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Nest density as determinants for habitat utilizations of Bornean orangutan (*Pongo pygmaeus wurmbii*) in degraded forests of Gunung Palung National Park, West Kalimantan

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ABSTRACT

*Prasetyo D, Sugardjito J (2011) Nest density as determinants for habitat utilizations of Bornean orangutan (*Pongo pygmaeus wurmbii*) in degraded forests of Gunung Palung National Park, West Kalimantan. Biodiversitas 12: 164-170.* Conversion of forests into non-forests areas particularly for the development of timber industry and oil palm plantation in Ketapang district, West Kalimantan province was drastically increased recently. We have conducted an assessment for the density of Bornean orangutans *Pongo pygmaeus wurmbii* L. in degraded forests of the boundary of Gunung Palung National Park, West Kalimantan in 2004 and 2005. We used line-transects nest-count to survey 39,6 km length at 13 sites including 7 in side the park and the other 6 situated out side the park which holds a difference status of forest management. The differences of nest density between degraded forests habitat was calculated. The old degraded forest which has been logged for 5 years or more, were containing more new nests in a cluster compared to the recently as well as currently logged. The highest number of orangutan's nests could be found in the old degraded forest in side the park, whereas the lowest one was obtained in the currently logged protection forest with the density of 3.70 ind/km^2 and 0.06 ind/km^2 respectively. We compare these results with the survey undertaken previously in the area when the logging and forest conversion activities have just begun in the region in 2001.

Key words: degraded forests, nest-count, orangutan density, *Pongo pygmaeus wurmbii*.

INTRODUCTION

West Kalimantan forests support one of Borneo's few remaining large orangutan populations. Most of these populations, however, are inhabit forests outside protected areas and hence, are threatened by conversion for concession-based timber industry and oil palm plantation. Together with inconsistency of land-use policy, the establishments of palm oil and timber industries have resulted in highly fragmented and degraded forests (EIA 1998; Rijksen and Meijaard 1999; FWI 2002). It has been shown that deforestation rate in the Ketapang district of west Kalimantan was significantly increased between 2000 and 2005. The primary dry lowland and peat swamp forests in Ketapang district were reduced 15% and 28% respectively during this period (Adhikerana and Sugardjito 2010). Unfortunately, those forests provide good habitat for orangutan.

The orangutan is known to inhabit primary and secondary forest and is typically found in lowland dipterocarp, freshwater and peat swamp forests. It has also been recorded from hill forests up to about 1,500 m although it occurs in a lower density than in other forest habitats (MacKinnon 1974; Rijksen 1978; Payne 1988; Rijksen and Meijaard 1999; Yanuar et al. 1996). All of those forest habitats, however, are under pressures. Further, habitat degradation and fragmentation have been identified as the major driver of extinctions of many tropical forest species (Laurance et al. 1998). It has been long recognized that the main factor of deforestation is human population pressures (Brown and Pearce 1994).

In the beginning of implementation of district autonomy, forest encroachments for subsistence agriculture nearly existed in all over area in Indonesia including Kalimantan. Previous results estimated that the total area of orangutan habitat in Kalimantan has decreased 2.8% annually (Wich et al. 2008). Pressures from hunting for bush meat and pet trade have even made the Bornean orangutan population more vulnerable and it leads to the status of the species into endangered (Sugardjito 1995; Ancrenaz et al. 2008).

The population estimate of Bornean orangutan has been made by previous authors who have ever made gross survey in the island. MacKinnon (1985) has estimated the population of orangutan in Kalimantan about 156,000 whereas, Sugardjito and van Schaik (1991) have suggested the population which inhabits protected areas in Kalimantan was ranging between 20,000 and 30,000 individuals. Later on 2004 in the orangutan population and habitat viability analysis, the experts have proposed the total number of orangutan population in Kalimantan was 54,000 (Singleton et al. 2004).

The Gunung Palung National Park which is located in the districts of Ketapang and Kayong Utara is suitable habitat for orangutans. The forest landscape in this region consists of various types of habitats from coastal lowland forest up to hill forest. This type of habitats provides orangutans to move and utilize different habitats in order to exploit food sources in the area (Leighton 1993). With the rapid reduction of forest habitat especially after intensive forest conversion between 2000 and 2005 (Adhikerana and Sugardjito 2010), the assessment on population status of orangutan in the degraded forests of Gunung Palung area is urgently needed. The purpose of this survey was to assess the status of orangutan population in the Gunung Palung National Park, specifically in its boundary areas where human pressures are mostly occur. Further, the principal aims of our field survey were to estimate orangutan population densities in degraded forest habitats with various degrees of disturbances and to identify the determinants of intensity utilization of degraded forests by orangutans.

MATERIALS AND METHODS

Study sites

The sites which are located in boundaries of Gunung Palung National Park either in side or out side the park have been selected. We chose the area surrounding the boundaries of the park which are frequently under pressure due to human activity and it leads to disturbances. The periods of disturbances were different between sites. Some have been disturbed more than 5 years while the others just disturbed between 2 and 5 years before the survey. The followings are 13 sites that have been surveyed during 2004 and 2005 (Figure 1, Table 1).

Lubuk Baji

Located in side the Park with the geographic positioned at S 01°13'05.6" and E 110º00'36.1". The area categorized as old degraded forest consists of primary lowland forest which forms a continuous canopy of trees between 20 and 30 m high. The illegal logging was very few in this site and it was happened in a period between 1998-2003. In the adjacent boundary, there are community's garden occupied by fruit trees such as durian, lansium, rambutan and mangoesteen.

Sungai Benawai

Situated within the Park with geographical positioned at S 01°12'46.9" and E 110º01'48.5". The habitat categorized as current degraded forest consists of peat swamp forest with open canopy trees of less than 20 m with less than 30 cm diameter at breast high. The majority of tree species belongs to Dipterocarpaceae trees that are commonly used as host tree for strangling figs the staple food of orangutan. Land-use conflict occurs in this site. Local people were active to enter the area and open the garden while taken the wood.

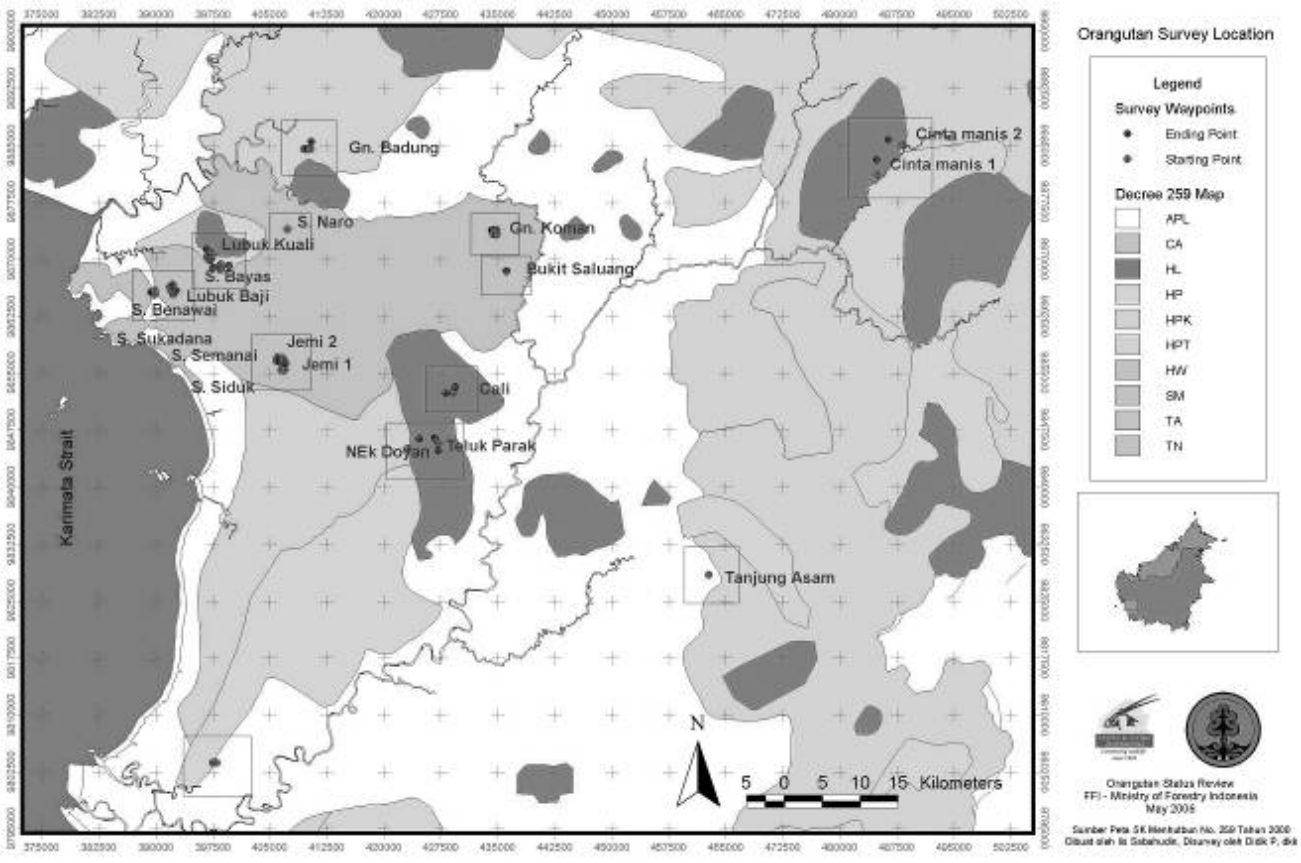

Figure 1. Survey sites inside Gunung Palung National Park and its surroundings.

Table 1. Habitat information in survey sites.

Location	Geographic positioned	Habitat type	Habitat status	Legal status
Lubuk Baji	S 01°13' 05.6"; E 110º 00' 36.1"	Primary lowland forest	Old degraded forest	NP
Sungai Benawai	S 01º 12'46.9"; E 110º 01'48.5"	Secondary peat swamp forest	Current degraded forest	NP
Sungai Bayas	S 01°10'51.6; E 110°05'19.7"	Primary peat swamp forest	Old degraded forest	NP
Jemi	S 7° 4' 6.34" S; E 181° 20' 42.17"	Primary lowland forest	Recent degraded forest	NP
Gunung Koman	S 74° 12' 11.25"; E 103° 51' 11.33"	Secondary lowland forest	Old degraded forest	NP
Bukit Saluang	S 7° 39' 28.254"; E 181° 31' 49.90"	Secondary lowland forest	Recent degraded forest	NP
Sungai Naro	S 7° 10' 33.508"; E 181° 29' 50.99"	Secondary Lowland and peat swamp forest	Recent degraded forest	NP
Nek Doyan	S 01º 24'03.5"; E 110º 18'34.4"	Secondary lowland forest	Current degraded forest	PF
Teluk Parak	S 01º 23'42.3"; E 110º 20'45.2"	Secondary lowland forest	Current degraded forest	PF
Cali	S 01º 20' 08.1"; E 110º 21' 48.5"	Secondary lowland forest	Current degraded forest	PF
Gunung Badung	S 7° 15' 25.404" E 181° 35' 12.19"	Secondary lowland and peat swamp forest	Recent degraded forest	PF
Lubuk Kuali	S 01° 10'23.1"; E 110° 04'11.2"	Secondary peat swamp forest	Old degraded forest	CF
Tanjung Pasar	S 01°46'35.3"; E 110°04'19.9"	Secondary peat swamp forest	Recent degraded forest	CF

Note: NP = National Park, PF = Protection Forest; CP = Community Forest.

Sungai Bayas

Located in side the Park with geo-positioned at S 01°10'51.6" and E 110°05'19.7", we categorized as old degraded forest. It consists of primary peat swamp forest with very little disturbances and holds many food tree species of orangutan. There are new growths of vegetation in some parts where forest fire occurred in 1997-1998.

Jemi

The site is situated in side the Park with geo-positioned at S 7°4'6.3" S and E 181° 20'42.1". It was logged by people in 1990s and categorized as recent degraded forest. It consists of lowland primary forest with very steep slope. The forest canopy is continuous with trees high more than 25 m and 50 cm dbh. The majority of trees grow especially the timber species such as Dipterocarpaceae and food trees of orangutan like.

Gunung Koman

As the part of National Park area, this site is categorized as old degraded forest with geo-positioned at S 74°12'11.2" and E 103°51'11.3". Surroundings the Gunung Koman forest was planted by commercial fruit trees, but local people still reserve the forest for water resources. Canopy covered was high density, is almost 65% with height of tree between 15-25 meters.

Bukit Saluang

The site is located in side the Park with geo-positioned at S 7°39'28.2" and E 181°31'49.9". It consists of lowland secondary forest and categorized as recent degraded forest. Some big productive trees still occur in this site, such as meranti and bangkirai.

Sungai Naro

In side the Park with the geo-positioned at S 7°10'33.5" and E 181°29'50.9". The access to this site only from river. Illegal selective cutting of trees occurs in small portion by local people, so we categorized as recent degraded forest. It consists of lowland and peat swamp forests habitat. Many big trees still left with the diameter more than 50 cm. Some food trees of orangutan can be found here such as nyatoh, kumpang, langsat whereas the commercial trees are bangkirai, belian, meranti, galam tikus.

Nek Doyan

Located out side the Park but, it is within the protection forest of Gunung Tarak with the geo-positioned at S 01º24'03.5" and E 110º18'34.4". It categorized as current degraded forest consists of lowland secondary forest with open canopy. It is dominated by trees with less than 20 m high at 30 cm dbh. There were only a few trees with 50cm e.g. available in scattered places. The food trees of orangutan (Ficus spp) are very few. Active logging and encroachment are found during survey. Wildlife hunting is also often in this site. Cultivated durian trees are found in this area.

Teluk Parak

It also located in side the protection forest of Gunung Tarak. It consists of lowland secondary forest and categorized as current degraded forest with open canopy and only few big trees are left. The geo-positioned of the site is S 01º23'42.3" and E 110º20'45.2". This site was the remained of forests after big forest fire in 1998. The trees left are mostly small size with diameter at brest height less than 30 cm. Illegal logging was found very active during the survey.

Cali

Situated in side of the protection forest in Gunung Tarak with the geo-positioned at S 01º20' 08.1" and E 110º21'48.5". The habitat is similar to Teluk Parak where illegal logging active and local people were encroaching forest to establish subsistence agriculture land and it is categorized as current degraded forest.

Gunung Badung

Located out side the Park with geo-positioned at S 7°15'25.4" and E 181°35'12.1". It was logged very recent as log trail can be found everywhere and we categorized as recent degraded forest. It consists of secondary peat swamp and lowland forests habitat with steep landscape. Many sungkai trees grow in the peat swamp area whereas in

lowland forest are medang, kubing, belian, gelam tikus and gaharu. Hunting of animal frequently occurs in this site.

Lubuk Kuali

Located at S 01°10'23.1" and E 110°04'11.2" out side the Park. It consists of peat swamp forest with little disturbances and categorized as old degraded forest. Big trees with diameter more than 30 cm and more than 30 m height are still available. The forest relatively in good condition with closed canopy and it situated in between north-east and north-west parts of the park.

Tanjung Pasar

Located closed to Ketapang town with geo-positioned at S 01°46'35.3" and E 110°04'19.9". It consists of secondary peat swamp forest with few food trees of orangutan and categorized as recent degraded forest. This forest is managed by community. Animal hunting frequently occur in this site although the target is not orangutan.

Procedures

The field survey was carried out during September - October 2004 and May – June 2005. Orangutan nests were counted by observers who walked slowly along line transects with minimum length 2 km. The distance between transect lines was at least 3 km apart. We defined logging here is hand logging which was common in the area (Cannon et al. 1994). This technique normally targets only a few commercial tree species and involves the use of hand-held chainsaws and human-powered removal of timber to water-courses (Whitmore 1984). It was not mechanized logging with heavy machinery, and therefore, is considered less destructive to forest structure (Ayres and Johns 1987).

The nature of forest disturbance was recorded qualitatively in three categories: (i) 'current', i.e. areas currently subject to timber extraction, (ii) 'recent', i.e. areas subject to timber extraction within the last 2 - 4 years, and (iii) 'old', i.e. areas in which timber extraction had not taken place for at least 5 years. This classification was modified from Morrogh-Bernard et al. (2003). All nests visible from the transect line were recorded.

Nest count was conducted at each transect line and the perpendicular transect-to-nest distances (m) were measured for every nest observed. The decay stage of nests was categorized in five classes following van Schaik et al. (1995) i.e. (i) fresh, leaves still green; (ii) older nest still in original shape, leaves still attaches but brown; (iii) old, holes appearing in nest; (iv) very old, twig and branches still present, but no longer in original shape; 5) only twigs still present. Orangutans build a nest near to the last food tree they visited during their daily activity (Sugardjito 1983). We measured the distance between nests when we encountered several nests in one spot during nest count survey.

Data analysis

Orangutan nest densities for each habitat type were calculated using the software program called DISTANCE 4.0 release 2 (Buckland et al. 1993). This technique uses data of transect length, number of nest observed, and perpendicular distance of each nest from the transect line. Then nest densities are converted to orangutan densities. Following van Schaik et al. (1995) we used the following basic formula for calculating nest density (Dn) from line transect surveys.

Dn = N / (L x 2w), N = number of nest observed, L = the length of transect covered (km), and w = the effective strip width of habitat type censuses. Then nest density was converted into orangutan density (Dou) through addition of some parameters. Dou = Dn x 1/ (p x r x t), where p, is the proportion of nest makers in the population, r, is the rate at which nests are produced (number per individual per days), t, is the estimated time a nest remains visible. The t value has been obtained from published data, (399 for peat swamps, 259 for dry low land and 380 for hill forests). Johnson et al. (2005). As for r value, we used 1 since the published range of r values for Borneo have been identified between 0.9 and 1.16 nests per individual per day (Lackman-Acrenaz et al. 2001; Johnson et al. 2005).

We measured the distances between nests of the same nest class category in one spot when we detect more than one nest. This is in order to detect the differences of visiting frequency of orangutans in different category of degraded forests. Chi-square test has been used to detect the differences.

RESULTS AND DISCUSSION

Orangutan is a cryptic arboreal animal and difficult to detect in the forest. They build a nest every days for sleeping and sometime it makes a resting nest during the day (Prasetyo et al, 2009). Nest count survey, therefore, provides the only feasible means of obtaining orangutan density estimates in a short period of time. A total of 678 orangutan nests were observed along 39.6 km of transects through peat swamp, lowland and hill forests. The following orangutan densities derived from nest count have been calculated from the data shown in Table 2.

The density of orangutan in Sungai Bayas was the highest. The site was little disturbed due to small illegal logging for more than 5 years ago. However, since 2003 the orangutan patrol and monitoring units or OPMU has regularly patrolled and monitored the illegal activities in this area. Consequently, the disturbances did not expand to a wider range of the habitat and other wildlife species could also be protected from hunting. Various categories of orangutan nests can be observed in this site. Previous authors indicated that orangutan suffer temporary, density declines following reduced impact logging (Felton et al. 2003; Morrogh-Bernard et al. 2003; Johnson et al. 2005; Marshall et al. 2006) but recover to pre-logging densities if forests are allowed to regenerate (Knop et al. 2004). Recovery can be realized by retaining soft-pulp fruit bearing trees and climbers while strictly enforcing patrol system to protect the animal from hunting (Robertson and van Schaik 2001). This would be the case for Sungai Bayas forest habitat.

Table 2. Number of orangutan nests observed in Gunung Palung National Park and surroundings.

Location	Nest	Transect lenght (m)	Density estimate (ind/km^2)	Forest status
Lubuk Baji	40	1800	2.19	NP
Sungai Benawai	69	2400	2.35	NP
Sungai Bayas	148	4000	3.70	NP
Jemi	57	6000	2.08	NP
Gunung Koman	1	1000	0.06	NP
Bukit Saluang	43	3000	0.88	NP
Sungai Naro	53	3500	1.48	NP
Nek Doyan	8	2250	0.09	PF
Teluk Parak	20	2000	0.80	PF
Cali	14	2000	0.16	PF
Gunung Badung	36	4400	2.06	PF
Lubuk Kuali	152	4000	2.30	CF
Tanjung Pasar	37	3250	1.50	CF
Total	678	39600		

Note: NP = National Park, PF = Protection Forest; CP = Community Forest.

As for sites of Lubuk Baji and Sungai Benawai, the density was a bit lower than the previous site because, the logging was occurred when the decentralization just began in 2001 or 3 years before the survey was conducted. Monitoring and patrolling system in these areas should be reinforced continuously in order to enable forest regeneration and to protect orangutan from human pressure, as well as durian plantation surrounded the forest.

Previous report indicated that population density of orangutan in the Gunung Palung National Park was 3 ind/km^2 overall with primary peat swamp forest densities of over 4 ind/km^2 (Johnson et al. 2005). We estimate that in the recently disturbed areas (2-5 years previously) in side the park still holds an orangutan density of 2 ind/km^2. The lowest population density has been found in survey sites of the adjacent protection forests, Gunung Tarak i.e. Nek Doyan, Teluk Parak, and Cali. These areas were logged when we did a field survey and the density of orangutan was found 0.09 ind/km^2 which is low compared to the area where recently disturbed in side the park. The survey team has encountered with some loggers when surveyed in these 3 sites. Although the status are protection forest, but no forest management is undertaken. According to the previous study, the habitat of orangutan particularly outside the park was reduced up to 3.1 km^2 each year due to logging activities either legal or illegally, and forest conversion for agriculture, mining and plantation (Meijaard and Wich 2007). The direct impact for orangutan was loss of their food trees as well as nesting trees. It has been identified that orangutans build their nests in trees near to the last food trees they visited during the day (Sugardjito 1983). Large body size, arboreal, and frugivorous are the characteristics of orangutans. Tree stands are, therefore, very critical to the survival of orangutans. The analysis shows that the cluster of nests with various categories of classes between levels of forest disturbance are different (X^2 = 8,40 and p < 0,01). This result was similar to previous findings that orangutan density was reduced less in peat swamp forests rather than in dry lowland forests after logging (Felton, et al. 2003; Aveling 1982; Rao and van Schaik 1997). The high number of nests in clusters with various categories of classes in the old degraded forests such as Sungai Bayas and Lubuk Kuali have indicated that visiting frequencies of orangutan to these sites were high (Figure 2).

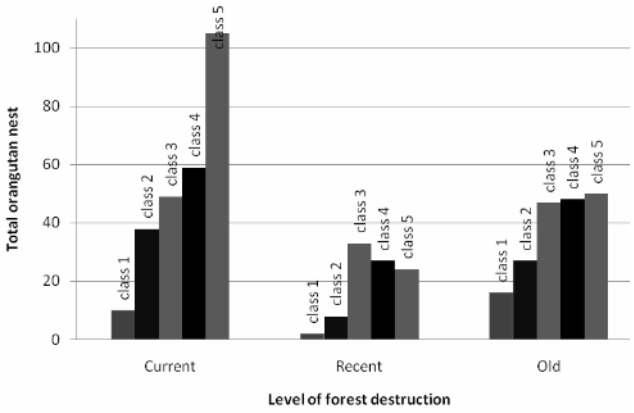

Figure 2. The distributions of orangutan nest classes in different level clusters of forest destruction.

In contrast, the similar phenomenon can not be found in survey sites which are logged during the field survey. Further, in addition to the high visiting frequencies, the old degraded forests have also been visited by a group of orangutans instead of an individual. This can be shown by the number of nests of the same category which are built in a cluster. Due to the forest of Lubuk Kuali is situated between two parts of boundaries of the park i.e. north-west and north-east, it might functions as a corridor area..

When fruit availability is abundant, orangutans may form a social group to harvest fruit sources while moving from one to another block of forests (te Boekhorst et al. 1990; Sugardjito 2009). The forest of Lubuk Kuali may serve as a path way for orangutan when fruiting availability abundant. The existence of this site, therefore, is very crucial to the survival of orangutan population in the area. Despite the importance of providing connection between forest blocks, the status of Lubuk Kuali is a customary forest which is managed by community. There is no legal protection status. Awareness program to socialize the function of this forest in term of wildlife corridor is therefore, critically importance to sustain orangutan population in Gunung Palung National Park. It does not only for the protection of orangutan but it would secures other wildlife species that regularly utilized Lubuk Kuali forest corridor. The importance of forest corridor is to connect fragmented forest in order to provide wildlife species to secure their breeding and seasonal movement to harvest their food sources (MacArthur and Wilson 1967). The main threat to orangutans in the Gunung Palung region has been identified as hand-logging (Meijaard and Neijman 2000), whereas particular threat to the Gunung Tarak forest is the development of the short cut road that connects villages between Naek Doyan to Teluk Parak and Cali.

This road will separate the forest of Gunung Tarak into two parts while providing the way for illegal loggers to carry logs out.

Lubuk Baji and Sungai Bayas are the sites where the nests of orangutan were detected most. These two sites are the boundaries which are situated in side the park and regularly patrolled by Orangutan Protection and Monitoring Unit or it is popularly called OPMU. These sites were destructed 5 years or more before the survey conducted and therefore, it might be recovered quickly due to the active operations of OPMU since 2003 in the area (Adhikerana and Sugardjito 2010). In contrast, the situations are very different in the locations of Gunung Tarak protection forest such as Nek Doyan, Teluk Parak, and Tanjung Pasar where ongoing distruction still occur during the survey. Orangutan almost disappears in all sites of these degraded forests. When hand logged in this forest did not expand to a wider area and quickly to be controlled it is possible that in five years the area could be utilized for the reintroduction of orangutan rehabilitants. Thirty two thousands hectares of Gunung Tarak forest at least could support 0,35 ind/km^2 of orangutan if it is well protected. It is essential that conservation measures are taken to protect orangutan outside protected areas. By implementing conservation oriented management in the production or protection forests where orangutan exists, it would reduce the number of orangutans captured.

Timber or palm oil companies normally capture the orangutan when they encountered in their concessionary areas and transfer it to the nearest rehabilitation centre. This action has taken a lot of resources including the cost of handling and caring of the animal in the centre prior to release in the wild. In the strategies and conservation action plan of orangutan it was recommended that the rehabilitation centers will be closed by 2017 (Suhartono et al. 2007). By then the centre will only focus on the reintroduction program. The aim of this strategy is to protect the population of orangutan in their natural habitat instead of securing the individuals in rehabilitation center. Creating an alternative to protected areas, where more local management is actively participated, would create local support commitment for conservation, which is assumed to be crucial for success. This effort has been initiated by Fauna and Flora International in collaboration with the district government and private sectors through orangutan conservation support program in large multifunction landscapes in the Ketapang district of west Kalimantan.

CONCLUSION

The existence of orangutan's nests in a forest habitat could be used as an indicator of visiting frequency of the species to the respective habitat. This study showed that the highest number of orangutan's nests was found in the old degraded forest inside the park, whereas the lowest one was obtained in the currently logged protection forest with the density of orangutan at 3.70 ind/km^2 and 0.06 ind/km^2 respectively. The high number of nest with difference classes found in a cluster indicates that the forest habitat has been used frequently by the species. The implication for this finding is when the selective hand logged forests are well protected in order to secure the orangutans from hunting then the logged forest habitat would recover and it could be used again by orangutans.

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REFERENCES

Adhikerana AS, Sugardjito J (2010) Characterizing forest reduction in Ketapang district, West Kalimantan, Indonesia. Biodiversitas 11: 46-54.

Ancrenaz M, Marshall A, Goossens B, van Schaik C, Sugardjito J, Gumal M, Wich S (2008) Pongo pygmaeus. In: IUCN 2010. IUCN red list of threatened species. Version 2010.4.www.iucnredlist.org.

Aveling RL (1982) Orangutan conservation in Sumatra, by habitat protection and conservation education. In: de Boer LEM (eds.) The orangutan: its biology and conservation. Dr. W. Junk Pub. The Hague.

Ayres JM, Johns AD (1987) Conservation of white uacaries in Amazonian varzea. Oryx 21: 74-80.

Brown K, Pearce D (1994) The causes of tropical deforestation: the economic and statistical analysis of factors giving rise to the loss of the tropical forests. University of British Columbia Press. Vancouver.

Buckland ST, Anderson DR, Burnham KP (1993) Distance sampling: estimating abundance of biological population. Chapman and Hall. London.

Cannon CH, Peart DR, Leighton M, Kartawinata K (1994) The structure of lowland rainforest after selective logging in west Kalimantan, Indonesia. For Ecol Manag 67: 49-68.

EIA [Environmental Investigation Agency] (1998) The politics of extinction: the orangutan crisis and the destruction of Indonesia's forests. EIA. London, UK.

Felton AM, Engstrom LM, Felton A, Knott CD (2003) Orangutan population density, forest structure and fruit availability in hand-logged and unlogged peat swamp forests in West Kalimantan, Indonesia. Biol Conserv 114: 91-101.

FWI (2002) The state of the forest: Indonesia. Global Forest Watch. Washington, D.C.

Johnson AE, Knott CD, Pamungkas B, Pasaribu M, Marshall AJ (2005) A survey of the orangutan (*Pongo pygmaeus wurmbii*) population in and around Gunung Palung National Park, West Kalimantan, Indonesia based on nest counts. Biol Conserv 121: 495-507.

Knop E, Ward PI, Wich SA (2004) A comparison of orangutan density in logged and unlogged forest on Sumatra. Biol Conserv 120: 187-192.

Lackman-Ancrenaz I, Ancrenaz M, Saburi R (2001) The Kinabatangan Orangutan Conservation Project (KOCP). In: The apes: challenge for the 21st century, Conference Proceedings, May 10-13, 2000, Brookfield, Illinois.

Leighton M (1993) Modeling dietary selectivity by Bornean Orangutans: Evidence for integration of multiple criteria in fruit selection. Intl J Primatol 14 (3): 257-313.

Laurance WF, Ferreira LV, Rankin-de Merona JM, Laurance SG (1998) Rain forest fragmentation and dynamics of Amazonian tree communities. Ecology 79: 2032-2040.

MacArthur RH, Wilson EO (1967) The theory of island biogeography. Princeton University Press. Princeton, NJ.

MacKinnon J (1974) The behaviour and ecology of wild orangutans (*Pongo pygmaeus*). Anim Behav 22: 3-74.

MacKinnon K (1985) The conservation status of non-human primates in Indonesia. In: Benischke K (eds) Primates: the road to self-sustaining population. Springer, New York.

Marshall AJ, Nardiyono, Engstrom LM, Pamungkas B, Palapa J, Maeijaard E, Stanley SA (2006) The blowgun is mightier than the chainsaw in determining population density of Bornean orangutans (*Pongo pygmaeus morio*) in the forest of East Kalimantan. Biol Conserv 129: 566-578.

Meijaard E, Neijman V (2000) Distribution and conservation of proboscis monkey (*Nasalis larvatus*) in Kalimantan, Indonesia. Biol Conserv 92: 15-24.

Meijaard E, Wich S (2007) Putting orangutan-population trends into perspective. Current Biol 17: R540.

Morrogh-Bernard H, Husson S, Page SE, Riely JO (2003) Population status of the Bornean orangutan (*Pongo pygmaeus*) in the Sebangau peat swamp forest, Central Kalimantan, Indonesia. Biol Conserv 110: 141-152.

Payne J (1988) Orangutan conservation in Sabah. WWF Malaysia. Kuala Lumpur.

Prasetyo D, Ancrenaz M, Morrogh-Bernard HC, Atmoko SSU, Wich SA, van Schaik CP (2009) Nest building in orangutans. In: Wich SA, Atmoko SSU, Mitrasetia T, van Schaik CP (eds). Orangutans. Geographic variations in behavioral ecology and conservation. Oxford University Press. New York.

Rao M, van Schaik CP (1997) The behavioral ecology of Sumatran orangutans in logged and unlogged forest. Trop Biodiv 4: 173-185.

Rijksen HD (1978) A field study of Sumatran orangutans (*Pongo pygmaeus abelii* Lesson 1827). H. Veenman and Zonen B.V. Wageningen, The Netherlands.

Rijksen HD, Meijaard E (1999) Our vanishing relative: the status of wild orangutans at the close of the twentieth century. Kluwer, Doordrecht, the Netherlands.

Robertson JMY, Schaik CP (2001) Causal factors underlying the dramatic decline of the Sumatran orangutan. Oryx 35: 26-38.

Singleton I, Wich S, Husson S, Stephens S, Utami Atmoko S, Leighton M, Rosen N, Traylor-Holzer K, Lacy R and Byers O (eds.) (2004) Orangutan population and habitat viability assessment: final report. IUCN/SSC Conservation Breeding Specialist Group. Apple Valley, MN.

Sugardjito J (1983) Selecting nest sites of Sumatran orangutans, *Pongo pygmaeus abelii* in the Gunung Leuser National Park, Indonesia. Primates 24: 467-474.

Sugardjito J (1995) Conservation of orangutans: threats and prospects. In: Nadler RD, Galdikas BMF, Sheeran LK, Rosen N (eds.) The neglected ape. Plenum press. New York.

Sugardjito J (2009) Characterizing social interactions and grouping patterns of Sumatran orangutan (*Pongo pygmaeus abelii*) in the Gunung Leuser national Park, Sumatra. Biodiversitas 10: 94-97.

Sugardjito J, van Schaik CP (1991) Orangutans: current population status, threats, and conservation measures. In: Tenaza R, Prasetyo L (eds.) Proceedings of the Conservation of the great apes in the New Word Order of the environment, 15-22 December 1991. Ministry of Forestry, Republic of Indonesia. Jakarta.

Suhartono T, Susilo D, Andayani N, Utami SS, Sihite J, Saleh C, Sutrisno A (2007) Strategy and action plan for conservation of Indonesia orangutans at 2007-2017. Ministry of Forestry. Jakarta, Indonesia. [Indonesia]

te Boekhorst IJA, Schurmann CL, Sugardjito J (1990) Residential status and seasonal movements of wild orangutans in the Gunung Leuser Reserve (Sumatra, Indonesia). Anim Behav 39: 1098-1109.

van Schaik CP, Priatna A, Priatna D (1995) Population estimates and habitat preferences of orangutans based on line transects of nests. In: Nadler RD, Galdikas BMF, Sheeran LK, Rosen N (eds.) The neglected ape. Plenum press. New York.

Whitmore TC (1984) Tropical forest of the Far East. Clarendon Press. Oxford.

Wich SA, Meijaard E, Marshall AJ, Husson S, Acrenaz M, Lacy RC, van Schaik CP, Sugardjito J, Simorangkir T, Traylor HK, Doughty M, Supriatna J, Dennis R, Gumal M, Knott CD, Singleton I (2008) Distribution and conservation status of the orangutan (*Pongo* spp.) on Borneo and Sumatra: How many remain? Oryx 42: 329-339.

Yanuar A, Saleh C, Sugardjito J, Wedana I (1996) Density and abundance of primates with special focus on West, Central and East Kalimantan's rain forests. Report to the Red Alert Programme of Fauna and Flora International. Cambridge, U.K.