SPATIAL DISTRIBUTION OF FRUIT ABUNDANCE AND DIVERSITY, AT THE HEIGHT OF THE DRY SEASON RELATIVE TO THE RIVER AND THE POSSIBLE LINK WITH ORANG-UTAN, *PONGO PYGMAEUS,* DISTRIBUTION

Nesbitt, Michelle Carrie : 990556796
Biology B.Sc Final Project (BLGY 3040)

ABSTRACT

A survey of the availability of fruit in an area of a peat swamp forest in the Sungai (River) Sebangau catchment, Central Kalimantan, Borneo, Indonesia was carried out in 2001, for the first time. Fruit availability is qualified as the distribution of fruiting trees, diversity of species and abundance of actual fruit in the canopy and on the forest floor. Fruit and their parent trees observed along line transect cut through the forest and evaluated in relation to their distance from the river. Only low numbers of tree species bear fruit during the dry season, however a significant relationship of increasing abundance and diversity with close proximity to the river was recorded.

Orang-utans are the major frugivore of the studied forest and their distribution was evaluated along the same transects as fruit, using nests as indictors of presence. No link between fruit availability and orang-utan distribution was found. In fact orang-utans showed a preference for an area with relatively low fruit abundance. Perhaps fruit is only a possible predeterminant of orang-utan density in the high fruiting season, December to May, and less important at the time of this study, August - September, mid-dry season.

INTRODUCTION

The movement of animals within a habitat is affected by the existence of predators, the amount of competition by other animals occupying the same or closely related ecological niches and the availability of food. (Dowdeswell, 1966) Environmental conditions and physiological demands can also impose limits upon such activity. (Delany, 1982) Forest habitats in particular are complex in structure and ecology and necessitate adaptive yet variable behaviours from its inhabitants, (Krebs & Davies, 1987) and requires the use of a great variety of strategies between months of the year and sub-habitats. Differences in topography and the underlying ecological factors of this variation, such as soil

fertility (Payne & Andau, 1989) contribute to the uneven distribution of forest trees, variations in their production rates, (Meijaard, 1997) and hence food quality (Dasmann, 1981) and availability for the indigenous animal populations. Climate and seasonality also play a large part in determining distribution of food and subsequently the distances over which animals must move to obtain it. (Dowdeswell, 1966) In general, movement by animals in search of food is considered erratic. Gannets, for example, travel great distances to find food, while other animals are reported to base themselves within a small area, seldom moving from it, like Tits. (Dowdeswell, 1966) Animals that remain within an area or territory experience seasonal fluctuations of their environment, which invariably includes changes in resource abundance and availability. (Poulsen *et al*., 2001) When the resource is food variation in feeding behaviour and ecology is observed, in the primate species this usually translates to an alternative strategy from fruit choice. The *Lophocebus albigena* (grey cheeked mangabey) changes its fruit dominated diet in lean periods (Poulsen *et al*., 2001); *Alouatta seniclus* (the red howler monkey) in the dry season when food is distributed more irregularly utilise smaller, lower quality patches if they happen to be closer (Sekulic, 1982); *Cercopithecus mitis labiatus* (samango monkeys) also become less selective in their food choice when fruit is not abundant during the months of the dry season. (Lawes *et al*., 1990) Similarly *Pongo pygmaeus* (orang-utans) choose to alter their food preference for fruit in accordance with the availability of the surrounding vegetation at different times of the year, perhaps leading to behavioural changes and the use of alternative foraging strategies.

Knowledge of the orang-utan has existed for over 300 years and yet until recently they were unpopular in studies and subsequently not well understood. Brief studies on grouping, diet and their nests began of the Borneo species (*Pongo pygmaeus pygmaeus*) in the 1960's. (Scott & Selsor, 1961) Popularisation of the red apes has grown and their unusual social organisation, behaviour and ecology in the wild now draw much attention. (Horr, 1972; Rodman, 1973; Galdikas, 1974, Mac Kinnon, 1974) Intensive studies have lead to a greater understanding

of the orang-utan and aim to improve the chances of survival for this increasingly rare ape. Listed as an endagered species by the ICUN (Groombridge, 1993) they are now confined to certain areas of South East Asia. (Meijard, 1997)

Orang-utans are large, long-armed red apes found within the forest islands of Borneo and Sumatra. They inhabit both the rain and peat swamp forests along the coasts i.e. at low altitude, (Meijaard, 1997) in particular preference is habitats dominated by large trees of the Diptocarpaceae species. (Knott, 1999; van Schaik et al., 1995) 'Mast fruiting' describes a unique pattern in which 88% of tree species fruit at the same time (van Schaik, 1986) every two to ten years. Although not exhibited in peat swamp forests evidence of a high variability in fruit production, temporally and spatially (Fleming *et al*., 1987) is still observed. Thus resulting in remarkable fluctuations in both type and quantity of fruit obtainable (Knott, 1998) in differing areas and in particular between seasons of the year.

Fruit is the ripened ovary of a flowering plant containing the ripe seeds sometimes in cases or with coats, and can be fleshy i.e thick and puply, or non-fleshy. Other types of fruit include the berry, a fleshy fruit with seeds lying free in the pulp; the drupe, a more-or-less fleshy fruit with a hard stony endocarp; and the true nut a dry one- or two-seeded fruit with a hard woody pericarp. High proportions of tree species in most tropical forests have fleshy fruits, generally at least 60%. (Turner, 2001) There is considerable variation in the nutritional composition of the fruit pulp, but as a majority have high lipid or carbohydrate and low protein concentrations. Fruit is a valuable source of energy for animals (Turner, 2001) but due to spatial and temporal variation in fruit production and availability fruigivores cannot be solely reliant and dependencies often turn to alternatives in low fruiting seasons.

Orang-utans are recorded to prefer fruit, both pulp and seed (Galidaka, 1988, Leighton, 1993) that are succulent, fleshy, brightly coloured and bearing no protective seed cover. (Gautier-Hion et al., 1985) All dispersed seeds of the fruits eaten offer a reward to their mutualist dispersers. (Thompson, 1982) It is possible

that an evolutionary link has occurred, i.e. the easier the fruit is to process for the orang-utan, the greater the percentage of its seeds will be dispersed and subsequently producing more sibling trees.

The diet of the orang-utan (generally frugivorous) as with other primates discussed earlier varies according to availability of foods within the forest at that time. (Knott, 1999) Preference appears to be feeding in trees with large patches of fruit (Leighton, 1993) however, during poor food times reliance turns to the more plentiful but lower quality foods of the forest, such as leaves, bark, and insects. (Knott, 1999; Rodman, 1977;Galdikas, 1988) Chapman and Chapman (1990) however, reported no such relationship between diet variability and habitat productivity and seasonality they believed orang-utans food preference was random. In this study orang-utans were primarily frugivorous (90% of feeding time spent eating fruit) one month and the next were primarily foligovorous (75% of food eaten was leaves); (Mackinnon, 1974) furthermore the diet majority of the orang-utans was not the same in any consecutive months. (Chapman & Chapman, 1990) These results contradicted the more common association between foraging behaviour and diet selectivity with the changing seasons and subsequent fluctuations in fruit throughout the year. (Mac Kinnon 1974; Rodman 1988; Knott 1998; Yolatos 1998)

Fluctuations in fruit availability provide orang-utans with the opportunity to store any excess energy as fat, which can then be utilised during poorer times. (Knott, 1998) Fruiting season appears to coincide with the wet season, hence abundance is predicted to be greatest at this time. Fruit species vary between different forest types and not only have profound implications on the behaviour of the animals that eat the fruit, in this case orang-utans but also on their ranging behaviour (White et al., 1995) and subsequent distribution of where they construct their nests. (Mac Kinnon, 1974) Orang-utans construct a new nest each night, to sleep in and frequently during the day to rest and play in. (Sugardjito, 1983) Nests can therefore be used as a suitable and direct indication of orang-utan presence and distribution.

A peat swamp forest according to its definition should consist of low stature trees, poorly developed ground cover with occasional abundant palms (Longman & Jenik, 1987) growing in perennially flooded areas. In Kalimantan peatland covers around 6 million hectares of the lowlands. Numerous distinct habitat sub-types have been identified within the studied peat swamp forest. These vary in structure, from the wet low pole forest nearer to the river to the dry deep peat tall interior forest of the watershed further in land. Differences in thickness and hydrology of the peatlands also varies between habitat sub-types; coastal peatlands have relatively thin peat (<3m in depth) compared to the sub-coastal and interior peatlands (>3m). (Morrogh-Bernard *et al*., in press) Distinct forest types are associated with having significantly different orang-utan density. Orang-utan densities are highest in forests on floodplains. Changes in altitude reflect significant changes in orang-utan population sizes. (van Schaik *et al*., 1995) Payne and Andau (1989) suggest the decrease in soil fertility and plant nutrient content with increasing altitude leads to the decline of fruit production and thus apparent differences seen in orang-utan densities. Van Schaik *et al*. (1995) most plausibly ascribes the decline of orang-utan inhabitants with increasing altitude to the declines in abundance of fruits, specifically with fleshy insides.

Fruit in peat swamp forests is only available in any great abundance for a specific part of the year. (Morrogh-Bernard *et al*., in press) Animals who chose this as their preferred food source must learn to adapt in the dry season by consuming alternatives, which may be reflected in their foraging habits. Travelling of longer distances and consequently greater energy expenditure would be observed if fruit was to be a fundamentally important food source throughout the entire year. So are the same patterns of close proximity nesting to fruiting trees observed when fruit availability is poor, as they are when density is high?

The principal aim of this study was to investigate the preferential dietary source of the orang-utan: fruit, its abundance, diversity and distribution in relation to

increasing distance from the river. Finally an attempt to identify any significant relationship between the availability of fruit and the distribution of orang-utans out of the wet / fruiting season will take place.

MATERIALS AND METHOD

Site analysis

The *Natural Laboratory* study area, some 500km of tropical peat swamp forest is located in the Pt. Setia Alam Jaya Timber concession, 20 km south-west of Palankarya in the upper catchment of Sungai Sebangau, Central Kalimantan, Borneo (latitiute 0^0, longitude 110^0). (Fig. 1)

The study area is covered with peat swamp forest allocated to logging concessions, where semi-mechanised methods of timber extraction are taking place. Over recent years much research in this study area has put its efforts into learning a little more about the distribution and density of orang-utans and evaluating the effects of natural and human interference on the orang-utans. The changes in population figures between studies over the years has allowed this site to attract more support and funding in order to help conserve the remaining population still threatened by habitat destruction and hunting, as much as possible.

Access to the primary peat swamp forest is possible via an old railway that runs south-south west up into the forest passing through a range of forest sub-types; mixed swamp, low pole and then tall interior forest. Two of these were surveyed during this study. Up to a distance of 6 kilometres from the river is dominated by mixed swamp forest. This forest canopy has three strata with a maximum height of 35m and peat that has a depth of up to 6m. The next 7 kilometres or so is known as the low pole. Low canopy forests have only two strata and due to their relatively low commercial value of the dominant tree species are less subjected to timber extraction.

Fig. 1a shows the island of Borneo. Fig 1.b shows the main river tributaries of Borneo. Fig 1c shows a more detailed view of the study area in Central Kalimantan.

Off the railway, transects were cut at a bearing 270°. Trigonometry is used in the form of the equation $D = d_1 + (\sin 20.l)$ to describe the distance of all fruit and nests discovered on the transect lines in order to standardise all distances relative to a common point, in this case the rivers edge.

$\alpha = 20^{o}$
l = distance along the transect
χ = distance from base camp
d_1 = 1km + χ
    = distance from the river to the start of the
transect along the railway

Fig.2 shows a diagrammatic view of the study area, and the transect lines on which data was collected, and how trigonometry was required to determine actual distance from the river's edge.

Distribution and abundance of fruit was assessed using a number of transects through the site. On the same transects, surveys were conducted to assess the orang-utan nest distribution.

Field procedure

Field surveys were carried out during August and September 2001.

At least two observers walked the transect line very slowly, often stopping and looking all around them to achieve greater accuracy. (van Schaik et al., 1995)

Transects commenced 100m in from the railway, were a minimum of 1 km in length and were on average 1km apart. Exact distances and locations of both nests and fruit were recorded, as were their visible characteristics, and abundance.

Line transects are the most straight forward to survey; they are easily repeatable, allowing fruit and nests to be located and additions or changes to be easily distinguished. (van Schaik *et al*., 1995) However, people vary in their ability to spot nests, fruit and make decisions on categories, and so bias can be reduced if the same people can carry out all the surveying and transect walking. (Payne, 1994) Volunteers surveying the forest for this study were of similar abilities, and were in groups that included a local student experienced in their knowledge of the forest and with much practise in spotting nests.

Differences in forest structure will inevitably affect the visibility and therefore proportion of the nests spotted. The uneven terrain of the transect line will also vary and the likelihood is that less accurate observations will be made on the more broken terrain trecks, as concentration may be diverted from the survey.

Abundance of fruit

The method of direct observation was used to record fruit abundance of both fruit on the ground and on the trees. Direct observation although usually fairly difficult in denser forests is still considered the most convenient method to give representative view of what fruit is in a forest, (Zhang & Whang, 1995) and is ideal in the relatively unstratified study forest.

At least two observers walked very slowly along the transect stopping and scanning the forest canopy and ground litter every 5 metres or so, while recording all fruit observed. (van Schaik *et al*., 1995) Looking all around as often as possible reduces the chances of missing any fruit directly on and above the transect line in particular, thus improving the accuracy of the line survey technique. (Buckland et al., 1993)

Fruit on the ground were counted individually as often as possible. For those that occurred is higher numbers a random square metre was counted and multiplied proportionately to give an estimation of the total.

Abundance of fruit on the tree branches was counted using binoculars. An estimated area was counted for presence of fruit and then multiplied according to the total size of the canopy in relation to the proportion counted.

Regarding the amount of fruit available abundance is used but is best expressed as the number of sources per km. (van Schaik *et al*., 1995) This gives an estimate of the number of points at which fruits can be obtained within a specified distance and representatively a given area.

Diversity of fruit

Fruit and fruiting trees visible from the trail had their description recorded as fully as possible, in order to aid classification of the species of fruit. Specifics of the description are described in the data collection sheet above. (table 1)

Fruit was categorised into a number of types based on its morphological characteristics e.g. colour, size, shape and texture, with the aid of a self-devised data collection sheet. (table 1) Complications in defining fruit characteristics include the fact that fruits of the same species can vary in colour and size depending on their life cycle stage. As yet in Borneo many species of tree's including those that fruit have been described (Galdikas, 1988; Leighton & Leighton, 1993) but not all. As a result of predicted complications arising, a basic key was constructed based on the fruits external and internal morphology. (table 2) Together with descriptive characteristics of the tree on which it grows samples were shared with a local hebarium, where more specific analysis of the fruit and the associated bark could take place. (table 2)

FRUIT								
shape			spherical	roundish	oval	acorn-like	pear-shaped	cup-shape
colour								
texture			smooth	rough	shiney	spikey	furry/hairy	velvety
inside	**no. of seeds**							
	different colour							
	sappy		yes	no				
specific features								
size								
type			berry	fleshy	non-fleshy	nut		
amount on forest floor								
spread on ground			evenly round base		scattered	patchy	one side / area	
TREE								
canopy type			circular	tapered to top		tapered to bottom	diamond	broken clumps
tree type			straight	slanted	divergent			
spread on tree			even	patchy	random			
			edge of trees	at branch points		all along		
grouping of the fruit			singles	pairs	3	4+		
canopy area	**Angle to top**							
	Angle to bottom							

Table. 1 shows the morphological characteristics recorded for each individual fruit collected and for the parent tree on which it grew or lay next to.

Distance along the transects where fruit was found was recorded, as was the abundance and morphological characteristics.

Orang-utan nests

Orang-utans occur at low densities and have a cryptic semi-solitary nature hence it is almost impossible to conduct adequate surveys from orang-utan sightings. (Payne, 1994)

It is well understood that orang-utans construct nests daily and consequently nests are commonly used in surveys as good indicators of the orang-utan population present. (Ghiglieri, 1984) Nest count surveys are considered to be a reliable accurate method especially for studies over a short period of time, (Morrogh-Bernard *et al*., 1999) provided they are carried out by enthused and

practised observers. (van Schaik *et al.*, 1995) They are particularly easy in this study forest because of its relatively unstratified structure. Line transects have been reported to be less affected by such problems as spatial clumping and miss spotting nests than when counting nests within a known plot area. (van Schaik et al., 1995) Line transects and nests surveying are used in this project due to their simplicity yet proven success (Brockelman & Ali, 1987) and accuracy. However this method does assume that all objects located exactly on or above the trail are discovered, and that the transect is located randomly in the habitat. (Buckland et al., 1993; Burnham et al.,1980)

Distance along the transect at which the nest is perpendicular to; the perpendicular distance from the transect line; and the side of the path on which the nest was found was recorded. Each nest was also assigned an age class representational of is stage of decay, criteria used (adapted from Morrogh-Bernard et al., 199) are stated below :

A. Fresh: green leafed firm and solid sleeping platform
B. Older: leaves are brown but nest still solid and in original shape
C. Old: holes appearing in nest, most leaves have gone
C. Very old: only twigs and branches remain, no longer in original shape

Assessment of the rate of decay can also be interpreted as duration of visibility, knowledge of which becomes useful when comparing the present fruit availability and the number of nests constructed near these fruit sources whilst they are in season.

RESULTS

Abundance

The most obvious potential food sources are the fruit that lay on the ground and in the tree canopy itself. Although some fruit is usually always available within forest habitats, amounts can vary greatly during the year (Galdikas, 1988) but more importantly for this study, can vary throughout the forest.
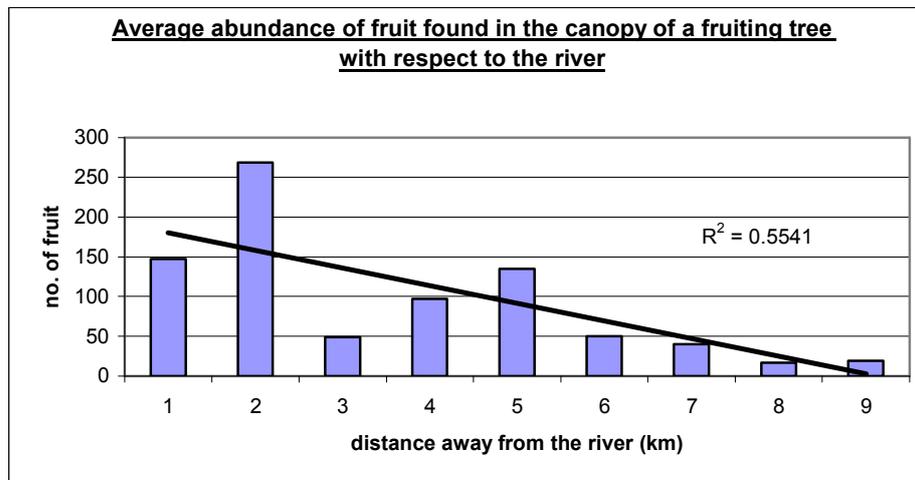
Average abundance of fruit found in the canopy of a fruiting tree with respect to the river

$R^2 = 0.5541$

no. of fruit

distance away from the river (km)

Fig. 3 shows the average amount of fruit counted in the trees of all species at varying distances form the river.

Fruit is found in tree canopies throughout the entire surveyed area of the forest. Fig, 3 presents the data on the distribution differences in the amounts of fruit found on fruiting trees. The abundance of fruit in the canopy is significantly ($p<0.03$, $r^2 = 0.55$) negatively correlated to the distance of that specific fruiting tree from the river. Amounts furthest away from the river (7 km and further) are a lot lower, with an average of only 20 fruit per tree in season; significantly less than between 1 and 3 km from the river where an average of 78 individual fruits were estimated in the canopy of any tree noted to be in fruit.

Fruit on the ground is however much easily observed and amounts more accurately estimated from direct observation due to reduced error which may arise from the use of binoculars, as well as using estimated proportions to multiply estimated counts.
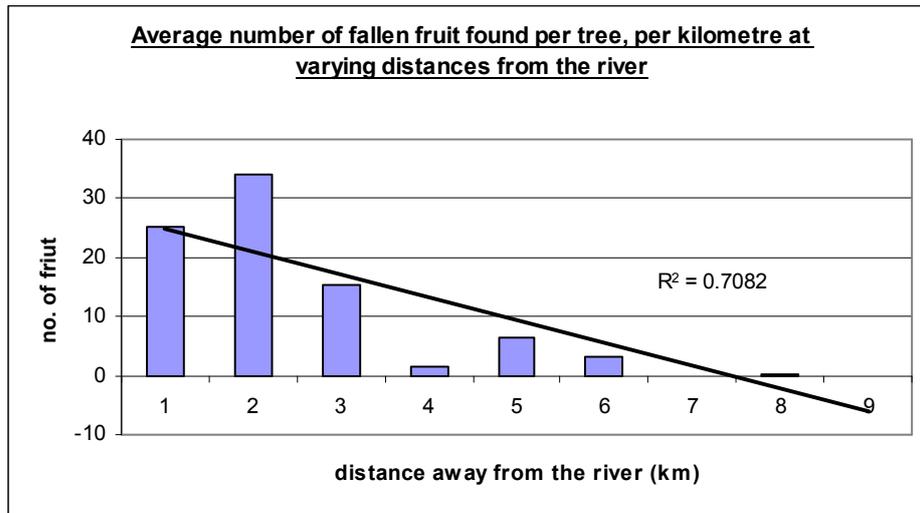
Average number of fallen fruit found per tree, per kilometre at varying distances from the river

$R^2 = 0.7082$

no. of friut

distance away from the river (km)

Fig. 4 shows the average amount of fruit that had fallen to the ground per tree at different distances from the river.

Fig. 4 presents the distribution of amounts of fruit dropped by trees. Fruit on the ground was not found in all areas of the forest. Fallen fruit was found in significantly low numbers away from the river, with an average of only 2 fruit per tree found at km 4-5. From there on average amounts of fruit found on the ground stay low, in fact no fruit was being dropped by trees from 7 km onwards. There is a significantly ($p<0.005$, $r^2 = 0.71$) stronger negative correlation between fallen fruiting abundance and distance of the parent tree from the river. However not identical, similar relationships of both fruit in the canopy and around the base of the tree can be seen when comparing each with respect to the river i.e. a negative linear correlation of abundance as distance from the river increases.
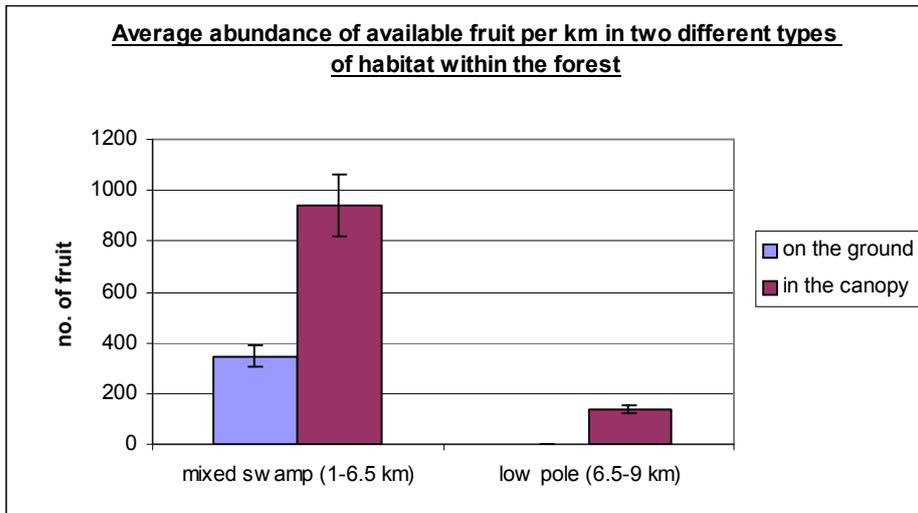
Fig. 5 shows the differences in the average number of fruit found per tree in the canopy and that which had fallen to the ground between the two different habitat sub-types within the study area.

Each transect only measured one habitat type along its complete length however, as distance increases from the river ecology i.e. vegetation and structure of the forest does change. In fact the three transect furthest away from the river were surveying low-pole forest and not mixed swamp forest. Fig. 5 gives data on the average abundance of both canopy and fallen fruit per km surveyed in both habitat types. The mixed swamp forest has a particularly high average abundance of fruit both on the branches 938 (s.e = +/-122.6) and on the litter of the forest floor 347 (s.e = +/- 40.8), compared with the low pole.
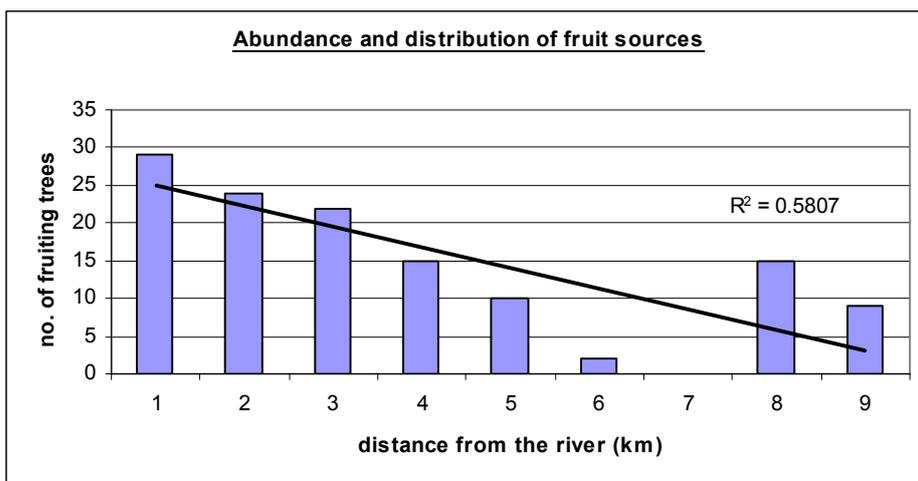

Fig. 6 shows the number of actual trees in fruit in relation to their distance from the river

Clear differences in the amount of parent fruit trees found within a kilometre of the forest were observed at varying distances from the river. By using the term source, every point at which any species or quantity of fruit is observed is inferred to as equal. With the surveyed area the number of places at which fruit can be obtained significantly ($p < 0.02$, $r^2 = 0.58$) decreases with increasing distance from the river.

Closer to the river there is not only more trees in fruit (fig. 6) but each individual tree bears a greater abundance. (fig. 3)

Diversity

Of the 17 species categories collected only 3 have been identified. Morphological descriptions of the fruit are described, from which they were then put into groups.

Table. 2 shows the categorised descriptions of different species

Species	size (diam.)	colour	shape	texture	seeds	special feat.s	type	Species identification
A	0.5 cm	bottle green	oval	smooth & shiney	1 light green	sticky flesh	berry	
B	1-2 cm	orangey	roundish	rough	4 small	partitioned inside	-	Baccaurea bracheata
C	0.5 cm	red & white	spherical	smooth			berry	
D	4-6 cm	redy-dark brown	oval	velvety	4 red nuts	thick shell	nut	
E	1 cm	pale green	ovalish	smooth	2 yellow	top has indentation/pit	-	Eugenia havilandi
F	<1 cm	green	spherical	smooth			berry	
G	1-2 cm	bright green	spherical	slightly rough	1 tiny	white flesh	fleshy	
H	5 cm	green	spherical	smooth		apple-like	-	
I	3 cm	yellowy-brown	round	furry	bobbly & external	orange insides	-	
J	2 cm	green	roundish	smooth		divides into hexagon pieces	-	Magnoliaceae aromadendron
K	4 cm	light green	round	smooth	2 oval nuts	cream flesh	nut	
L	<1 cm	redy-black	spherical	smooth		red stalk	berry	
M	4 cm	yellowy-green	oval	smooth			-	
N	1 cm	pale green	odd	smooth		spherical with protruding horns	-	
O	2 cm	pale green	roundish	smooth but bumpy	green flesh		-	
P	2-4 cm	green	round	rough			fleshy	
Q	miscellaneous							

Exact numbers of the fruit sources of each species are then presented in Fig. 7. Species G appears to be the most common fruit in the mixed swamp forest, i.e. 1-6.5km, whereas in the low pole Species L seems to take precedence.
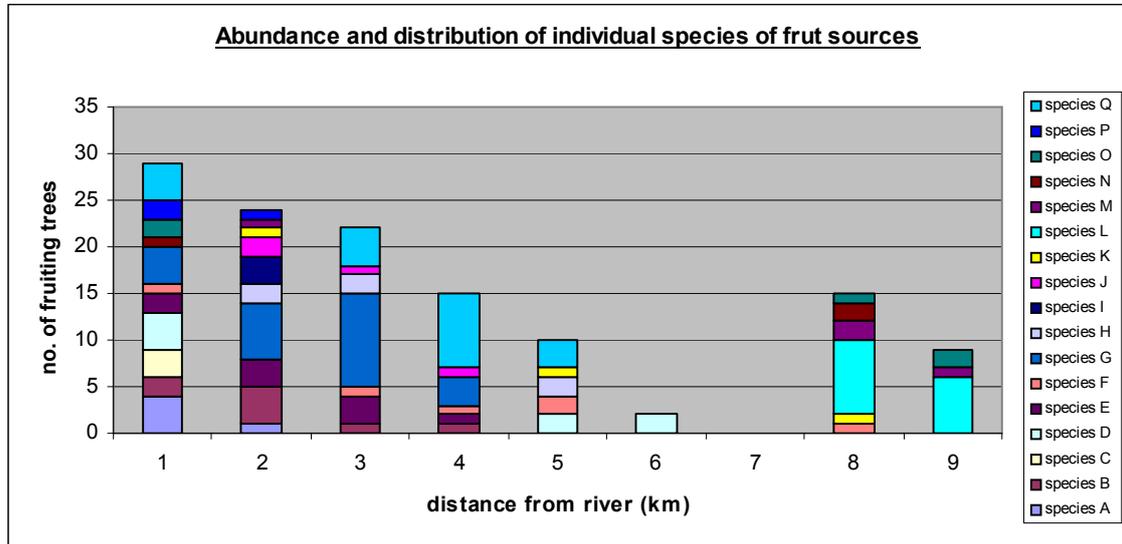

Fig. 7 shows the individual amounts of each fruiting tree species at various distances from the river.
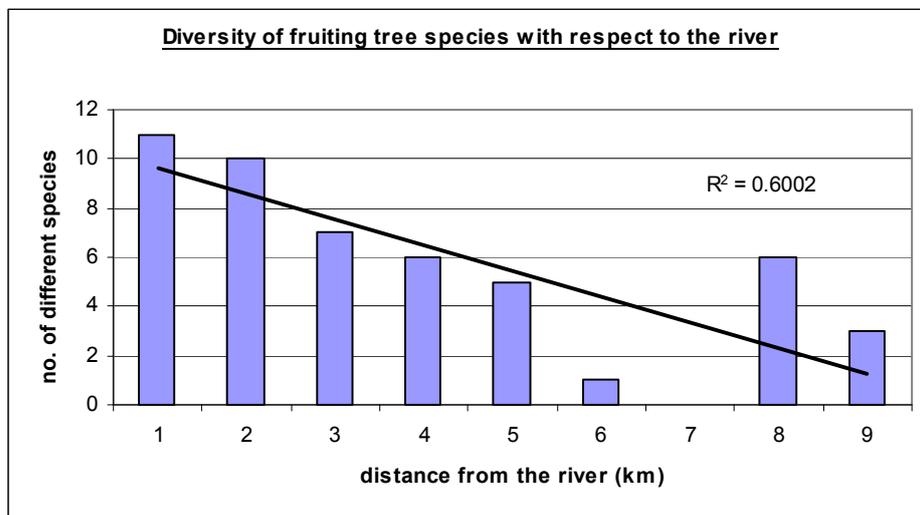

Fig. 8 shows the number of different fruiting trees species found at varying distances from the river.

The number of different fruiting tree species present within the surveyed forest decreases with increasing distance from the river; a significant (p<0.02 , r^2=0.60) negative correlation. (Fig. 8) A total of 17 species groups were recorded to be in

fruit at the time of the survey, 65% of which were observed in kilometre 1. Transects further away from the river proved to represent proportionately less of the total of species identified. Diversity of fruiting trees is greatest closest to the river.
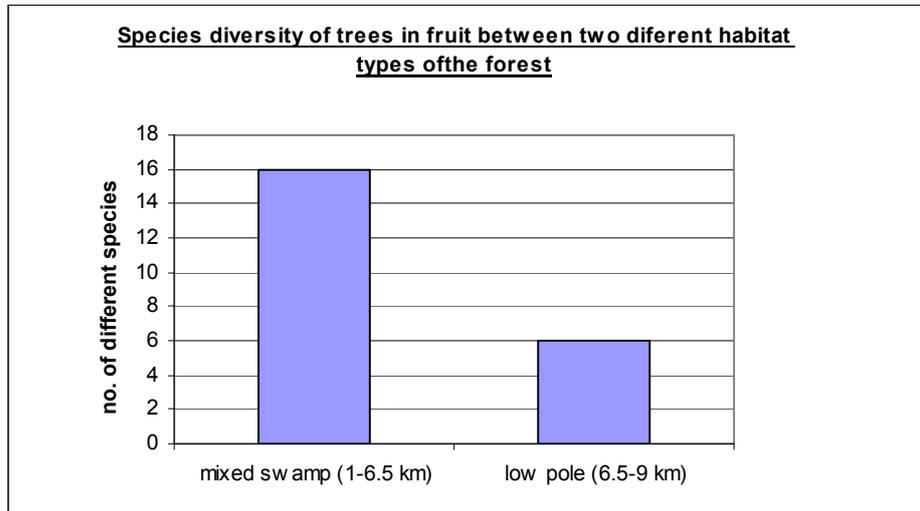

Species diversity of trees in fruit between two diferent habitat types ofthe forest

Fig. 9 shows the diversity of the species of trees in fruit in two different forest habitat sub-types.

The most obvious drop in species diversity is from 6 km onwards which is better represented in Fig. 9, which compares the diversity of fruiting trees species between the two habitat types. 94% of all the fruiting trees species identified have some sort of representation in the mixed swamp forest, compared with 38% present in the low pole.

Orang-utans

Two peaks in the abundance of nest constructed in different areas of the forest are observed 27 at km 1 and 40 nests between 6-8 km. The lowest number of nests found within a kilometre stretch of the forest was 5 at 3km. Fig. 10 presents data on the differences in the abundance of nests constructed in relation to their distance from the river. There appears to be no significant ($p > 0.5$, $r^2 = 0.06$) correlation between orang-utan nest abundance or distribution with increasing distance from the river.
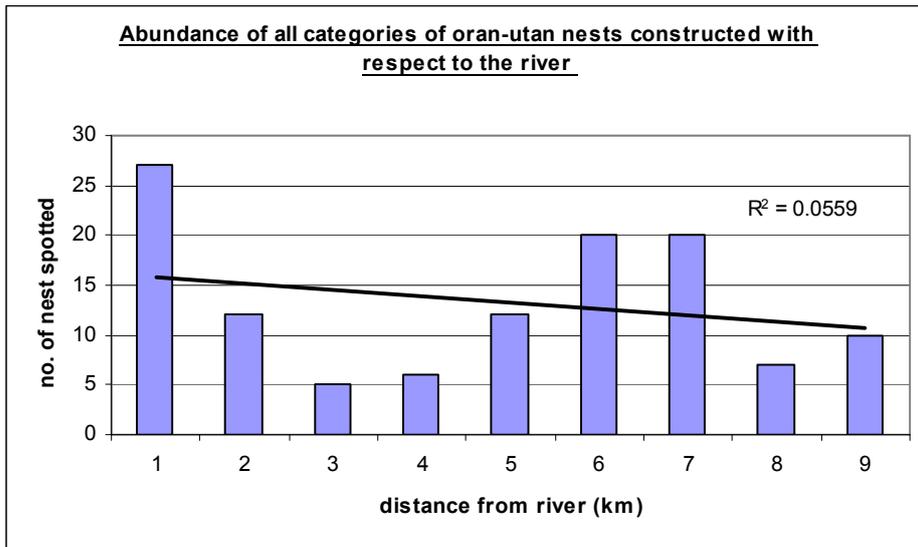
Abundance of all categories of oran-utan nests constructed with respect to the river

$R^2 = 0.0559$

no. of nest spotted / distance from river (km)

Fig. 10 shows the number of nests spotted in different kilometre zones travelling into the forest.

The highest numbers of nests built in a kilometre is found closest to the river, as is the highest abundance of fruiting trees. (fig. 6) At this particular area of the forest abundance of fruit both on the ground (fig. 4) and on the trees (fig. 5) is at its second greatest, 34 and 269 respectively.

However, the second highest abundance of nest is actually recorded in an area (6-8km) where only a tiny amount of fruit was found. In fact this peak in orang-utan nests correlates with the lowest abundance of fruit throughout the forests strata. (both litter and canopy)
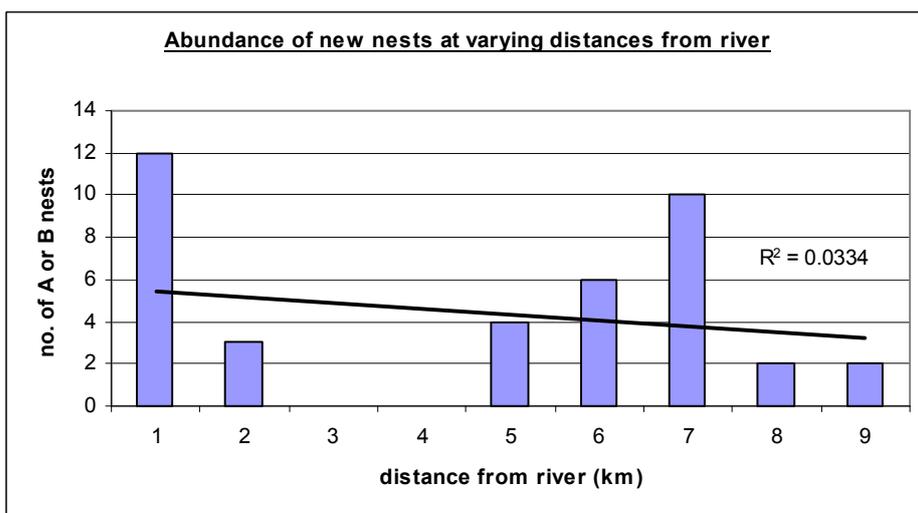

Abundance of new nests at varying distances from river

$R^2 = 0.0334$

no. of A or B nests / distance from river (km)

Fig. 11 shows the number of A and B classified nests per kilometre zone relative to the river.

Complications arise when using data from two different habitats as continuous when aiming to compare the possibility of variables as related. In addition fruit (one of the variables) was surveyed for its presence in one month, consequently orang-utan nests that have been constructed for significantly longer than this time period are only going to increase the chances of no correlation. Fig. 11 describes the abundance and distribution of new nests, i.e. categorised as A or B during the month of the survey in only the mixed swamp forest. There is no real significant ($p > 0.6$, $r^2 = 0.10$) correlation between the orang-utan nest data and distribution from the river. This is due to the lack of new nest between 3 and 5 km and fairly constant abundance with an average of 4.5 A and B nests per kilometre at 2, 5 and 6km. The general decreasing abundance of nests correlates to the decreasing amount of fruit, with the exception of kilometres 3 and 4.

DISCUSSION

Abundance and Diversity

According to Galdikas (1988) the highest numbers of trees in fruit are expected in December and May marking respectively the beginning and end of the wet season. The lowest abundance of fruit in the canopy is commonly in the month of August (Galdikas, 1988) coinciding with the height of the dry season. Although the study was conducted in the dry or low fruiting season, during the months of August and September which directly correspond to the lowest measurements of rainfall (monthly averages of 108 and 85mm respectively, for 88-98) (Toma *et al*., 2000) a significant correlation of fruit abundance with distance from the river is recorded.

Closer to the river there are more fruiting trees present, each bearing a greater amount of fruit on their branches as well as dropping greater amount of fruit around its base. A greater abundance of fruit on the ground implies increased maturity or ripeness of the fruiting parent trees. Abundance and diversity is presumably connected to productivity of which biotic and abiotic limiting factors can have an effect. Nutrient availability, soil pH and height of the water table are

most probably more similar to the optimum requirements of fruiting trees near the river at this time of year, compared to ground ecology further away from the river. Vegetational differences are significantly related to rainfall and run-off (MacKinnon, 1974) in particular.

Obtainability of nutrients must vary spatially within this ecosystem irrespective of the assumed depletion throughout the forest during the dry season. Closer to the river peat is shallower (Morrogh-Bernard *et al*., in press) and from the data collected it can be assumed that this may aid the inhabiting tree's ability to extract nutrients. Fruiting trees at greater distance from the river are probably waiting for the rainy season when water is more abundant to produce larger, more succulent fruits at higher yields. Abundance and diversity of valleys and floodplains is greater than in higher areas. (MacKinnon, 1974) Although the change in altitude of the studied forest within 9km of the river is probably minimal, some effect might be occurring and can therefore as possible partial explanation of the increased abundance and diversity of fruit nearer to the river.

As well as continuous spatial differentiation of factors affecting the productivity rates of the resident trees, distinct variations in micro-environment are likely to be the cause for the differences seen between the two habitat types studied.

Orang-utans

From previous studies it is clear that orang-utans are able to modify the time they spend feeding (Rodmann, 1977; MacKinnon, 1974) their dietary composition (Galdikas, 1988) and food selectivity (Leighton, 1993) in response fluctuations in fruit availability. But does the availability of fruit, regarded as abundance and distribution have an effect on orang-utan distribution i.e. choice of location when constructing nests? A potential food source is considered any species of tree bearing fruit at the time of the survey. Unfortunately it became difficult to actually quantify potential orang-utan fruit sources accurately because identification of

samples became more complicated than at first hope but by creating a general overview of the available of all fruit, this can be considered as representative.

According to the majority of previous reports (Galdikas, 1974 & 1988; MacKinnon74; Payne & Andau, 1989) orang-utans nest near a good food source. Comparing distribution and abundance of fruit with orang-utan nests in this study however, shows no correlation, except at kilometre 1 when both variables are greatest. It is presumed that orang-utans frequently nest near the last food tree they ate in. (MacKinnon, 1974) However, they do not nest in the fruit tree for risk of unnecessary conflict with other orang-utans. (Morrogh-Bernard *et al*., in press) The basis for this study relied upon the fact that orang-utans are primarily frugivorous apes, and so when they have finished eating for the day they would construct nest nearby the last fruiting tree, hence a correlation between nest and fruiting tree distribution was expected. However, this sleeping location pattern is not without exception, sometimes orang-utans are reported to travel distances of 500m from their last feeding site and nest on accessible travel routes. (MacKinnon, 1974) Fruit scarcity is linked with increased time spent travelling (Rodmann, 1988) presumably in search of food but could also help explain the lack of correlation between fruit and nest distribution. Transects within the study area are on average 1 km apart and so overlap between the grouped distances may be adding error to the data and subsequent relationship or lack of, between orang-utans and fruit.

Orang-utans rely on only a few fruiting species (Rodmann, 1977) in their diet and consequently only nest around those trees, making it more difficult to use a general assumption of fruiting tree distribution as representational. Species like durian, neesia and mango produce large fruits, but fruit rarely, are found at very low densities (Rodmann, 1988) and were thus unlikely to be found on any of the surveys. In actual fact much of the fruit found is small in size and therefore likely not to be orang-utan food. However, there is still an underlying importance to the surveys conducted and that is the general idea that the amount of trees that are

23

fruiting at any one time will be proportional to the amount of orang-utan food available at that time.

If a high percentage of orang-utan food trees consist of upper canopy or emergent trees then it is likely that these would be less common but provide larger sources of food than lower strata canopies. (Galdikas, 1988) Surveys were conducted via direct observation which means scanning for fruit (the most common types of which were small and green, i.e. camouflaged) of the tallest vegetation is almost impossible and at best highly inaccurate, that was if you could even tell the tree was bearing fruit at all. If the taller trees were the ones in fruit and they did offer a greater density of fruit then orang-utans then this could help explain why in some areas measured the abundance to fruiting trees was low and yet newly constructed nests were recorded. Alternatively perhaps preference leans more towards the construction material in that nest location is species specific because of sturdy tree crowns or strong branches for the basic framework of the nest.

The carrying capacity of an area especially during non-fruiting season has an effect on population stability. (Boekhoerst, 1990) Competition with other fruigivores, e.g. birds and bats, will increase when fruit is scarce. However, orang-utans are at an advantage due to their ability to utilise foods not available to other animals and may explain their apparent, relative high numbers in the low production forest habitat of the low-pole. Resident males are also reported to emigrate when preferred foods are scarce. The current thinking behind this choice is to reduce competition with females. According to Rodmann (1977) males eat less energy rewarding yields even when at high procurement, leaving bark, leaves and fruit on the trees for females with the underlying possibility of advantages being given to their mates and subsequent offspring. Males are less reliant on high food abundance and quality than females probably because infants usually accompany females. (Morrogh-Bernard *et al*., in press) Previous studies conducted in this study forest believe that males primarily use the low-pole habitat and perhaps this can be added to and help explain the relatively high

population of orang-utans in the low pole where fruit abundance is particularly depleted.

Orang-utans using this habitat type could possibly be surviving on a low and possibly even negative energy budget that could have profound effects if this choice of habitat becomes a long term decision. An alternative explanation of the presence of orang-utans in an area of low production forest is that they are using this area as an escape from the disruption and destruction of human activities, in particular logging. Logging has been recorded to influence the relative abundance of different food types as well as their dispersion, which inevitably has an effect on the ranging behaviour. (Johns, 1986) When a habitat becomes fragmented its resources become more clumped. In the study this may have an effect on the accuracy of the measurements of fruit availability along the transect as representational for the larger area. Orang-utans will also feed less selectively in habitats with increased clumping or patches of fruit, (Johns, 1986) which can occur as a result of human activities. Predation risk for orang-utans is from humans and is variable between habitat types but should have little effect on whether they nest near a fruit tree or not. However orang-utans may still move away to less disrupted habitats, i.e. from the mixed swamp to the low pole.

Different areas or habitats give variation in the forests specifics, availability of fruit in particular, (Rodmann, 1977) on offer and subsequently reliance of the individual inhabitants must vary accordingly. Mixed swamp is the preferred habitat choice of the orang-utans within the study area. The low-pole forest however also has a high nest density and consequently alternative predeterminants of density to fruit are suspected. Fruit is low here and subsequent logic would lead us to believe other foods such as bark, leaves and flowers make up a higher percentage of the orang-utans diet. The low pole is considered a possible corridor habitat (Morrogh–Bernard *et al*., in press) between the mixed swamp and the tall interior. It could be that the nests recorded in this area are of orang-utans moving away, i.e. passing through to find greater abundance's of food in alternative habitat sub-types.

Orang-utans have adapted methods of coping with the annual fluctuations in fruit availability of South East Asian forests, by efficient storage of fat (Knott, 1999) and foraging opportunistically (MacKinnon, 1971 ; 1974) i.e. making use of seasonal foods. During periods of low fruit availability energy stores have to be consistently relied upon. (Knott, 1998) In fact fluctuations in fruit availability may be a critical factor influencing orang-utans behaviour and social organisation. (Knott, 1998)

Consumption of fruit and flowers is negatively correlated with leaves and even more so with bark. (Galdikas, 1988) Hence when fruit is in low abundance orang-utans are expected to turn to bark, leaves and flowers. A key point to consider when trying to explain why distribution is not correlated with fruit abundance or distribution in this study.

Variation in the eating of fruit or not, by orang-utans gives an implication towards the existence of nomadic tendencies of this species, that results in movement relative to the availability of food. (Leighton & Leighton, 1993) But the ability to eat many alternative food sources in times of low fruit availability causes problems when trying to evaluate the relationship between one specific food source; fruit and nest distribution. During the dry season other factors are likely to be of greater importance in influencing the distribution of orang-utans.

CONCLUSION

This is the first ever study of fruiting abundance in the Sebangau peat swamp forest, hence improvements are inevitable. Maybe transect lines should be walked twice in order to reduce the possibility of missed fruit in particular because of their small size. As long as habit structure allowed transect lines could be longer in minimum length (2km). Perhaps square plot areas could be measured as well as transect line in order to investigate the presence of spatial clumping expected in forests used for timber extraction. Other inadequacies of the data include the lack of data of previous months of the year. Observations could be better evaluated if the differences in relative abundance could be

compared with other months in the year, as better understanding of orang-utan movements and the complexity of the adjustments they need to be made in their feeding ecology.

However, a significant correlation between increased fruit availability and decreased distance from the river was observed. Closer to the river there were more fruiting trees present, a greater diversity of species and each individual trees had a greater abundance of fruit both in the canopy and on the ground

Comparing fruit abundance with orang-utans distribution is very difficult even in the best of conditions in the height of the wet season, and so there is a necessity to be at least tentative when analysing an interpreting the data. No relationship was found linking orang-utan distribution with the abundance or even spread of fruiting trees. In a study forest such as this, where illegal logging is more than just a common occurrence it provides regular income for the locals, then human destruction and disturbance is probably having a far greater effect on daily selection of nest location than the distribution of fruit. Nevertheless, with more acute (just orang-utan fruit species), year-round, data a clearer more significant correlation between fruit and orang-utan nest distribution would be expected.

REFERENCES CITED

Brokelman, W Y & Ali, R (1987) Methods of surveying and sampling forest primte populations. In: *Primate Conservation in the Tropical Rain Forest*, pp23-62 (eds. C.W. Marsh and R.A. Mittermeier). Alan R. Liss, New York.

Buckland, S T, Anderson, D R, Burnham, K P & Laake, J L (1993) *Distance Sampling: Estimating Abundance of Biological Populations*. Chapman and Hall, Londan.

Burnham, K P, Anderson D R & Laake, J L (1980) Estimation of density from line transect sampling of biological populations. *Wildlife Monograms* no. **72**.

Chapman & Chapman (1990) Dietary Variability in Primate Populations. *Primates.* **31**, 121-128

Dasmannn, R F (1981) *Wildlife Biology,* ed. 2nd . Wiley, New York Chichester.

Delany, M J (1982) *Mammal Ecology*. Blackie, Glasgow.

Dowdeswell, A H (1966) *An Introduction to Animal Ecology*, ed. 2nd. Methuen, London.

Fleming et al. (1987) In: Orang-utan Behaviour and Ecology, *The Non-human Primates*, (ed.s P. Dolhinow and A. Fuentes) pp50-57. Mayfield Publishing Company, Mountain View, California.

Galdikas, B M F (1974) In: Orang-utan Behaviour and Ecology, *The Non-human Primates*, (ed.s P. Dolhinow and A. Fuentes) pp50-57. Mayfield Publishing Company, Mountain View, California.

Galdikas, B M F (1988) Orang-utan Diet, Range, and Activity at Tanjung Puting, Central Borneo. *International Journal of Primatology* **9**, 1-35

Gautier-Hion, A. Duplantier, J-M., Quris, R., Feer, F., Sourd, C., Decoux, J-P., Dubost, G., Emmons, L., Erard, C., Hecketweiler, P., Moungazi, A., Rousilhon, C. & Thilollay, J-M. (1985) Fruit characters as a basis of fruit choice and seed dispersal in a tropical forest vertebrate community. *Oecologia*, **65**, 324-337

Ghiglieri, M P (1984) *The Chimpanzees of Kilabe Forest; a Field study of Ecology and Social Structure*. Columbia University Press, New York.

Groombridge (1993) In: Orang-utan Behaviour and Ecology, *The Non-human Primates*, (ed.s P. Dolhinow and A. Fuentes) pp50-57. Mayfield Publishing Company, Mountain View, California.

Horr, D A (1972) The Borneo orang-utan: population structure and dynamics in relationship to ecology and reproductive strategy.

Johns, A D (1986) Effects of selective logging on the behavioural ecology of West Malaysian primates. *Ecology* **67**, 684-694

Knott, C D (1998) Changes in orang-utan calorie intake, energy balance and ketones in response to fluctuating fruit availability. *International Journal of Primatology* **19**, 1061-1079

Knott, C. (1999) Orang-utan Behaviour and Ecology In: Dolhinow, P. and Fuentes, A. (eds) *The Non-human Primates*, Mayfield Publishing Company, Mountain View, California, pp 50-57

Krebs, J R & Davies, N B (1987) An introduction to Behavioural Ecology, ed. 2nd . Blackwell Scientific Publications, Oxford.

Lawes, M J, Henzi, S P & Perrin, M R (1990) Diet and feeding behaviour of samango monkeys (*Cercopithecus mitis labiatus*) in Ngoye Forest, South Africa. *Folia Primatol* **54**, 57-69

Leighton, M (1993) Modelling Dietary Selectivity by Borneon Orang-utans – Evidence for Integration of Multiple criteria in Fruit Selection. *International Journal of Primatology* **14**, 257-313

Longman, K A & Jenik, J (1987) Tropical Forest and its environment, ed. 2nd. John Wiley & sons, New York.

MacKinnon, J (1974) The behaviour of wild orang-utans (*Pongo pygmaeus*). *Animal behaviour* **22**, 2-74

MacKinnon, J (1977) In: Orang-utan Behaviour and Ecology, *The Non-human Primates*, (ed.s P. Dolhinow and A. Fuentes) pp50-57. Mayfield Publishing Company, Mountain View, California.

Meijaard, E (1997) The importance of swamp forest for the conservation of orang-utans (*Pongo pygmaeus pygmaeus*) in Kalimantan, Indonesia. In: Biodiversity and Sustainability of Tropical Peatlands (ed.s J.O. Rieley & S.E. Page) pp243-54. Samara Publishing, Cardigan UK.

Payne, J. (1986) Surveying orang-utan populations by counting nests from a helicopter: a pilot survey in Sabah.

Payne, J & Andau, M (1989) *Orang-utan. Malaysia's Mascot*. Berita, Kuala Lumpar, Malaysia.

Poulsen, J R, Clark, C J & Smith, T B (2001) Seasonal variation in the feeding ecology of the grey-cheeked mangabey (*Lophocebus albigena*) in Cameroon. *American Journal of Primatology* **54**, 91-105

Rodmann, P S (1973) Population composition and adaptive organisation among orang-utans of the Kutai Reserve. In: *Comparative ecology and Behaviour of Primates* (eds. J.H. Michael and J.H. Crook) pp171-209. Academic Press, London.

Rodmann, P S (1977) Feeding behaviour of orang-utans of the Kutai Nature Reserve, East Kalimantan. In: *Primate Ecology: Studies of Feeding and Ranging Behaviour*

inLemurs, Monkeys and Apes (ed. T.H. Clutton-Brock) pp383-413. Academic Press, London

Rodmann, P S (1988) Diversity and consistency in ecology and behaviour. In: *Orang-utan Biology* (ed. J. Schwartz) pp31-51. Oxford University Press, New York.

Scott & Selsor (1961) In: Orang-utan Behaviour and Ecology, *The Non-human Primates*, (ed.s P. Dolhinow and A. Fuentes) pp50-57. Mayfield Publishing Company, Mountain View, California.

Sekulic, R (1982) Daily and seasonal patterns of roaring and spacing in four red howler *Alouatta seniculus* troops. *Folia Primatol* **39**, 22-48

Sugardjito, J (1983) Selecting nest sites by Sumatran orang-utans (*Pongo pygmaeus abeli*) in the Gunung Leuser National Park, Indonesia. *Primates* **24**, 467-474

Thompson (1982) In: Orang-utan Behaviour and Ecology, *The Non-human Primates*, (ed.s P. Dolhinow and A. Fuentes) pp50-57. Mayfield Publishing Company, Mountain View, California.

Toma et al., (2000) In: Orang-utan Behaviour and Ecology, *The Non-human Primates*, (ed.s P. Dolhinow and A. Fuentes) pp50-57. Mayfield Publishing Company, Mountain View, California.

Turner, I M (2001) The ecology of trees in the Tropical rain Forest, pp151-55. Cambridge University press, Cambridge.

Van Schaik, C P (1986) Phenological changes in a Sumatran rain forest. *Journal of Tropical Ecology* **2**, 327-347

van Schaik, C P, Azwar, & Priatna, A (1995) Population estimates and Habitat Preferences of Orang-utans based on line transects of nests. In *The Negleted Ape*. Plenum Press, New York.

White, L J T, Rogers, M E, Tutin, C E G, Williamson, E A & Fernandez, M (1995) Herbaceous vegetation in different forest types in the Lopes Reserve, Gabon – Implications for Keystone Food Availability. *African Journal of Ecology* **33**, 124-141

Youlatos, D (1998) Seasonal variation in the positional behaviour of red holing monkeys (*Alloatta seniculus*). *Primates* **39**, 449-457

Zhang & Whang (1995). In: Orang-utan Behaviour and Ecology, *The Non-human Primates*, (ed.s P. Dolhinow and A. Fuentes) pp50-57. Mayfield Publishing Company, Mountain View, California.