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Original investigation

Fine-scale distributions of carnivores in a logging concession in Sarawak, Malaysian Borneo

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ABSTRACT

Coarse-scale patterns of distribution and abundance of species are the outcome of processes occurring at finer spatial scales, hence the conservation of species depends on understanding their fine-scale ecology. For Bornean carnivores, little is known about fine-scale predictors of species occurrence and it is assumed that the two main threats to wildlife on Borneo, habitat disturbance and hunting, also impact their occurrence. To increase our understanding of the Borneo carnivore community, we deployed 60 cameras in a logging concession in northern Sarawak, Malaysian Borneo, where different landscape covariates, both natural and anthropogenic, were present. We built single-species occupancy models to investigate fine-scale carnivore occupancy. Overall, forest disturbance had a negative effect on Hose's civet (*Diplogale hosei*), banded civet (*Hemigalus derbyanus*) and yellow-throated marten (*Martes flavigula*). Further, banded civet had greater occupancy probabilities in more remote areas. Logging roads had the most diverse effect on carnivore occupancy, with Hose's civet and masked palm civet (*Paguma larvata*) negatively affected by roads, whereas Malay civet (*Viverra tangalunga*), short-tailed mongoose (*Herpestes brachyurus*) and leopard cat (*Prionailurus bengalensis*) showed higher occupancy closer to roads. Canopy height, canopy closure, number of trees with holes (cavities) and distance to nearest village also affected occupancy, though the directions of these effects varied among species. Our results highlight the need to collect often overlooked habitat variables: moss cover and 'kerangas' (tropical heath forest) were the most important variables predicting occurrence of Hose's civet. The preservation of such forest conditions may be crucial for the long-term conservation of this little-known species. Our results confirm that logged forests, when left to regenerate, can host diverse carnivore communities on Borneo, provided less disturbed habitat is available nearby, though human access needs to be controlled. We recommend easy-to-implement forest management strategies including maintaining forest next to logging roads; preserving fruiting trees and trees with cavities, both standing and fallen; and blocks of remote, less disturbed, mid- to high-elevation forest with understorey vegetation.

Introduction

The islands of Southeast Asia are recognized as global biodiversity hotspots (Myers et al., 2000) and within insular Southeast Asia, Borneo is recognised as an evolutionary hotspot hosting high levels of mammalian species richness and endemicity (de Bruyn et al., 2014). Borneo currently suffers high levels of deforestation, losing its forest cover at nearly twice the rate of the rest of the world's humid tropical forests. Within the last four decades, over 30% of Borneo's forests were cleared (Gaveau et al., 2014). Of the geopolitical units on Borneo, the Malaysian state of Sarawak has the least proportion of intact forest remaining at 14.6% compared to 19.1% in Sabah, 32.6% in Kalimantan and 56.9% in Brunei (Gaveau

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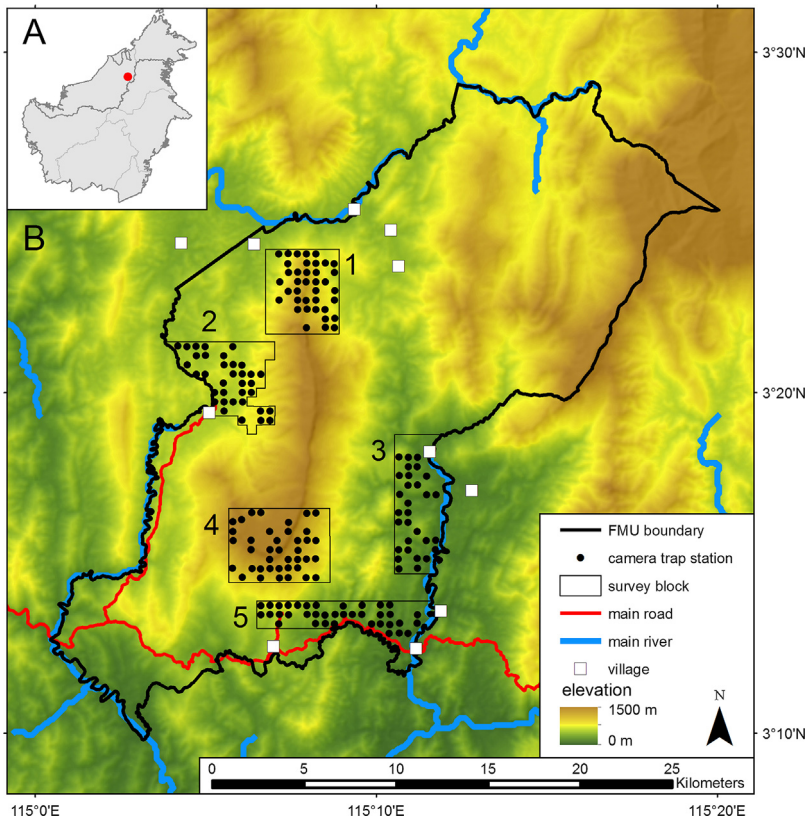

Fig. 1. Location of the Sela'an Linau Forest Management Unit (FMU) on Borneo (A). Locations of our five study blocks with camera arrays and locations of main roads, rivers and villages (B). Numbering of blocks follows descriptions in Table 1.

et al., 2014). The coverage of protected areas in Sarawak remains low at 4.2% of total land area (DOS, 2011). Much of the forest loss and degradation in Sarawak has been due to logging, as evidenced by the greatest density of logging roads on Borneo (Gaveau et al., 2014). Moreover, only one logging concession in Sarawak is currently certified as sustainably managed by the Malaysian Timber Certification Scheme. In contrast to other provinces on Borneo, no logging concession has been certified by the international Forest Stewardship Council (Mathai et al., 2016a).

In addition to habitat conversion, degradation and fragmentation, hunting is a serious threat to many mammals on Borneo (e.g. Bennett et al., 2000; Brodie et al., 2015a), presumably including carnivores. Hunting may be a larger problem in Sarawak and Kalimantan than in Brunei and Sabah because of larger populations of forest- and wildlife-dependent indigenous communities (Bennett et al., 2000). The effects of hunting and wild meat consumption on Bornean carnivore populations are largely unknown (Mathai et al., 2016a), though illegal hunting and wildlife trade are increasing (Shepherd et al., 2011).

Twenty-five carnivore species occur on Borneo including more endemics than any other island except Madagascar (Shepherd et al., 2011). About half of these carnivores are classified by The IUCN Red List of Threatened Species as globally threatened (IUCN, 2016) with little available information on their basic ecology and tolerance to habitat disturbance (Mathai et al., 2016a). Additionally, most studies conducted in Borneo, and particularly in Sarawak, were focussed on coastal areas and lowland forests due to easier logistics, resulting in little information on highland species. Recently, some understanding of coarse-scale distribution of many carnivore species within Borneo was achieved (Mathai et al., 2016a), but fine-scale predictors of species persistence are lacking, with few studies addressing the effects of physical and anthropogenic covariates on Bornean carnivores. Fine-scale ecological studies provide the context and basis for studying processes and resultant patterns of distribution, abundance, diversity and interactions of species (Landres et al., 1999). Because animals often select resources differently at different scales, habitat associations found in distribution-wide studies cannot necessarily be translated to small-scale distribution of individuals (e.g., Boyce, 2006; Mayor et al., 2009). Bornean carnivores are ecologically diverse (i.e. different forest type, trophic niche, response to anthropogenic disturbances) and functionally important (i.e. as seed dispersers (Nakashima et al., 2010) and top predators), and thus, may be good indicators of the performance of different management and conservation strategies.

We analysed fine-scale distributions of carnivores within the Sela'an Linau Forest Management Unit (SL FMU), a logging concession in interior Sarawak, comprising lowland, upland and montane forest, the last two being little-studied forest types. We used an occupancy framework to investigate the role of habitat quality (i.e. vegetation structure) and anthropogenic factors such as logging, forest disturbance, distance to logging roads and human settlements and hunting. We then applied our results to forest management applications to facilitate the long-term conservation of the carnivore community in logging concessions.

Methods

Study area

The SL FMU (3°11′–29′N; 115°00′–20′E) is a logging concession of 55,949 ha in the Upper Baram region of interior northern Sarawak (Fig. 1A). The FMU's terrain is undulating with elevations from 250 m to 2000 m above sea level (a.s.l.). It receives high rainfall