Ecological Indicators 87 (2018) 167–177

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original Articles

How conspecific primates use their habitats: Surviving in an anthropogenically-disturbed forest in Central Kalimantan, Indonesia

Minerva Singh[a,*], Susan M. Cheyne[b,c,d], David A. Ehlers Smith[b,e]

[a] Department of Plant Sciences, Downing Street, University of Cambridge, Cambridge, CB2 3EA, UK
[b] Borneo Nature Foundation, Jn. Bukit Raya Induk 82, Bukit Hindu, Palangka Raya 73112, Kalimantan Tengah, Indonesia
[c] Faculty of Humanities, Social Sciences and Law, Oxford Brookes University, Oxford OX3 0BP, UK
[d] School of Anthropology and Conservation, University of Kent, Canterbury, Kent CT2 7NR, UK
[e] University of KwaZulu-Natal, School of Life Sciences, Private Bag X01, Scottsville, Pietermaritzburg 3209, South Africa

ARTICLE INFO

Keywords:
Anthropogenic disturbance
Biodiversity hotspots
Forest structure
Habitat suitability
MaxEnt
Remote sensing

ABSTRACT

Kalimantan (Indonesian Borneo) is a biodiversity hotspot at risk because of severe forest loss, degradation and burning events. Habitat loss and anthropogenic altering of forest structures pose a threat to forest-dependent taxa, including multiple endemic primate species. Conservation management schemes may be enhanced by evaluating how forest-dependent primates use their habitat for fulfilling life-history requirements, the role of natural forest structures thereon, and any corresponding impacts from anthropogenic disturbance and modification of forests. We investigated how forest-structure variables and landscape scale anthropogenic disturbance factors influenced the life-history behaviours (sleeping, ranging and feeding) of two endemic and sympatric primate species, *Presbytis rubicunda* (red langur) and *Hylobates albibarbis* (Bornean agile gibbon), in Sabangau tropical peat-swamp forest, Central Kalimantan. We aimed to identify key factors that influence habitat suitability for both species, and determine the influence of similar factors when selecting habitat for various activities such as sleeping, feeding and ranging. GPS locational data for each behaviour were analysed in conjunction with forest-structure parameters present (derived from LiDAR, ALOS-PALSAR), landscape-scale habitat related factors, and proximity to landscape-scale disturbance factors including burned areas. A Maximum Entropy (MaxEnt) algorithm was employed for estimating habitat suitability for the different activities of each species based on the afore-mentioned variables. By using a combination of forest sub-class, structure and disturbance variables within the MaxEnt framework, distribution maps of suitable langur and gibbon sleeping, ranging and feeding habitats were produced. Langurs and gibbons had limited overlaps in terms of feeding, ranging and sleeping habitats. In all cases, landscape-scale variables including those related to landscape scale anthropogenic disturbance had the highest percentage contribution for explaining habitat suitability in comparison to forest-structure variables such as canopy heights (derived using LiDAR data). Additionally, variables influencing habitat selection varied between species; while langur feeding, ranging and sleeping were all influenced by distance from burned forests, gibbon sleeping habitat selection was influenced by distance from the forest edge, and ranging and feeding habitat selection was most affected by distance from burned areas. The insights gained from this study may help inform conservation management of these species and guide forest management strategies accordingly to ensure habitat structure is maintained to facilitate activities by sympatric primate species.

1. Introduction

Southeast Asia has among the highest rates of global deforestation, and is poised to lose a substantial proportion of its biodiversity by 2100 (Sodhi et al., 2010). If the existing trends of deforestation continue, biodiversity hotspot regions, such as those in Indonesia, may lose many species, with emphasis on endemic and conservation-dependent species (Brooks et al., 2002). Kalimantan (Indonesia Borneo) is home to many charismatic and threatened species, including the critically endangered Bornean orangutan (*Pongo pygmaeus*), the endangered proboscis monkey (*Nasalis larvatus*), Sumatran rhinoceros (*Dicerorhinus sumatrensis*), and Bornean pygmy elephant (*Elephas maximus borneensis*). Over the past several decades, Indonesia has undergone significant forest loss (Gaveau et al., 2014; Hansen et al., 2013), and this problem

* Corresponding author at: Department of Plant Sciences, David Attenborough Building, Downing Street, University of Cambridge, Cambridge, CB2 3EA, UK.
E-mail address: Minerva.Singh@glasgow.ac.uk (M. Singh).

https://doi.org/10.1016/j.ecolind.2017.12.041
Received 10 April 2017; Received in revised form 16 December 2017; Accepted 17 December 2017

is especially severe in Kalimantan where even lowland forests located within the protected area network have undergone a significant decline (Curran et al., 2004; Miles, 2007). Oil-palm expansion is one of the major drivers of forest loss and largest threats to biodiversity in the region (Wilcove and Koh, 2010). In Kalimantan, the area under oil palm increased by more than 200% from 2000 to 2010 (Carlson et al., 2013). Additionally, forest fires, which are a near-annual occurrence in many parts of Indonesia, and especially Kalimantan, pose a threat to the region's biodiversity (WWF, 2016).

Consequently, many forest-dependent taxa, including threatened and endemic primate species, have experienced population declines (Cheyne et al., 2016). Forest loss, and even modest habitat modification, can have a negative impact on primate densities (Cattau et al., 2015). Given that a large percentage of primary lowland rainforests have already been converted to different land-use types such as oil palm plantations (Miettinen et al., 2011), tropical peat-swamp forests represent habitat strongholds for many of Borneo's conservation-dependent and endemic primate species (Ehlers Smith et al., 2013a,b; Ehlers Smith, 2014a,b).

Kalimantan's forests contain many sympatric primate species, representing a diverse array of habitat requirements and niche occupancies, which must be accounted for when considering conservation management plans. For example, tall trees have been identified as 'important drivers of primate population densities' in the tropical peat-swamp forests in Sabangau (Central Kalimantan) and the abundance of large, fruit-bearing trees determines the presence of red langurs (*Presbytis rubicunda)* (Ehlers Smith and Ehlers Smith, 2013; Ehlers Smith et al., 2013a,b). The presence of median height tress and canopy cover are important correlates of densities of the sympatric Bornean agile gibbon (*Hylobates albibarbis)* (Hamard et al., 2010). It has been further suggested that orangutans use different parts of the forest canopy for different behaviours (Morrogh-Bernard et al., 2014). Hence, a detailed examination of forest structure and how different aspects of forest canopy may influence the performance of activities such as sleeping, ranging (a wandering behaviour used to explore the area of forest occupied by a group, comprised of location points collected while following primates (Clutton-Brock, 2012)) and foraging can help focus conservation initiatives for safeguarding primate species.

Anthropogenic disturbances such as burning usually operate at a landscape scale (Cardoso et al., 2013) and are instrumental in fragmenting continuous forests into a mosaic of forest patches. Anthropogenic disturbances combined with degradation and fragmentation of tropical forest habitats are significant drivers of local-scale extinctions of mammal species (Michalski and Peres, 2005). It has been suggested that anthropogenic disturbances may also adversely affect the long-term persistence of primate species in the disturbed forests of Kalimantan (Morrogh-Bernard et al., 2003). However, our knowledge of the influence of forest structure variables, the role of selective logging, the anthropogenic disturbance factors and its effect on a landscape on primate habitat selection for different life-history behaviours is limited. It may be possible to quantify the role of anthropogenic disturbance factors in conjunction with remote sensing data of derived correlates of vegetation structure (Ehlers Smith and Ehlers Smith, 2013) on the behaviour and habitat selection of threatened primate species.

Light Detection and Ranging (LiDAR) is a 3D mapping system that has been extensively used for characterizing the vertical structure of tropical forests, forest biophysical parameters, structural heterogeneity and other 3D attributes of forest canopy, which may influence species persistence (Singh et al., 2015; Englhart et al., 2013; Davies and Asner, 2014). A significant body of research has focussed on using LiDAR to identify forest-structure variables influencing avian species richness and persistence (Boelman et al., 2007; Flaspohler et al., 2010; Mülleret al., 2010). Fewer studies have attempted to use LiDAR derived canopy structure variables to examine the richness, persistence and habitat preference of non-volant species. LiDAR and multi-spectral variables were used together to identify the forest structure variables influencing the occupancy of six different mammals in Borneo (Niedballa et al., 2015). Little application has been used for examining primate habitat preferences; where it has been applied, data have been used for quantifying primate habitat preferences in the Neotropics (Palminteri et al., 2012; McLean et al., 2016). Research by Palminteri et al. (2012) discovered that mean canopy height influenced quadrat use by bald-faced saki monkeys (*Pithecia irrorata*), while McLean et al. (2016) showed that movement decisions of primate species were influenced by canopy height along with density of crown vegetation. Furthermore, a global scale analysis of primate distribution revealed that a combination of factors, including the variation in canopy vertical structure (derived from LiDAR), productivity and bioclimatic variables such as rainfall influence primate species persistence (Gouveiaet al., 2014). Based on these studies, it may be argued that LiDAR data can help encapsulate how different parts of the forest canopy facilitate the performance of behaviours (such as sleeping, ranging and foraging) by different primate species. In addition to LiDAR data, other RS data notably those derived from Landsat have been used to identify suitable habitat for mobile taxa in the tropics (Singh et al., 2017; Lahoz-Monfort et al., 2010)

RS data together with species presence data may be applied to machine learning algorithms to identify suitable habitats and variables influencing habitat selection (Eldegard et al., 2014). Maximum Entropy (MaxEnt) (Phillips et al., 2006) is a machine learning algorithm which has been extensively used for estimating and mapping the habitat preferences of many different species. This technique offers the advantage of being able to utilise species presence-only records and needs very few records to produce robust predictions of suitable habitats (Thorn et al., 2009; Tinoco et al., 2009). By identifying factors influencing habitat selection, MaxEnt not only identifies suitable habitats, but is also a powerful tool for disentangling the role of environmental and landscape scale anthropogenic influences (Abade et al., 2014). It has been used to show, for example, that landscape-scale factors, such as landscape-scale disturbances influence species persistence more than local-scale stand factors (Zhaoet al., 2013).

While MaxEnt has been extensively applied for habitat suitability mapping of many mammal species, to the best of our knowledge, this is the first time it has been used for identifying habitats and important variables that influence specific life-history behaviours by sympatric primate species. The aim of this research is to evaluate how micro-habitat-scale forest structure and landscape scale variables (such as anthropogenic disturbances and ensuing landscape configurations) influence activities such as sleeping, ranging and feeding, habitat selection and suitability for two sympatric primate species, the red langur (from here on, "langur") and Bornean agile gibbon (from here on, "gibbon") in Sabangau, Kalimantan. The specific objectives of the research are to (a) identify which forest structures and landscape scale factors influence habitat suitability for sleeping, ranging and feeding for the two species, and (b) determine if both species were influenced by similar forest structures and/or landscape factors while selecting habitat for different life-history, which may in turn form a cohesive conservation management plan.

2. Materials and methods

2.1. Study area

The tropical peat-swamp forests of Sabangau are located in the Central Kalimantan, Indonesia (Ehlers Smith and Ehlers Smith, 2013). At about 6000 km^2, it is the largest remaining contiguous block of lowland forest on Borneo. The data collection for the research was carried under the Orangutan Tropical Peatland Project - Centre for the International Cooperation in Sustainable Use of Tropical Peatlands (CIMTROP) collaboration. This project is located within the 500 km^2 Natural Laboratory for the Study of Peat Swamp Forests in the northern Sabangau Forest (2°19′S and 113°54′E; Fig. 1). The area is characterized