

Bornean Orang utan (*Pongo pygmaeus*) Habitat Associations in Relation to Forest Structure and Disturbance

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Abstract

Habitat associations of orang utans (*Pongo pygmaeus*) in relation to forest structure and intensity of anthropogenic disturbance were investigated in a Bornean peatswamp forest. Nest density was estimated, and forest structure and intensity of disturbance calculated within samples of forest. Nest density was inversely correlated with logging intensity, which supports the theory that orang utan avoid areas of disturbance. Nest density was found to be significantly correlated with open areas. Further support for this observation was provided by the results of a discriminant function analysis, which found that the amount of open area could be used to discriminate between samples that were devoid of nests and samples that contained nests. It is suggested that orang utan may favour these areas as nest sites because of the increased predator/conspicuous detection and outlook ability that may be associated with this type of microhabitat. The findings suggest that forest structure may influence nest site location, and that the level of disturbance may influence area usage, and overall whole animal density.

Keywords: orang utan, habitat association, nest count survey, peatswamp forest.

Introduction

Current knowledge regarding the distribution, population size and conservation status of the orang utan (*Pongo pygmaeus*), although incomplete, suggests that the species is in decline (e.g. Soemarna *et al.*, 1995, Rijksen and Meijaard, 1999), and has led to its' classification as an endangered species by the World Conservation Union (IUCN, 2000). In recent years, habitat loss as a result of timber extraction, forest fires, and conversion for agriculture and human settlement have become the principal cause of this decline (Rijksen and Meijaard, 1999; Yeager, 1999). Although able to persist in selectively logged forests studies have reported marked declines of orang utans after logging. Orang utans appear to be more susceptible to the affects of habitat disturbance than other primates, and do not persist in forest converted to rubber and palm oil plantations, as are common in Indonesia and Malaysia.

Within Kalimantan, Indonesia, one of the last remaining strongholds of the orang utan, little of the available remaining habitat is under any form of protection, and much of the

forests are now designated as timber concessions. Over the last three decades Indonesia's government has allocated over 60 million hectares of forest to commercial logging companies (McCarthy, 2001). Furthermore, with few effective regulatory structures in Indonesia's forestry sector, increasing demand for timber has resulted in large volumes of wood being harvested from illegal sources (ITFMP, cited in McCarthy, 2001).

Clearly, these pressures will remain to be the principal threat to the orang utan's survival, and as such, must be dealt with accordingly. The establishment of more protected areas and the design of logging techniques and exploitation systems that are less damaging to biodiversity are thus important strategies to help reduce the decline of orang utans. Research efforts, therefore, need to identify the best habitat within the current range and the factors that influence habitat quality, and also determine the ecological mechanisms that lead to the decline of orang utans in selectively logged forest.

Surveys to determine orang utan nest (arboreal sleeping platform) density along line transects are an established method of studying the species' habitat preference (van Schaik *et al.*, 1995). Orang utans build new nests each night, and occasionally nests are constructed during the day for resting, or to shelter from rain (MacKinnon, 1974). Nests are more commonly encountered than the animals themselves, and since they persist for a number of days, they fluctuate less in density over time at a single location, making them particularly suitable for survey work. The nest is situated close to feeding sites or travel routes and so the distribution of nests over a particular area indicates those parts of the range utilised by orang utans (MacKinnon, 1974). Nest density is proportional to time spent in a particular area (Rao & van Schaik, 1997), and therefore nest density can be used to indicate habitat associations; areas of higher nest density can be considered better orang utan habitat. Whole animal density can be derived from nest density estimates by incorporating the rate at which nests are produced, the rate at which nests degrade, and the proportion of animals that build nests, into the calculation (van Schaik *et al.*, 1995).

Inter-island differences in orang utan density have been observed; Sumatran orang utans occur at about 1.5 –2 times that of Bornean orang utans in comparable habitat (Sugardjito & van Schaik, 1991). Both islands, however, exhibit a similar pattern of orang utan distribution in different habitats. The richest habitats tend to be swamp and lowland alluvial forest, which support almost twice the orang utan densities of surrounding adjacent uplands (Sugardjito & van Schaik, 1991; van Schaik, & Aswar, 1991; Meijaard, 1997; Russon *et al.*, 2001). Indeed, orang utans are largely lowland animals, being rare above 1000 metres, and virtually absent above 1500 metres (van Schaik *et al.*, 1995; van Schaik *et al.*, 2001). Within Bornean peat swamp forest, orang utan density varies according to habitat sub-type. Mixed swamp and tall interior forest sub-types contain greater numbers of orang utan than low pole forest (Morrogh-Bernard, *in press*) (for descriptions of forest type see Page *et al.*, 1999).

The reasons for these patterns are becoming increasingly understood, and appear related to fruit availability. The abundance of strangling figs and soft pulp fruit in general, have been shown to be significant predictors of orang utan density (Djojosedharmo and van Schaik, 1992; Leighton, 1993), and in undisturbed forest are

preferentially eaten by orang utans (Rijksen, 1978; Djojosedharmo and van Schaik, 1992; van Schaik *et al.*, 1995). More productive habitats contain a higher proportion of soft-pulp fruits (van Schaik & Mirmanto, 1985 cited in van Schaik 2001), and due to volcanic activity Sumatra has higher fruit productivity than Borneo. Similarly, fruit productivity declines with altitude, and alluvial and flood plain habitats are more productive than adjacent uplands, thus producing the observed differences in orang utan density.

Productivity and its resultant affect on fruit production account for much of the variation in orang utan density in undisturbed forest, but disturbance can also influence habitat quality. Studies using nest counts concluded that orang utan density in selectively logged forest were around one half to one third of that found in pristine forest (Rijksen, 1978; Davies and Payne, 1982; Payne, 1987; van Schaik and Azwar, 1991; Rao and van Schaik, 1997; Morrogh-Bernard *et al.*, in press).

The ecological mechanisms behind the decline of orang utan are currently little understood. The extraction of timber may directly result in the mortality of some individuals. Creation of logging roads to extract the timber results in increased use of the forest, and thus hunting pressure, not only for food, but also for the pet trade. Orang utans are particularly prone to hunting due to their slow reproductive rate, which is due to the time taken to reach sexual maturity (around 12 years) and their extremely long inter birth period (normally 8 years) (Galdikas and Wood, 1990; Rijksen and Meijaard, 1999). The reduction in density has also been attributed to the movement of individuals away from logged forest (Russon *et al.*, 2001, Morrogh-Bernard *et al.*, in press), as well as direct ecological changes brought about as a result of the logging process. Through direct behavioural observations Rao & van Schaik (1997) revealed that relative to animals living in pristine forest, animals living in logged forest show a shift from frugivory to folivory, travel more, rest less, and increase energetically expensive locomotor behaviour.

Orang utan are able to persist in disturbed forest, but little is understood about the factors that affect habitat quality in this environment. Owing to the fact that disturbed forest are becoming an increasingly common habitat for orang utans it is perhaps even more important that we understand more about habitat associations of orang utans in these forests, and the factors that determine habitat quality. The present study will investigate the habitat associations of Bornean orang-utans in a disturbed peat swamp forest in relation to forest structure and levels of anthropogenic disturbance. Fine scale samples of orang utan nest density are analysed along with associated forest structure variables and indicators of logging disturbance.

Study Area

The study took place within the upper catchment of the Sungai (River) Sabangau, 20 km south-west of Palangkaraya, Central Kalimantan, Borneo, Indonesia (Fig. 1). The catchment consists of a large (5000 km²), continuous area of forested peatland (Page *et al.*, 1999), and supports a high biodiversity (Page *et al.*, 1997) including a large, self-sustaining orang-utan population (Morrogh-Bernard *et al.*, in press). Sampling was

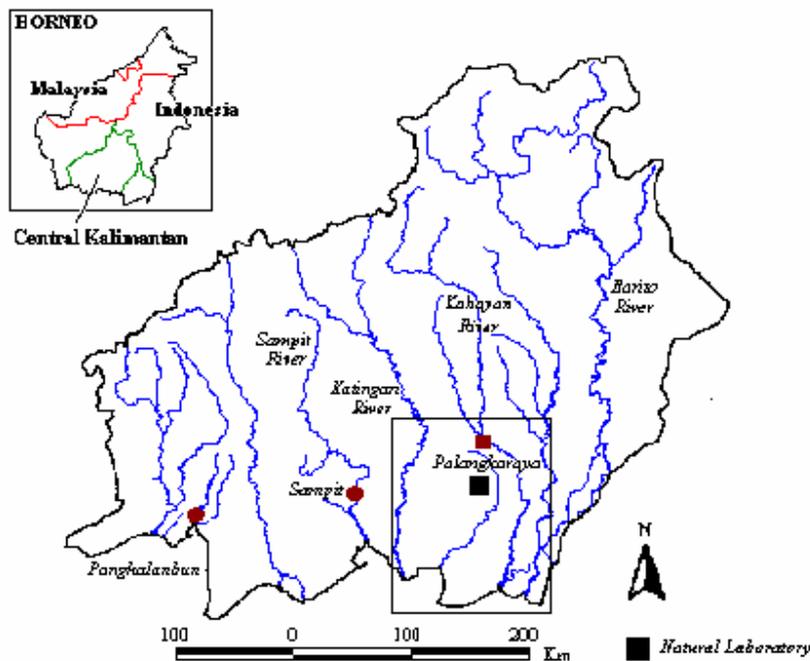


Fig. 1. Map of the Sabangau catchment showing the two study sites (Unfinished).

limited to two areas (Site A and site B) of mixed-swamp forest (Page *et al.*, 1999) that have been subjected to intense levels of disturbance. Ending in 1997, parts of the forest were selectively logged over a 20-year period, and have since been subjected to varying levels of uncontrolled illegal logging. To date, most of the commercially viable trees (>35 cm DBH) have been removed, and now logging effort is focussing on the smaller remaining trees. To enable the logs to be transported out of the forest a network of logging skids and narrow canals have been cut out of the peat. Consequently, the forest is a patchwork of dense secondary forest with a discontinuous canopy, interspersed with clear, open areas. The permanently high water table and the high understory light levels, as a consequence of canopy disruption, have resulted in dense undergrowth of *Pandanus* and *Freycinetia* spp. (pandans).

Methods

Nest density survey

Field research was carried out between July and September 2001. Fifteen transects totalling 17.8 km (14.8 km –Site A; 3 km –Site B) were surveyed for the presence of orang utan nests. With the exception of three transects, which were newly cut for the purposes of this study, the transects at Site A had been pre-cut during a

previous study (Morrogh-Bernard *et al.*, 2001). The transects were predominantly separated by 1 km and ran perpendicular to a disused timber extraction railway. All three Site B transects were newly cut, and were located 100 m from the basecamp. The transects ran in opposing compass directions (110, 130, 180).

Nests were observed by slowly walking along each transect line, frequently pausing to look behind and above. For each nest encountered, the perpendicular distance from the transect to the nest (m) and the distance along the transect (m) were recorded.

The nest abundance data for each of the transects were divided up into 100 m sections, and a nest density value was calculated for each section. The software programme Distance 3.5 (Thomas *et al.*, 1998) was used to determine nest density by calculating the area censused based on the effective strip width. This width (w) is estimated from a detection function fitted to the observed distribution of perpendicular line-to-nest distances (Buckland *et al.*, 1993). Nest density can then be estimated as:

$$d = N / (L \times 2w)$$

where:

- d = nest density (nests/km²)
- L = length of transect section (km)
- N = number of nests observed along the transect section
- w = effective width of strip of habitat censused (km)

Forest Structure data

To relate nest densities to forest structure and disturbance vegetation sampling points were located at the centre of each 100m section of transect described above. At each point the following variables were recorded: (i) Diameter at breast height (DBH) (cm) and maximum canopy height (m) of 1 central and 10 nearest neighbour trees >7cm DBH. The distance from the centre tree to the furthest tree was measured, allowing the calculation of tree density; (ii) number of cut stems >7cm DBH within a 5m radius of the central tree; (iii) estimated % canopy cover directly overhead. The disturbed forest no longer has a continuous canopy at 30m and a sub canopy at 15m as in pristine forest (Page *et al.*, 1999). Instead there is a patchy canopy of variable height, constructed by secondary trees (12-16m) and the occasional large semi-mature tree that has escaped logging. Thus, the canopy cover value provides an indication of the continuity of the sub/low level canopy that remains.

The number of cut stems within 3m either side of each transect, the number of logging skids and canals (wet and dry) that crossed the transect, and the estimated canopy gap size directly above the transect (m²) were recorded along a belt transect. The presence of strangling figs and the amount of soft pulp fruit on forest floor were also recorded. Data were recorded within 100m sections, which were centred on each of the

sampling point sites, thus providing information relating to the two 50m sections of transect either side of each sampling point.

Data Analysis

Principal Components Analysis

A Principal Component Analysis (PCA) was performed using the software program SPSS vol. 10.0 on the Forest Structure data to reduce the co-linearity of the data. All eleven variables were entered into the analysis. A varimax rotation was performed, and the Factor scores were saved as variables. Scatter plots of all couplings of the Factor scores were examined for significant patterns. Data points were labelled as either nests present, or nest absent. Data points were also labelled according to nest density. A two-tailed Spearman's Rank Correlation Coefficient analysis was performed between the nest density data and the PCA Factor scores; a-priori probability was set at $p < 0.05$.

Discriminant Function Analysis

A Discriminant Function Analysis was performed using the software program SPSS vol. 10.0 to identify whether the forest structure data could be used to discriminate samples that contained nests from those that were devoid of nests. The PCA Factor scores were entered as the independent variables, the method used was 'stepwise Wilk's Lambda', prior probabilities were computed from group size, and within-groups covariance matrix was used.

Results

Effective strip width

The effective strip width was calculated to be 12.8 m and 24.7 m for Site A and Site B respectively. The distribution of transect line to nest distances from Site B did not conform to a normal distribution, therefore, the figure given may not be an accurate estimation of effective strip width. Nevertheless, the higher effective strip width in this area is in line with the open nature of the forest in this area, and so detection distances would be expected to be higher.

Principal component analysis

The PCA analysis reduced the eleven variables into six potentially biologically meaningful factors (Table 1), and retained 78.83% of the information. Graphical analysis of scatter plots between all the pairs of factors, where points were labelled both with nest density and presence/absence of nests, failed to highlight any relationship between nest density/presence and the factor scores.

Table 1. Results of the PCA and correlation analyses, showing the factor loadings and resultant factor scores. Figures in brackets are the factor loadings.

Factor loadings	Variable name	Correlation with nest density
Canopy (0.855) Density (0.782) Gaps Area (-0.352)	(1) Canopy Quality	n.s.
D.B.H. (0.85) Height (0.839)	(2) Mean Tree Size	n.s.
No. Dry Canals/100m (0.839) No. Wet Canals/100m (0.857)	(3) No. Logging Canals	n.s.
No. Skids (0.821) No. Gaps/100m (0.743) No. Stumps/100m (0.436)	(4) Open & logged forest	p <0.05
Stumps/5m circle (0.860) Number stumps/100m (0.709)	(5) Logging Intensity	p <0.05
Dead tree density (0.952)	(6) Dead tree density	n.s.

Correlation with nest density

Correlation analysis reveals a weak inverse relationship between nest density and logging intensity (Factor 5) ($r_s = -0.17$, $p = 0.035$; Fig. 2a) and a weak positive relationship between nest density and the amount of open areas (Factor 4) ($r_s = 0.18$, $p = 0.023$; Fig. 2b). Nest density was not correlated with canopy quality ($r_s = 0.84$, n.s.), mean tree size ($r_s = 0.06$, n.s.), number of logging canals ($r_s = 0.82$, n.s.), or dead tree density ($r_s = -0.11$, n.s.).

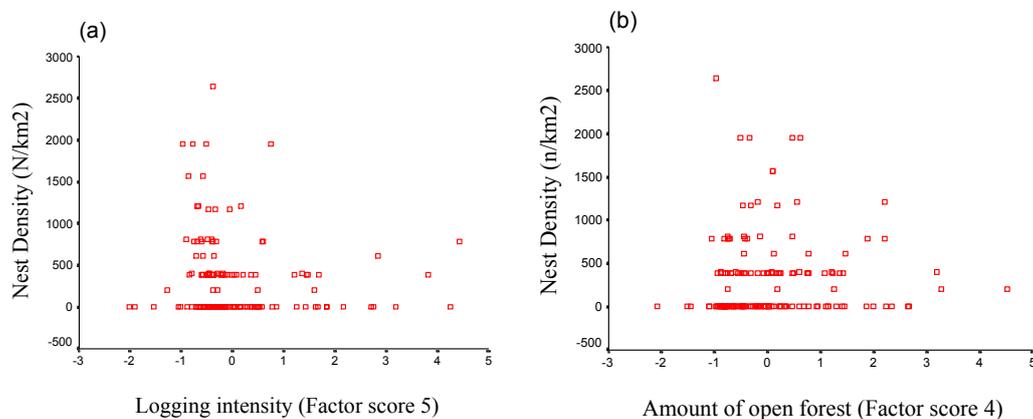


Fig. 2. The observed relationship between nest density and logging intensity (a), and amount of open forest (b).

Discriminant analysis

Discriminant analysis revealed that PCA factor 4, the amount of open area (Table 1), could be used to discriminate between samples that contained nests and samples that were devoid of nests (Wilks' lambda = 0.96, $\chi^2 = 6.59$, $p < 0.01$). The single

discriminating variable correlated perfectly with factor 4; the other PCA factors were found to be insignificant. Samples devoid of nests were found to be negatively associated with amount of open areas, and samples with nests present were positively associated (functions at group centroid -0.178 , 0.226 respectively). Cross validation reveals that the classification accuracy is fairly low, with 58.3% of the samples allocated to their correct group.

Discussion

Nest density and logging intensity

The results of the present study suggest that orang utans may avoid higher intensity logged areas by adapting the fine scale use of their range. Other studies have noted a movement of orang utans at a larger scale in response to logging, and it is thought that this movement is the cause of the reduction of orang utan density following habitat disturbance (Morrogh-Bernard *et al.*, 2002). MacKinnon (1971) suggested that orang utans move out of areas exposed to disturbance, but may return once the disturbance has ceased. Other studies have attributed high densities in areas previously logged to the displacement of orang-utans (Russon *et al.*, 2001, Morrogh-Bernard *et al.*, 2002). Russon *et al.* (2001) found that disturbed and sometimes seriously degraded areas yielded high nest densities. It was suggested that the area is experiencing post-disruption recovery, and that more recent habitat disturbances elsewhere may have displaced orang utans into the previously logged areas. Such movements of individuals have been referred to as 'refugee crowding' (Rijksen and Meijaard, 1999) and may ultimately lead to the forest exceeding its' carrying capacity.

In comparison, long term studies at Ketambe and Suaq Balimbing, in Sumatra, suggest that orang utan densities remain stable in areas adjacent to forest that is subject to selective logging (van Schaik *et al.*, 2001). van Schaik *et al.*, (2001) have recognised a dichotomy in the use of space between transient and resident orang utans. Residents tend to be highly conservative in the use of their range, and do not expand into new areas after the loss of part of their range to deforestation

The present study suggests that within areas of disturbed forest, where orang utans will be unable to move out of disturbed forest and into undisturbed forest, orang utans may adapt the small-scale use of their range, and spend reduced amounts of time foraging in more heavily disturbed areas. Individual orang utans that tend to avoid certain areas within their range will effectively be reducing their range and thus the amount of resources available to them, which in turn may increase the likelihood of succumbing to disease.

Nest location and open areas

The results of this study suggest that areas containing orang utan nests tend to be more open in structure than areas that are devoid of nests, and that nest density is positively related to the amount of open area. The higher density of nests in more open

areas may be a result of orang utans having a preference for these areas for day to day activities such as foraging. Alternatively, the relationship may be related to a preference for nest site location relating to these sites. Although increased light levels associated with logging activities can result in increased fruit production, particularly figs (Plumptre & Reynolds, 1994) the extent of tree removal that has resulted in the creation of open areas is far more likely to have reduced the amount of available fruit rather than increase it. Furthermore, it is widely held that orang utans tend to avoid areas of disturbance, of which the open areas are likely to be a result.

Nest site location preference appears then to be a more plausible cause for the observed relationship. Situating nests adjacent to forest gaps may enable orang-utans to increase predator detection (MacKinnon 1974). MacKinnon (1974) found that nest clumping tends to occur on west facing slopes, and suggested that the warmth of the evening sun, the shelter from evening winds and the extensive view afforded by these positions make them attractive. Harrison and Kurt, (cited in MacKinnon, 1974) stress the importance of a good outlook in the avoidance of predators. The results of this study appear to support this hypothesis; open areas may increase the ability of orang utans to detect predators. Aside from man, Bornean orang utans have two potential predators, the clouded leopard and the python (although adult males are probably unaffected by the latter). Studies have shown that predator avoidance can be a significant factor in the location of orang utan nests. Sugardjito (1983) showed that adult male and female orang utans choose nest sites in or close to the last food tree visited, whereas more vulnerable individuals i.e. adolescents and females with young, selected nests sites both away from and at greater distances from their last visited food tree, particularly if it was a fruit tree. The strategy of the vulnerable individuals is thought to reduce predation risk, as fruiting trees often produce aggregations of frugivores and attract predators. Clouded leopards regularly return to the same place where the presence of food is predictable; a strategy also adopted by man.

Setiawan *et al.*, (1996) question the role of predation by the clouded leopard on nest location choice, and suggest that orang utans build nests away from fruit trees in order to avoid threat from conspecifics who may seek out the same food source. Female Bornean orang utans are potentially at risk from male orang utans, particularly subadult males, due to the risk of forced copulations (Galdikas, 1985a; 1985b) and possible risk to offspring. Therefore, behavioural strategies that minimise contact with conspecifics may be advantageous for vulnerable individuals.

The location of nests adjacent to open areas may therefore be a behavioural strategy employed to increase predator and/or conspecific detection for individuals at risk from these pressures i.e. adolescents and females with young. However, the low correlation value between open areas and nests density, although significant, suggests that it is unlikely that this strategy plays a major role in nest site location choice, and that orang utans would travel significant distances to locate open sites for nesting. It is more likely that orang utans may choose to nest in such a site if it is in close proximity to their last feeding site.

This hypothesis appears to contradict the negative relationship between nest density and logging intensity discussed above, because open areas are likely to be a result of disturbance. However, it must be considered that the orang utans living in the forest studied in this study are unable to escape entirely disturbed forest due to the overall extent of logging in the immediate area. Therefore, although orang utan may change the small scale use of their range in response to logging activities, their nests will always be associated with disturbed areas.

It is now widely held that orang utan populations are threatened by habitat loss as a result of logging. The present study reveals that orang utans tend to avoid logging disturbance on a small scale; a response that may put them at increased risk from disease. The results provide further evidence that protection from illegal logging activities is required immediately.

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References

- Davies, A.G., & Payne, J.B. 1982. *A Faunal survey of Sabah*, World Wildlife Fund, Malaysia, Kuala Lumpur.
- Djojosedharmo, S., and van Schaik, C.P. 1992. Why are orang utans so rare in the highlands? *Tropical Biodiversity*, **1**: 11-22.
- Engström, L. 2000. Effects of selective hand-logging on orangutan habitat quality and population density in Gunung Palung National Park, Borneo, Indonesia; with focus on forest structure and nest resources. M.Sc. Thesis. Upsala University.
- Galdikas, B.M.F. 1985a. Subadult male orangutan sociality and reproductive behaviour at Tanjung Putting. *American Journal of Primatology*, **8**: 87-99.
- Galdikas, B.M.F. 1985b. Adult male sociality and reproductive tactics among orangutans at Tanjung Putting. *Folia Primatologia*, **45**: 9-24.
- Galdikas, B. M. F. and Wood, J. W. (1990) Birth spacing patterns in humans and apes. *American Journal of Physical Anthropology*, **83**, 185-191.

IUCN (2000) *Red List of Threatened Species*. www.iucn.org/redlist/2000.

Leighton, M. 1993. Modelling dietary selectivity by Bornean orangutans: evidence for integration of multiple criteria in fruit selection. *International Journal of Primatology*, **14** (2): 257-313.

MacKinnon, J. 1971. The orang-utan in Sabah today. *Oryx*, **11** (2-3): 141-191.

MacKinnon, J. 1974. The behaviour and ecology of wild orang-utans (*Pongo pygmaeus*). *Animal Behaviour* **22**: 3-74.

McCarthy, J.F. 2001. *Decentralisation and Forest Management in Kapuas District, Central Kalimantan*. Centre for International Forestry Research, Bogor, Indonesia.

Meijaard, E. 1997. The importance of swamp forest for the conservation of the orang utan (*Pongo pygmaeus*) in Kalimantan, Indonesia. In: J.O Rieley and S.E. Page (eds.) *Proceeding of the International Symposium on the Biodiversity, Environmental Importance and Sustainability of Tropical Peat and Peatlands*. Samara Publishing, Cardigan, UK.

Morrogh-Bernard, H., Husson, S. Page, S. E., & Rieley, J.O. 2002. Density, distribution and population size of the Bornean orang-utan (*Pongo pygmaeus*) in the peat swamp forest of the Sabangau catchment, central Kalimantan, Indonesia. *Biodiversity and Conservation* (In Press).

Page, S.E., Rieley, J.O., Doody, K., Hodgson, S., Husson, S., Jenkins, P., Morrogh-Bernard, H., Otway, S. and Wilshaw, S. 1997. Biodiversity of tropical peat swamp forest: a case study in Central Kalimantan. In: Rieley, J.O., Page, S.E. (Eds.), *Biodiversity and Sustainability of Tropical Peatlands*. Samara Publishing, Cardigan, U.K., pp. 231-242.

Page, S.E., Rieley, J.O., Shotyk, W., & Weiss, D. 1999. Interdependence of peat and vegetation in a tropical peat swamp forest. *Philosophical Transactions of the Royal Society London B*, 354, 1885-1897.

Payne, J. 1987. Surveying orangutan populations by counting nests from a helicopter: a pilot survey in Sabah. *Primate Conservation* **8**: 92-103.

Plumptre, A.J., & Reynolds, V. (1994) The effects of selective logging on the primate populations in the Bundongo forest reserve, Uganda. *Journal of Applied Ecology*, **31**: 631-641.

Phillips, V.D. 1998. Peat swamp ecology and sustainable development in Borneo. *Biodiversity & Conservation*, **7** (5): 651-671.

Rao M., and van Schaik C.P. 1997. The behavioural ecology of Sumatran orangutans in logged and unlogged forest. *Tropical biodiversity* 4 (2): 173-185.

Rijksen, H.D., 1978. *A Field Study of Sumatran Orang utans (Pongo pygmaeus abelii Lesson 1827)*, Wageningen: H Veenman and Zonen B.V.

Rijksen, H. D., & Meijaard, E. 1999. *Our Vanishing Relative: The Status of Wild Orangutans at the Close of the Twentieth Century*. Kluwer Academic Publishers, Dordrecht.

Russon, A.E., Erman A., & Dennis, R. 2001. The population and distribution of orangutans (*Pongo pygmaeus pygmaeus*) in and around the danau sentarum wildlife reserve, west Kalimantan, Indonesia. *Biological Conservation*, 97 (1): 21-28.

Setiawan, E., Knott C.D. & Budhi, S. 1996. Preliminary assessment of vigilance and predator avoidance behaviour of orangutans in Gunung Palung National Park, West Kalimantan, Indonesia. *Tropical Biodiversity* 3(3): 269-279.

Soemarna, K., Ramono, W. & Tilson, R. 1995. Introduction to the orang-utan population and habitat viability analysis (PHVA) workshop. In: *The Neglected Ape*. Nadler, R. D. Galdikas, B. F. M. Sheeran, L. K. & Rosen, N. (Eds). Plenum press. New York & London. 81-83.

Sugardjito, J., & van Schaik, C.P. (1991) Orang-utans: Current Populations Status, Threats and Conservation Measures. In: *Proceedings of the Great Ape Conference*, December 15-22, 1991, Indonesia.

Thomas, L., Laake, J.L., Derry, J.F., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Strindberg, S., Hedley, S.L., Burt, M.L., Marques, F., Pollard, J.H. and Fewster, R.M. 1998. Distance 3.5. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK.

van Schaik, C.P., & Aswar. 1991. Orangutan densities in different forest types in the Gunung Leuser National Park (Sumatra), as determined by nest counts. Report to LSB Leakey Foundation.

van Schaik. C. P., Priatna. A. & Priatna, D. (1995). Population estimates and habitat preferences of the orang-utan based on line transects of nests. In: *The Neglected Ape*. Nadler, R. D. Galdikas, B. F. M. Sheeran, L. K. & Rosen, N. (eds.). Plenum Press. New York & London, . 129-147.

van Schaik, C.P., Monk, K., & Yarrow Robertson, J.M. 2001. Dramatic decline in orang-utan numbers in the Leuser ecosystem, Northern Sumatra. *Oryx*, 35(1): 14-25.

Yeager, C. P. (Ed.), 1999. Orangutan Action Plan. WWF Indonesia.