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IMPACTS OF THE 2015 FIRE SEASON ON PEAT-SWAMP FOREST BIODIVERSITY IN INDONESIAN BORNEO

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SUMMARY

Southeast Asia's tropical peat-swamp forests (PSFs) are important for biodiversity conservation, but decades of peat mis-management, illegal logging and largely unrestricted agricultural development in Kalimantan has led to peat drainage in most areas and consequent fire vulnerability. This was highlighted in 2015, when a strong El Niño event led to extensive peatland fires, which reached their peak during August to October 2015. Thousands of square kilometres of peatland were burned, including fires in/around such important PSFs as Sabangau, Mawas, Katingan and Tanjung Puting. We consider the potential impacts of these fires on Kalimantan's biodiversity. The huge majority of PSF fauna species will have been negatively impacted, owing to (1) forest area/habitat loss, including destruction of entire smaller forest fragments; (2) toxic haze inhalation; (3) impacts of drought and low sunlight on forest trees; and (4) increased river acidity. Less mobile, longer-lived and slower-breeding species, such as the endangered Bornean orangutan and southern Bornean gibbon, are expected to be among the worst affected. Negative impacts will persist and worsen in future, if Kalimantan's mis-managed and drained peatland area continues to increase, and strict burning bans are not enforced.

Keywords: *peat-swamp forest, biodiversity, fire, Indonesia, orangutan.*

INTRODUCTION

Peatland fires in Indonesia, and Kalimantan in particular, are now an annual dry season occurrence that are most severe during drier conditions associated with El Niño events (Spessa *et al.*, 2015). Fire prevalence has increased over time, owing to a combination of peat mis-management and drainage, which in many cases has occurred over decades, coupled with fire use by both industrial plantations and local communities, particularly in degraded areas (Page *et al.*, 2009). Prior to 2015, the most severe fire season on record in Kalimantan occurred during the strong 1997-98 El Niño event. Comparisons of the Oceanic Niño Index and other indicators suggest that the 2015-2016 El Niño event is of near identical strength to that of 1997-98 (NOAA, 2016),. During the peak Kalimantan fire season from August-October 2015, a total 49,615 hotspots were detected by NASA MODIS satellites, with 54% in peat areas (http://www.globalforestwatch.org/).

Fire damaged millions of hectares of peatland in Indonesia and released 810-2,570 Mt of carbon into the atmosphere during the 1997-98 El Niño; an amount equivalent to 13-40% of annual fossil fuel emissions at that time (Page *et al.*, 2002). Reports from this period indicate that 20 million people suffered from respiratory problems due to toxic haze inhalation for prolonged periods, with 19,800-48,100 premature mortalities (Heil, 2007), and national economic losses totalled USD 20 billion (Varma, 2003). While the impacts of these fires on carbon emissions, public health and the economy are becoming better understood, our knowledge of their impacts on biodiversity is limited. Here, we provide a preliminary and non-exhaustive overview of some potential biodiversity impacts of the 2015 fires, which we will build on over the coming months through further publications.

METHODS

Fire hotspot data were sourced from the Global Forest Watch portal and NASA FIRMS Earth Data server provider; peat distribution data from (WI, 2004) via Global Forest Watch; and orangutan distribution data from the IUCN (Ancrenaz *et al.*, 2008). Land cover change in Block C of the ex-Mega Rice Project (MRP) in 2015 was assessed by conducting supervised classifications on Landsat data from 8th August 2006 (pre-fire), and composites of data from 14th October and 23rd November 2015 (post-fire) (cf. Cattau *et al.*, 2015). We conducted a preliminary estimate of burned area in Block C during the 2015 fire season by establishing a 3-2-1 band combination and using

a QGIS Semi-automatic Classification Plugin to obtain the shape-file, establishing 7 as Range radius for Region of Interest creation and performing a spectral angle mapping algorithm (3.0 thresholds). Pollution data (PM 10) were obtained from the Indonesian Meteorology, Climatology and Geophysics Agency (BMKG). Data on forest litterfall were collected from 16 traps (1 m^2) on a monthly basis in the Natural Laboratory of Peat-Swamp Forest (NLPSF), Sabangau since 2005, using methods described in Harrison *et al.* (2007). Data on fish populations from 20 wire fish traps and water pH at sampling locations along a 7.6 km stretch of the Sabangau River were collected for pre- and post-fire as part of a larger study involving monthly fish and water surveys in the river (see Thornton *et al.*, 2016 for methods). No litterfall, fish or water sampling were conducted during the height of the fires in October 2015, when field conditions were unsafe, but these data were collected before, during the initial stages of, and after the 2015 fire period.

RESULTS

The precise amount of peatland and forest area burned, and overlap with up-to-date fauna species' ranges (based on Struebig *et al.*, 2015), will be the topic of future publications. However, comparison of NASA FIRMS fire hotspot data between August and December 2015 and WI peatland distribution indicates that 24.1% of hotspots in Central Kalimantan occurred in areas with a peat depth > 2 m (Figure 1a). Further, comparison of hotspot and IUCN orangutan distribution data indicate that 29.9% of hotspots occurred within the orangutan's distribution range (Figure 1b). This included fires in/around the Sabangau (home to 6,900 orangutans), Tanjung Puting National Park (6,000 orangutans), Mawas (3,500 orangutans) and Katingan Forests (3,000 orangutans) (population sizes from Wich *et al.*, 2008).

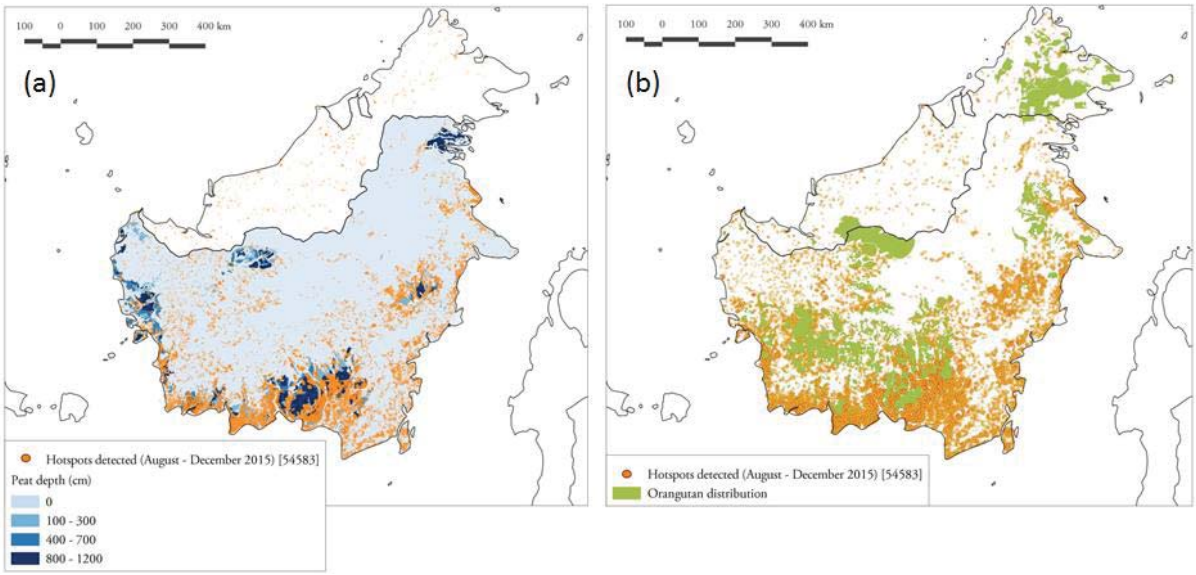

Figure 1. Overlap between NASA FIRMS fire hotspots from August-December 2015, with (a) WI peat distribution and depth data, and (b) IUCN Bornean orangutan distribution data. *See text for descriptions of data sources.*

Analysis of forest loss in individual PSF areas further illustrates this. For example, in the 55,000 ha Sabangau NLPSF, we estimate that two particularly large fires at both the forest edge and in the interior burned a combined 5,665 ha of forest in 2015 (10% of the total area). On-the-ground observations and drone photo-compositions of the burn scar suggest almost complete tree mortality in much of this area (M. E. Harrison and B. Ripoll Capilla, pers. obs.). This occurred despite the presence and extraordinary fire-fighting efforts of the CIMTROP Community Patrol Team protecting this long-term research site. Forest was also burned around the Tuanan research area in Mawas, where a Borneo Orangutan Survival Foundation (BOSF) fire-fighting team operates (Ela, 2015).

In more heavily drained and degraded PSF, such as Block C of the ex-MRP, even larger areas have suffered fire damage. From our preliminary analysis, we estimate that total forest cover reduced by 40.1% from 106,554 ha in August 2008 to 63,848 ha in October/November 2015 (Figure 2). This estimate is likely conservative, because fires continued to burn for more than 15 days after 14th October 2015. Comparison with August 2015 satellite images indicates this owes mostly to the 2015 fires, though some is also due to previous agricultural expansion and fires. Within this burned area, entire individual smaller PSF patches have been burned (Figure 2). This suggests a high probability of local faunal extinctions in some areas, in particular for less mobile species (i.e., those with limited dispersal capabilities and/or showing very strong territoriality). This is supported by observations of starving orangutans, feeding on ferns and nesting on the ground in burned PSF areas (L. Sugiarti, pers. comm.).

Further ecological impacts of the 2015 fires beyond direct forest loss are also evident, including:

1. Large increases in total litterfall in the Sabangau Forest during each of the three El Niño/major haze events within our 2005-2015 dataset (mean 1,079.2 ± 707.9 kg/ha/mo from August-November during the 2006, 2009 and 2015 El Niño/fire seaons; vs. 697.0 ± 697.0 kg/ha/mo during the same months in non- El Niño/major years; Mann-Whitney, $p < 0.001$).
2. Prolonged high levels of airborne pollutants. In Palangka Raya, PM10 levels reached 12 times "hazardous" levels on some days (e.g., 3,761 $\mu g/m^3$ on 20st October 2015; is 300 $\mu g/m^3$ considered hazardous), with a mean daily value of 1,120 $\geq \mu g/m^3$ in October 2015 (BMKG, unpublished data). This level of pollution is known to have serious health consequences for humans (see Introduction), and similar health impacts should be expected across wildlife species. In particular, colleagues from the Borneo Orangutan Survival Foundation's Central Kalimantan Orangutan Rescue Project at Nyaru Menteng reported acute respiratory and other ailments related to smoke inhalation, particularly among young orangutans at the centre (Harvey, 2015); gibbon territorial singing is compromised (Cheyne, 2007); and the thick haze, which on occasion reduces visibility to < 10 m, is almost certain to impact animals such as birds and fruit bats, which are dependent on sight to find food and mates.
3. An almost five-fold increase in acidity of the Sabangau River post-fires and consequent impacts on fish: river pH dropped from a pre-fire mean of 3.88 to 3.20 immediately after the fires. This corresponded with a decline in fish captures per unit effort from 18.21 to 4.02, respectively.

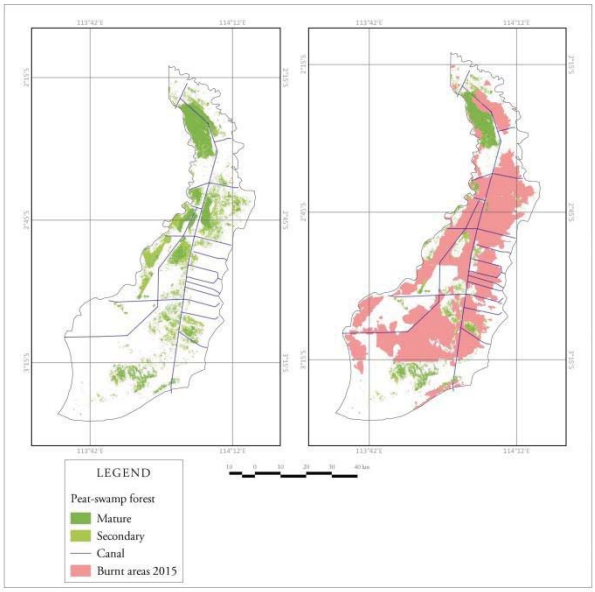

Figure 2. Peat-swamp forest cover in Block C of the ex-Mega Rice Project in August 2008 (left) and November 2015 (right – also shows areas burned during the 2015 fire season). *See text for descriptions of data sources.*

DISCUSSION

Although preliminary, our analysis indicates overall strong negative impacts of the 2015 peat and forest fires in Kalimantan on biodiversity. Firstly, fire hotspot distribution in 2015 showed strong overlap with both peatlands (54%) and the range of the (soon to be) Critically Endangered Bornean orangutan (30%). Further analyses will refine these figures, by incorporating accurate estimates of burned peat area (Hooijer *et al.*, unpublished data) and more up-to-date distribution data (Struebig *et al.*, 2015). The loss of habitat includes the apparently complete burning of entire smaller forest fragments in some areas, such as Block C of the ex-MRP. Reports of large numbers of orangutans rescued from fire-struck peatland areas confirm this (e.g., Mawas, (Hermanu, 2016). We can therefore state with some confidence that this loss of habitat alone will have had severe negative impacts on this already highly threatened and slow-breeding ape species.

A total 123 mammal, 268 bird, 75 reptile, 27 amphibian and 219 freshwater fish species have been recorded from South-east Asian peat-swamp forests (Posa *et al.*, 2011). The distribution of many of these species bears strong similarities to that illustrated above for the Bornean orangutan; i.e. a preference among many mammal and bird species for lowland and peat-swamp forests (Payne and Francis, 1985; Phillipps and Phillipps, 2009; Struebig *et al.*, 2015). PSF fires are known to cause extremely high tree mortality, plus decreases in tree species richness and non-tree flora abundance (Yeager *et al.*, 2003). Despite the fact that very few fauna species appear restricted to PSFs (Posa *et al.*, 2011), the huge areas of peatland and lowland forest burned suggest that habitat loss resulting from the 2015 fires will have had negative impacts on most species found in peat-swamp forests, and strong negative impacts on many, including local extinctions of selected species in some areas.

Similarly, given the known human health impacts of prolonged exposure to haze from peat fires, the observations quoted above on rescued orangutans (Harvey, 2015) and wild gibbon singing (Cheyne, 2007), and the thickness of the haze during the peak of the 2015 fire season, it is inconceivable that the region's wildlife did not experience negative health impacts, even in unburned forest areas. As in humans (who can to some extent mitigate health impacts through wearing face masks), this will include chest and breathing ailments, lethargy and reduced physical performance, which should be expected to have negative impacts on both fitness and mortality. Such impacts may be particularly severe in sight-reliant species, which likely suffer from additional nutritional stresses owing to compromised ability to find food. Impacts may also be more severe in longer-lived animals that experience

multiple haze events during their lifetime and in slower-breeding species, for which the impacts of any reductions in breeding fitness or increases in mortality may be more long lasting.

Further, it is likely that many non-sight-dependent species will have suffered additional nutritional stress, through either reduced drinking water availability and/or reduced fruit/flower availability in forests. Although this latter relationship has yet to be confirmed (this will form the subject of a future analysis by the authors), the dramatic increases in forest litter-fall observed during haze periods (Harrison *et al.*, 2007; this study) coupled with reduced photosynthesis by forest trees during haze periods (Davies and Unam, 1999) suggests that trees are likely to need to divert resources to replacing shed leaves following severe haze events, which we hypothesise will lead to decreased resource investment in reproduction; i.e. reduced availability of fruit and flower foods for forest fauna.

Finally, evidence from our fish and river surveys indicates that the impacts of these fires are not limited to terrestrial ecosystems and species. The recorded decrease in pH of Sabangau River water is likely to cause changes in fish behaviour and potentially survival (Thornton *et al.*, 2016). A decrease in water pH can disrupt the ion balance in fish by inhibiting active salt uptake, which can impact gill function and structure (Gonzalez *et al.*, 1998). Decreasing river pH is therefore likely to cause a decrease in local fish catches, as documented in our fish surveys, which in turn is expected to have negative implications for the income and livelihoods of local communities, given high levels of local fish consumption.

CONCLUSION

Our preliminary and non-exhaustive assessment highlights a number of negative impacts of the 2015 peat and forest fires on biodiversity in Kalimantan. This is due to forest loss, including reduced size of large forest patches and complete loss of some smaller forest patches, health impacts of prolonged haze inhalation, potentially compromised availability of and/or ability to find food by forest animals, plus increasing river acidity and reduced local fish catches. We suggest that these impacts affect a very large number of species, and are likely felt most strongly in species that are forest dependent, long-living, slow breeding, flying, sight dependent and/or that live in typically stagnant or slow-flowing waterways. Among the species that possess these characteristics are many that are already threatened, including flagship species such as the highly endangered Bornean orangutan and southern Bornean gibbon, for which the impacts of the 2015 fires raise particular conservation concern. While on-the-ground fire-fighting efforts will remain essential during dry periods to reduce fire spread and prevalence, and thus reduce forest loss and haze, in the long term the fire problem can only be effectively addressed by improved legislation, law enforcement, public awareness and ultimately peat management. Such developments must become a national and international priority if the devastating biodiversity (and human) impacts of the 2015 fire season are not to be repeated during the next strong El Niño event.

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