

# The effects of forest fire on the nesting success of the Red-knobbed Hornbill *Aceros cassidix*

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## Summary

We assessed the impact of forest fire on the nesting success of the endemic Red-knobbed Hornbill *Aceros cassidix* in north Sulawesi, Indonesia. Pre- and post-fire breeding activity was monitored at 60 nest trees. Low rainfall and possible reductions in fruit abundance did not appear to have an effect on initial nest uptake or on subsequent chick production at non-burnt nests, which were comparable to previous years. However, there was an adverse effect on productivity at nests that directly experienced fire and the accompanying heat and smoke in the vicinity, resulting in a post-fire nest success (62%) that was significantly lower than in previous years (78.6–80%). Population recruitment dropped by an estimated 47% to 0.17 fledglings/breeding pair. Our data suggest that, given the reproductive profile of this species and the ability of fire to reinforce its own negative effects on forest habitats, Red-knobbed Hornbill populations may be vulnerable to the potential effects of repeated fires.

## Introduction

In 1997 exceptionally intense and widespread fires caused extensive damage to the tropical forests of Indonesia. Contrary to its better-known role in South America, the periodic climatic phenomenon of El Niño induced an unusually severe and extended dry season across the Indonesian archipelago. Early estimates indicated that up to five million hectares of land were burnt (Schweithelm 1998). The combination of drought conditions and detrimental land-use practices enables fires to spread through tropical forests previously believed to be fire-resistant (Ginsberg 1998). The few post-fire surveys undertaken in Indonesian tropical forest have shown that fire damage is positively correlated with the level of prior human disturbance (Schindele *et al.* 1989), and previous history of burning (Kinnaird and O'Brien 1998, Yeager 1997). Although the ecological effects of catastrophic fires are poorly understood, studies of bird and mammal populations have pointed to survival being primarily dependent on both a species's mobility and its ability to adapt to post-fire changes in the availability of food resources (Doi 1988, Kinnaird and O'Brien 1998, Mayer 1989, Wirawan 1985).

Hornbills are among the more highly mobile species of Indonesia's forests and may be capable of escaping the immediate threats of fire. However, their breeding habits (including a prolonged nesting period) and diet may combine to promote their vulnerability. All true hornbills are cavity nesters and females seal

themselves into the nest, often undergoing a simultaneous moult of their flight feathers (Kemp 1995), which leaves female birds defenceless against passing fires for a large portion of the year. In addition, Asian hornbills are generally highly frugivorous; a loss of fruit trees or changes in phenological patterns due to drought and heat stress may have adverse effects (M. Leighton 1983 unpublished report), especially during the breeding season when males cannot range so widely and provisioning demands are high.

An ongoing seven-year study into the ecology of the Red-knobbed Hornbill *Aceros cassidix* at the Tangkoko-Dua Saudara Nature Reserve, Sulawesi (hereinafter Tangkoko) provided us with the base-line ecological data needed to carry out a comparative study on the effects of fires on the Red-knobbed Hornbill during the 1997–1998 breeding season. Tangkoko is a 8,900 ha reserve bordered by ocean and agricultural lands which are subject to habitat modification, adding to the reserve's isolation from nearby forest blocks. Such isolation increases the vulnerability of animal populations in the face of catastrophic events such as forest fires (Soulé 1987). Fires entered Tangkoko in August 1997 from adjacent agricultural land and were extinguished by rains in October 1997. An estimated 55% of the forest area was damaged (R. Lee, 1998 *in litt.*).

The Red-knobbed Hornbill occurs at extremely high population densities at Tangkoko (average, 51 hornbills/km<sup>2</sup>) (Kinnaird *et al.* 1996) and nesting densities are as high as 10.4 pairs/km<sup>2</sup> (Kinnaird and O'Brien 1999). Several aspects of Red-knobbed Hornbill ecology and behaviour have already been investigated, including studies of breeding biology (Kinnaird and O'Brien 1993, Kinnaird and O'Brien 1999), feeding ecology (Suryadi *et al.* 1994), movement patterns (M. F. Kinnaird *et al.* 1996 unpublished report) and population abundance and distribution (M. F. Kinnaird *et al.* 1996).

In this paper, we examine the effects of forest fires on the breeding success of the Red-knobbed Hornbill. Specifically, we investigate the effects of smoke and fire at nest sites on Red-knobbed Hornbill and nest tree mortality. These data provide insight into the vulnerability of this species to large-scale forest fires and help predict the consequences of future fires on this insular population.

### Study area and methods

Data were collected in the Tangkoko Nature Reserve (1°34'N, 125°14'E), situated on the northern arm of Sulawesi. The reserve is of high conservation importance due to both the number of forest types it protects (lowland rainforest, submontane rainforest, elfin cloud-forest, beach-forest and casuarina forest) and high numbers of endemic species. Our study was conducted in a 5 km<sup>2</sup> research site on the northern slope of the Tangkoko volcano. The site includes primary forest, naturally disturbed forest and previously burnt forest (see Kinnaird and O'Brien 1995, for a more detailed description of the study area). The study area had previously experienced fire damage in 1992 with an estimated 129 ha (25.8%) being classified as severely damaged with both the substage and canopy affected. Annual rainfall for Tangkoko averages 1790 mm but rainfall for 1997 was 924 mm, with only 51 mm falling between June and October.

We began monitoring 60 previously used nest trees at the beginning of the Red-knobbed Hornbill breeding season in June 1997. A nest was classified as

Table 1. Summary of nest activity for burnt and non-burnt habitat

Status of nest trees	Pre-burn active nests	Post-burn	
		Active nests	Non-active nests
Burnt	23	11 (48%)	12 (52%)
Non-burnt	19	15 (78%)	4 (22%)
Total	42	26 (62%)	16 (38%)

active if we detected the following indicators: vocalizations from inside the nest; male observed delivering food to the nest; an intact nest seal or the distinctive sound of the nest being sealed by the female; fresh faecal material below the nest. Fires entered the reserve in August, after females had incarcerated themselves in their nests, and burnt for two months into October. We conducted a post-fire check of the nests in November to assess activity status and nest tree damage. During the post-fire assessment, breeding attempts were classified as unsuccessful if previously active nests were subsequently found empty. We also noted whether the nest tree and habitat within a circular plot of 15 m radiating from the base of the tree had been damaged by fire. Damage was characterized as canopy, subcanopy or substage.

We used data from Kinnaird and O'Brien (1993 and 1999) for comparisons of reproductive success and information on previous forest fires. Additional data, on occupancy and nest heights, were available for a subset of nests which we had surveyed in 1996 (A.J.C. pers. obs.).

## Results

Of 61 nest trees recorded in use in 1996, 11 fell between the 1996 and 1997 breeding seasons. This was probably due to a combination of stress from drought conditions and strong seasonal winds (pers. obs.). A further three trees were rendered unusable because of fire damage. This was a significantly higher proportion of available nest trees lost (23%) than the average of 2.2% (1.33/year) for previous years (1993–1996), ( $z$ -test:  $z = 11.93$ ,  $P < 0.001$ ).

All female hornbills had entered nests by 6 August 1997 ( $n = 42$ ). Although this was a year of severe drought, nest uptake (70.0%; 42/60) and nest density (8.4 pairs/km<sup>2</sup>) were comparable to previous years (1993–1996, 67.1–80.3% and 8.2–10.4 pairs/km<sup>2</sup>, respectively).

Hatching, fledging and overall nesting success were high and fairly constant between 1993 and 1995 (88.5–90.7%; 88.0–89.9%; and 78.6–80%, respectively); but the 1997 post-fire nest success was only 62% (26/42), a significantly lower proportion than in preceding years ( $z = 2.535$ ,  $P = 0.0112$ ). Two dead chicks, with underdeveloped feathers, and a charred female found outside three nest trees provided evidence of attempts to flee nests prematurely.

Of the 42 nests known to be active before the onset of fires, 23 (55%) were in burn areas. Comparison of burn and non-burn sites showed that nests not subjected to fire were significantly more likely to be successful than nests which experienced fire ( $z = 3.617$ ,  $P = 0.0003$ ; see Table 1). A comparison of the 1997 post-fire success rate for nests that did not experience fire, with hatchling success in previous years, showed no significant difference ( $z = 0.853$ ,  $P = 0.3937$ ).

Kinnaird and O'Brien (1999) estimated that in a normal year the Tangkoko Red-knobbed Hornbill population averaged a recruitment rate of 0.32 fledglings/female per year. In 1997, based on nesting densities of 9.0 females/km<sup>2</sup>, nesting success of 50% and a population density of 51 birds/km<sup>2</sup>, the population increased by only 0.17 fledglings/female. This amounts to a drop in population recruitment of 47%.

Contrary to expectations we found no evidence to suggest that nests situated in already degraded forest were more likely to burn than those in undisturbed habitats. Conversely, nests in undisturbed habitat ( $n = 11$ ) suffered significantly more fire damage than those in disturbed or previously burnt habitats ( $z = 2.9946$ ,  $P = 0.0027$ ).

## Discussion

Red-knobbed Hornbills experienced a marked decrease in nest success as an immediate result of the 1997 fires. A supposed reduction in food abundance, caused by low rainfall or a loss of fruit trees in the fire, had no apparent effect on chick production. The overriding factor contributing to the decrease in productivity was the presence of fire and associated heat and smoke at or close to the nest tree, presumably resulting in direct mortality of the female and chick or nest abandonment by the female.

M. Leighton (1983 unpublished report) attributed an absence of hornbills immediately after forest fires to the mortality of a large percentage of fruit trees, upon which they depended for food. Fruit is also the primary component of the Red-knobbed Hornbill diet, making up over 80% of food items delivered to the nest by the male (Kinnaird and O'Brien 1999). Although approximately 55% of the reserve was burnt, a comparison of nesting success between burn sites, non-burn sites and previous seasons indicated that only nests directly affected by the fire were subject to an increase in nest failure or abandonment. However, as Red-knobbed Hornbills are thought to time chick fledging with peaks in fruit abundance (Kinnaird and O'Brien 1999) any disruption to fruiting patterns may have longer-term consequences through effects on juvenile development and survival.

The increased fire damage suffered by nests in undisturbed forest over those in lightly disturbed or previously burnt forest could have resulted from differences in forest structure and fuel loads between these habitats. We noted that during the prolonged dry spell, drought stress caused many trees to drop their leaves resulting in a build-up of leaf litter especially in the high biomass, undisturbed forest. Increased solar radiation to the forest floor would have contributed to the drying out of the lower strata. We propose that in these conditions, the combination of abundant leaf litter and the better-formed subcanopy found in undisturbed forest may have carried the fire to hornbill nests more effectively.

Ultimately, the reduction in chick production for 1997 probably represents only a temporary fluctuation in the demography of this population. Perhaps of more significance is the loss of breeding females and further degradation of Red-knobbed Hornbill habitat through a loss of nest trees and possibly fruiting trees. It is very likely that severe forest fires will reoccur in Tangkoko at the next El Niño event. As fire is able positively to reinforce its own negative effects on

forest habitats (Ginsberg 1998), there is the potential in the future for a long-term adverse effect on population stability.

Fire is an increasing threat to the biodiversity of Indonesia's flora and fauna; although it has always played a part in the disturbance of Indonesia's forests, the scale and intensity has increased in the past three decades due to human actions. These findings highlight the problematic nature of attempting to conserve species in a small isolated reserve and the need for reliable, long-term ecological data if we are to learn what impacts such catastrophic events have on the ecology and future conservation of the region's wildlife.

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