Animal Conservation (2005) **8**, 27–31 © 2005 The Zoological Society of London. Printed in the United Kingdom DOI:10.1017/S1367943004001787

Effects of ENSO-induced forest fires and habitat disturbance on the abundance and spatial distribution of an endangered riverine bird in Borneo

Resit Sözer and Vincent Nijman[†]

Institute for Biodiversity and Ecosystem Dynamics/Zoological Museum, University of Amsterdam, P.O. Box 94766, 1090 GT Amsterdam, The Netherlands

(Received 15 March 2004; accepeted 2 June 2004)

Abstract

Droughts induced by the 1997–1998 El Niño Southern Oscillation (ENSO) event sparked large-scale forest fires affecting millions of hectares on Borneo. We studied the effects of ENSO-induced disturbances on a riverine bird, the critically endangered white-shouldered ibis, *Pseudibis davisoni*, along the Mahakam River in East Kalimantan, Indonesian Borneo. Island-wide fire hotspots were more likely to occur near rivers and part of our study area was indeed affected by fire. Based on 25 boat surveys (2590 km) that yielded 91 records, we recorded significant changes in abundance and spatial distribution of this bird in our study area. Encounter rates were higher during the pre-ENSO (1992–1996) periods than the post-ENSO (1997–2000) ones and differed between seasons. No ibises were seen post-ENSO along river sections that were affected by the fires, whereas pre-ENSO encounter rates were 2.4 birds/10^2 km. Encounter rates along those sections that were not affected by the forest fires more than doubled from 2.0 birds/10^2 km pre-ENSO to 5.6 birds/10^2 km post-ENSO. This was most probably due to enhancement of displaced birds. In view of the permanent character of the change in spatial distribution, active protection of the remaining stretches of riverine forest is of the utmost importance for the survival of white-shouldered ibis.

INTRODUCTION

The 1997–1998 El Niño Southern Oscillation (ENSO) event was the most severe and widespread in recorded history (Guilderson & Schrag, 1998; Timmermann *et al*., 1999). In Southeast Asia and, in particular, in Sumatra and Borneo, ENSO-induced droughts sparked large-scale fires affecting millions of hectares of rainforest. In Borneo, this resulted in large-scale habitat inversions, where intact forest with patches of secondary forest became a matrix dominated by burned forest surrounding remnant unburned patches (Siegert *et al*., 2001). On a small scale, within this matrix, unburned patches remain mostly near small streams and in permanently inundated areas (Slik & Eichhorn, 2003; Fredriksson & Nijman, 2004), but on a larger scale, fire hotspots were more likely to occur near rivers (Fuller & Fulk, 1998). This, in all likelihood, results from the fact that on Borneo human population density is higher along rivers and many of the 1997–1998 forest fires were human-induced (Rijksen & Meijaard, 1999). Undisturbed tropical rainforest is normally highly resistant to fire because of low loads of available fuel, low fuel-energy content and high humidity even during drought. Fire became a significant threat to the rainforest in Borneo only recently because of a positive feedback between logging and fire occurrence (Siegert *et al*., 2001). Hence it is expected that few, if any, rainforest species are adapted to recurrent fires.

A number of studies have focused on the impact of ENSO-induced disturbances on rainforest communities (Kinnaird & O'Brien, 1998; Harrison, 2000) and individual species or species groups (Suzuki, 1992; Lindsey *et al*., 1997; Anggraini, Kinnaird & O'Brien, 2000; O'Brien *et al*., 2003). No studies have been conducted on the effects of the ENSO-induced disturbances on riverine forest-dependent species; yet, on the basis of the distribution of fire the impact may be significant in riverine forest. For example, Yeager & Fredriksson (1998) state that the endangered proboscis monkey, *Nasalis larvatus*, a species tightly dependent on low-lying riverine forest (Meijaard & Nijman, 2000), had probably the greatest part of its remaining habitat destroyed by fire in comparison to any other primate in Borneo; yet quantitative studies on any riverine species are lacking.

A critically endangered bird that may have been greatly affected by the loss of riverine forest is the white-shouldered ibis, *Pseudibis davisoni*. Formerly occurring throughout Southeast Asia, this species has declined precipitously during the course of the twentieth century and it is now confined to a few sites in Indochina and Indonesian Borneo (Collar *et al*., 2001). In Borneo, this

[†]All correspondence to: V. Nijman. Tel: 31-20-525 7181; E-mail: nijman@science.uva.nl

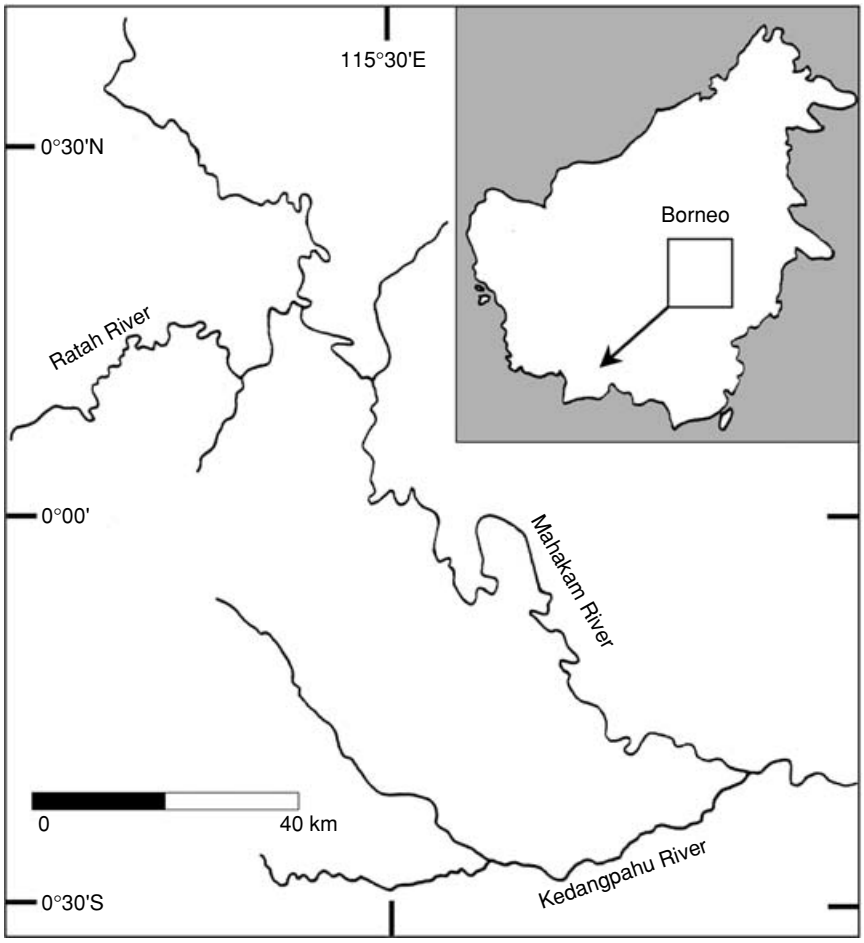

Fig. 1. The study area along the Upper Mahakam River and its tributaries. The inset shows the island of Borneo with the location of the study area indicated.

species is mostly, if not exclusively, linked to medium to large rivers, with the largest population remaining along the Mahakam River, East Kalimantan (Sözer & van der Heijden, 1997; Collar *et al*., 2001). The 1997–1998 forest fires were particularly severe and widespread in East Kalimantan, with 5.2 million ha of forested land affected (Siegert *et al*., 2001; Fuller, Jessup & Salim, 2004), including parts of the distribution range of the white-shouldered ibis.

The aim of this study was to assess the impact of ENSO-induced disturbances on the abundance and spatial distribution of the white-shouldered ibis in Borneo's Mahakam area, by comparing areas that were surveyed prior to, as well as after, the 1997–1998 ENSO event.

MATERIAL AND METHODS

Data acquisition

In 1992, 1995, 1996, 1997, 1999 and 2000, systematic surveys of white-shouldered ibis were conducted along the Mahakam and its tributaries (Fig. 1). The study area was demarcated such that white-shouldered ibis had been recorded in all parts (Holmes, 1991); in addition, we conducted qualitative surveys in large parts of the Mahakam River basin and found the species to be confined to the study area. Counts were made from boats on the Mahakam River and from small, motorised canoes on the smaller tributaries and upstream parts of the Mahakam River. A typical survey covered between 80–150 km of river and lasted between 2–4 days, with a total survey effort of 69 days. Twenty-three surveys were conducted with a total survey-effort of 2590 km, i.e. 1540 km pre-ENSO and 1050 km post-ENSO. The median annual survey-effort was 370 km (range 350–960 km). R. S. was present on all surveys with at least one other observer always being present, including V. N. on some occasions. For each encounter we noted the number of birds and the habitat on the surrounding riverbanks.

Analyses

Each survey provided an encounter rate that forms the basis for our analysis. Surveys were conducted at all months of the year. Within-year surveys were conducted at, at least, 1–2 week intervals. Hence, we consider surveys to be independent from each other. Encounter rates are expressed as number of birds/10^2 km, but tests are based on the original data scaled down to the smallest survey effort (ranging between 50–1050 km).

For analysis, the Mahakam River was divided into five sections (I–V) plus one section on the Ratah River (VI), a tributary of the Mahakam River (Fig. 1). Sections were between 20–50 km in length. The downstream parts of the distribution range of the white-shouldered ibis (Sections I and II) were severely affected by the 1997–1998 forest fires with virtually all forest burned, whereas the other parts were not or less notably affected (but see discussion, below, for secondary effects). The 1997-surveys were conducted in August–September, during a period of prolonged drought and roughly at the onset of large fires; it is included in the analysis as post-ENSO. Note that although in 1991–1992 there was a minor ENSO event, this did not lead to large-scale forest fires on Borneo and did not (noticeably) affect our study area or its wide surroundings. Hence since we are focusing on the effects of the 1997–1998 ENSO event, the 1992-surveys were included as pre-ENSO.

The Mahakam River is situated near the equator, crossing it north of Long Iram, and experiences a fairly constant climate. Two monsoons, a south-east or 'dry' monsoon from roughly May to October and a north-west or 'wet' monsoon from roughly November to April determine the pattern of rainfall. Although there are no true seasons, for testing whether there were 'seasonal' differences in encounter rates the year was divided into a dry (May–October) and a wet (November–April) season. These periods coincide roughly with low and high water levels in the Middle Mahakam Wetlands (Gönner, 2000). Although sightings of juvenile white-shouldered ibis do not seem to be confined to a particular time of the year (Sözer & van der Heijden, 1997), for those waterbirds in the region for which data are available, breeding is concentrated in the dry season, as defined above (Gönner, 2000; our unpublished results).

Since most data collected were not normally distributed, non-parametric tests were used (Siegel & Castellan, 1988). For testing whether the observed frequencies of occurrence were homogeneously distributed over all classes and whether significant differences existed between the different classes, a log-likelihood analysis (G-test of goodness-of-fit) was used. To obtain a better approximation to χ^2, William's correction to the G statistic was applied ($G_{adj.}$: Sokal & Rohlf, 1995). Significance was assumed when $P < 0.05$ in a two-tailed test.

RESULTS

During the surveys, 91 white-shouldered ibis were recorded (65 birds pre-ENSO and 26 post-ENSO), with an average encounter rate of 3.5 birds/10^2 km, i.e. 4.2 birds/10^2 km pre-ENSO and 2.4 birds/10^2 km post-ENSO. For none of the sections did the encounter rate differ significantly between survey-direction, i.e. upstream or downstream (1992–1995: binomial test all $P > 0.5$; 1997–2000: binomial test all $P > 0.6$). Subsequently data from both directions were pooled.

There is no annual difference in encounter rates between each of the sections during the pre-ENSO period (Kruskal–Wallis one-way ANOVA, $H = 0.9$, d.f. $= 2$, $P > 0.5$) or the post-ENSO period (Kruskal–Wallis one-way ANOVA, $H = 0.7$, d.f. $= 2$, $P > 0.5$: Table 1). For all sections combined, encounter rates differed slightly between seasons, with pre-ENSO encounter rates of 1.1 birds/10^2 km in the dry season versus 2.1 birds/10^2 km in the wet season ($G_{adj.} = 2.8$, $P < 0.10$) and post-ENSO encounter rates of 0.9 birds/10^2 km in the dry season versus 3.9 birds/10^2 km in the wet season ($G_{adj.} = 7.0$, $P < 0.01$).

Comparing sections that were surveyed before and after the ENSO-induced disturbances, it was clear that there was a large difference in encounter rates (Table 2). Prior to 1997, sections I and II had an encounter rate of 1.2 birds/10^2 km for both seasons combined (based on 1400 km of survey-effort), whereas from 1997–2000 not a single bird was observed during some 600 km of survey-effort. In sections III and VI, however, the encounter rate changed from 2.0 birds/10^2 km (750 km survey-effort) to 5.6 birds/10^2 km (450 km survey-effort): this difference was significant ($G_{adj.} = 15.8$, d.f. $= 1$, $P < 0.01$). The change in encounter rates in the burned section was observed in both seasons, but the decline was significant for the wet season only ($G_{adj.} = 10.4$, d.f. $= 1$, $P < 0.01$). Although data presented in Table 2 suggested that the decrease in encounter rate in the burned sections were accompanied by an increase in the encounter rate in unburned sections, only for section VI during the wet

Table 1. Encounter rates of white-shouldered ibis *Pseudibis davisoni* (birds/10^2 km) along sections of the Mahakam River and the Ratah River, East Kalimantan, prior to and following the1997–1998 El Niño Southern Oscillation (ENSO) event

Section	I*	II	III	IV	V	VI
Pre-ENSO (1992–1996)	Unburned					
Dry season	0	1.2	0	0	0	4.0
Wet season	0	3.1	0.4	16.1	2.7	3.0
Post-ENSO (1997–2000)	Burned		Unburned			
Dry season	0	0	0	–	–	3.0
Wet season	0	0	8	–	–	9.5

*White-shouldered ibis has been observed in this section pre-ENSO outside our study period.

Table 2. Encounter rates of white-shouldered ibis *Pseudibis davisoni* (birds/10^2 km) for burned and unburned sections, prior to and following the 1997–1998 El Niño Southern Oscillation (ENSO) event

Section Period	I and II (burned in 1997) (dry season–wet season)	III and VI (unburned) (dry season–wet season)
Pre-ENSO (1992–1996)	1.2 (0.6–1.6)	2.0 (2.5–1.6)
Post-ENSO (1997–2000)	0 (0–0)	5.6 (1.5–8.8)

season did encounter rates increase significantly (binomial test, $n = 24$, $x = 6$, $P < 0.03$).

DISCUSSION

A number of studies have demonstrated significant ENSO-induced changes in densities and composition of rain forest communities or individual species (Suzuki, 1992; Lindsey *et al*., 1997; Anggraini *et al*., 2000; Cleary, 2003). Almost invariably, many of the forest-dependent species become less abundant or even locally extinct and other, less forest-dependent species invade the area or increase in abundance. Individuals of long-lived species, such as some species of primate or hornbill persist, reluctant or unable to relocate themselves (Suzuki, 1992; Anggraini *et al*., 2000).

Much of the decline of the white-shouldered ibis can be attributed to land-use changes in Southeast Asia, with many wetlands being converted into agricultural lands. The white-shouldered ibis makes regular use of large trees on river banks for roosting and for breeding it is most probably dependent on relatively undisturbed stretches of forest (Sözer & van der Heijden, 1997; Collar *et al*., 2001). Prior to the forest fires, the Mahakam River population has been estimated at some 100 individuals (Sözer & van der Heijden, 1997) and, as such, this population was seen as one of the species' strongholds (Collar *et al*., 2001).

In the present study, we documented significant changes in the abundance and spatial distribution of white-shouldered ibis in different parts of the Mahakam River and we demonstrated a correlation with ENSO-induced disturbances. The most obvious and easily identifiable disturbance is the loss of forest due to fire (exacerbated by salvage felling: van Nieuwstadt, Shiel & Kartawinata, 2001). Secondary effects such as a change in the depositional character of river habitats (with finer substrates and more eroded banks: Iwata, Nakano & Inoue, 2003), a decrease in water clarity (as result of an increase in erosion) and an increase in temperature regime (as a result of loss of over-hanging trees) may also play a role in the observed changes, since these may interfere with the birds' ability to find food on the riverbanks and gravel beds. In those parts where the riverine forest was largely burned following the ENSO-induced droughts, the species was no longer present, whereas encounter rates more than doubled in those parts where the riverine forest remained. This may suggest a significant displacement of white-shouldered ibis from downstream burned areas to upstream unburned areas, but also demonstrates a significant loss of habitat. The fact that in the burned sections during the 2000 wet season surveys, almost 3 years after the forest fires had ceased, not a single white-shouldered ibis was observed indicates that these changes in spatial distribution are long-term. We fear that the increase in density of white-shouldered ibis along some stretches may be temporary, since unburned stretches may suffer from over-crowding.

None of the riverine forest included in our study is included in the protected area network (although some proposals have been put forward: Momberg, Jepson & van Noord, 1998) and most larger stretches have been handed out as logging concessions. Even though forestry regulations do not allow riverine forest to be logged, law enforcement is lacking and trees along rivers may in fact be the first to be felled (if not by concessionaires, then by illegal loggers). As demonstrated in our study, in parts of its former stronghold the white-shouldered ibis is no longer present. Therefore, protection of the remaining stretches of its forest habitat along the Mahakam River becomes all the more important, not just for the ibises but also for other (endangered) river-dependent wildlife. Since even the best-preserved riverine forest along the Mahakam is surrounded by a matrix of (selectively) logged and burned regenerating forest and deforested land, it is prone to forest fire. Active protection of these forests during the dry season by e.g. maintaining fire breaks and permanent fire patrols is recommended even though we are fully aware that this is unlikely to be achieved in the Mahakam area in the foreseeable future. Nevertheless, protection of the remaining riverine habitat is a top-priority and we feel that this is best achieved by a pragmatic approach involving concessionaires, local authorities (including those from nearby villages) and local non-governmenal organisations (NGOs), with institutional and financial support from international donors.

Acknowledgements

We would like to thank the Indonesian Institute of Sciences (LIPI) and the Directorate General for Forest Conservation and Nature Protection (PHKA) and especially A. Rachmat (SBKSDA, Samarinda) and Dr D. M. Prawiradilaga (LIPI, Bogor), for allowing us to conduct our studies. M. Lammertink and two reviewers made constructive comments on the manuscript.

REFERENCES

Anggraini, K., Kinnaird, M. & O'Brien, T. (2000). The effects of fruit availability and habitat disturbance on an assemblage of Sumatran hornbills. *Bird Conserv. Intern*. **10**: 189–202.

Cleary, D. F. R. (2003). An examination of scale of assessment, logging and ENSO-induced fires on butterfly diversity in Borneo. *Oecologia* **135**: 313–321.

Collar, N. J., Andreev, J. V., Chan, S., Crosby, M. J., Subramanya, S. & Tobias, J. A. (Eds) (2001). *Threatened birds of Asia: the BirdLife International red data book*. Cambridge: BirdLife International.

Fredriksson, G. M. & Nijman, V. (2004). Habitat use and conservation status of two elusive ground birds (*Carpococcyx radiatus* and *Polyplectron schleiermacheri*) in the Sungai Wain Protection Forest, East Kalimantan, Indonesian Borneo. *Oryx* **38**: 297–303.

Fuller, D. O. & Fulk, M. (1998). *Satellite remote sensing of the 1997–1998 fires in Indonesia: data, methods and future perspectives*. Jakarta: WWF-Indonesia.

Fuller, D. O., Jessup, T. C. & Salim, A. (2004). Loss of forest cover in Kalimantan, Indonesia, since the 1997–1998 El Niño. *Conserv. Biol*. **18**: 249–254.

Gönner, C. (2000). Birds of Lake Jempang and the Middle Mahakam Wetlands, East Kalimantan. *Kukila* **11**: 13–36.

Guilderson, T. P. & Schrag, D. P. (1998). Abrupt shift in subsurface temperatures in the tropical Pacific associated with changes in El Niño. *Science* **281**: 240–243.

Harrison, R. D. (2000). Repercussions of El Niño: drought causes extinction and the breakdown of mutualism in Borneo. *Proc. R. Soc. Lond., ser. B* **267**: 911–915.

Holmes, D. A. (1991). Note on the status of white-shouldered ibis in Kalimantan. *Kukila* **5**: 145–148.

Iwata, T., Nakano, S. & Inoue, M. (2003). Impacts of riparian deforestation on stream communities in a tropical rain forest in Borneo. *Ecol. Applic*. **13**: 461–473.

Kinnaird, M. F. & O'Brien, T. G. (1998). Ecological effects of wildfire on lowland rainforest in Sumatra. *Conserv. Biol*. **12**: 954–956.

Lindsey, G. D., Pratt, T. K., Reynolds, M. H. & Jacobi, J. D. (1997). Response of six species of Hawaiian forest birds to a 1991–1992 El Niño drought. *Wilson Bull*. **109**: 339–343.

Meijaard, E. & Nijman, V. (2000). Distribution and conservation of the proboscis monkey (*Nasalis larvatus*) in Kalimantan, Indonesia. *Biol. Conserv*. **92**: 15–24.

Momberg, F., Jepson, P. & van Noord, H. (1998). *Kalimantan biodiversity assessment*. WWF Indonesia Technical Memorandum No. 4. Jakarta: WWF-Indonesia.

O'Brien, T. G., Kinnaird, M. F., Nurcahyo, A., Prasetyaningrum, M. & Iqbal, M. (2003). Fire, demography and the persistence of siamang (*Symphalangus syndactylus*: Hylobatidae) in a Sumatran rainforest. *Anim. Conserv*. **6**: 115–121.

Rijksen, H. D. & Meijaard, E. (1999). *Our vanishing relative. The status of wild orang-utans at the close of the twentieth century*. Dordecht: Kluwer.

Siegel, S. & Castellan, N. J. Jr. (1988). *Nonparametric statistics for the behavioral sciences*. New York: McGraw-Hill Book Company.

Siegert, F., Ruecker, G., Henrichs, A. & Hofmann, A. A. (2001). Increased damage from fires in logged forest during droughts caused by El Niño. *Nature* **414**: 437–440.

Slik, J. W. F. & Eichhorn, K. A. O. (2003). Fire survival of lowland tropical rain forest trees in relation to stem diameter and topographic position. *Oecologia* **137**: 446–455.

Sokal, R. R. & Rohlf, F. J. (1995). *Biometry. The principles and practice of statistics in biological research. 3rd ed*. New York: W. H. Freeman.

Sözer, R. & van der Heijden, A. J. W. J. (1997). An overview of the distribution, status, and behavioural ecology of the white-shouldered ibis in East Kalimantan. *Kukila* **9**: 126–140.

Suzuki, A. (1992). The population of orangutans and other non-human primates and the forest conditions after the 1982–83's fires and droughts in Kutai National Park, East Kalimantan, Indonesia. In *Forest biology and conservation in Borneo*: 190–205. Ismail, G., Mohamed, M. & Omar, S. (Eds). Kota Kinabalu: Yayasan Sabah.

Timmermann, A., Obernuber, J., Bacher, A., Esch, M., Latif, M. & Roeckner, E. (1999). Increased El Niño frequency in a climate model forced by future greenhouse warming. *Nature* **398**: 694–697.

Van Nieuwstadt, M. G. L., Sheil, D. & Kartawinata, K. (2001). The ecological consequences of logging in the burned forests of East Kalimantan, Indonesia. *Conserv. Biol*. **15**: 1183–1186.

Yeager, C. P. & Fredriksson, G. M. (1998). *Fire impacts on primates and other wildlife in Kalimantan, Indonesia during 1997/1998*. Jakarta: WWF-Indonesia.