.21667	22.95040	.638	-87.7561	33.3228
2	1	40.61667	28.35388	.484	-34.1763	115.4096
	3	45.03286	28.14359	.386	-29.2054	119.2711
	4	13.40000	28.83860	.966	-62.6716	89.4716
3	1	-4.41619	22.07075	.997	-62.6353	53.8029
	2	-45.03286	28.14359	.386	-119.2711	29.2054
	4	-31.63286	22.69009	.508	-91.4856	28.2199
4	1	27.21667	22.95040	.638	-33.3228	87.7561
	2	-13.40000	28.83860	.966	-89.4716	62.6716
	3	31.63286	22.69009	.508	-28.2199	91.4856

### Homogenous sets for Distances to Last Feeding Trees.

class	N	Subset for alpha = .05
3	21	21.6338
1	20	26.0500
4	18	53.2667
2	9	66.6667
Sig.		.305

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 15.135.

b. The group sizes are unequal. The harmonic mean of the group sizes is used.

Type I error levels are not guaranteed.

## B.7 Distance to the First Feeding Tree Analysis

### Tukey Test for Multiple Comparison of Distances to First Feeding Trees.

(I) class	(J) class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-12.72222	15.56773	.846	-53.9903	28.5459
	3	-30.09064(*)	10.12909	.022	-56.9416	-3.2397
	4	-3.90972	10.58098	.983	-31.9586	24.1391
2	1	12.72222	15.56773	.846	-28.5459	53.9903
	3	-17.36842	15.47841	.678	-58.3998	23.6629
	4	8.81250	15.77783	.944	-33.0126	50.6376
3	1	30.09064(*)	10.12909	.022	3.2397	56.9416
	2	17.36842	15.47841	.678	-23.6629	58.3998
	4	26.18092	10.44912	.070	-1.5184	53.8802
4	1	3.90972	10.58098	.983	-24.1391	31.9586
	2	-8.81250	15.77783	.944	-50.6376	33.0126
	3	-26.18092	10.44912	.070	-53.8802	1.5184

\* The mean difference is significant at the .05 level.

### Homogenous sets for Distances to First Feeding Trees.

class	N	Subset for alpha = .05
		1
1	18	21.2778
4	16	25.1875
2	5	34.0000
3	19	51.3684
Sig.		.118

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 10.791.

b. The group sizes are unequal. The harmonic mean of the group sizes is used.

Type I error levels are not guaranteed.

## B.8 Multivariate Analysis

### Discriminant Function Analysis

#### Structure Matrix

	Function		
	1	2	3
treeheightcode	-.821(*) )	.345	-.051
nestheightcode(a)	-.783(*) )	.320	-.105
speciescode	.593(*) )	-.048	-.267
supportingtrees(a)	.437(*) )	-.062	.027
architecture(a)	-.123(*) )	.000	-.074
dbhcode	-.623	.682(*)	-.357
basaldiam(a)	-.604	.614(*)	-.376
forestquality(a)	.066	-.123(*)	.023
nestposition	.548	.382	.742(*)
surroundhealth(a)	-.136	.054	-.338(*)
canopyhealth(a)	.040	-.202	.215(*)

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions. Variables ordered by absolute size of correlation within function.

\* Largest absolute correlation between each variable and any discriminant function

a. This variable not used in the analysis.

#### Standardized Canonical Discriminant Function Coefficients

	Function		
	1	2	3
speciescode	.483	.051	-.438
treeheightcode	-.953	-.593	.939
nestposition	.281	.653	.797
dbhcode	.359	1.404	-.953