UNIVERSITY OF OXFORD

FHS IN BIOLOGICAL SCIENCES

UNDERGRADUATE PROJECT REPORT

Candidate Number	**5 0 3 7 6**
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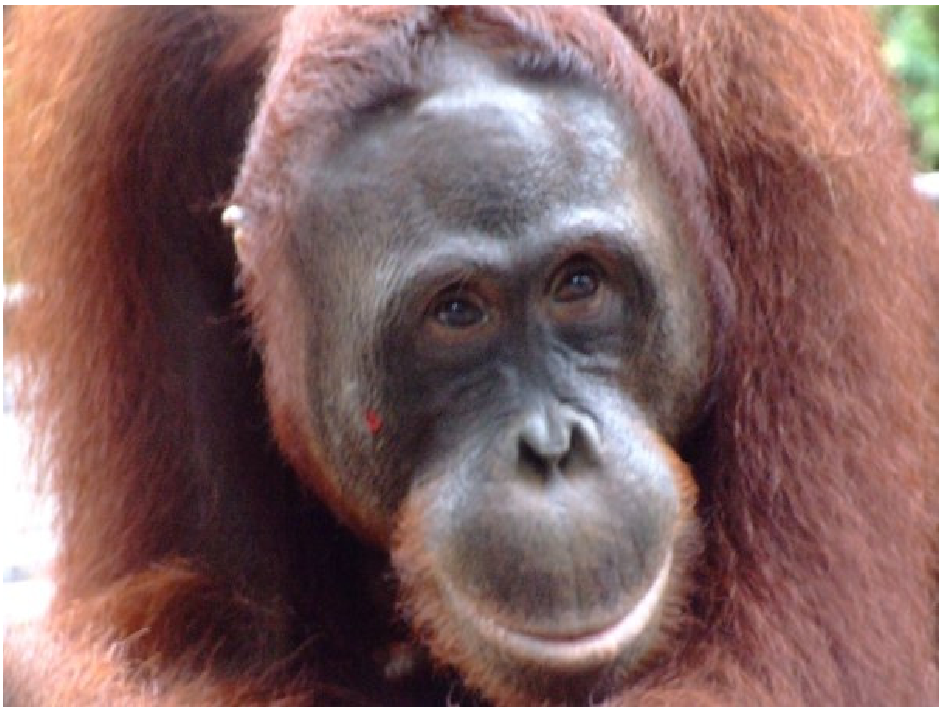
TITLE:

Nesting Preferences of the Bornean Orang-utan *Pongo pygmaeus wurmbii* in a Disturbed Tropical Peat Swamp Forest, Sabangau National Park, Kalimantan, Southern Borneo, Indonesia.



Word Count *(Maximum 7,000)*	6837

Abstract

Nesting preferences of Bornean orang-utans were investigated within the confines of a mixed swamp forest habitat within a selectively logged disturbed tropical peat swamp forest. A total of 180 nests were identified and measured over a period of 10 weeks in the dry season between July and September 2008. Nests built with branches from only one tree were found in 26 tree species, of which 6 were found to be positively selected for and 2 negatively selected for. The average total leaf area, leaf area to branch ratio and the strength of the branch were found to be significant in explaining the level of selection of a species. In addition, an analysis of each nest site location was conducted. Orang-utans were found to prefer very stable trees located in an area with a high density of large trees and with a high degree of canopy cover directly above the nest.

Contents

Section A: Introduction

The investigation was divided into two distinct stages. First, the tree species selected (both positively and negatively) for nesting were identified and possible factors for selection analysed. Secondly, location specific data was collected and compared against control data. The combination of these two approaches allows a broad range of factors to be considered in the process of nest site selection. From detailed analysis of these, and building on previous studies, it is possible to create a list of factors which determine the selection of a particular tree or location for nesting.

1) Relation of study to contemporary conservation strategies

The IUCN classifies *Pongo pygmaeus* as endangered, with an estimated total population of 45,000 – 65,000 (Caldecott and Miles, 2005). It identifies the five most significant threats to survival as habitat loss to agriculture and palm oil plantations, illegal logging, forest fires, hunting and habitat fragmentation. Conservation of orang-utans therefore requires considerable habitat protection. To maximise the effectiveness of conservation efforts, priority should be given to areas of optimum habitat. (van Schaik, 1995) When considering issues such as national park boundaries, it is important to recognise areas that can support the highest densities of orang-utans. (Cowlishaw and Dunbar, 2000) Whilst year-round food availability is considered the most major determinant of optimum habitat, (Felton et al, 2002; Djojosudharmo and van Schaik, 1992; Blouch, 1997) availability and quality of nest sites also play an important role (Marshall, 2002; MacKinnon, 1971). Due to the great diversity of habitats that host orang-utans, no broad rules can be found for general habitat conservation from habitat specific research; rather it provides policy makers with location specific data that can contribute to the selection and prioritisation of conservation efforts (Cowlishaw and Dunbar, 2000) In Sabangau National Park, only one study of nesting preferences has been conducted (Gibson, 2005) whose primary focus was the effect of age and sex classes on nesting preferences. It is hoped that this study will help contribute to the body of knowledge used in the protection and management of the forest.

2) Relation of study to previous behavioural studies

Overall, the field of nesting preferences of orang-utans has been little studied, although a great deal of research has been conducted on nesting preferences of other primates (Di Bitetti et al, 2000; Fruth and Hohmann, 1996; Brownlow et al, 2001, Furuichi et al, 2004)

Early authors on orang-utan nesting preferences speculated that selection of the nest site was based upon single criteria such as the ability of a tree to support (Schaller, 1961), the availability of edible leaves (MacKinnon 1974), or the ability to observe potential threats (Harrisson, 1969; Rijksen, 1978). Since these studies, the focus in the field has been upon preferences of different individuals within populations, based upon age and sex classes (Sugardjito, 1983; Gibson, 2005) and not upon optimum habitat criteria.

Gibson (2005) is the only study of this kind conducted in the Sabangau National Park, and while this was primarily a study of age-sex class effects upon nesting preferences, it did draw important conclusions upon optimum habitat criteria. Gibson identified a variety of factors which affected the selection of a particular tree or of a location. However, while the study identified some tree species which were preferred, the study did not attempt to identify any characteristics of these species which made them preferable. In addition, the study of location specific preferences failed to take account of some important variables of security and comfort. The models developed in Gibson's study were able to explain a degree of the variance in nest site selection. However, by the inclusion of other factors in this study, particularly those relating to the security and comfort of a nest that were not included in Gibson's, it may be possible to better explain the level of variation in nest tree and nest site selection.

3) Nest building

To understand nesting preferences it is necessary to understand the process of nest building. Orang-utans build new nests every night, solely for sleeping (Sugardjito, 1983). In addition, day nests are occasionally built especially by infants (Galdikas, 1988). Nest building skills are usually well developed by three years of age, but infants usually share nests with their mothers until six to eight years. There is an intermediate period between the ages of six and seven where infants make their own nests but sleep in the mother's nest for part of the night (van Noordwijk and van Schaik, 2005). Nest building is not an innate behaviour but rather is taught by observation, primarily of the mother (van Schaik et al, 2003).

The process of nest building can be separated into three parts; building a foundation, making a rim and adding lining (Russon et al., 2006). Building a firm foundation requires cross-structuring several branches from a single or from multiple trees, and usually involves serious bending or breaking of side branches (Fruth and Hohman, 1996). Creating a rim involves the production of a circular like pattern using smaller sub-branches and twigs (Ancrenaz et al., 2004). Creating lining utilises leafy branches usually from the nest tree itself, but it has been reported to come from sources as far away as 30m from the nest tree (MacKinnon, 1974; Rijiksen, 1978). In captivity, leaf carrying has been observed where individuals carry leaves prior to building the nest (Russon et al., 2006). In addition, the use of leafy branches as pillows and blankets has been observed (Mackinnon, 1974; Rijksen 1978; van Schaik, 2003). Thus orang-utans ideally require from a nest tree the materials with which to do these three processes. It would be reasonable to predict that nest trees would have strong and flexible branches with lots of leaves.

Nests can be made from a single tree or from multiple trees. Single tree nests involve the bending of multiple branches from the same tree, whilst multiple tree nests can utilise the branches of up to five trees. Often, multiple tree nests have a single branch from one tree species which is the dominant structural branch and a single dominant comfort branch from a different tree species used as a lining. For this reason, multiple tree nests will be eliminated from the species specific investigation.

Section B: Investigation Objectives

The overall objectives of the investigation are:-

- To create a current list of tree species used for nesting within mixed swamp forest
- To identify the criteria for or against selection
- To identify the criteria for selection of the location of a nest site

To answer these questions, first, tree species selected (both positively and negatively) by orang-utans for nesting were identified and data relating to potential reasons for selection analysed; secondly, location specific data was collected and compared against control data. The combination of these two approaches encompasses a broad range factors in the process of site selection.

1) Species specific investigation

Gibson (2005) identified 19 species in the Sabangau which were positively selected as nest tree species across three types of forest, tall pole, low pole and mixed swamp forest. No distinction was made between the types of forest habitat. This investigation will attempt to determine only those species selected for or against in mixed swamp forest. To identify whether some form of species selection has taken place, it is necessary to see if orang-utans nest in these trees at a greater frequency than could be expected by chance.

For each species, data was recorded for the following variables; sap volume, sap viscosity, sap stickiness, branch strength, total leaf area, average leaf area, leaf area to branch length ratio, and rooting system.

When making a nest orang-utans bend and break many branches (Fruth and Hohman, 1996) and in so doing, release sap which if sticky would stick to the hair of the orang-utan. No studies have so far investigated the effect of different types of sap upon nesting. However, it was proposed that trees which emit a large volume of viscous and sticky sap will be selected against.

Schaller (1961) identified the fact that supporting branches used as nests must have sufficient strength. This strength is required both as structural support and to ensure that bent and partially broken branches remain intact in the nest itself. It was therefore hypothesised that species which were positively selected for would have strong branches.

As noted above, leaves are an important part of the nest, providing a lining and sometimes a blanket or pillow for the orang-utan. It was predicted that the total leaf area, average leaf area, and leaf area to branch ratio would be high in selected trees to afford the orang-utan maximum comfort.

2) Location specific investigation

Many previous studies have focused on location specific variables. These can include characteristics of the nest tree which are not consistent between all individuals of a species or characteristics of the immediate proximity.

Many of the studies focus on the effect of tree density on orang-utan nesting in relation to the effect of selective logging. However, while studies show high large tree density correlates strongly with high orang-utan density (Hussen, 2001; Marshall, 2002; MacKinnon, 1971; Rijksen, 1978; Davies and Payne, 1982; van Schaik et al., 1995a; Russon et al., 2001) some studies have shown that following the end of disturbance, densities can return to pre-logging levels (Mackinnon, 1971). In these cases, no correlation between tree density and orang-utan density can be seen. Higher densities of orang-utans in selectively logged areas have also been reported (Rijksen and Meijaard, 1999; Russon et al., 2001) but it is unclear whether this was caused by displacement from nearby areas disturbed by more intensive logging. In Sabangau forest, studies (Cheyne, Unpublished) have shown that different types of forest correlate with different orang-utan densities. It is hypothesised that tree density is a significant contributing factor in this correlation. An additional issue addressed was whether the availability of large trees in an area affects the choice between nest building with a single tree and nest building using resources from multiple tree species. It was predicted that in areas of low density, orangutans are less likely to be able to find a single tree which meets their nesting criteria and are therefore more likely to use multiple trees to nest in.

Exposure, defined as the percentage of the tree canopy surrounded on a horizontal plane by canopy from other trees, may have a considerable impact upon nest site preference. Several authors have identified preference of orang-utans towards nesting in areas on the edge of vegetation breaks. Some authors (MacKinnon, 1974; Rijksen, 1978) have suggested this is comparable to other great apes known to use vegetation breaks as look-out posts. However, Gibson (2005) notes that orang-utans, unlike other great apes, are "generally not alert in the nest", and therefore concealment from predators may be more significant, though this hypothesis was not supported by the data. Felton (2003*)* found that preference was shown for locations with fewer gaps in surrounding canopy. In Sabangau forest, Gibson (2005) found overall preference for the least exposed classes of trees based upon an index of interconnectivity.

It may be proposed, however, that there are multiple factors in play here. Exposure is a complicated measure that falls into all three of our proposed nesting criteria (security, comfort and ease of making). High levels of exposure will have an impact upon security due to predation trade-off between visibility and camouflage. In addition, exposure may have both a positive or negative effect on security as a result of exposure to the wind; trees which are more exposed will receive more wind during storms and thus the nest may be more likely to be disrupted or even the tree to fall over. However, it could be said that trees with high exposure have already survived tropical storms and are thus have been proven to be stable. Exposure to wind would also have a negative effect upon the comfort criteria, while the ease of making the nest would be facilitated by a high degree of cover, due to the availability of resources.

Therefore, this study of exposure attempted to distinguish any index of interconnectivity from the measure of exposure; the estimation of the exposure is based upon the percentage of the tree exposed to the wind. This means that it is possible for a tree to be not exposed, even when there is no interconnectivity of the canopy. It was hypothesised that this different approach to measurement would result in a preference towards low exposed trees due to the trade-offs between the different factors outlined above.

Only one study of orang-utan preferences has used indices of canopy cover directly above the nest tree (Felton et al., 2003). In this study, canopy cover was integrated into a model of structural characteristics for canopy connectivity. This current study attempted to use canopy cover as an index of comfort since canopy cover above the nest affords a degree of protection from rain and wind. The influence of tree height over canopy cover is separated in the multivariate analysis. It was predicted that a preference for high levels of canopy cover would be shown.

Past research has dealt with single indicators of tree stability such as rooting system (Gibson, 2005) which appear to affect preference by providing stability against high winds. However, it is proposed that orang-utans will detect the stability of a tree by the level of sway as it moves through the tree, and this is not by the result of a single characteristic. For this reason, an index of stability was devised incorporating the height of the tree, the area of the trunk at height 1.3m above the roots and the effective basal area (i.e. the area above the surface covered by roots). This index would then be scaled to allow comparison between indices of stability. It was hypothesised that orang-utans would show preference for trees with high levels of stability.

No studies of nesting preferences have so far included the angle of the tree as a variable in the location selection process. However, there is evidence that the angle of the tree has a significant impact on the stability of a tree during high winds (Coutts, 1983). For this reason it was hypothesised that orang-utans would select trees with low angles of lean.

Gibson (2005) showed that over all orang-utans showed preference for healthy trees, although the degree of selection varied between individuals of different age and sex classes. Unhealthy trees are more likely to fall down in storms or have branches break in the wind. It is therefore predicted that orang-utans will show a preference for trees with high degrees of health.

The location specific variables measured will therefore be density of large trees, percentage canopy cover, exposure, stability, angle of lean and health.

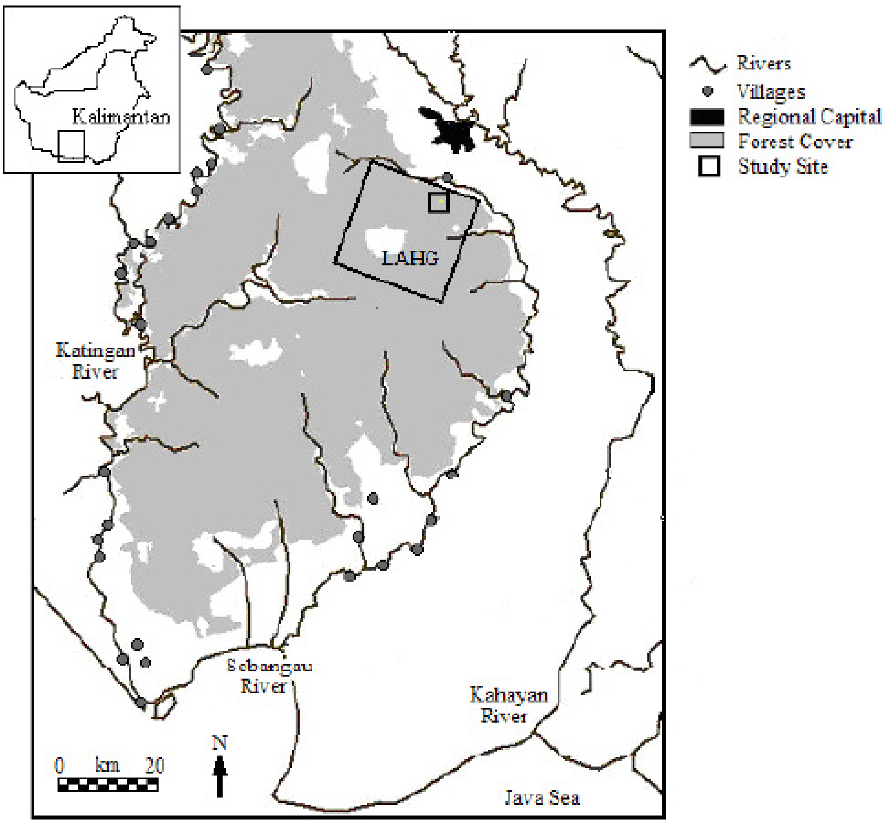
Section C: Methods

1) Study site

The study took place in the Natural Laboratory for the Study of Peat Swamp Forest (NLSPSF), at the base of the Orang-utan Tropical Peatland Project (OuTROP) associated with the Centre of International Cooperation in Management of Tropical Peatland (CIMTROP) at the University of Palankarya. The NLSPSF is situated in the Sabangau National Park, 20 km South West of Palankarya, the regional capital of Central Kalimantan, Indonesian Borneo.

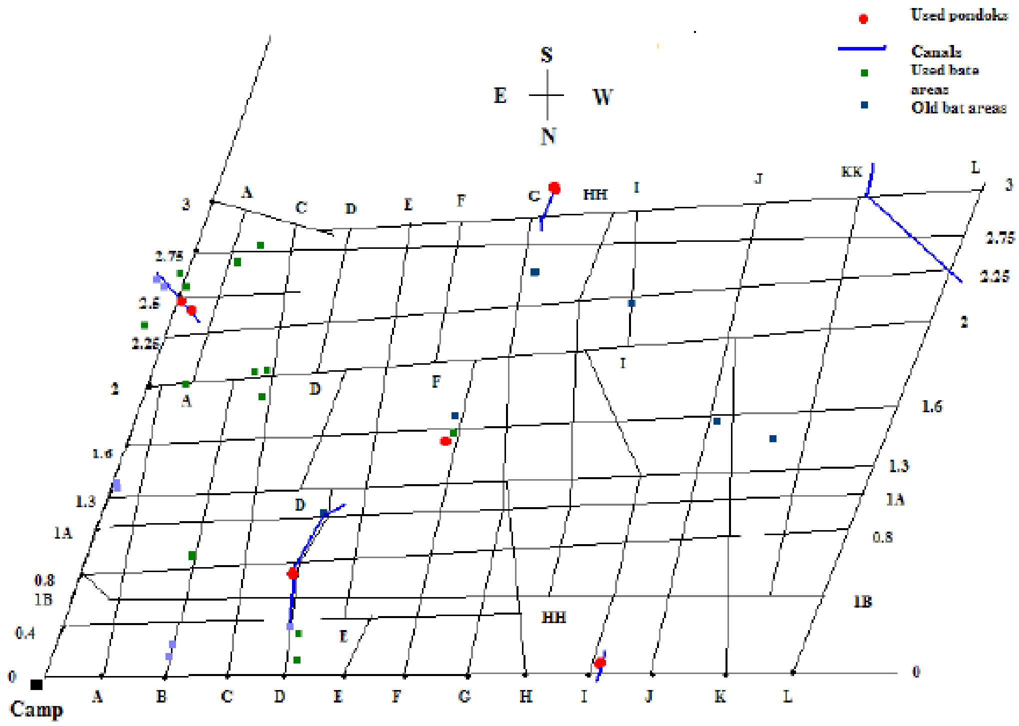
Central and Southern Kalimantan, has an estimated population of the sub species *Pongo pygmaeus wurmbii* of 25,000 individuals, (Husson, 2004)

Fig.1: Map of the Location of the Natural Laboratory (Courtesy of OuTROP)



The Natural Laboratory consists of thee main types of peatland forest: tall-pole, low-pole and mixed swamp forest. Due to time limitations, the investigation was limited to the mixed swamp forest in the $4km^2$ grid directly south of the research camp. To ensure that the study was only conducted in mixed swamp forest, only transects between 0 and 1.6 South, and 0 and E West (see fig. 2) were used. The transects to be sampled within this grid were chosen at random.

Fig.2: Map of the transect system in the Natural Laboratory (Courtesy of OuTROP)



The Natural Laboratory was selectively logged by the Setia Alam Jaya company for 25 years until 1997. During this time, a system of canals were dug to transport trees which have resulted in considerable drainage of the swamp forest. Consequently, there are fewer large trees, and some native species occur in lower frequencies than similar unlogged forest type.

The climate of the area is hot and humid with maximum temperatures reaching a seasonal maximum of 36^oC . Generally the wet season lasts from November to March/April.

2) Species Specific Methods

The list of species investigated included all species in which orang-utans had nested as well as 20 in which they had not. These 20 non-nest species were identified with the aid of a database of all the trees within the control plot, which was used to then identify the non-nest species which had the highest frequency of individuals of a certain size. This size was a trunk diameter of a minimum of 13cm at the height of 1.3m.

Having identified the species which were to be investigated, individuals were found in the control plots with the help of a local Indonesian guide. Branches were selected from below to be appear to be a typical branch from that particular tree. The total number of leaves on a branch were counted, and in addition, the first 50 leaves on each branch were measured for length and maximum width. In addition, the length of the branch which had leaves on it was recorded, as was the number of attempts required to snap the branch. To keep this consistent it was done by the same person every time. In addition sap data was taken by cutting an area of $3cm^2$ at a height of 1.3 above the roots. Sap viscosity was measured by the time taken for sap to run 10cm or the distance moved in 5 minutes. Sap volume and stickiness were estimated into four classes.

3) Location specific investigation methods

Nest tree data was collected by walking transects and identifying nests according to the nest density methods invented by van Schaik (van Schaik, 1995).

Once nest trees had been identified all the location specific data was recorded. The species of the tree was identified with the help of local Indonesian staff. Measurements were then taken of the tree density of the area using the point centre quarter method (Cottan and Curtis, 1956). The effective basal area was then measured by measuring the circumference of the roots. The trunk cross-sectional area was calculated by measuring the circumference at a height of 1.3 m above the top of the roots. Exposure and canopy cover were estimated into 10% classes. Tree heights were estimated into 5m classes. The health of the nest tree was classified by the proportion of branches that had full coverage of leaves according to the index devised by Gibson (2005) shown below.

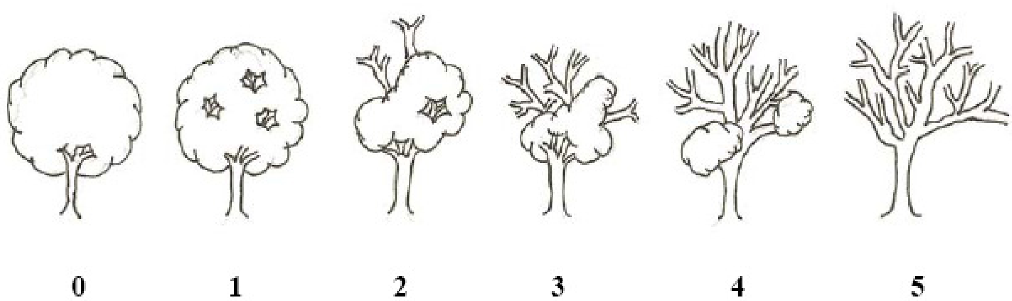


Fig.3: Gibson's Indicies of tree health (courtesy of OuTROP)

System of indices for the tree health, where 0=100% leaf cover, 1=80%, 2=60%, 3=40%, 4=20%, 5=0%

To keep subjective measures consistent and to allow for comparative analysis, the same person carried out all the tests.

Control data for large tree (over 20cm in diameter) density was recorded every 25m along every other transect in both directions. Other control data was taken from the control plots used for all research at the station, known to represent the forest as whole; these are on transects 0.4, 1A, and 1.6. This control data involved measuring all the characteristics of nest trees (except density) on every tree over the minimum diameter (13cm) found in the nest tree sample.

4) Statistical Methods

Jacob's D Co-efficient was calculated using the formula below (Jacob's, 1974)

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

Where D= coefficient of selection, r = proportion of trees in the nest sample of a given species and p= proportion of trees in the study area of that given species.

To calculate the area of a leaf, the leaf was assumed to be an ellipse. This allowed the leaf area to be calculated using the formula

$$\text{Area} = \pi \times \text{width} \times \text{length}$$

An index of stability was created which combined three factors, height, trunk area at 1.3m above the roots and the effective basal area, i.e. the area of the ground's surface covered by roots. To do this it was necessary to imagine the combinations of these factors which would cause the greatest stability. The most stable tree would have a low height and a high trunk area and a large root area. The least stable tree would be tall in height and have a small trunk area and a small root area. A normality test was applied to the data, and was shown to be normally distributed. This allowed each factor to be scaled on a scale of 1 to 2 preventing any mathematical errors when dealing with 0. Thus the formula below was derived for use with scaled values.

$$\text{Stability} = \frac{\text{root area} \times \text{trunk area}}{\text{height}}$$

Statistics were carried out with the aid of the following programmes, Microsoft Excel and MINITAB 15. All data was tested before programmes were run to ensure they met the requirements of the model, for example, normal distribution, no co-linearity or co-variation. All the data used was normally distributed and no transformation was required. Tests used were chi-squared, Jacob's D, two tailed t-tests, regression analysis, and multi-variant analyses of variance in the form of Principle Component Analyses and balanced MANOVAs. Significance levels for p used for all tests was $p<0.05$.

The principle component analysis (PCA) was selected as means to analyse factors affecting species selection as a number of the variables were related and thus showed a degree of co-linearity. PCA is an orthogonal linear transformation which transforms the data into a co-ordinate system allowing it to identify the percentage of variance explained by variables and avoid issues of multicollinearity.

The balanced MANOVA was selected as a means to analyse factors affecting location selection since it an appropriate way of testing the equality of means for different responses. The test was suitable since the data was balanced (i.e. all treatment combinations had the same number of observations) and it was the most appropriate test since it took into account all of the data covariance. The Wilks's co-efficient was used in testing the response variable since this test has shown be more reliable with balanced data.

Section D: Results

1) Species specific investigation

Species selection

In total, orang-utans nested in 52 different species of which 26 were single nest trees. These species were afforded a coefficient of selection using Jacob's Preference Indices (Jacobs, 1974) along with the 20 most common species in the control plots that did not have nests in. Jacob's D takes into account the proportion of a species in the nest sample and the proportion of the species in the forest as a whole, as represented by the control sample.

Fig.4: Level of Selection of Tree Species

Jacob's D co-efficient D ranges between -1 for strong negative selection and +1 for strong positive selection.

LATIN NAME	LOCAL NAME	D
Aglaia rubiginosa	Kajalaki	0.47
Baccaurea bracteata	Rambai	-1.00
Blumeodendron elateriospermum / tokbrai	Kenari	-0.19
Calophyllum hosei	Jinjit	-0.67
Calophyllum sclerophyllum	Kapurnaga	-1.00
Calophyllum soulattri	Takal	-1.00
Calophyllum sp. 3	Kapurnaga laut	0.47
Campnosperma coriaceum	Terontang	0.71
Campnosperma squamatum	Teras Nyating	-1.00

Cephalomappa sp. 1	Kerandau 1	-1.00
Combretocarpus rotundatus	Tumih	-1.00
Cotylelobium cf. lanceolatum	Rasak	-1.00
Cratoxylon arborescens	Geronggang 2	-1.00
Cratoxylon glaucum	Geronggang	-1.00
Ctenolophon parvifolius	Bintan - rambut merah	-1.00
Cyathocalyx biovulatus	Kerandau	-1.00
Dactylocladus stenostachys	Mertibu	-1.00
Diospyros bantamensis	Malam Malam	-1.00
Diospyros confertiflora	Arang	-1.00
Diospyros siamang	Ehang	-1.00
Diospyros sp. 7	Kayu Arang	-1.00
Dipterocarpus borneensis	Keruing	-1.00
Dyera lowii	Jelutong	-1.00
Elaeocarpus cf. griffithi	Elaeocarpus sp 1	-1.00
Elaeocarpus mastersii	Mangkinang	0.92
Garcinia sp. 1	Aci	-0.54
Gonystylus bancanus	Ramin	-1.00
Horsfieldia crassifolia	Mendarahan DB	-0.49
Ilex hypoglauca	Sumpung	-1.00
Isonandra lanceolata	Nyatoh Palanduk	-1.00
Knema intermedia	Kerandau Merah	-1.00
Koompassia malaccensis	Kempas	0.16
Lithocarpus rasas	Pampaning	-1.00
Lithocarpus sp. 1 cf. dasystachys	Pampaning Bitik	-1.00
Lithocarpus sp. 3	Takorak	-1.00
Lithocarpus sp. 3	Pampaning Bayang 1	0.48
Litsea cf. Elliptica	Medang	0.65
Litsea cf. rufo-fusca	Tampang	0.79
Madhuca mottleyana	Katiau	-1.00

Magnolia bintuluensis	Medang Limo	-1.00
Memecylon sp. 1	Jambu Jambu	-1.00
Mesua sp. 1	Tabaras akar tinggi	0.27
Mezzetia leptopoda / parviflora	Pisang Pisang Besar	0.36
Myristica lowiana	Mahadarah 3	-1.00
Neoscortechinia kingii	Pupu Palanduk	0.04
Nephellium lappaceum	Rambutan Hutan	-1.00
Palaquium cochlearifolium	Nyatoh Gagas	-1.00
Palaquium leiocarpum	Hangkang	-0.77
Palaquium pseudorostratum	Nyatoh Babi	-1.00
Palaquium ridleyii	Nyatoh burung	0.16
palaquium ridreii	Nyatoh babi / mark mark	0.30
Phoebe cf. grandis	Tabitik	0.16
Pittosporum sp. 1	Prupuk	-1.00
Polyalthia hypoleuca	Alulup	0.47
Sandoricum beccanarium	Papung	0.16
Santiria cf. griffithi	Teras Bamban	-1.00
Santiria cf. laevigata	Geronggang Putih	-1.00
Santiria sp. 1	Geronggang Putih 3	-1.00
Santiria sp. 3	Sesepat	-1.00
Shorea teysmanniana	Meranti Sumut	0.12
Stemonurus cf. scorpiodes	Tabaras yg tdk punya akar	-1.00
Syzygium garcinifolia	Jambu Burung	-0.30
Syzygium havilandii	Tatumbu	0.16
Syzygium sp. 2	Kemuning Putih	-0.04
Syzygium sp. 3 cf. nigricans	Jambu Burung Kecil	-1.00
Syzygium sp. 5	Kayu Lalas	-1.00
Ternstroemia magnifica	Tabunter	-1.00
Tetractomia tetrandra	Rambangun	-1.00
Tristaniopsis sp. 4	Blawan Punai	-1.00

Xylopia coriifolia	Nonang	-1.00
Xylopia fusca	Jangkang Kuning	0.17

To test the significance level of these co-efficients a chi squared test was performed. The critical value for 1 degree of freedom at p = 0.05, 3.84

Within the sample, 8 species where found to be nested in proportions significantly different to those at which they are found in the forest as a whole. These are listed below.

Fig.5: Significantly Selected Species for Nesting

LATIN NAME	LOCAL NAME	D	Chi Squared
Elaeocarpus mastersii	Mangkinang	0.92	320.99
Campnosperma coriaceum	Terontang	0.71	84.67
Litsea cf. Elliptica	Medang	0.65	28.11
Litsea cf. rufo-fusca	Tampang	0.79	19.13
Calophyllum hosei	Jinjit	-0.67	5.87
Diospyros bantamensis	Malam Malam	-1.00	5.45
Palaquium leiocarpum	Hangkang	-0.77	5.40
Lithocarpus sp. 3	Pampaning Bayang 1	0.48	4.46

As can be seen from the table above, six out of the eight significant species are selected for positively (i.e. have a positive Jacob's D coefficient).

Species characteristics

Which variables were responsible for the preference given to a species was then tested by means of a multivariate analysis in the form of a Principle Component Analysis to identify any relationships between the measured variables and the degree of selection (Appendix 1).

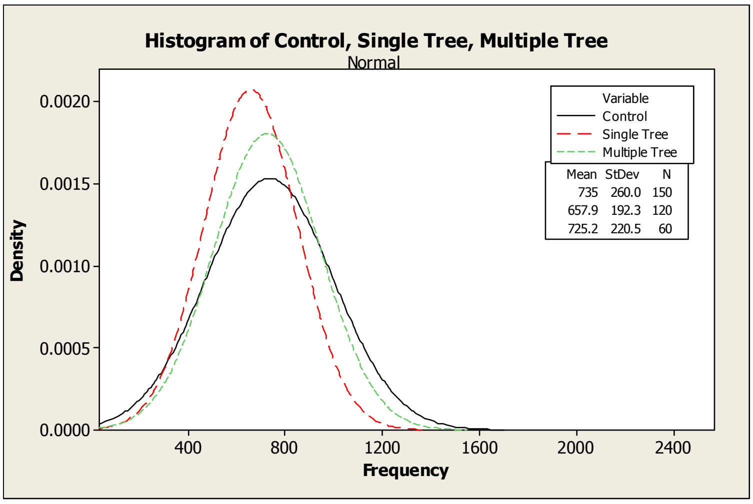
The PCA (Fig.6) shows different co-ordinate systems of taking into account the variance. For example, PC1 has an Eigenvalue (variance) of 3.0289 which accounts for 30% of the total variance. At this level of 30% of the variance three variables are significant in explaining the variance; total leaf area (PC1=-0.26), Leaf Area to Branch ratio (PC1=0.003) and the strength of the branch (PC1=0.026). This is the principal component matrix which is significant so a large proportion of the variance remains unexplained.

2) Location specific investigation

Density

Of the 180 nest sites measured, 120 nests were in only one tree and 60 in multiple trees. The tree density of the study area was measured at 150 individual sites. T-tests were performed to identify statistical differences between densities at nest trees and control densities, single nest trees and multiple nest trees, between single nest trees and control and multiple nest trees and control. Fig. 7 below shows the relationship between the tree sets of data.

Fig.7: Histogram of control tree, single tree nest tree, and multiple tree nest tree density



There was a statistical difference between nest trees and control sites (p = 0.034) as shown in Fig. 8 below. There was also found to be a significant difference between single tree nest tree densities and control densities (p= 0.005) as seen in Fig.9, Single nest tree densities and multiple nest trees (p= 0.046) as seen in Fig.10, but no significant difference between multiple nest tree density and control density (P= 0.783) as seen in Fig.11. Together these results show selection for lower densities by orang-utans but in areas of background density orang-utans nest using multiple trees. T-tests are shown in Appendix 2.

Fig.8: Histogram of nest tree density against control densities

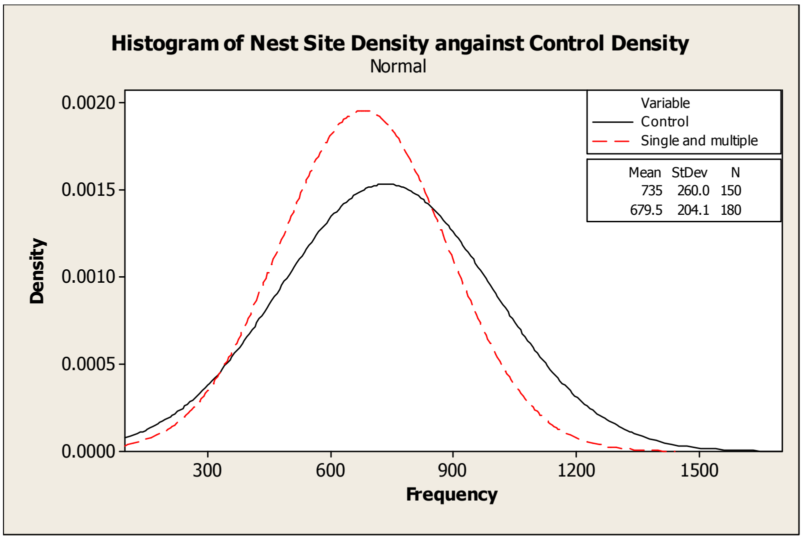


Fig.9: Histogram of single tree nest tree, and control densities

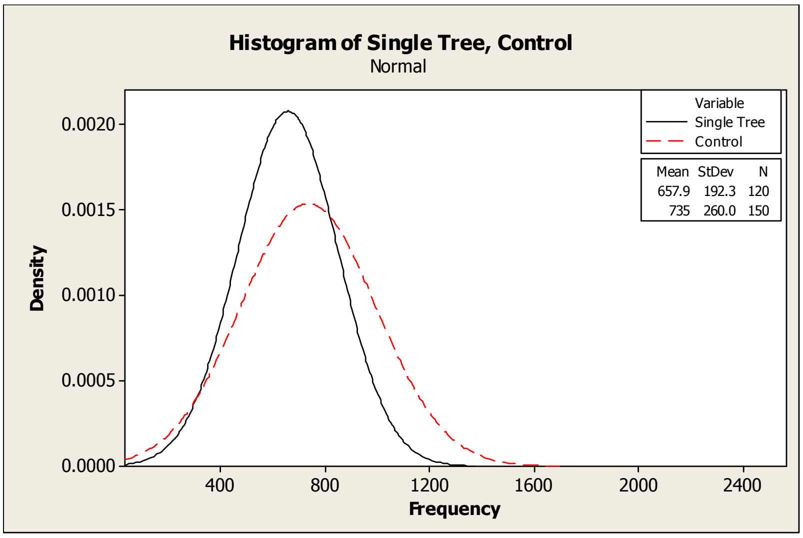


Fig.10: Histogram and t-test of single tree nest tree, and multiple tree nest tree densities

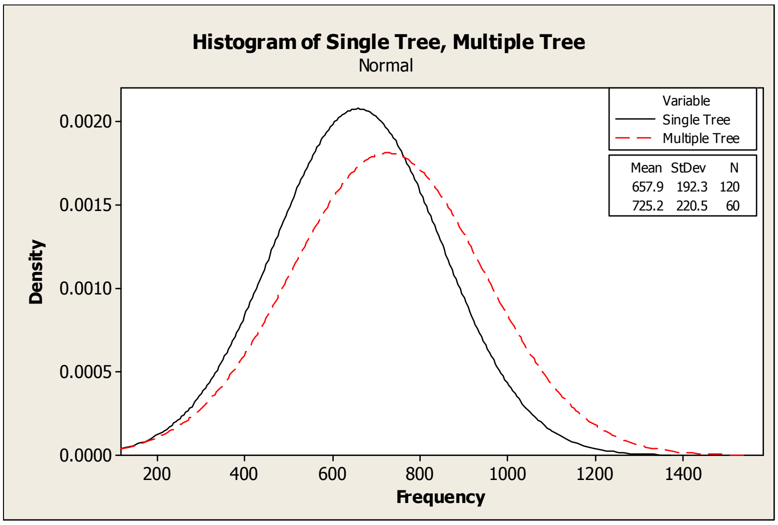
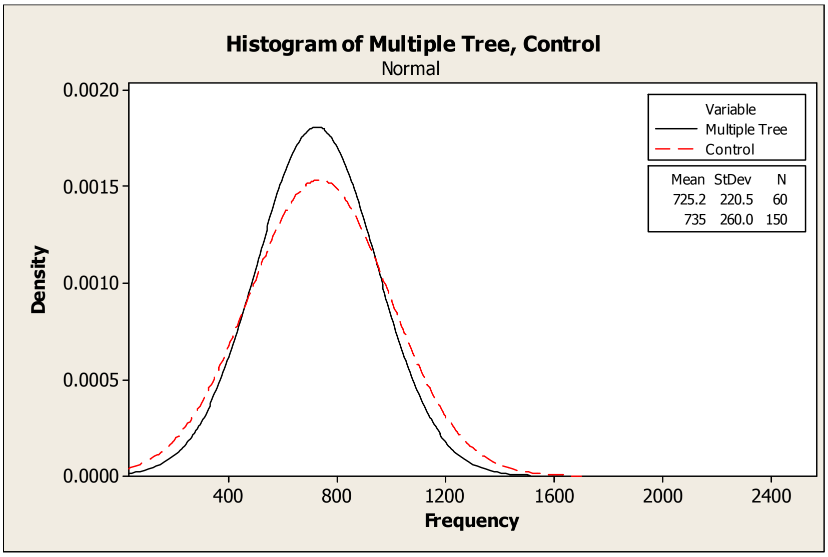


Fig.11: Histogram and t-test of multiple tree nest tree, and control density



Exposure, canopy cover, angle of lean, stability and health

Before stability data could be scaled, normality tests had to be conducted upon the tree variables used in the index, that is, height, effective basal area and trunk area at 1.3m. All three of these variables were found to be normally distributed and had p values of less than 0.005.

Location variables were then analysed in multivariate analysis of variance in the form of a general MANOVA (see appendix 3).

The general MANOVA (Fig.12) shows three of the variables tested to be significant in explaining the whether a tree is a nest tree or not. These variables are; the percentage canopy cover (F= 5.546, P= 0.000), the angle of the tree (F=5.517, P=0.019), and the stability index of the tree (F=9.61, P=0.004).

Section E: Discussion

1) Species specific investigation

Of the 26 single tree species in which orang-utans nested, only 8 species were found to have been nested in frequencies different to which would be predicted by their abundance in the forest. Positively selected species made up 52% of nest tree selections. However, this figure does not mean that in 52% of cases the tree species was the determining factor in which tree was selected. Rather, there is an interaction between species specific and location specific selection which was not investigated and thus is not quantifiable. The number of tree species negatively selected for is much lower than might be expected but may be due in part to the high species diversity. This is because while a species may never be selected by an orang-utan, because it occurs in the control plots in low frequencies, or not at all, the negative selection is not noted. Much higher sample sizes are necessary to eliminate this error.

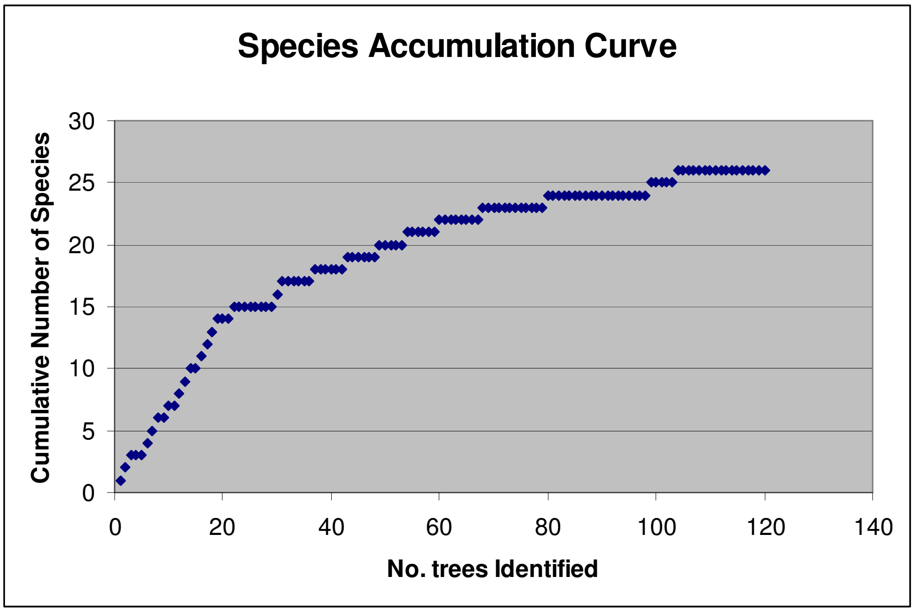
Of the variables measured in order to explain the level of species selection, only the total leaf area, the strength of the branches and leaf area to branch ratio were found to be significant within a PCA explaining 30% of the variance. The average size of leaves, the number of leaves, the number of secondary branches and the volume, viscosity and stickiness of the sap were found to have no affect on the level of selection afforded to a species. The total leaf area and the leaf area to branch ration are both direct factors influencing the comfort of a nest and thus indicate that orang-utans value comfort in the nest. The strength of the branch is an important contributor to the security of the nest as a strong branch is both less likely to break and also less likely to be dislodged in high winds.

However, the model built only explains a small amount of the variation, approximately 30%. This could be due to a number of reasons. Firstly, many other species specific characteristics were not measured, for example branching pattern, rooting system, sap toxicity. It is possible that an extension of this investigation would be able to create a model which explained to a greater degree the level of selection afforded to a species. Secondly, the tree species may have a certain geographical distribution which causes them to be situated in locations which are themselves preferred by the orang-utans. Thus in fact, what appears to be species selection is in fact location based selection. A third explanation is that species share common characteristics, such as height of full grown trees, which are not inherent all individuals and thus can not be classed as species specific characteristics, but which may play a part in the apparent selection of a nest tree on the basis of species.

An additional bias in the species specific investigation is the way in which characteristics of a species were measured. Due to time restrictions, many of the variables such as number of leaves or average leaf area were measured simply by the averaging of measurements from two branches from different trees. Both the branches and the trees were chosen at random, but this does not eliminate the considerable margin of error that results from the assumption that the branches chosen are representative of all branches on the tree and all trees of that species. To eliminate this bias it would be necessary to conduct the measurements on a much greater number of trees until the standard deviations were acceptable within the sample size to give a good approximation of the mean. To minimise damage to the forest this would require rope-access work to prevent the cutting down of a large number of branches.

Another potential source of bias is the sample sizes used. The nature of species accumulation curves (Ugland, 2003) means that the larger the sample size, the more species will be identified. The species accumulation curve below for single tree nest species shows that the graph does plateau to a certain extent and thus the presentation of all the major species is probably included.

Fig.13: Species Accumulation Curve for single tree nest species



However, due to the way that data was recorded, it was not possible to conduct a species accumulation curve on the control data. This represents a major flaw in the design of the project. Due to the greater number of species found in the control plots than the sample plots, it is unlikely that all species were sampled and their correct frequencies found. This would lead to the mis-identification of selected trees, which may in turn affect the results of the study into the causes of selection. To improve the accuracy of this project, it would be necessary to increase the sample size of the control data and to conduct the sample in such a way that it is possible to know when a plateau of species accumulation is reached.

Despite these biases this study shows that species level selection of nesting trees does occur and that it is based upon specific criteria.

2) Location specific investigation

Studies of densities showed a preference of orangutans for nesting in areas of high density of large trees (defined as trees with a diameter at height 1.3m of greater than 20cm). Nests composing of more than one tree were found in areas of forest with significantly lower densities than nests consisting of single trees. This suggests that in sub-optimum densities, orang-utans will often compromise by using more than one tree. The preference for high densities of large trees may be attributed to the higher densities of trees in the natural, unlogged forest. Thus density can be considered an important issue in process of optimum nest site selection. However, there are a number of inherent biases in this method of investigation the effect of density. Areas of large tree density are statistically more likely to be nested in, not necessarily because they are preferred but because a suitable nest tree is more likely to be found there due to the higher number of potential nest trees. To control for this it would be necessary to map the density of the whole forest and control for the number of trees by comparing a high density area with a larger low density area which contained the same total number of large trees.

The multivariate analysis showed three variables to be statistically significant in explaining the selection of a location. These variables are the percentage canopy cover, the angle of the tree and the stability of the tree. The percentage canopy cover is an indicator of both comfort and stability since a high degree of canopy cover directly above suggests a location sheltered form the wind which might reduce the chances of tree fall, but also provides good protection from the rain, more of an indicator towards a preference for comfort. The angle of the tree is directly related to the security of the nest as a leaning tree is more likely to fall over. The significance of the stability index shows the importance of taking into account all aspects of tree stability in determining optimum habitats.

Again, there are some inherent biases in the way the investigation was conducted. The index of stability is inherently a biased measurement. In the absence of any published papers on the matter, equal weighting was given to height, trunk area at height 1.3m and the effective basal area, but in reality this is unlikely to be the case. In addition, in the location specific investigation, the type of rooting system was not taken into account because it contributed to the effective basal area. In reality, the number of, angle and thickness of stilts and buttresses would affect the stability of the tree. There were also more fundamental biases in the methods used, for example by the very nature of the transect method of nest identification, trees with high exposure are more likely to be spotted, thus there may have actually been a trend for exposure but a skew of the sample meant that this was not apparent. The same can be said for different height levels which may skew the index of stability. To minimise this impact it would be better to search the transect with different groups of people walking in different directions.

Thus orang-utans can be said to select a nest site on its location and take into account indices of security and comfort when selecting a location for nesting.

3) Conservation and behavioural conclusions

Since no other similar studies have been conducted, it is impossible to say whether these findings are typical. Repeat investigations, with much larger sample sizes would be needed, to allow for a significant degree of confidence, as well as the elimination or minimization of all the biases identified above.

However, this study does confirm much of the research that precedes it, in that it shows selection of nest sites by orang-utans does occur, both at the species and location level by means of specific variables. In addition, it identifies some of the possible criteria on which selection is based. Although this study was restricted to one type of habitat within the National Park, it suggests a methodology useful for investigating other habitat types. It also shows that while previous research shows a great deal of selection in different age-sex classes, identifying optimum nesting habitat on a population wide basis is much more difficult.

The study highlights some aspects of wild behaviour of orang-utans, which has been shown in previous studies, in that it shows they possess a sophisticated method of identification and decision making in where to nest based upon criteria of comfort as well as security.

This investigation suggests that the abundance of certain nest tree species will have an effect upon optimum habitats. Likewise the variables of the canopy cover directly above the nest, the angle of the tree, the forest density of large trees and the combination of effective basal area, trunk area and tree height as a measure of the stability of the tree, are all variables that should be considered when assessing optimum habitat criteria for orang-utan conservation.

Acknowledgements:

Special thanks to my supervisor Dr Susan Cheyne.

Thanks also for the help of Simon Husson, Helen Morrogh-Bernard Sophie Curtis and Ari and all those at OuTROP. Thanks to my college tutor Dr Peter Darrah.

Thanks also to those volunteers who assisted me with some of the data collection.

Some expenses for the data collection for this project was partially funded by a Worcester College Travel Grant and the Zoology Department, for which I am extremely grateful.

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Appendix 1

Principal Component Analysis: Ave Size of , No. Leaves, Total leaf a, Viscosity

Eigenanalysis of the Correlation Matrix

Eigenvalue	2.7367	2.1153	1.4623	1.0182	0.5878	0.5582	0.2617	0.1371
Proportion	0.304	0.235	0.162	0.113	0.065	0.062	0.029	0.015
Cumulative	0.304	0.539	0.702	0.815	0.880	0.942	0.971	0.986

Eigenvalue	0.1227
Proportion	0.014
Cumulative	1.000

Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Ave Size of Leaf	-0.181	0.067	0.484	0.587	0.554	0.181	0.156
No. Leaves	0.289	-0.124	-0.508	-0.203	0.503	0.523	0.256
Total leaf area	-0.026	0.647	0.056	-0.173	0.078	0.108	-0.134
Viscosity	0.525	-0.013	0.130	0.040	-0.093	-0.424	0.584
Sitckyness	0.544	-0.065	0.234	0.098	0.082	0.035	-0.046
Volume	0.541	0.079	0.154	0.025	0.040	0.089	-0.654
Leaf to branch Ratio	0.003	0.566	0.171	-0.426	0.218	-0.131	0.211
No. Secondary Branches	0.133	0.422	-0.221	0.480	-0.519	0.410	0.206
Strength	0.026	0.228	-0.575	0.402	0.317	-0.554	-0.186

Variable	PC8	PC9
Ave Size of Leaf	-0.140	-0.030
No. Leaves	-0.097	0.022
Total leaf area	-0.043	0.714
Viscosity	-0.373	0.191
Sitckyness	0.783	0.109
Volume	-0.434	-0.225
Leaf to branch Ratio	0.124	-0.586
No. Secondary Branches	0.026	-0.209
Strength	0.109	-0.042

Appendix 2

Two-Sample T-Test and CI: Control, Nest

Two-sample T for Control vs Single and multiple

	N	Mean	StDev	SE Mean
Control	150	735	260	21
Single and multiple	180	679	204	15

Difference = mu (Control) - mu (Single and multiple)
Estimate for difference: 55.5
95% CI for difference: (4.1, 106.9)
T-Test of difference = 0 (vs not =): T-Value = 2.13 P-Value = 0.034 DF = 279

Two-Sample T-Test and CI: Control, Single Tree

Two-sample T for Control vs Single Tree

	N	Mean	StDev	SE Mean
Control	150	735	260	21
Single Tree	120	658	192	18

Difference = mu (Control) - mu (Single Tree)
Estimate for difference: 77.1
95% CI for difference: (22.9, 131.4)
T-Test of difference = 0 (vs not =): T-Value = 2.80 P-Value = 0.005 DF = 266

Two-Sample T-Test and CI: Control, Multiple Tree

Two-sample T for Control vs Multiple Tree

	N	Mean	StDev	SE Mean
Control	150	735	260	21
Multiple Tree	60	723	221	29

Difference = mu (Control) - mu (Multiple Tree)
Estimate for difference: 12.3
95% CI for difference: (-58.1, 82.7)
T-Test of difference = 0 (vs not =): T-Value = 0.35 P-Value = 0.730 DF = 126

Appendix 3

MANOVA for Exposure
s = 1   m = 0.0   n = 155.0

Criterion	Test Statistic	F	DF Num	DF Denom	P
Wilks'	0.99790	0.328	2	312	0.721
Lawley-Hotelling	0.00210	0.328	2	312	0.721
Pillai's	0.00210	0.328	2	312	0.721
Roy's	0.00210				

MANOVA for % Canopy cover
s = 1   m = 4.5   n = 155.0

Criterion	Test Statistic	F	DF Num	DF Denom	P
Wilks'	0.83644	5.546	11	312	0.000
Lawley-Hotelling	0.19554	5.546	11	312	0.000
Pillai's	0.16356	5.546	11	312	0.000
Roy's	0.19554				

MANOVA for Health
s = 1   m = 1.5   n = 155.0

Criterion	Test Statistic	F	DF Num	DF Denom	P
Wilks'	0.97946	1.309	5	312	0.260
Lawley-Hotelling	0.02097	1.309	5	312	0.260
Pillai's	0.02054	1.309	5	312	0.260
Roy's	0.02097				

MANOVA for Angle
s = 1   m = -0.5   n = 155.0

Criterion	Test Statistic	F	DF Num	DF Denom	P
Wilks'	0.98262	5.517	1	312	0.019
Lawley-Hotelling	0.01768	5.517	1	312	0.019
Pillai's	0.01738	5.517	1	312	0.019
Roy's	0.01768				

MANOVA for FIG
s = 1   m = -0.5   n = 155.0

Criterion	Test Statistic	F	DF Num	DF Denom	P
Wilks'	0.99941	0.184	1	312	0.668
Lawley-Hotelling	0.00059	0.184	1	312	0.668
Pillai's	0.00059	0.184	1	312	0.668
Roy's	0.00059				

MANOVA for Stability
s = 1   m = -0.5   n = 155.0

Criterion	Test Statistic	F	DF Num	DF Denom	P
Wilks'	0.97315	8.610	1	312	0.004
Lawley-Hotelling	0.02760	8.610	1	312	0.004
Pillai's	0.02685	8.610	1	312	0.004
Roy's	0.02760				