Population density of Presbytis rubicunda in a small primary dipterocarp forest in East Kalimantan, Indonesian Borneo

Article · September 2014

5 authors, including:


Elena Bersacola
Oxford Brookes University


David A. Ehlers Smith
University of KwaZulu-Natal


Yaya Rayadin
Universitas Mulawarman


Susan Cheyne
Oxford Brookes University

POPULATION DENSITY OF *Presbytis rubicunda* IN A SMALL PRIMARY DIPTEROCARP FOREST IN EAST KALIMANTAN, INDONESIAN BORNEO

Elena Bersacola[1*], David A. Ehlers Smith[1,2], Wiwit J. Sastramidjaja[3], Yaya Rayadin[4] and Susan M. Cheyne[2,5]

[1] Faculty of Humanities and Social Sciences, Oxford Brookes University, Headington Campus, Gipsy Lane, Oxford, OX3 0BP, UK. E-mail: hellenbers@gmail.com

[2] Orangutan Tropical Peatland Project, Jl. Semeru 91, Palangka Raya, 73112, Central Kalimantan, Indonesia. E-mail: dehlers-smith@outrop.com

[3] E-mail: wiwitjuwita@gmail.com

[4] Pusat Studi Reboisasi Hutan Tropis Lembab, Universitas Mulawarman, Jl. Kihajar Dewantara Kampus Gunung Kelua Samarinda, Samarinda, 75123, East Kalimantan, Indonesia. E-mail: yrayadin@yahoo.com

[5] Wildlife Conservation Research Unit (WildCRU), Department of Zoology, University of Oxford, The Recanati-Kaplan Centre, Tubney House, Abingdon Road, Tubney, Oxon, OX13 5QL, UK. E-mail: susan.cheyne@zoo.ox.ac.uk

[*] Corresponding author

ABSTRACT

Tropical rainforests on Borneo are rapidly shrinking due to human activities and related fires. Monitoring wildlife populations in their remaining habitats is crucial for developing effective conservation strategies. In 2012, we conducted surveys in Balikpapan Bay within the Sungai Wain forest, Indonesia, to estimate the population density of Maroon Langur *Presbytis rubicunda* (Müller, 1838). We surveyed Sungai Wain's primary core area using distance sampling of line transects, and assessed the vegetation structure using 100 m^2 square plots. We calculated density of *P. rubicunda* at 5.35 groups/km^2 (95% CI=3.4-8.43). Cluster size ranged between two and eight individuals and group size averaged 5.2 individuals (SE=1.4). The habitat within the core area of Sungai Wain appears suitable to support a high density of this colobine. Anthropogenic activities in the surrounding areas, as well as encroachment and illegal logging within the regenerating habitat, could become threats for *P. rubicunda* in Sungai Wain. This forest represents an important refuge for this primate in Balikpapan Bay. We recommend further surveys in degraded and regenerating forests to quantify the remaining suitable habitat for *P. rubicunda* in East Kalimantan.

Keywords: Colobinae, conservation, distance sampling, habitat, langur, refuge

INTRODUCTION

Tropical rainforests in Southeast Asia have decreased massively since 1990 (Stibig et al., 2014). For example, between 2000 and 2010 the total forested area on Borneo decreased by 12% with a mean annual forest cover loss of 1.3% (Miettinen et al., 2011). Human activities such as logging, mining, habitat conversion for oil palm plantations, as well as an increase in magnitude of *El Niño* droughts and fires, are the driving causes of deforestation (Curran et al., 1999; Sodhi et al., 2004). Except for the Maroon Langur *Presbytis rubicunda* (Müller, 1838), all endemic primates of Borneo are considered threatened, and are classified as either Vulnerable, Endangered or Critically Endangered by the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN, 2013). *Presbytis rubicunda* is believed to be widespread and may persist in degraded habitats; however, the population is decreasing due to habitat loss and hunting for medicine (Nijman & Meijaard, 2008). Densities of *P. rubicunda* in Kalimantan differ across habitats and study sites (Davies, 1984; McConkey & Chivers, 2004; Marshall, 2010; Nijman & Nekaris, 2012; Ehlers Smith & Ehlers Smith, 2013), but in disturbed habitats or at high elevations (>750 m) group densities of this species generally decrease and populations may not be viable (Blouch, 1997; Marshall, 2010).

In 2012, we conducted a survey in the Sungai Wain Protection Forest (SWPF), Indonesia. The SWPF is located within Balikpapan Bay, a large lowland ecosystem that extends to the Mahakam River, about 70 km north of Sungai Wain (Wilson & Wilson, 1975; Stark et al., 2012). Part of the forest outside the SWPF was already selectively logged and encroached upon by humans in the 1970s (Wilson & Wilson, 1975), and was later affected by the *El Niño* fires in 1982-83 (Cleary & Genner, 2004). In 1998, subsequent fires were started at a nearby logging concession and quickly spread inside the SWPF (Fredriksson, 2002). The 1998 fires caused further change in the forest structure, reducing the primary habitat to a 40 km^2 core area. Most of the core area's surrounding habitat consisted of burned forest, with intact fragments along rivers (Fredriksson, 2002). It is likely that during and after the fires, primates and other animals relied on these intact fragments and the core area for refuge, thus altering their density and ranging patterns (S. Lhota, pers. comm.). Over the subsequent seven years following the 1998 fires, the vegetation structure and species composition of burned areas changed substantially (Fredriksson et al., 2006; Slik et al., 2011). Pioneer species such as *Macaranga gigantea* (Rchb.f. & Zoll.) Müll.Arg. dominated the landscape (Slik et al., 2008). Canopy cover and tree diversity began to increase in more recent years, and in 2010 there were indications that Malayan Sun Bears *Helarctos malayanus* (Raffles, 1821) were gradually moving back to the regenerating forest (Fredriksson et al., 2012).

According to the IUCN Red List of Threatened Species, the average density of *P. rubicunda* across Borneo is estimated to be 2.6 (SD ± 1.4) groups/km^2 (Nijman & Meijaard, 2008). No density estimate is available for *P. rubicunda* in the SWPF prior the 1998 fires; but surveys conducted there in 1999-2005 indicated a high density of this primate, with 3.3 groups/km^2 (Nijman & Nekaris, 2012). The aim of our study was to obtain a new population density estimate of *P. rubicunda* in the SWPF and identify possible conservation threats to the population present in the area. We also hope that our data help encourage local and national authorities to increase their efforts to protect the remaining forests of this region.

METHODS

We acquired all the relevant permits and visas for the research from the Indonesian State Ministry of Research and Technology (RISTEK), adhering to Indonesian legislation. Our research was purely observational in nature. We collected data between May and July 2012.

Study area

The SWPF (S1°16', E 116°54') occupies an area of approximately 100 km^2 (Fig. 1), and is located within the administrative area of Balikpapan, Kalimantan's second largest city and the second major oil production and commerce centre in Indonesia. The SWPF is categorised as *Hutan Lindung*, meaning that it does not have official protection but was established to be managed as a water catchment area for the oil company 'Pertamina' in Balikpapan. The SWPF is part of the Balikpapan Bay ecosystem, which consists of a network of freshwater rivers, marine waters, mangroves, dipterocarp as well as other non-mangrove forests (Stark et al., 2012). It is characterised by high biological diversity, and taxa present in Balikpapan Bay include Sunda Clouded Leopard *Neofelis diardi* (G. Cuvier, 1823), Proboscis Monkey *Nasalis larvatus* (Wurmb, 1787) and the Critically Endangered Mahakam River subpopulation of Irrawaddy Dolphin *Orcaella brevirostris* (Owen in Gray, 1866). Road construction, logging and the increase in magnitude of fires due to deforestation are major conservation threats in Balikpapan Bay, as animal populations and habitats are becoming increasingly fragmented. At present, the SWPF's core area is the largest lowland primary forest left in the south-eastern part of East Kalimantan (Fredriksson, 2002).

The study site (20 km^2) lies within the northern part of the primary forest within the 40 km^2 core area. We used a system of thirteen parallel-line transects, which were already established prior to our study. The transects were set 70-600 m apart (average=286.8 m, SD=121.1) and were 1.70-2.06 km in length (Average=1.99 km, SD=0.11). The forest within the transect system was a mixture of humid and dry hilly dipterocarp forest, with occasional small swamp forest patches. The average annual rainfall in the SWPF is 2790 mm (Simbolon et al., 2012).

Study species

Presbytis rubicunda is a medium-bodied, gracile arboreal colobine (males 6.3 kg, females 6.0 kg; Davies & Payne, 1982) endemic to the island of Borneo and the adjacent Karimata Island (Nijman & Meijaard, 2008). They live in single-male, multi-female groups ranging from 3 to 12 individuals (Supriatna et al., 1986; Davies, 1987; Ehlers Smith & Ehlers Smith, 2013), and extra-group males typically form all-male bands or travel alone (Davies, 1987; Ehlers Smith & Ehlers Smith, 2013). *Presbytis rubicunda* has been observed mainly feeding on fruits, seeds and young leaves, with the proportions of consumption of these items vary-

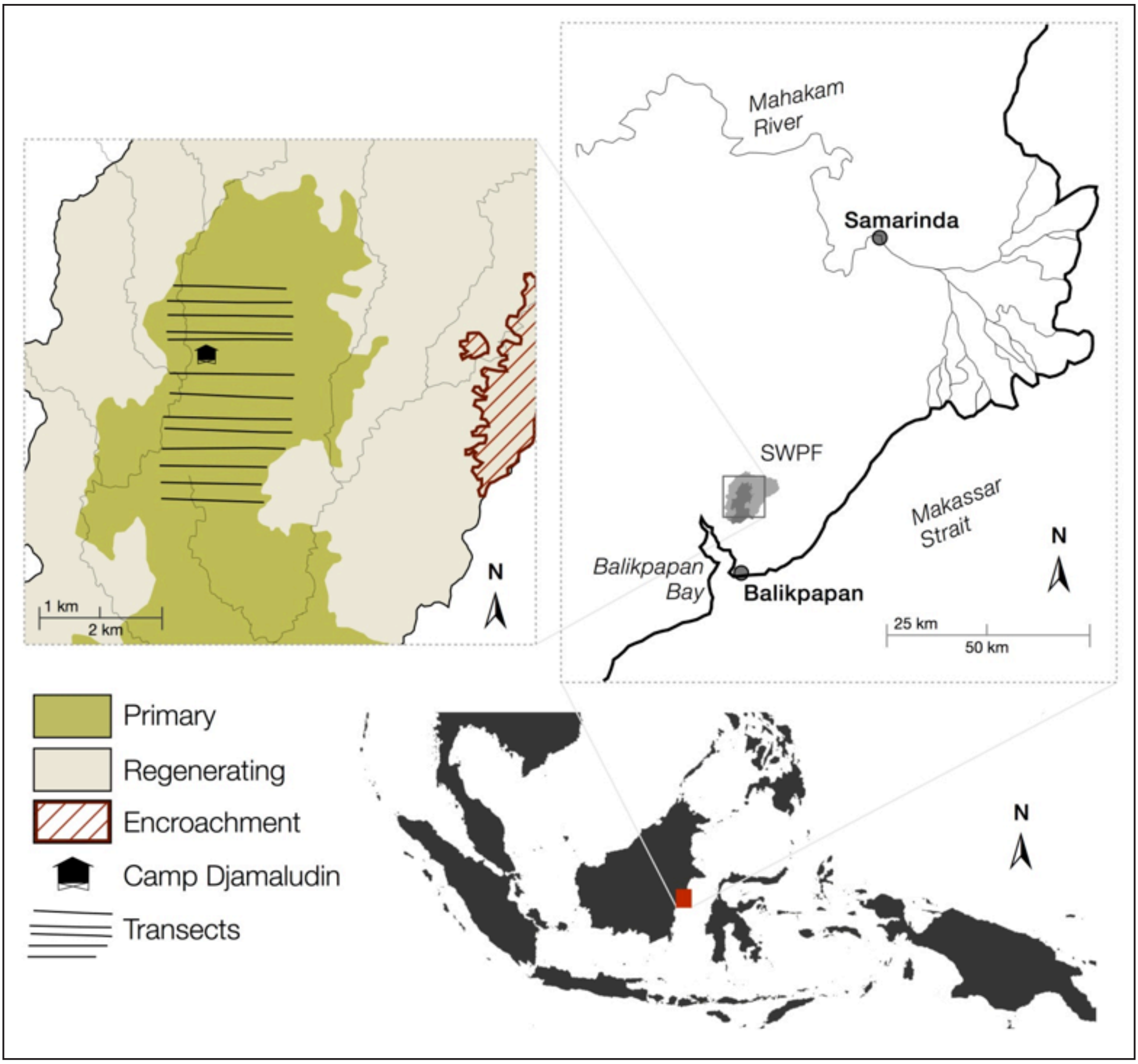

Fig. 1. Map and location of study site

ing across sites (Supriatna et al., 1986; Davies et al., 1988; Davies, 1991; Marshall, 2004; Hanya & Bernard, 2012; Ehlers Smith et al., 2013b). Home ranges of this species were reported at a number of sites, ranging from 0.33 ha in Tanjung Puting (Supriatna et al., 1986) to 108.3 ha in Sabangau Forest (Ehlers Smith et al., 2013a)

Transect surveys

To monitor wild population trends over time and understand changes in ecological patterns, repeated surveys must be conducted using standardised methods. The importance of repetitive surveys using identical methods to identify a population trend is highlighted by previous studies (Mitani et al., 2000; Mbora & Meikle, 2004). Distance sampling is based on the detection function *g(y)*, i.e., the statistical probability of seeing an object at a ≥0 m distance from the transect line (Buckland et al., 2001), and is considered an effective method for estimating and monitoring densities of various taxa, such as deer (Focardi et al., 2005), birds (Marques et al., 2007) and primates (Johnson et al., 2005; Ehlers Smith & Ehlers Smith, 2013). Analysis with the program DISTANCE (Thomas et al., 2010) enables users to choose different parameters to obtain a fit between the statistical model and the survey data.

We estimated population density of *P. rubicunda* using distance sampling on line transects (Buckland et al., 2001; Thomas et al., 2010). We walked thirteen parallel transects in two or three teams simultaneously, maintaining >750 m distance between teams during all surveys. All team members conducted prior practice surveys and one week of training on data collection with an established survey protocol. During surveys we measured distances visually, as the use of laser range finders could not provide us with true distances because of the dense structure of the forest. To ensure that distances were recorded precisely and to reduce researcher bias, we carried out distance training with the aid of a measuring tape and laser range finder every 4-5 days throughout the study period.

At each detection of *P. rubicunda* we collected the following data: group size, group spread, distance between the observer and the centre of the group, compass bearing of the centre of the group and the transect (later calculated to angle and then perpendicular distance), height above ground of observed animals, group composition and response behaviour to our presence. We recorded all data at the animals' initial location. As *P. rubicunda* is known to split into subgroups for foraging during the day (Supriatna et al., 1986), we considered all animals encountered within 100 m of the first detection as the same group, thus as a single sighting event. We walked two transects per team; one in the morning between 06:30 and 11:00 h and one in the afternoon between 13:30 and 18:00 h, at an average walking speed of ~1 km/h. We did not conduct surveys during midday hours, rainy days or strong wind as *P. rubicunda* becomes less active during these periods, thus reducing detectability (DA Ehlers Smith, pers. obs.). Where possible, we followed and observed the langurs until we could obtain full group counts. On 17 of such encounters we were able to observe groups gathering and remaining on emergent trees for approximately 20 minutes; thus were confident that all animals in the group were counted.

Vegetation sampling

To measure habitat characteristics we established 73 plots, a sample size considered large enough to obtain a good representation of the habitat within the study site (Ganzhorn, 2003). Plots measured 10 m x 10 m, and were systematically located on both sides of transect lines at a minimum distance of 30 m from each other to ensure sampling independence. To assess vegetation structure we recorded the following data: diameter at breast height (DBH) of all the ≥10 cm DBH trees, height of all ≥10 DBH trees (measured on an ordinal scale: 1-5 m, 6-10 m, etc.) and total number of trees (Ganzhorn, 2003; Hamard et al., 2010).

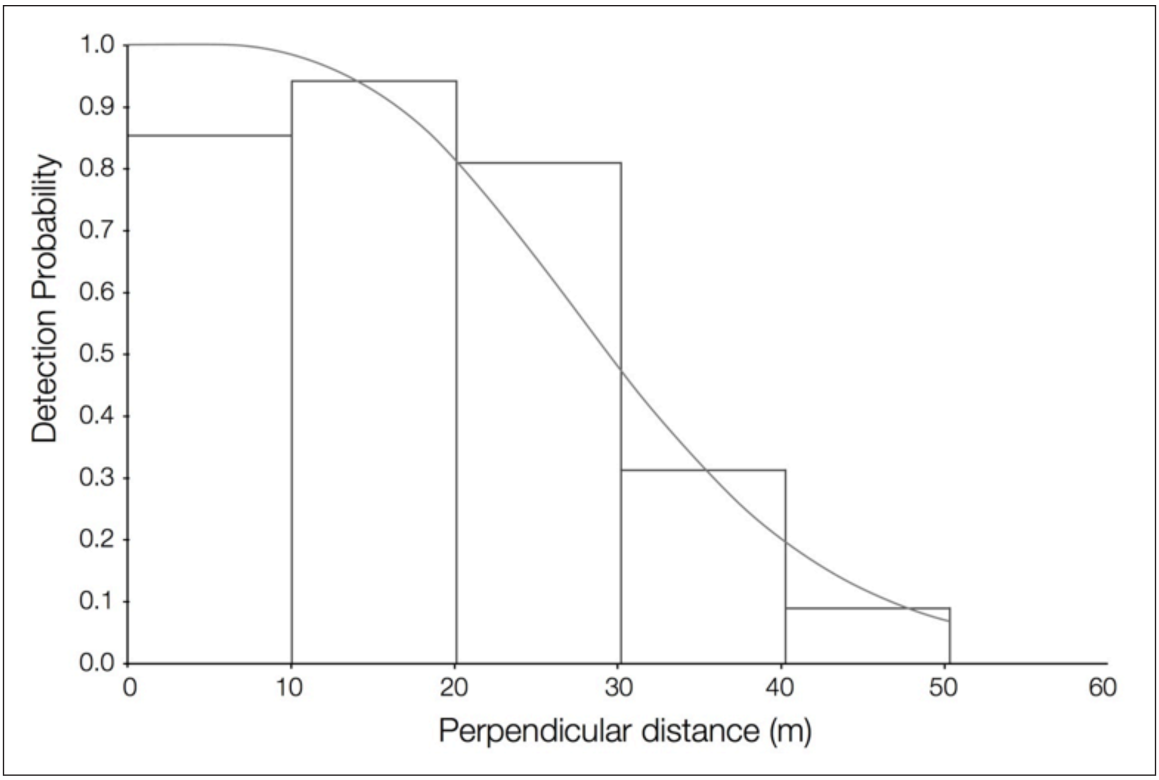

Fig. 2. Estimated detection function for *P. rubicunda* based on the best model computed in DISTANCE.

Data analysis

We entered survey data into DISTANCE v. 6.0 (Thomas et al., 2010), and evaluated a number of models for selecting the one with the best fit. We analysed the survey data using three detection probability functions: uniform, half-normal and hazard rate, with and without cosine and simple polynomial adjustments. Upon a visual inspection of the sighting distances histograms (Fig. 2), we discarded the outermost observations by selecting a right truncation (32-50.4 m) to eliminate obvious outliers (Buckland et al., 2001). Cut points were maintained at equal sighting distance intervals. We used the Akaike's Information Criterion (AIC) and assessed the delta AIC as an indicator for selecting the model (Buckland et al., 2001; Burnham & Anderson, 2002).

To estimate the mean cluster size we used the size-bias regression computed by the software DISTANCE, which tests the observed cluster size against the estimated detection probability (Buckland et al., 2001). In addition, we considered that mean cluster size was likely to be underestimated due to the difficulty in detecting all animals in the group during census in a dense forest (Hassel-Finnegan et al., 2008). Therefore we calculated the average number of individuals/km^2 and abundance both with the mean cluster size (3.88, SE±0.25) as well as from the mean group size calculated from observations where full group counts were obtained.

RESULTS

There was no significant difference in the number of observations of *P. rubicunda* (N_1=26, N_2=26, N_3=17; chi-square: $\chi^2(2)=2.348$, p=0.309), and in the means of estimated perpendicular distances (ANOVA: F(2, 66)=0.211, p=0.810) across the three survey teams. The estimated cluster size did not differ across the three survey teams (Kruskal-Wallis: H(2)=0.884, p=0.643), as well as across transect lines (Kruskal-Wallis: H(12)=19.701, p=0.073). We also found no correlation between estimated perpendicular distances and cluster sizes (N=69) (Spearman's: r_s=0.007, p=0.956), thus we concluded there was no inter-observer bias in the sighting data.

Population density

We surveyed 13 line transects for a total effort of 207.12 km. During the surveys we observed 69 groups of *P. rubicunda*, with a mean encounter rate of 0.32 groups/km surveyed (95% CI=0.26-0.40). Observed mean cluster size was estimated to be 3.76 individuals (SE=0.20). Based on the size-bias regression computed by DISTANCE, the expected cluster size was estimated at 3.88 individuals (SE=0.25). All six models selected as the potential best ones displayed a delta AIC <2 (Burnham & Anderson, 2002). Differences between Akaike weights were minimal (<0.01). The half-normal key with cosine adjustments had the lowest AIC (195.13) and was thus chosen as the most suit-

Table 1. Density estimates obtained from various models as computed by DISTANCE v. 6.0

Model (adj., RT)	AIC	ESW	Density (groups/km^2)	N	GOF K-S p	GOF Chi-sq p	Detection Probability
Half-normal (C, >50.4 m)	195.13	30.26	5.35 (3.4-8.43,0.23)	415	-	0.461	0.6 (0.4-0.91, 0.21)
Half-normal (>32 m)	424.62	30.04	4.90 (3.43-7.01, 0.18)	370	0.913	0.477	0.94 (0.70-1.00, 0.15)
Half-normal (SP, 9%)	447.38	30.89	4.92 (3.74-6.47, 0.13)	374	0.916	0.873	0.91 (0.78-1.00, 0.07)
Half-normal (10%)	437.54	29.33	5.10 (3.57-7.29, 0.18)	386	0.838	0.366	0.87 (0.65-1.00, 0.14)
Hazard-rate (10%)	437.35	30.56	4.90 (3.77-6.37, 0.13)	381	0.911	0.491	0.9 (0.79-1.00, 0.07)
Uniform (10%)	436.61	33.82	4.43 (3.5-5.58, 0.11)	335	0.361	0.438	1.00 (1.00-1.00, 0.0)

Note: Densities are provided with the 95% confidence interval and the coefficient of variation.
RT=right truncation; AIC=Akaike's Information Criterion; ESW=effective strip width; N=abundance; GOF K-S p=goodness of fit Kolmogorov-Smirnov test; GOF Chi-sq p=goodness of fit Chi-square test; Cos=cosine adjustment; SP=simple polynomial adjustment

able model. It also showed a high goodness of fit value (0.461 chi-square tests of probability), with a detection probability of 0.6 (95% CI=0.4-0.91, Table 1). Density of *P. rubicunda* in the 20 km^2 pristine dipterocarp forest was estimated to be 5.35 groups/km^2 (95% CI=3.4-8.43) and 20.76 individuals/km^2 (95% CI=12.97-33.24) based on the half-normal/cosine.

We were able to obtain full group counts on 17 occasions, from which we calculated the mean group size to be 5.2 individuals, and the population density to be 27.82 individuals/km^2.

Other primates recorded

In addition to *P. rubicunda* within the study area we observed six individuals (two groups) of Bornean Orangutan *Pongo pygmaeus* (Linnaeus, 1760), 14 individuals (six groups) of Müller's Gibbon *Hylobates muelleri* Martin, 1841, ≥8 individuals (two groups) of Pig-tailed Macaque *Macaca nemestrina* (Linnaeus, 1766), ≥4 individuals (two groups) of Long-tailed Macaque *M. fascicularis* (Raffles, 1821) and four individuals (one group) of White-fronted Langur *Presbytis frontata* (Müller, 1838).

Vegetation sampling

We recorded 653 trees in the primary forest in a total sampling area of 0.73 ha and computed vegetation variables (Table 2).

Of the total trees recorded, most trees (85%) were <20 m tall, a few (15%) were 20-40 m tall and a very few (0.2%) exceeded 40 m. The height of *P. rubicunda* above the ground (16-20 m) was significantly higher than the median vegetation height (11-15 m) (Mann-Whitney U=5369.5, p<0.001).

Table 2. Vegetation characteristics within the primary forest in SWPF.

Vegetation attributes	SWPF primary forest*
Mean DBH (cm)	23.8 (± 0.8)
Density (stems/ha)	894.5 (± 27.5)
Proportion of ≥20 cm DBH trees (%)	38.4
Basal area (m^2/ha)	59.7 (± 4.6)
Median tree height (m)	11-15
Canopy cover (%)	84.5 (± 1.90)

* Values are given with standard errors.

DISCUSSION

Density of *P. rubicunda* within the 20 km^2 primary dipterocarp forest in Sungai Wain was relatively high within genus *Presbytis* (Kirkpatrick, 2012). Densities of Hose's Langurs *P. hosei* (Thomas, 1889) are reported to range from 5.5 individuals/km^2 in a young secondary forest to 18.9 individuals/km^2 in primary hill forest (Nijman, 2004). A density of 7.8 individuals/km^2 was estimated for Natuna Island Langur *P. natunae* (Thomas & Hartet, 1894) on Bunguran Island (Lammertink et al., 2003), and 13.5 individuals/km^2 were reported for Mentawai Langur *P. potenziani* (Bonaparte, 1856) on Siberut Island (Watanabe, 1981).

Compared with previous distance sampling density estimates of *P. rubicunda* (Blouch 1997; Marshall, 2010; Ehlers Smith & Ehlers Smith, 2013), this study showed the highest group density to date. Our mean group size and group density differ from those reported by Nijman & Nekaris (2012), most likely due to differences in methods of survey design and data analysis (Table 3). Our population density estimate, however, is comparable to that from the 1999-2005 surveys in the SWPF (Nijman & Nekaris, 2012). Thus at present, the Sungai Wain population of *P. rubicunda* appears to be stable within the primary forest. In Sarawak, similar population densities of *P. rubicunda* were found in the primary dipterocarp forests, where sympatric primate species assemblages coincided with those living in the SWPF (Blouch, 1997). These data suggest that undisturbed dipterocarp forests can support relatively high densities of *P. rubicunda*.

Between 2001 and 2012 it appears that there was an increase in tree density within the SWPF's primary habitat, with a slight bias towards larger trees. Our overall tree density (≥10 cm DBH) was double that found by Slik & Eichhorn (2003) in the same habitat in 2001. The proportion of ≥20 cm^2 DBH trees that we found in 2012 was 2.6 % higher than that reported by Slik & Eichhorn (2003). These are promising results for the conservation of *P. rubicunda* in the SWPF, as large trees represent a significant source of food for this colobine (Ehlers Smith et al., 2013b; Ehlers Smith & Ehlers Smith, 2013). A relatively high availability of large, preferred-food-bearing stems appears to play a crucial role for determining the presence of *P. rubicunda* (Ehlers Smith & Ehlers Smith, 2013). Within the mixed-swamp forest in Sabangau, Ehlers Smith et al. (2013b) found a positive correlation between fruiting tree DBH and the length of time that *P. rubicunda* spent feeding.

In the SWPF the majority of trees were well below 15 m high. In Barito Ulu vegetation height was found to be higher relative to the SWPF, with the mean height

Table 3. Comparison of density estimate of *P. rubicunda* across Borneo.

Study site	Forest type	Pop. density (ind/km²)	Group size	Survey method	Group size estimation method	Source
Sungai Wain Protection Forest, East Kalimantan, Indonesia	Primary dipterocarp forest	27.1	8.2	Line transect (4)	Complete counts from 54 groups observed during surveys	Nijman & Nekaris, 2012
Sungai Wain Protection Forest, East Kalimantan, Indonesia	Primary dipterocarp forest	27.8	5.2	Line transect (13), DISTANCE	Complete counts from 17 group encounters during survey	This study
Sabangau, Central Kalimantan, Indonesia	Peat swamp forest	17.5	7	Line transect (12), DISTANCE	Observation and complete counts of 7 groups	Ehlers Smith & Ehlers Smith, 2013
Gunung Palung NP, West Kalimantan, Indonesia	Alluvial bench	10.5	4.5	Line transect (2), DISTANCE	Observation during surveys	Marshall 2004; 2010
Gunung Palung NP, West Kalimantan, Indonesia	Lowland sandstone	5.9	2.9	Line transect (2), DISTANCE	Observation during surveys	Marshall, 2004; 2010
Gunung Palung NP, West Kalimantan, Indonesia	Freshwater swamp	7.8	5	Line transect (2), DISTANCE	Observation during surveys	Marshall, 2004; 2010
Gunung Palung NP, West Kalimantan, Indonesia	Peat swamp	2.5	3.8	Line transect (2), DISTANCE	Observation during surveys	Marshall, 2004; 2010
Gunung Palung NP, West Kalimantan, Indonesia	Lowland granite forest	7.3	3.8	Line transect (2), DISTANCE	Observation during surveys	Marshall, 2004; 2010
Gunung Palung NP, West Kalimantan, Indonesia	Upland granite forest	6.9	3.3	Line transect (2), DISTANCE	Observation during surveys	Marshall, 2004; 2010
Gunung Palung NP, West Kalimantan, Indonesia	Montane forest	1.24	3.2	Line transect (2), DISTANCE	Observation during surveys	Marshall, 2004; 2010
Lanjak Entimau Wildlife Sanctuary, Sarawak, Malaysia	Primary dipterocarp forest	21.5	4.4	Line transect, TRANSECT	Estimation from counts and sound movements during survey	Blouch, 1997
Lanjak Entimau Wildlife Sanctuary, Sarawak, Malaysia	Primary and secondary dipterocarp forest	20.8	4.4	Line transect, TRANSECT	Estimation from counts and sound movements during survey	Blouch, 1997
Lanjak Entimau Wildlife Sanctuary, Sarawak, Malaysia	Primary and secondary heavily disturbed forest	5.4	4.4	Line transect, TRANSECT	Estimation from counts and sound movements during survey	Blouch, 1997
Barito Ulu, Central Kalimantan, Indonesia	Mixed lowland dipterocarp forest	8.4	4.3	Regular monitoring	Regular monitoring	McConkey & Chivers, 2004

Study site	Forest type	Pop. density (ind/km2)	Group size	Survey method	Group size estimation method	Source
Sepilok, Sabah, Malaysia	Lowland dipterocarp forest	18.9	7	Line transect	Observations during surveys across different sites in Sabah	Davies, 1984
Tanjung Putting Reserve, Central Kalimantan, Indonesia	Mixed lowland forest	9.8	6.1	Total group counts within study area	Observation and complete counts of 9 groups	Supriatna et al., 1986

Note: Where known, survey methods, number of transect lines in parentheses and software for analysis are indicated.

of trees ranging from 19 m in old secondary forest to 22.1 m in primary forest (Brearley et al., 2004). From the observations made during our survey, *P. rubicunda* appeared to prefer exploiting the canopy above the median vegetation height. In Sabangau Forest, *P. rubicunda* exclusively selected large, tall trees as sleeping sites (≥27 cm DBH and ≥16 m tall trees [Ehlers Smith, 2014a]). In addition, Nijman & Nekaris (2012) found that as a response to human presence, *P. rubicunda* fled upwards more often and would only use the ground or under-storey as a fleeing route on rare occasions. This species is therefore likely to rely on taller emergent trees to avoid predators and use the relatively high canopy to travel and feed. These findings might have important conservation implications, as selective logging causes a decrease in abundance of large trees and mean vegetation height (White et al., 1995; Okuda et al., 2003). To date, virtually no evidence is available on the effect of negative changes in habitat structure for *P. rubicunda*. In the SWPF, human encroachment and illegal logging are gradually increasing within the regenerating habitat. Meijaard et al. (2008) proposed that *P. rubicunda* is likely to be negatively affected by logging due to their diet consisting of mainly fruit and seeds. While *P. rubicunda* is able to increase leaf consumption when necessary, in logged areas and closer proximities to humans, colobines are also exposed to risks of disease (Gillespie & Chapman, 2008) and hunting (Nijman, 2005; Marchal & Hill, 2009).

Between 2000 and 2010 nearly 10% of the habitat occupied by *P. rubicunda* was lost due to habitat conversion (Ehlers Smith, 2014b). In 2012, logging concessions within the range of the subspecies present in the SWPF, *P. r. rubicunda* (Müller, 1838), accounted for 40.8% of the total remaining area (Ehlers Smith, 2014b). The relatively high abundance of *P. rubicunda* within the SWPF's primary habitat makes this forest an important conservation area for this species in East Kalimantan. At present, the SWPF is still connected to the ecosystem of Balikpapan Bay. Populations of *P. rubicunda* are present in Bukit Bangkirai Forest, a 15 km^2 rainforest approximately 6 km north of the SWPF, as well as along the coast of Balikpapan Bay. While the SWPF is becoming increasingly encircled by human activities, it remains unknown to what extent *P. rubicunda* is able to move between these areas.

We recommend further density assessments of *P. rubicunda* in regenerating and disturbed habitats across East Kalimantan. A focus on determining the primate carrying capacity of both primary and regenerating forests should also be considered. These investigations will provide us with the required information to quantify the remaining suitable habitat and develop further status assessments and conservation plans.

ACKNOWLEDGEMENTS

We would like to thank *Le Conservatoire pour la Protection des Primates* and AZA Ape Tag Conservation Initiative for kindly funding our research. We thank the Indonesian State Ministry of Research and Technology for their permission to conduct our study. We also thank Pak Agus, Professor Vincent Nijman, Dr Stanislav Lhota, and the Universitas Mulawarman, Samarinda for their support. For the fieldwork we thank the survey team: Sabri, Misran, Joely, Arye, Aidil and the logistic team at Camp Djamaludin, Sungai Wain. We are also grateful to the anonymous reviewers for their useful comments on previous versions of this manuscript.

REFERENCES

Blouch, R.A. 1997. Distribution and abundance of orang-utans (*Pongo pygmaeus*) and other primates in the Lanjak Entimau Wildlife Sanctuary, Sarawak, Malaysia. *Tropical Biodiversity* **4**: 259-274.

Brearley, F.Q., Prajadinata, S., Kidd, P.S. and Proctor, J. 2004. Structure and floristics of an old secondary rain forest in Central Kalimantan, Indonesia, and a comparison with adjacent primary forest. *Forest Ecology and Management* **195**: 385-397.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers D.L. and Thomas, L. 2001. *Introduction to Distance Sampling: Estimating Abundance of Biological Populations*. Oxford University Press, Oxford, UK.

Burnham, K.P. and Anderson, D.R. 2002. *Model Selection and Multi-model Inference: a Practical Information-theoretic Approach*. Springer, New York, USA.

Cleary, D.F.R. and Genner, M.J. 2004. Changes in rain forest butterfly diversity following major ENSO-induced fires in Borneo. *Global Ecology and Biogeography* **13**: 129-140.

Curran, L.M., Caniago, I., Paoli, G.D., Astianti, D., Kusneti, M., Leighton, M., Nirarita, C.E. and Haeruman, H. 1999. Impact of El Niño and logging on canopy tree recruitment in Borneo. *Science* **286**: 2184-2188.

Davies, A. 1984. An Ecological Study of the Red Leaf Monkey (*Presbytis rubicunda*) in the Dipterocarp Forests of Sabah, Northern Borneo. PhD dissertation, University of Cambridge, UK.

Davies, G. 1987. Adult male replacement and group formation in *Presbytis rubicunda*. *Folia Primatologica* **49**: 111-114.

Davies, G. 1991. Seed-eating by red leaf monkeys (*Presbytis rubicunda*) in dipterocarp forest of northern Borneo. *International Journal of Primatology* **12**: 119-144.

Davies, A.G. and Payne, J. 1982. *A Faunal Survey of Sabah*. WWF Malaysia, Kuala Lumpur, Malaysia.

Davies, A.G., Bennett, E.L. and Waterman, P.G. 1988. Food selection by two South-east Asian colobine monkeys (*Presbytis rubicunda and Presbytis melalophos*) in relation to plant chemistry. *Biological Journal of the Linnean Society* **34**: 33-56.

Ehlers Smith, D.A. 2014a. Preliminary evidence for the hired guns hypothesis and indirect mate defense in a wild group of red langurs (*Presbytis rubicunda*) in Sabangau tropical peat-swamp forest, Central Kalimantan, Indonesian Borneo. *Asian Primates Journal* **4**(2): 2-15.

Ehlers Smith, D.A. 2014b. The effects of land-use policies on the conservation of Borneo's endemic *Presbytis* monkeys. *Biodiversity and conservation* **23**: 891-908.

Ehlers Smith, D.A. and Ehlers Smith, Y.C. 2013. Population density of red langurs in Sabangau Tropical Peat-Swamp Forest, Central Kalimantan, Indonesia. *American Journal of Primatology* **75**: 837-847.

Ehlers Smith, D.A., Ehlers Smith, Y.C. and Cheyne, S.M. 2013a. Home-range use and activity patterns of the Red Langur (*Presbytis rubicunda*) in Sabangau Tropical Peat-Swamp Forest, Central Kalimantan, Indonesian Borneo. *International Journal of Primatology* **34**: 957-972.

Ehlers Smith, D.A., Husson, S.J., Ehlers Smith, Y.C. and Harrison, M.E. 2013b. Feeding ecology of red langurs in Sabangau Tropical Peat-Swamp Forest, Indonesian Borneo: frugivory in a non-masting forest. *American Journal of Primatology* **75**: 848-859.

Focardi, S., Montanaro, P., Isotti, R., Ronchi, F., Scacco, M. and Calmanti, R. 2005. Distance sampling effectively monitored a declining population of Italian roe deer *Capreolus capreolus italicus. Oryx* **39**: 421-428.

Fredriksson, G.M. 2002. Extinguishing the 1998 forest fires and subsequent coal fires in the Sungai Wain Protection Forest, East Kalimantan, Indonesia. **In**: *Communities in Flames*, P. Moore, D. Ganz and L.C. Tanet (eds.), pp. 74-80. Food and Agriculture Organisation, Bangkok, Thailand.

Fredriksson, G.M., Danielsen, L.S. and Swenson, J.E. 2006. Impacts of El Nino related drought and forest fires on sun bear fruit resources in lowland dipterocarp forest of East Borneo. **In**: *Plant Conservation and Biodiversity*, D.L. Hawksworth and A.T. Bull (eds.), pp. 249-264. Springer, The Netherlands.

Fredriksson, G.M., Garshelis, D.L., Sastramidjaja, W.J. and Menken, S.B.J. 2012. Exploring the use of sign surveys for monitoring relative abundance of sun bears: a case study in burned and unburned forests in East Kalimantan, Indonesian Borneo. **In**: *Effects of El Niño and Large-Scale Forest Fires on the Ecology and Conservation of Malayan Sun Bears* (Helarctos malayanus) *in East Kalimantan, Indonesian Borneo*, G.M. Fredriksson (ed.), pp. 131-160. PhD dissertation, University of Amsterdam, The Netherlands.

Ganzhorn, J. 2003. Habitat description and phenology. **In**: *Field and Laboratory Methods in Primatology*, J.M. Setchell and D.J. Curtis (eds.), pp. 40-56. Cambridge University Press, Cambridge, UK.

Gillespie, T.R. and Chapman, C.A. 2008. Forest fragmentation, the decline of an endangered primate, and changes in host-parasite interactions relative to an unfragmented forest. *American Journal of Primatology* **70**: 222-230.

Hamard, M., Cheyne, S.M. and Nijman, V. 2010. Vegetation correlates of gibbon density in the peat-swamp forest of the Sabangau catchment, Central Kalimantan, Indonesia. *American Journal of Primatology* **72**: 607-616.

Hanya, G. and Bernard, H. 2012. Fallback foods of red leaf monkeys (*Presbytis rubicunda*) in Danum Valley, Borneo. *International Journal of Primatology* **33**: 322-337.

Hassel-Finnegan, H.M., Borries, C., Larney, E., Umponjan, M. and Koenig, A. 2008. How reliable are density estimates for diurnal primates? *International Journal of Primatology* **29**: 1175-1187.

IUCN. 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Downloaded on 07 January 2014.

Johnson, A.E., Knott, C.D., Pamungkas, B., Pasaribu, M. and Marshall, A.J. 2005. A survey of the orangutan (*Pongo pygmaeus wurmbii*) population in and around Gunung Palung National Park, West Kalimantan, Indonesia based on nest counts. *Biological Conservation*, **121**: 495-507.

Kirkpatrick, R.C. 2011. The Asian colobines: diversity among leaf eating monkeys. **In**: *Primates in Perspective*, C.J. Campbell, A. Fuentes, K.C. Mackinnon, M. Panger and S.K. Bearder (eds.), pp. 189-202. Oxford University Press, Oxford, UK.

Lammertink, M., Nijman, V. and Setiorini, U. 2003. Population size, Red List status and conservation of the Natuna leaf monkey *Presbytis natunae* endemic to the island of Bunguran, Indonesia. *Oryx* **37**: 472-479.

Marchal, V. and Hill, C. 2009. Primate crop-raiding: a study of local perceptions in four villages in North Sumatra, Indonesia. *Primate Conservation* **24**: 107-116.

Marques, T.A., Thomas, L., Fancy, S.G. and Buckland, S.T. 2007. Improving estimates of bird density using multiple-covariate distance sampling. *The Auk* **124**: 1229-1243.

Marshall, A.J. 2004. Population Ecology of Gibbons and Leaf Monkeys across a Gradient of Bornean Forest Types. PhD dissertation, Harvard University, USA.

Marshall, A.J. 2010. Effect of habitat quality on primate populations in Kalimantan: gibbons and leaf monkeys as a case study. **In**: *Indonesian Primates*, S. Gursky and J. Supriatna (eds.), pp. 157-177, Springer, New York, USA.

Mbora, D.N.M. and Meikle, D.B. 2004. Forest fragmentation and the distribution, abundance and conservation of the Tana river red colobus (*Procolobus rufomitratus*). *Biological Conservation* **118**: 67-77.

McConkey, K.R. and Chivers, D.J. 2004. Low mammal and hornbill abundance in the forests of Barito Ulu, Central Kalimantan, Indonesia. *Oryx* **38**: 439-447.

Meijaard, E., Sheil, D., Marshall, A.J. and Nasi, R. 2008. Phylogenetic age is positively correlated with sensitivity to timber harvest in Bornean mammals. *Biotropica* **40**: 76-85.

Miettinen, J., Shi, C. and Liew, S.C. 2011. Deforestation rates in insular Southeast Asia between 2000 and 2010. *Global Change Biology* **17**: 2261-2270.

Mitani, J.C., Struhsaker, T.T. and Lwanga, J.S. 2000. Primate community dynamics in old growth forest over 23.5 years at Ngogo, Kibale National Park, Uganda: implications for conservation and census methods. *International Journal of Primatology* **21**: 269-286.

Nijman, V. 2004. Effects of habitat disturbance and hunting on the density and the biomass of the endemic Hose's leaf monkey *Presbytis hosei* (Thomas, 1889) (Mammalia: Primates: Cercopithecidae) in east Borneo. *Contributions to Zoology* **73**: 283-291.

Nijman, V. 2005. Decline of the endemic Hose's langur *Presbytis hosei* in Kayan Mentarang National Park, east Borneo. *Oryx* **39**: 223-226.

Nijman, V. and Meijaard, E. 2008. *Presbytis rubicunda*. **In**: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>. Downloaded on 07 January 2014

Nijman, V. and Nekaris, K.A.I. 2012. Loud calls, startle behaviour, social organization and predator avoidance in arboreal langurs (Cercopithecidae: *Presbytis*). *Folia Primatologica* **83**: 274-287.

Okuda, T., Suzuki, M., Adachi, N., Quah, E.S., Hussein, N.A., Manokaran, N. 2003. Effect of selective logging on canopy and stand structure and tree species composition in a lowland dipterocarp forest in peninsular Malaysia. *Forest Ecology and Management* **175**: 297-320.

Simbolon, H., Suzuki, E. and Susanti, R. 2012. Some vegetation types studied with the same methodology in Indonesia. **In**: *The Biodiversity Observation Network in the Asia-Pacific Region*, S. Nakano, T. Yahara and T. Nakashizuka (eds), pp. 71-92. Springer, Japan.

Slik, J.W.F. and Eichhorn, K.A.O. 2003. Fire survival of lowland tropical rain forest trees in relation to stem diameter and topographic position. *Oecologia* **137**: 446-455.

Slik, J.W.F., Bernard, C.S., Van Beek, M., Breman, F.C. and Eichhorn, K.A. 2008. Tree diversity, composition, forest structure and aboveground biomass dynamics after single and repeated fire in a Bornean rain forest. *Oecologia* **158**: 579-588.

Slik, J.W.F., van Beek, M., Bernard, C., Bongers, F., Breman, F.C., Cannon, C.H. and Sidiyasa, K. 2011. Limited edge effects along a burned-unburned Bornean forest boundary seven years after disturbance. *Biotropica* **43**: 288-298.

Sodhi, N.S., Koh, L.P., Brook, B.W. and Ng, P.K.L. 2004. Southeast Asian biodiversity: an impending disaster. *Trends in Ecology and Evolution* **19**: 654-660.

Stark, D.J., Nijman, V., Lhota, S., Robins, J.G. and Goossens, B. 2012. Modeling population viability of local proboscis monkey *Nasalis larvatus populations*: conservation implications. *Endangered Species Research* **16**: 31-43.

Stibig, H.J., Achard, F., Carboni, S., Raši, R. and Miettinen, J. 2014. Change in tropical forest cover of Southeast Asia from 1990 to 2010. *Biogeosciences* **11**: 247-258.

Supriatna, J., Manullang, B.O. and Soekara, E. 1986. Group composition, home range, and diet of the maroon leaf monkey (*Presbytis rubicunda*) at Tanjung Puting Reserve, Central Kalimantan, Indonesia. *Primates* **27**: 185-190.

Thomas, L., Buckland, S.T., Rexstad, E.A., Laake, J.L., Strindberg, S., Hedley, S.L., Bishop, J.R.B., Marques, T.A. and Burnham, K.P. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology* **47**: 5-14.

Wantanabe, K. 1981. Variation in group composition and population density of the two sympatric Mentawaian leaf-monkeys. *Primates* **22**: 145-160.

White, F.J., Overdorff, D.J., Balko, E.A. and Wright, P.C. 1995. Distribution of ruffed lemurs (*Varecia variegata*) in Ranomafana National Park, Madagascar. *Folia Primatologica* **64**: 124-131.

Wilson, C.C. and Wilson, W.L. 1975. The influence of selective logging on primates and some other animals in East Kalimantan. *Folia Primatologica* **23**: 245-274.