RELATIVE POPULATION DENSITY OF *Tarsius dianae* IN MAN-INFLUENCED HABITATS OF LORE LINDU NATIONAL PARK, CENTRAL SULAWESI, INDONESIA

Indra Yustian[1], Stefan Merker[2], Jatna Supriatna[3], and Noviar Andayani[4]

[1] Dept. of Biology, Faculty of Mathematics and Natural Sciences, University of Sriwijaya, Indonesia.
[2] Institute of Anthropology, University of Mainz, Germany.
[3] Conservation International Indonesia and Department of Biology, University of Indonesia.
[4] Wildlife Conservation Society-Indonesia Program and Department of Biology, University of Indonesia, Indonesia.

ABSTRACT

The aim of this study was to know the impact of human activities on population density of *Tarsius dianae* by estimating the relative population density in four habitat types differently influenced by man. The study was conducted in the vicinity of Kamarora, at the northeastern boundary of Lore Lindu National Park, Central Sulawesi. Four different habitats were chosen: (H1) primary or old secondary forest; (H2) secondary forest ± 30 years after clearance with small-scale selective logging; (H3) forest with interspersed small coffee and cocoa plantations; and (H4) forest with selective logging and plantations. The tarsiers' sleeping sites were determined using triangulation. Relative population density was estimated by measuring the average distances between three nearest neighbors. The results suggest that different human-influenced habitat have different effects on tarsier's density. The smallest distances (116.2 ± 18 m) between sleeping sites, which represent the highest estimated population density (57.1 groups in one square km), were found in habitat type H1, the least disturbed habitat. Estimated population density in habitat type H3 or "forest plantations" was 38 groups/km^2, followed by habitat type H2 or secondary forest with selective logging 36.4 groups/km^2, and the smallest population density was estimated at 32.9 groups/km^2 in habitat type H4 or forest with selective logging and plantations.

Keywords: population density, *Tarsius dianae*, sleeping trees, *Ficus* spp., Sulawesi.

INTRODUCTION

Eight species of tarsiers are currently recognized, six of which are endemic to Sulawesi and surrounding islands. These are: Dian's tarsier *Tarsius dianae* Niemitz *et al.*, 1991 (or perhaps synonymous *T. dentatus* Miller & Hollister, 1921 according to Brandon-Jones *et al.,* 2004), endemic to lower mountains of Central Sulawesi; the Pygmy tarsier *T. pumilus* Miller & Hollister, 1921, which is found in the high mountains in Central Sulawesi; Spectral Tarsier *T. spectrum* Pallas, 1778 (or perhaps the correct name for this species is *T. tarsier* Erxleben 1777 as mentioned by Brandon-Jones *et al.,* 2004 and Merker & Groves, 2006), endemic to lowlands, with the type locality in northern Sulawesi; Sangihe Island tarsier *T. sangirensis* Meyer, 1896, endemic to the Sangir-Talaud; Peleng Island tarsier *T. pelengensis* Sody, 1949; and the last described Lariang tarsier *T. lariang* Merker & Groves, 2006. The two species not found in Sulawesi are Philippine Tarsier *T. syrichta* Linnaeus, 1758 which live in the southern islands of the Philippines, and Western Tarsier *T. bancanus* Horsfield, 1821 in Borneo, Bangka, Belitung, and southern parts of Sumatra. (Musser & Dagosto, 1987; Niemitz *et al.,* 1991; Tremble *et al.,* 1993; Groves, 1998; Supriatna & Wahyono, 2000).

T. dianae was described as distinct from other tarsier species morphologically, anatomically, and in vocalizations, by Niemitz *et al.* (1991). This species might be the predominant species in Central Sulawesi, based on vocalizations (Nietsch, 1999).

Like many other primates, tarsiers are arboreal and use trees and plants as feeding sites or for sleeping sites. The sleeping sites of tarsiers vary with habitat type. In primary forest, tarsiers are often found to sleep in tree cavities, especially of strangler figs (*Ficus* spp.). In secondary vegetation, tarsiers can sleep in tree cavities, bamboo stands, or shrubs (MacKinnon & MacKinnon, 1980; Tremble *et al.,* 1993; Leksono *et al.,* 1997). Gursky (1998) found *Ficus caulocarpa* was often used by Spectral tarsier as a sleeping tree in Tangkoko-Batuangus Nature Reserve.

Tarsius dianae suffers the risk of population decline as primary rain forest in the island is converted into plantations and transmigration settlements. Sulawesi has lost over 20% of its forest cover during 1985–1997, which is 1,890 km^2 per year (Holmes, 2002). Forest clearance even occurs inside conservation areas, including Lore Lindu National Park in Central Sulawesi. Besides coffee and cocoa plantations, exploitation of woods, bamboo and rattan, are one of the most common human activities in Sulawesi.

Bynum (1999) identified some variables to detect and monitor the influence of human activities on lowland rain forest in Lore Lindu NP. Those variables, i.e. the number of stumps, exotic trees, large trees and rattan, are very useful to determine and monitor disturbances in lowland forest in Lore Lindu NP.

Although extinction risk of *Tarsius dianae* is not high at the moment (IUCN category Lower Risk/conservation-dependent), increased human activities in Lore Lindu National Park may present a serious threat to this endemic species. While there have been many field studies about tarsiers (e.g. MacKinnon & MacKinnon, 1980; Crompton & Andau, 1986, 1987; Musser & Dagosto, 1987; Niemitz *et al.*, 1991; Tremble *et al.*, 1993; Gursky, 1998; Nietsch, 1999; Merker & Muehlenberg, 2000; Merker *et al.*, 2004 & 2005; Merker, 2006), information on the possible impacts of human activities on tarsier density is needed for a conservation program to be effective. Only MacKinnon & MacKinnon (1980), Merker & Muehlenberg (2000), and Merker *et al.* (2004 & 2005) showed that there can be a different population density in different habitats.

The main objectives in this study were to estimate the relative population density of *Tarsius dianae* in four habitat types with different levels of human activities in Lore Lindu National Park. This information is needed to assess the conservation status and conservation action of the genus *Tarsius*.

MATERIALS AND METHODS

The study was conducted in the Kamarora field station, situated at approximately 700–900 m above sea level (asl) at the northeastern boundary of Lore Lindu National Park, Central Sulawesi, about 70 km southeast of Palu (Figure 1). Kamarora is the type locality of *T. dianae*. Data collection was carried out from February to June 2001. Four forest patches, each 10-20 ha, were selected as sampling sites. Those sites were: (H1) pristine forest or the "least disturbed forest"; (H2) secondary forest with small-scale selective logging, or "slightly disturbed forest"; (H3) secondary forest interspersed with several small (0.2–0.5 ha) old coffee and cocoa plantations, or "moderately disturbed forest"; and (H4) forest with either logging and intensive plantations still occurring or "heavily disturbed forest".

To localize tarsier sleeping trees in a given area, we recorded all audible duet songs the animals performed every morning around dawn. By triangulating (Kenward, 1987; Muehlenberg, 1993) the positions of the call sources and multiple repetition of this procedure, tarsiers could be traced to their sleeping sites. Once all the sleeping sites in each habitat were known, mapping all sleeping sites in the investigated areas and measuring the distances between the groups resulted in relative population density estimates (Brockelman & Ali, 1987). To ensure their confinement to one specific habitat, only groups living in the center of each forest patch were considered. We assumed that one sleeping site represent one groups. The average distance of three nearest neighbors was used to estimate the range size of one group and then to estimate the population density in a given area (detail method in Merker, 2003 and Merker *et al.*, 2004).

Sixteen randomly-selected point samples were evaluated to assess the level of human disturbance in each habitat (Bynum, 1999; Merker *et al.*, 2004 & 2005). At each point, a 10 m x 10 m quadrate was made, and we measured the number of stumps, exotic trees, and trees of diameter at breast height > 50 cm. The disturbance parameters were determined in each and then integrated into a disturbance index (described in Merker, 2003 and Merker *et al.*, 2004) to compare the relative intensities of anthropogenic influence.

To determine the extent to which food abundance and locomotor support affect the distribution of tarsier, the availability of insects

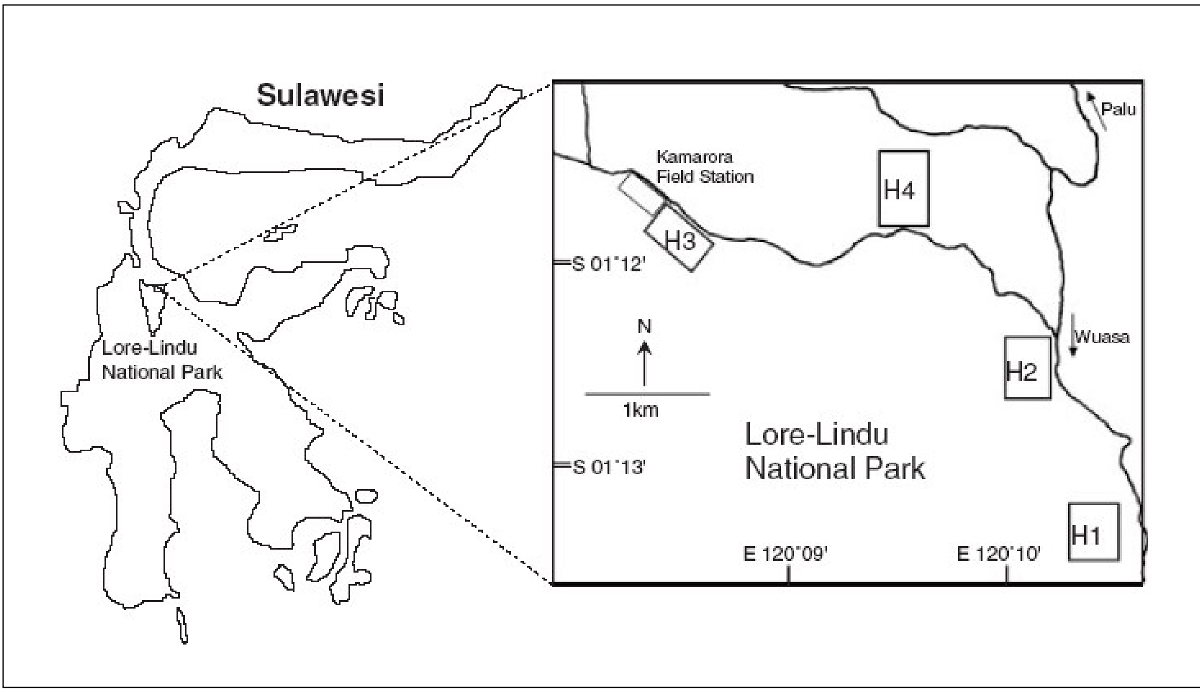


Figure 1. Map of Sulawesi and location of the study plots along the northeastern boundary of Lore Lindu National Park (after Merker, 2006).

and substrate density were also assessed. At eight sample points in each habitat type, the abundance of insects eaten by Sulawesi tarsiers (Nietsch, 1993; Tremble *et al.*, 1993) was estimated using two methods (Merker, 2003; Merker *et al.*, 2004): (1) to count moths, winged termites and mantids, a Petromax kerosene pressure lantern was fastened at 1.5 m in a small tree, and during the subsequent 5 min all visible insects with body length >1 cm attracted by the light were counted; by differentiating the animals by species, size and location it was possible to avoid repeat counts of single specimens. (2) to count grasshoppers, crickets and cicadas, insects vocalizing within a 10 m radius around the sample point within 5 min were counted; repeated counts were avoided by noting specific vocalization patterns and the locations of individuals. At each of the eight sample points three replicate counts, each on a different evening, were made over 19.00-21.00.

Based on the results of the habitat-use analysis by Crompton & Andau (1986 & 1987) and Merker (1999 & 2003), the branch/trunk/sapling trees with a diameter between 1-4 cm were measured, in vertical and horizontal orientation, to analyse the substrate for locomotion abundance. The sampling method used PCQ, with 16 randomly placed points in each habitat.

All data sets were tested for normality using the Kolmogorov-Smirnov test. For normally distributed data, ANOVA and the Least Significant Difference Post Hoc Test were used, and the non-parametric Median Test was used to detect significant differences between habitats. Spearman's r_s was used to test correlations between parameters. All tests are two-tailed. (Sokal and Rohlf, 1995)

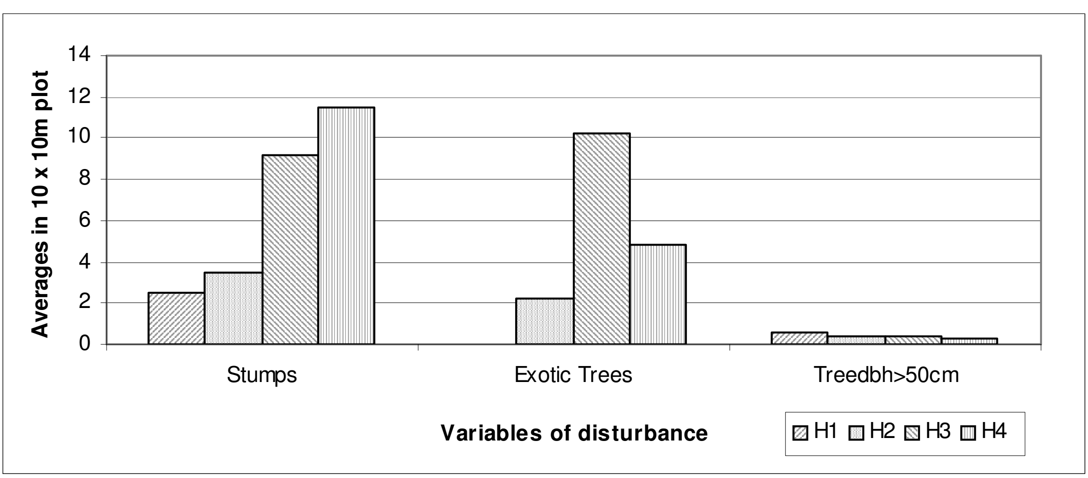
RESULTS

Observed groups of *Tarsius dianae* always came back to their initial sleeping site each morning. However, there is a tendency that tarsier moved to alternate sleeping sites when disturbed. Average distance to three nearest neighbors and estimated population densities are shown in Table 1. The smallest distances to nearest neighbors (116.2 ± 18.0 m, n = 9 groups), which is calculated and estimated to the highest density 57.1 groups/km^2, were found in H1, the least disturbed habitat. Meanwhile, in habitat where both logging and plantations still occurred (H4), distances between sleeping sites was the greatest (152.9 ± 7.1 m, n = 9 groups), giving the estimated tarsier population

Table 1. The average distances between three nearest neighbors, relative population density of *Tarsius dianae*, number of stumps, insects density and locomotor support abundance in four different habitats at Lore Lindu National Park, Central Sulawesi.

	Habitat type			
	H1 (primary forest)	H2 (second forest with small scale logging)	H3 (second forest with small-scale interspersed plantations)	H4 (second forest with logging and pl;antations)
Average distances to three nearest neighbors ± SD (m)	116.2 ± 18.0	145.5 ± 13.7	142.4 ± 11.2	152.9 ± 7.1
No. of groups observed (n)	9	10	10	9
Population density ± SD (groups/km^2)	57.1 ± 21.5	36.4 ± 6.8	38.0 ± 5.8	32.9 ± 3.1
Average stumps density per 100 m^2	2.5 ± 4.4	3.5 ± 4.3	9.2 ± 10.3	11.5 ± 3.1
Average insects density ± SD (ind./5 min./point)	11.6 ± 1.7	12.1 ± 1.9	13.5 ± 2.6	10.3 ± 2.4
Locomotor support abundance ± SD (substrates per 100 m^2)	32.7 ± 4.2	115.0 ± 14.6	67.2 ± 8.5	77.8 ± 9.9

density as small as 32.9 groups/km^2. An intermediate number of groups were found where both secondary forest with small-scale logging (H2) and secondary forest with old plantations (H3) were present. Table 1 also shows the disturbances (represented by average number of stumps per 100 m^2 - while the other disturbance parameters is shown in Figure 2), insect abundance (individuals/5 minute/ sampling-point), and locomotors supports density (substrates per 100 m^2) in each habitat. The average distance between the sleeping site of a group and the sleeping sites of its three nearest neighbouring groups differed significantly between studied habitat type (ANOVA, $F_{3,19}$=3.76, P<0.05).



Legend explanation: H1 = least disturbed forest; H2 = slightly disturbed forest; H3 = moderately disturbed forest; H4 = heavily disturbed forest.

Figure 2. The average of some human activities variables in four habitat types at Lore Lindu National Park, Central Sulawesi.

There was no significant difference between habitat types in the number of insects (ANOVA, $P>0.05$). The results indicate relative population density was lower where stump density was higher (Spearman rank correlation rs-0.8). Population density was positively related to the abundance of insects but the relations were weak (Spearman rank correlation rs = 0.4).

DISCUSSION

Different habitat types, with different human activities, had different relative population densities of *T. dianae*, although no replicates were performed in each type so the differences recorded cannot be firmly attributed to habitat type. Primary forest, the least disturbed habitat, had the highest relative population density (Table 1). The relative population density of tarsier in primary forest (57.1 groups/km^2) was significantly greater compare to each other habitat types that are influenced by human land-use (ANOVA, $P<0.05$). There are no significant differences between tarsier population densities in the secondary forest with small-scale logging (H2) or secondary forest with small-scale interspersed plantations (H3) and secondary forest with both logging and plantations (H4).

Some studies mentioned that *Tarsius bancanus* was commonly found in secondary forest (i.e. Fogden, 1974; Niemitz, 1984). MacKinnon & MacKinnon (1980) also found that in Tangkoko-Batuangus, the population density at sea level of *Tarsius spectrum* in shrubby forest (10 indiv./ha) was greater than in primary forest at 1,000 m asl (only 5 indiv./ha). However, Gursky (1998) reported that *T. spectrum* were more abundant in the conservation area in Tangkoko-Batuangus (lowland rainforest, sea level).

Merker & Muehlenberg (2000) also found that forest with small-scale interspersed plantations had higher estimated population density of tarsier than other habitat types. Ganzhorn (1987) reported that population density of lemur species in Madagascar tended to be higher in old plantations than other habitat types, but not as high as in primary forest. Our research found that relative population density of *Tarsius dianae* in primary forest was higher than other habitat types. Unfortunately, considering the differences in methodology and specific site, it was not possible to make a direct comparison between this study and the other studies.

If we compare to the results in the year 1998 (Merker and Muehlenberg, 2000), there are a decreasing tendency on population density of *T. dianae* in Lore Lindu National Park. Merker and Muehlenberg (2000) reported that the lowest population density was 5.6 groups/10 ha, which is similar to the highest number in our results 57.1 groups/km^2. Indeed, there is no information about forest loss or change to other human land-use especially between years 1998 to 2001. Merker *et al.* (2004) showed a subsequent decline in *T. dianae* population densities and suggested that human activities affect the population and survival of *T. dianae* in Lore Lindu NP. Merker *et al.* (2005) mentioned that population density decreased with increasing anthropogenic influences. They also stated that focusing solely on population density, primary forest is the most important habitat for tarsier conservation. As mentioned by Merker *et al.*(2005), it is not clear what causes the lower abundance of tarsiers in the slightly disturbed habitats (H2) even though resources are plentiful. One possible reason may be the high susceptibility of these animals to visual and acoustic disturbance in their environment (Merker & Mühlenberg, 2000).

Conservation strategy for this unique and endemic species should consider the differences of human activities. Tarsiers can adapt to traditional land uses such as small-scale plantations or selective logging (Merker & Muehlenberg, 2000; Yustian, 2007). Slight disturbance may open up the forest canopy and result in a greater heterogeneity of the forest and subsequently a higher arthropod diversity and density. Insect abundance was found to be highest in the slightly disturbed habitats, H2 and H3, and lowest in the mixed-species plantation H4. The increased prey density in H2 and H3 may balance the adverse effects of selective logging and acoustic disturbance at these sites (Merker & Mühlenberg, 2000). More research is needed to study the role of small-scale plantations as the support habitat for tarsiers.

CONCLUSIONS

Different habitats with different level of human activities were found to have different relative population densities of *T. dianae*. The highest relative density was in primary forest, the least disturbed habitat (57.1 ± 21.5 groups/km^2), followed by relatively more disturbed habitats: forest with small-scale old plantations (38.0 ± 5.8 groups/km^2), secondary forest (36.4 ± 6.8 groups/km^2), and forest with both logging and plantations (32.9 ± 3.1 groups/km^2).

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