The effect of tropical forest modification on orangutan population density and movement

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Orangutans (*Pongo* spp.) are the only non-human great ape found outside of Africa. Historically, they ranged across much of Southeast Asia, although today populations are restricted to the islands of Sumatra and Borneo (Delgado & Van Schaik, 2000). Despite being heralded as conservation icons and boasting strict legal protection, all three species are considered Critically Endangered on the IUCN Red List of Threatened Species (Nowak, et al., 2017; Singleton, et al., 2017; Ancrenaz, et al., 2016). Orangutan populations face a multitude of threats including hunting, forest fires and climate change, however habitat loss and fragmentation, due largely to conversion to oil palm, continues to be the leading cause of population decline for all orangutan taxa (Nowak, et al., 2017; Singleton, et al., 2016; Ancrenaz, et al., 2016). Using a mosaic landscape, we investigated the effects of habitat modification on orangutan populations. We used commonly employed orangutan nest survey methods to determine orangutan population density across a gradient of modified forest habitats and to investigate if landscape feature and forest structural data can be used to predict orangutan density across modified landscapes.

The study was conducted at the Stability of Altered Forest Ecosystems project (SAFE: https://www.safeproject.net) and surrounding oil palm estates covering an area of approximately 13,000 ha, in the Malaysian state of Sabah, Borneo. The SAFE project itself covers 7200 ha and is currently undergoing a planned conversion to oil palm. Between 2013 and 2016, the site was salvage logged, with the exception of a network of replicated forest fragments and riparian reserves (Struebig et al., 2013, Ewers et al., 2011). The northern extent of the site includes the Ulu Segama Forest Reserve, a twice logged, continuous forest block of >1 million ha (Ewers et al., 2011). Ulu Segama contains one of the largest unfragmented populations of orangutans within Malaysia, consisting of 2,300 individuals (95% CI = 1,744 and 3,657, Ancrenaz et al., 2010). The remainder of the site comprises established oil palm plantations managed by Benta Wawasan Sdn. Bhd. and Sabah Softwoods Sdn. Bhd.

Between April and August 2017, we systematically placed transects ranging from 0.6 to 2 km across the full disturbance gradient and conducted orangutan nest surveys using the standing crop methods described by Spehar et al. (2010). To assess if three dimensional forest structural and landscape features explain variations in orangutan density across the study landscape, we employed forest structural metrics obtained from airborne LiDAR data (Jucker et al., in press) and several landscape variables derived in ArcGIS software (ESRI, 2011), using layers produced from satellite images (Deere et al., 2017). We used One Way ANOVA tests to assess differences in orangutan density between habitat types and Generalized Linear Models (GLM) to evaluate relationships between orangutan density relative to forest structural and landscape variables.

In total, we recorded 678 nests, along 44 transects with a combined survey effort of 51.3km. Mean orangutan density across the landscape was 2.01 individuals/km^2 but demonstrated considerable variation (range 0.09 to 4.52). Interestingly, there was no significant difference in orangutan density between the continuous logged forest sites (2.32 individuals/km^2, SD 0.84) and sites within the recently salvaged logged SAFE experimental area (2.35, SD 0.63). However, as predicted, orangutan density in remnant forest patches within oil palm estates was significantly lower (0.82, SD 0.45). The GLMs revealed that, other than habitat type, only canopy height SD had a significant (positive) effect on orangutan density, suggesting

that although remnant forest patches within modified landscapes can support orangutans, this is dependent on forest quality.

The results of the study reveal several interesting points which may have conservation implications. As expected, forest conversion to oil palm negatively effects orangutan populations, leading to reduced densities, however despite this, orangutans were still present in remnant forest patches within oil palm estates. This adds to the growing body of evidence that suggests orangutans have greater ecological resilience to disturbance than previously assumed. Although it is unlikely these areas alone can maintain viable populations, if managed appropriately, they may act as important corridors, connecting isolated populations and facilitating migration in response to climate change. Conversion to oil palm reduces the amount of available resources and increases the risk of human-orangutan conflicts, such as hunting and exposure to novel pathogens. However, with growing demand, further oil palm expansion is inevitable and with orangutan habitat the most suitable for oil palm production, any conservation strategy which fails to include these modified landscapes will hinder orangutan conservation.

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