BIOLOGICAL EFFECTS OF SMOKE FROM DRY-SEASON FIRES IN NON-BURNT AREAS OF THE SABANGAU PEAT SWAMP FOREST, CENTRAL KALIMANTAN, INDONESIA

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SUMMARY

Owing to large-scale peat drainage, dry-season fires are now the most serious threat to tropical peat swamp forests (PSF). In 2006, an El Niño event led to particularly dry conditions and extensive peatland and forest fires in Kalimantan, Indonesia. In the Sabangau PSF, we observed differences in both litter-fall (much higher in 2006 – smoky – than in 2001 – largely smoke free) and gibbon singing behaviour (gibbons sang less during smoky periods in 2006), which were most probably caused by the thick smoke clouds enveloping the area from September-November 2006. This indicates that, even though most burning occurs in cleared areas, high smoke levels may be having serious effects on forest flora and fauna in unburned forested areas. Furthermore, it is likely that the effects of smoke on forest dynamics and wildlife are not limited to these two examples, and that the effects could be quite widespread and potentially even more serious for the forest as a whole. Despite their preliminary nature, these observations provide further evidence of the negative impacts of fire and smoke on the wild systems of Kalimantan and, as such, strengthen the argument for making available increased resources to prevent and fight these fires.

Keywords: Sabangau, smoke, litter-fall, gibbon, tropical peatland, haze

INTRODUCTION

The important role of Indonesian PSF as a carbon store and reservoir of floral and faunal diversity is now widely recognised. While tropical PSF fires are not new, recent human disturbances, including water table drainage, deforestation/changes in land use and changes in the El Niño Southern Oscillation weather system, as a result of global warming, have led to increased frequency, incidence and severity of burning (Siegert *et al.*, 2001). This increased burning has serious negative impacts on forest cover (Fuller *et al.*, 2004, Page *et al.*, 2002), tree mortality (Siegert *et al.*, 2001), peat structure/stability, CO_2 release (Page *et al.*, 2002), human health (Kunii *et al.*, 2002), economy (Varma, 2003) and wildlife conservation (Singleton *et al.*, 2004).

Two factors that, to date, have escaped attention are the possible effects of smoke in non-burnt areas on (1) forest dynamics, and (2) animal behaviour, and consequent repercussions on breeding success and population viability. There are numerous reasons why these factors may be expected to be important. Smoke blocks out light, increases CO_2 concentration in the atmosphere and causes decreased solar flux, and this may influence animal health and behaviour, and photosynthesis and transpiration. The 2006 El Niño event led to large-scale forest fires in Kalimantan, which shrouded the area in smoke from September-November 2006, enabling us to conduct preliminary investigations on the influence of smoke on both forest dynamics (litter-fall (LF) production) and animal behaviour (gibbon, *Hylobates albibarbis*, singing; see Cheyne, in press for full details).

MATERIALS AND METHODS

The Study Site

This study was conducted in mixed swamp forest (MSF) sub-type at the Natural Laboratory of Peat Swamp Forest (NLPSF), in the River Sabangau catchment, near Palangka Raya, Central Kalimantan. This is an area of ombrogenous deep peat, supporting dense PSF (Page *et al.,* 1999; Shepherd *et al.,* 1997)**.**

Litter-Fall

Tree litter was collected from November 2000-01, a non-smoky year (Sulistiyanto *et al.*, 2004) and from December 2005-06 (smoky year). Litter-fall (LF) was collected twice monthly and separated into component parts (leaves, reproductive parts, branches <5 cm diameter, bark and miscellaneous debris) following Proctor (1983). Branches >5 cm diameter were excluded. For the purpose of this study, analysis was restricted to total LF. In 2000-01, litter was oven dried at 70°C for 48 hours, and 3 x 0.38m^2 traps were used in each of 3 plots, following the “Fixed and Roving” sampling regime (Rieley *et al.*, 1969, Wilm, 1946). In 2005-06, litter was oven dried at 40°C for two weeks, and 16 x 1 m^2 fixed systematically-positioned traps were used.

Gibbon Singing

Data on gibbon singing were collected between June-November 2006, and so encompassed three smoke-free months (June-August) and three smoky months (September-November). Each morning (n=120d), for each gibbon group, observers recorded (1) whether the gibbons sang that day or not, and (2) the duration of singing.

RESULTS

Litter-Fall

Two interesting differences in LF between 2000-01 and 2005-06 were observed: total annual LF in 2005-06 was higher (10,197.7 ± 2,224.9 kg ha^{-1}) than in 2000-01 (8,410.7 ± 2,095.0 kg ha^{-1}), and there were differences in the timing and height of peaks in LF production throughout the two years. In 2000-01, there were two peaks: highest production was towards the end of the dry season (August-September - 1,124.3 kg ha^{-1} 4weeks^{-1}) and the middle of the wet season (February-March - 849 kg ha^{-1} 4weeks^{-1}), whereas, in 2005-06, although the wet season (January) peak was of similar height (908.0 kg ha^{-1} 4weeks^{-1}), the end of dry season peak (October), when smoke was highest, was much higher (2,106.3 kg ha^{-1} 4weeks^{-1}).

Gibbon Singing

Gibbons sang on significantly fewer days in the smoky season and singing bout length was also significantly shorter ($p<0.05$ in both cases, Cheyne, in press).

DISCUSSION

The results put forward in this paper provide a preliminary indication that smoke from PSF fires may be having more far-reaching effects on the forests and wildlife than has yet been recognised. The two examples chosen here – LF and gibbon singing – indicate that fires may be having hitherto unknown effects on both forest dynamics and animal behaviour.

It is interesting to note that over half (982 kg ha^{-1}) of the difference in total annual LF between 2000-01 and 2005-06 (1,787 kg ha^{-1}) can be explained by the increased height of the 2005-06 end of dry season peak. Owing to the strong 2006 El Niño, the dry season was longer than normal and it is possible that water stress during this extended dry period could explain the difference noted here. Interestingly, the August-September 2006 peak was only 700.7 kg ha^{-1} 4 weeks $^{-1}$, much lower than the August-September 2001 peak of 1,124.3 kg ha^{-1} 4 $weeks^{-1}$.

It is also possible that part of the difference in LF between the two years could be explained by the different methods used ("Fixed and Roving" sampling in 2000-01 vs. fixed sampling only in 2005-06). By using one fixed and two roving traps, the "Fixed and Roving" sampling regime enables researchers to reduce the variation caused by dissimilarities in vegetation sub-units and discontinuities in the tree canopy, reducing standard error to a level comparable to using many fixed-position traps (Wilm, 1946; Rieley *et al.*, 1969). We believe that this is unlikely to account entirely for the differences in our two data sets, as the differences observed are so large.

It is quite conceivable that high smoke levels could exacerbate the effects of drought, causing further increases in LF. There are four ways in which we see smoke could affect LF:

1. By blocking out sunlight/reducing solar flux, smoke could reduce photosynthesis rates, which, in tropical trees that evolved in conditions of continual, strong sunlight, could cause a decrease in the health of the trees, causing them to drop more leaves.
2. Higher atmospheric CO_2 concentrations in smoky areas could go some way towards counteracting this, as photosynthesis increases with increasing atmospheric CO_2 concentration, even when light is limiting (Körner, 2006).
3. Large amounts of particulate matter in smoke could block up stomata, disrupting gas exchange and reducing CO_2 uptake.
4. Although temperature was higher in the 2006 smoke season (29.8±1.3 C) than in the non-smoke season (28.2±1.1 C) ($p<0.001$), reduced intensity of the sun's rays during the smoke season could effect transpiration rates, having possible knock-on effects on photosynthesis and LF.

Clearly, the effects of decreased light and increased CO_2 concentrations on photosynthesis are impossible to quantify at present, as responses to either variable vary depending on the availability of the other (e.g., Körner, 2006) and neither were measured in this study. Similarly, the effects of particulate matter on gas exchange and reduced light intensity on transpiration remain unquantified and, at the present time, it is therefore impossible to rule out any of these factors as influencing LF.

The observation that gibbons sang less during the smoke season is striking, particularly as gibbons generally sing more when rainfall is reduced (see Cheyne, in press, and references therein). It is impossible to identify the cause of the reduced singing with certainty but, considering the negative impacts of smoke on human health (Kunii *et al.*, 2002), reduced health (especially of the respiratory system, which is obviously important in gibbon singing and which is particularly susceptible to smoke-related problems in humans) seems the most likely candidate. That gibbons sing less during smoky seasons is important, as singing plays a fundamental role in territorial defence, pair bonding and communication, and so reduced singing for prolonged periods could ultimately effect reproduction (Cheyne, in press).

CONCLUSION

In conclusion, it seems likely that increased smoke during fire seasons could be affecting both LF and gibbon singing in NLPSF. There are two important implications of these findings. Firstly, they indicate that the effects of smoke on the forest and its wildlife can be important even in unburnt areas (previously, discussion has been limited to only burnt areas), and secondly, it is likely that the effects of smoke on forest dynamics and wildlife are not limited to the two examples discussed here, and that their effects could therefore be widespread, and even more serious for the forest as a whole. Despite their preliminary nature, these observations provide further evidence of the negative impacts of fire and smoke on the wild systems of Kalimantan and, as such, strengthen the argument for making available increased resources to prevent and fight these fires.

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