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ORIGINAL PAPER

Collateral damage: impacts of ethno-civil strife on biodiversity and natural resource use near Indian nature reserves

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Abstract Civil conflicts often affect the control of natural resources, altering their access and use. Using a combination of questionnaires, remote sensing, and a review of articles in the popular print media, we investigated the impact of a protracted armed conflict on forest loss, livelihoods, and forest use near two globally important tiger reserves in northeastern India. Over a 23 year period, we found evidence of large-scale forest loss in the vicinity of Nameri and Pakke Tiger Reserves. Nearly all (99 %) interviewees opined that the ethno-civil strife was to blame for declining forest cover. Most interviewees identified 1990 as the year of onset of strife-mediated deforestation. This is partially supported by a review of print-media articles that reported conflict, violence, displacement, and the onset of large-scale migration in the previous year. According to respondents, ethno-civil strife has radically altered access to, and use of forests, by resident communities (causing economic hardship, increased costs, and reduced availability of essential timber products), and has also accelerated forest loss and increased poaching. We conclude that forests and wildlife

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in these protected areas are at immediate risk from ethno-civil strife. Urgent interventions are needed to reduce the environmental and societal impacts of civil strife in this biologically crucial region of India.

Keywords Forest cover · India · Insurgency · Logging · Militancy · Park management

Introduction

India is a megadiverse country that includes parts of four global biodiversity hotspots (Mittermeier 2000). However, only a fifth of India's original forest cover remains today (Laurance 2007), much of which has been fragmented or degraded. These forests and their wildlife face various recurring threats (Datta et al. 2008; Puyravaud et al. 2010) including new roads, development projects, logging, hunting (Velho et al. 2012), and ethno-civil strife (Kushwaha and Hazarika 2004).

The control of natural resources during periods of civil unrest has been important in the conduct and trajectory of civil conflicts globally (e.g. Richards 2001; Le Billon 2002). This often has direct repercussions for biodiversity conservation (McNeely 2007). In parts of South America and Africa, for instance, violent conflict has led to increased forest loss and wildlife poaching (Dávalos 2001; Laurance 2004, 2013). Other effects of civil strife include large-scale human displacement, which can have cascading impacts on poaching and deforestation (McNeely 2003). Nonetheless, biodiversity might actually benefit from civil strife through the creation of refugia in conflict zones, reduced poaching through disarmament, and by focusing state resolve on conservation (McNeely 2007). On balance, however, contemporary civil strife is largely detrimental to wildlife and natural habitats given the scale, intensity, and lethal technologies often employed in such conflicts (Dudley et al. 2002).

Large parts of India currently have insurgent movements. Armed communists are estimated to be active in 160 of India's 604 administrative districts, and they control one-fifth of India's forests (Vidal-Hall 2006). The northeast Indian states, including Assam and Arunachal Pradesh, where this study is based, have an especially long history of insurgency and ethno-civil strife (Nag 2000).

We assessed potential links between ethno-civil strife and forest loss over a two-decade period in areas adjoining two internationally important tiger reserves in northeastern India. Areas around both, Nameri Tiger Reserve in Assam and Pakke Tiger Reserve in Arunachal Pradesh, have experienced sporadic guerrilla warfare and ethno-civil strife (South Asia Terrorism Portal 2013). The time-frame we investigated dates to before the current ethno-civil strife commenced in the 1990s, to the present. We evaluated the sociological effects of the conflict on people living near these protected areas as well as challenges they have created for biodiversity conservation.

Methods

Study area

Pakke Tiger Reserve (26°54′–27°16′N; 92°36′–93°09′E) is 862 km^2 in area and is situated in western Arunachal Pradesh. Nameri Tiger Reserve (26°51′–27°02′N, 92°38′–92°59′E) is

344 km^2 in area and lies in Assam immediately to the south of Pakke (Fig. 1). Nameri is fringed by several legally designated Reserve Forests, including Balipara (64 km^2), Chariduar (100 km^2), and Nauduar (80 km^2), whereas Pakke is bordered by the Papum (1,064 km^2) and Doimara (245 km^2) Reserve Forests.

The major ethnic groups that reside in the study area are the Assamese, Mishing, Nyishi, Adivasi, Nepali, and Bodo. The Bodo are an ethno-linguistic community recognized as a plains tribe by the Indian Constitution (Banerjee and Roy 2010). The Bodo were the earliest settlers in the plains of Assam, and initially practised shifting cultivation, later moving to settled wet-rice cultivation. Movements for political autonomy for the Bodo people began in colonial India under British Rule, and gained force in the 1980s. In response, the government of Assam constituted the Bodoland Autonomous Council in 1993, and then the Bodoland Territorial Council in 2003, providing administrative autonomy to the Bodo community (Banerjee and Roy 2010).

Although militant outfits in other parts of Assam, such as the Bodo Liberation Tigers, have disarmed and become part of the democratic process as recently as 2003, armed resistance towards the Indian government continues, mainly spearheaded by a faction of the National Democratic Front of Bodoland (NDFB). Notwithstanding a ceasefire agreement with the Indian government in 2005, the NDFB has continued with armed struggle. Sporadic violence targeting military and paramilitary personnel and civilians has occurred in the area to the south of Nameri and Pakke Tiger Reserves, and is the area on which this study focuses.

Remote sensing-based deforestation analysis

We assessed forest cover in the study region in 1989, 2002, and 2012. The 1989 data show forest cover before the movement of the Bodo people into the study region in the 1990s, and the latter images reveal subsequent forest loss. Apart from quantifying actual forest loss in terms of area, we also calculated annual deforestation rates between 1989–2002 and 2002–2012 using the formula $[\{(C2/C1)^{1/(t2\ -\ t1)}\} - 1]$ (FAO 1995), where $C1$ and $C2$ represent forest cover at time $t1$ and $t2$ respectively.

We used landsat images for winter months from 1989, 2002, and 2012 (combining two images in a mosaic for 1989) to obtain complete coverage of the study area and to correct for cloud cover. The images were radiometrically normalized using iMAD (Canty and Nielsen 2008), and classified using supervised classification. The same training areas obtained from high-resolution imagery available from Google Earth (for the years 2003 and 2012) were used for all images. The classification was validated using ground control points collected in 2012 and high-resolution imagery from Google Earth (accuracy = 93.02 %).

We explored potential factors determining the conversion of forested pixels to non-forest over the course of our study. Because forest loss can be affected by various factors, we constructed a candidate model set with 14 models that were combinations of the following variables (Table 1): legal status of the pixel (categorical variable: tiger reserve, protected buffer, or neither), linear distance to the nearest non-forest pixel, mean slope, forest-patch area, forest-patch edge-to-area ratio, distance to the nearest market, and distance to nearest major road. The candidate model set was generated by first building a global (most complex) model, and then eliminating a single variable in turn to create simpler models (Table 1). However, because distance to market was correlated with slope (Pearson's $R = 0.61$; $p < 0.01$) and distance to road was correlated with legal status (Pearson's $R = 0.40$; $p < 0.01$), we did not include models in which both variables of a correlated pair were simultaneously present (Table 1).

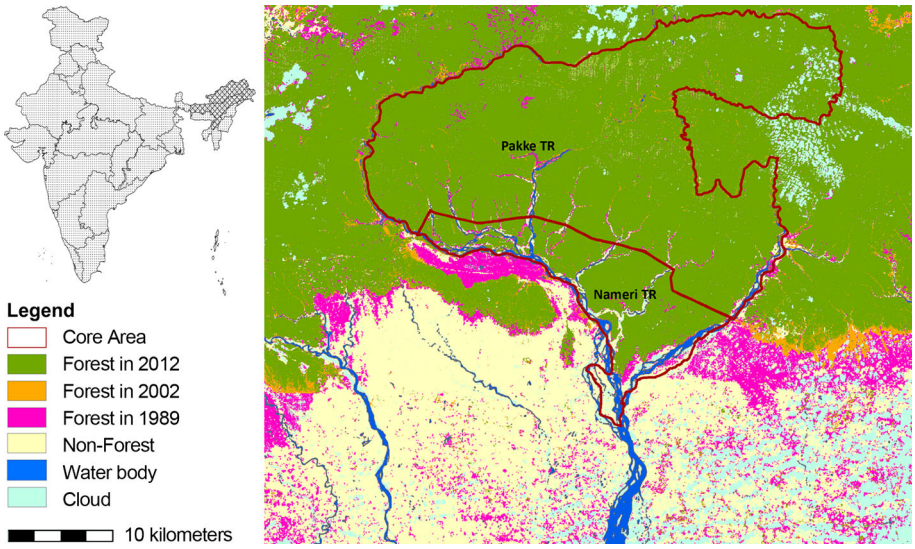

Fig. 1 Map of the study area showing the Pakke and Nameri Tiger Reserves in the Indian states of Arunachal Pradesh and Assam respectively (hatched areas in the outline map of India to the left). We assume that over the course of our study period, non-forest was not restored to forest. Therefore, green areas that depict forest in 2012 would also have been forest in 1989 and 2002, and orange areas that depict forest in 2002 were also forested in 1989

Although temperature and precipitation are classically included in these kinds of analyses, we excluded these variables from the a priori candidate model set because (a) at the 0.05 α level, both these variables were significantly correlated with slope ($r_{\text{temp}} = -0.63$ and $r_{\text{rainfall}} = -0.24$), which we retained, and (b) because we expect that conversion of forest to non-forest in this landscape is not driven by these abiotic variables, but by variables such as protection status of the forest-patch area.

For a finer-scale analysis on the change in forest cover near the two protected areas, we used ten 1 km buffers located along the southern edge of Nameri and Pakke Tiger Reserve. Areas obstructed by cloud cover in 1989 (6.62 % of the study area) were excluded. Spatial autocorrelation was avoided by running models on a randomly selected sample of pixels, and models were compared based on the Akaike Information Criterion (AIC) model-selection framework (Burnham and Anderson 2002). The AIC trades model fit against model complexity, and attempts to identify the "best simplest model" from a candidate set of competing models. In a set of models, the "best" model will typically have the lowest AIC value.

Quantifying socio-economic and wildlife effects

We conducted interviews of local residents from January to November 2012 using a questionnaire that contained a combination of semi-structured and open-ended questions (Appendix 1). The lead author and trained assistants resident in and around the local villages conducted interviews in Hindi and Assamese, two widely spoken languages in the area. Given the sensitive nature of this assignment we first assessed if the interviewee was comfortable with our writing or recording information during the interview; if not, then data were logged into data books immediately after each interview. During the interview, if the interviewee was reluctant to disclose information, we rescheduled the meeting, omitted

that question, or ended the interview, depending on their degree of reluctance. We were able to obtain 100 interviews with people living alongside Pakke and Nameri Tiger Reserves. We collected information on status of forest cover, potential change in forest cover, perceived reasons and timings of these changes, resulting implications in terms of forest access, and perceived solutions. Our study highlights the perceptions of villagers who were willing to discuss these sensitive issues, but possibly not of the population as a whole. We also conducted interviews with 20 members of the Arunachal Pradesh Forest Department (from 14 anti-poaching camps along Pakke–Nameri border) to assess their perceptions of the effects of ethno-civil conflict on park protection and wildlife conservation.

Review of popular-media articles

To partially validate the results of our questionnaire-based surveys, we compared the responses from our interviews with newspaper articles reporting ethno-civil strife-related news during our study period. We used the search engine LexisNexis Academic with the source type as newspapers (from 1 January 1980 to 31 December 2007) and "Bodo" as a key word with a filter to include location of articles from India. We used data on articles until the end of 2007 to avoid potential biases in retrieving articles, because complete archiving for some dailies on LexisNexis began only after this year.

Results

Decline in forest cover

The three Reserve Forests adjoining Nameri have now almost entirely disappeared, and forest loss from Assam appears to be spilling over to neighboring Arunachal Pradesh state (Fig. 1). Since 1989, about 118 km^2 of forests have been lost from a 10 km radius along the southern edge of the two tiger reserves. Forest loss continues to this day (Figs. 1, 2a), and it appears to have moved closer to the edges of Nameri and Pakke Tiger Reserves (Fig. 2b).

An analysis of the larger region, of which our study area is a part (Kushwaha and Hazarika 2004), shows a reduction of 446 km^2 in forest cover from 1989 to 2012, with 227.5 km^2 of forest loss between 2002 and 2012 (with 208.65 km^2 lost from 1989 to 2002). Annual deforestation rates were 0.43 % between 1989 and 2002, and 0.64 % between 2002 and 2012. Reported forest losses may be underestimates because 430 km^2 was excluded from analyses in southern areas of the study region due to cloud cover.

Using AIC-based model selection, the best-performing model (Table 1) included (a) distance to closest non-forest area, (b) distance to nearest market, (c) protection status of forest and (d) forest-patch area. All variables had a significant impact on forest loss (Table 2; $p < 0.01$ in all cases), with the probability of deforestation decreasing with distance from markets, distance from a non-forest, forest-patch area, and with legal protection as a tiger reserve. However, we note that in other models from our candidate model set, slope, and distance to road also had significant negative influences on the probability of deforestation.

Table 1 Candidate model set used to investigate the potential drivers of forest loss

Sl. no.	Model formulation	R^2	AIC	Δ AIC
1	~dist + dist market + forest-patch area + status	0.35	688,159.5	0
2	~dist market + forest-patch area + status	0.35	707,426.6	19,267.1
3	~dist + dist market + status	0.32	780,325.2	92,165.7
4	~dist + dist market + forest-patch area + dist road	0.34	785,685.6	97,526.1
5	~dist + slope + forest-patch area + status	0.30	835,102.8	146,943.3
6	~dist + slope + forest-patch area + dist road	0.29	863,444.3	175,284.8
7	~dist + dist market + forest-patch area	0.29	876,350.2	188,190.7
8	~slope + forest-patch area + status	0.29	886,476.6	198,317.1
9	~slope + forest-patch area + dist road	0.28	903,327.4	215,167.9
10	~dist + slope + forest-patch area	0.26	949,664.1	261,504.6
11	~dist + slope + status	0.26	967,353.6	279,194.1
12	~dist + slope + dist road	0.24	1,013,967	325,807.5
13	~dist + forest-patch area + dist road	0.23	1,027,519	339,359.5
14	~dist + forest-patch area + status	0.22	1,050,987	362,827.5

Model 1 (~distance to non-forest + distance to nearest market + forest-patch area + legal status) best explains the probability of conversion of forest to non-forest (Δ AIC = 0)

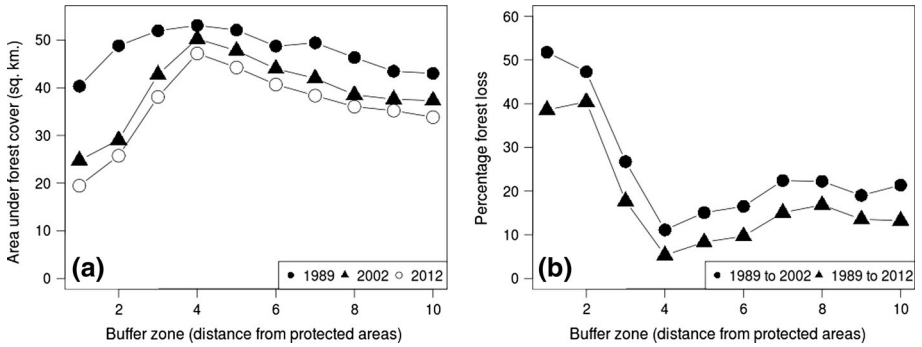

Fig. 2 Area under forest cover in a 10 km strip to the south of Pakke and Nameri Tiger Reserves (**a**), and the percentage of forest loss from baseline forest cover in 1989 between the 1989–2002 and 1989–2012 periods (**b**). The *x*-axis represents the ten 1 km wide strips (Fig. 1) from the southern border of the tiger reserves (buffer zone no. 1) to 10 km from the tiger reserves (buffer zone no. 10). As can be seen, forest loss was highest in the zones directly adjacent to the two tiger reserves

Table 2 Parameter estimates from Model 1 (Table 1)

Parameter	Coeff.	SE	*T*	*p*
Intercept	0.434	0.0004	1016.1	<0.01
Distance to market	−0.172	0.0003	−630.9	<0.01
Distance to non-forest	−0.035	0.0003	−139.2	<0.01
Forest-patch area	−0.138	0.0005	−307.1	<0.01
Status (tiger reserve, buffer, or unprotected)	−0.112	0.0003	−444.3	<0.01

All variables in the model have a significant impact in the probability of conversion of forest to non-forest

Impacts of ethno-civil conflict

Virtually all respondents (99 %) stated that Bodo ethno-separatists were responsible for forest loss. According to 90 interviewees, deforestation commenced around 1990 (95 % CI: 1990–1994).

Firewood is the primary, and often, the only cooking fuel in rural Indian households. In areas that are now insurgent-controlled, 86 % of respondents face fuelwood shortages for household use. The most common downstream impact on household economies (50 % of respondents) was that militants levy a 'cess tax' per bicycle load of fuel wood collected from these areas (median cost: \$0.55; range: \$0.20–1.00). This cost is in addition to the loss of a day's wage ($\sim$\$2.4), as accessing relatively remote areas where firewood is still available requires an entire day. Interviewees collected firewood 2–3 times per month. Assuming a person typically earns \$60 from 24 wage-days per month, and forfeits three wage-days in addition to paying a cess, residents are losing over 15 % of their income to firewood-related costs. Many residents are only partially employed and for these the economic burden of obtaining firewood is even greater.

For others who face time shortages or are not familiar with distant forests (40 % of respondents), the fuelwood crunch has forced them to procure firewood from members of the Bodo community. A bicycle-load of firewood is sold for $\sim$\$7.4 (range: \$4.6–9.2). Given the same daily wage calculation and assuming two loads of firewood are purchased per month, this results in residents having to pay $\sim$25 % of their income for firewood. Those who cannot afford to pay such a large sum at one time, purchase firewood on a daily basis for \$0.50 day^{-1}. The high cost associated with the cess or with firewood purchases has led to people to seek ways to maximize the duration of use for a given quantity of firewood. For instance, 28 % of respondents used sticks coated with cow dung to enhance the duration of firewood combustion.

Interviews also revealed shortages of other forest-based resources needed for daily life. For example, 28 % of respondents stated that they faced fodder shortages for domestic animals and hence were unable to keep as much livestock as they did prior to the the onset of ethno-civil strife. A few respondents (8 %) also cited shortages of timber and bamboo that increase the cost of building new houses or maintaining existing ones. A small house constructed of 0.5 m^3 of softwood (which lasts 5 years) would cost $\sim$\$400, whereas the same house constructed of hardwood (which lasts 10 years) would cost about twice that. Many people resort to constructing houses of bamboo, which is much cheaper ($\sim$\$40) but less durable (walls must be replaced every $\sim$3 years).

Forty percent of interviewees expressed feeling unsafe in their villages because of the threat of militancy and insurgency. This included fears of entering previously accessible forests that are now militant-controlled, extortion, and personal security.

Review of articles in the print media

Our search yielded 198 newspaper articles related to Bodo insurgency and militancy, with a peak in articles in 1989 and 1997 (Fig. 3). Articles from 1989 relate to ethnic riots involving Bodos, and the large-scale movement of both Bodo people and refugees fleeing ethno-civil violence and moving to parts of Arunachal Pradesh (with estimates ranging from 15,000 to 60,000 refugees in Arunachal Pradesh, spread across 6,000 refugee camps). The spike in the number of articles in 1997 is likely to be related to the 50th year of Indian independence, during which several secessionist militant groups intensified violent attacks.

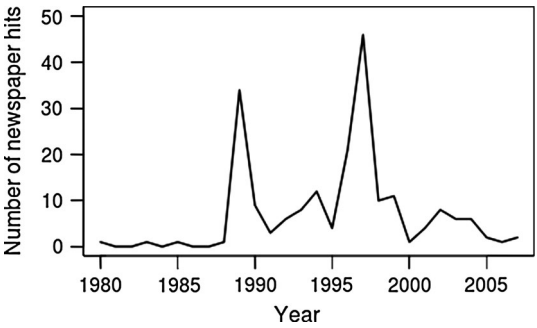

Fig. 3 Number of newspaper articles related to the Bodo movement and ethno-civil strife between the years 1980 and 2007 (from a search on LexisNexis Academic). The years 1989 and 1997 show a peak in the number of articles reporting Bodo militancy-related events

Impacts on wildlife

Anti-poaching staff are concerned that illegal logging has destroyed the habitat of the adjacent reserve forests in Assam and is now expanding into the state of Arunachal Pradesh. Residents living in reserve forests in Arunachal Pradesh form liaisons with loggers and cut timber illegally on a shared-contractual basis. Forest Department staff also stated that logs are floated at night down the Kameng (Bhoroli) River, which borders both tiger reserves, indicating high exploitation pressures on the reserve peripheries (Fig. 2b).

Species such as gaur (*Bos gaurus*), sambar deer (*Rusa unicolor*), and other prey of wild tigers are also being poached in the areas adjacent to the protected areas. Tusked elephants (*Elephas maximus*) that move out of the tiger reserve are vulnerable to hunters. Residents who want to hunt can easily procure muzzle-loading guns from insurgents for as little as $9, making the control of poaching a difficult task. Forest Department staff believe there is an emerging threat to both tiger reserves, as the scarcity of resources in areas outside the protected areas may lead to increased hunting, fishing, and logging pressures within the reserves.

Perceived solutions

Of the 99 respondents who suggested a solution to the problems they face, 34 % expressed despondency and stated there was no viable solution to the issue. About 12 % opined that members of the separatist group should be forcefully evicted by governmental agencies such as the army, police, or Forest Department. A few interviewees (10 %) suggested reforestation as a potential solution.

Discussion

Our results reveal massive forest loss in the southern buffer areas of the Nameri and Pakke Tiger Reserves, and may suggest that poaching of wildlife has also increased in the area. However, our results also reinforce the value of well-protected areas in ensuring continued forest cover and persistence of wildlife. Local residents overwhelmingly perceive armed militancy to be the primary driver of forest loss, and this perception is corroborated by our

print-media analysis that reveals large-scale movement of refugees triggered by ethno-civil violence and militancy (Fig. 3). In this region, an alternative view is that current forest loss reflects an intensification of the historical conversion of forest-based livelihoods to settled agriculture (Saikia 2011). Regardless, this region faces amongst the highest rates of deforestation in India, and for residents, restrictions on forest use and the threat of violent retribution has caused an acute reduction in access to essential forest-based resources, straining household economies.

The socio-economic and ecological changes we observed are not restricted to the two tiger reserves we studied. Nameri and Pakke are part of the Kameng Protected Area Complex, which at 3,500 km^2 in area is the largest contiguous forest tract in the Eastern Himalayas. The complex includes the Sonai Rupai Wildlife Sanctuary in Assam, the Eaglenest and Sessa Sanctuaries in Arunachal Pradesh, and their associated Reserve Forests. In a related study, 28 % of Shertukpen hunters living around Eaglenest Wildlife Sanctuary claimed that deforestation and hunting by Bodo militants were responsible for a decline in local wildlife (N. Velho, unpublished data).

The Bodo insurgency and ethno-civil conflict complicates one of the most serious environmental crises in India. Since 1990, the Sonai Rupai Wildlife Sanctuary in Assam has seen a dramatic decline in its original forest cover (Kushwaha et al. 2011). This Sanctuary, along with the Chariduar, Balipara and Nauduar Reserve Forests, comprise one of the most serious deforestation hotspots in the whole of India (Kushwaha et al. 2011). Similar to the 'zone of interaction' proposed by DeFries et al. (2010), the planning of this entire landscape must take into account maintaining the integrity of the Kameng and Pakke rivers as barriers to poaching and illegal logging. In addition, key ecological interactions (especially the maintenance of corridors for elephant movements), and persistence of the re-introduced and critically endangered pygmy hog (*Porcula salvania*) require identification and strengthening. This information is necessary to understand how the socio-economic situation (in terms of security and dependence on forest based products), can be aligned with conservation goals.

Circumstantial evidence suggests that much past forest clearing in our study area was for illegal logging. Our study area is part of the 'North Bank Landscape', a 40,000 km^2 area between the Brahmaputra River in the south and the Himalayan foothills in the north. From 1991 to 2001, our study area suffered much higher forest loss (24.9 %) than did the remainder of the North Bank Landscape (2.4 %). However, agricultural land expanded by an equal proportion, about 8.6 %, in both areas (Mazoomdar 2011).

In conjunction with other studies, our findings suggest that militancy and ethno-civil conflict has been a major contributor to forest loss and wildlife exploitation in northeastern India. Forests and other valuable natural resources have often been the foci of ethno-civil conflicts, especially in developing nations. In Cambodia, for instance, deforestation rose exponentially following the end of civil war, with large-scale commercial logging controlled by military commanders and corrupt forest officials (Le Billon 2002). Timber and other forest goods in Myanmar, which abuts northeastern India, are also key resources in armed conflict, especially between Kachin ethnic groups and the government (Global Witness 2003). Elephant populations in the Okapi Faunal Reserve in the Democratic Republic of Congo fell to almost half their original numbers because of unchecked ivory exploitation during the civil war (Beyers et al. 2011). Refugees displaced by civil strife, as well as combatants, are known to rely increasingly on illegally poached bushmeat (e.g. Draulans and van Krunkelsven 2002).

A worrying trend from our study area is that forest loss has been accelerating towards the neighbouring state of Arunachal Pradesh, with forests being cleared right

up to the boundaries of Nameri and Pakke Tiger Reserves. Protected areas are often important refugia for biodiversity during civil wars and conflicts (e.g. Beyers et al. 2011), and Nameri and Pakke are well-managed reserves where intensive patrolling has ensured that forests and wildlife persist. However, patrols alone might be unable to halt intense poaching in protected areas (de Merode et al. 2007), underscoring the importance of integrating conservation within a larger political framework. This requires the intervention of higher-level government agencies to ensure that conservation efforts of the Forest Department continue even during periods of civil strife.

Other aspects of the impacts of ethno-civil strife on the biodiversity of this landscape require investigation. For instance, 85 plant species from the larger landscape are documented to be of medicinal value (Saikia et al. 2006). However, we did not explore potential links between militancy and the harvest of commercially important medicinal plants. Also, we did not quantify the degree to which enthno-civil strife might increase the exploitation of threatened tree species such as *Aquilaria malaccensis* (Anak et al. 2000). Further studies on the utilisation of a larger cross-section of forest resources, and potential linkages of such use with ethno-civil strife are required to supplement this study.

Fallout from the ethno-civil conflict might also increase human-wildlife conflict in our study area. Conflict between humans and elephants, attributed to increasing forest loss, has increased sharply since 1980 (Chartier et al. 2011). For instance, 17 elephants were found dead from July to November 2001 in Sonitpur district, with the greatest concentration around Nameri Tiger Reserve (Gureja et al. 2007). Further forest loss could exacerbate such conflicts.

The problems of ethno-civil strife and its impacts on biodiversity are challenges that are likely to increase in the future, as the human populace continues growing on a trajectory likely to approach 11 billion this century (United Nations, Department of Economic and Social Affairs Population Division 2013). From our study, a diversity of factors appear to interact to influence deforestation in northeast India. In this biodiversity-rich landscape, preventing forests and wildlife from being further degraded will require efforts at multiple levels, encompassing both socio-economic and political challenges. For instance, better planning for the placement of roads around protected areas and natural habitats, especially in relation to the location of major markets, could be vital. However, these issues will also have to integrate socio-political considerations of ethnic land and forest rights, and the relationships between ethnic and tribal groups in the landscape. Most concretely, in the face of continuing erosion of biodiversity, a key measure is to strengthen the protection of existing nature reserves embedded in militant-affected areas.

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Appendix 1

Questionnaire used to collect interview data for this study in northeastern India.

Interviewee code: Date:

Name of settlement: District:

Tribe/ethnicity:

Approximate age: Sex: M/F

House-hold characteristics:

1. How long have you lived in this place?

(a) First generation (b) Second generation (c) More than two generations

2. What are your sources of livelihood? (enlist if more than one)

(a) Service (government) (b) Contract work (c) Agriculture (d) Daily wage labour

(e) Others

3. Do you own agricultural land?

(a) Yes (b) No

4. How much agricultural land do you own?

5. What source of fuel do you use for cooking?

(a) LPG (b) Firewood (c) Bio-gas (d) Others

6. Has there been a change in forest cover where you live?

(a) Yes (b) No (c) No change (d) Don't know

7. If yes, what is the main reason for decline in forest cover?

(a) Agricultural expansion (b) Logging (c) Militancy (d) Population increase

(e) Others

8. If yes, when did this change occur?

9. Do you face shortage of wood-based natural resources?

(a) Yes (b) No (c) Don't know

10. If yes, what are the shortages that affect your daily life the most?

(a) Firewood (b) House-building (c) Fodder for animals (d) Others

11. If you face firewood shortages how do you deal with this?

(a) Pay cess for fuelwood collection (b) Buy fuelwood (c) Use cowdung (d) Others

12. How do any other shortages because of change in forest cover affect you?

13. If there is a change in forest cover, what is this timber being used for?

(a) Home use (b) Sold to commercial markets (c) Both (d) Others (e) Don't know

14. If being sold in markets, where are these markets?

15. What do you feel are the best ways of dealing with this change in forest cover?

(a) Government (b) Non-governmental organizations (c) Involvement of local people

(d) No solution (e) Don't know (f) Others

References

Anak NA, Mulliken T, Song M (2000) Heart of the matter: agarwood use and trade and CITES implementation for *Aquilaria malaccensis*. Traffic International, Cambridge

Banerjee AC, Roy SS (2010) Problems and prospects of bodoland. Mittal Publishers, New Delhi

Beyers RL, Hart JA, Sinclair ARE, Grossmann F, Klinkenberg B, Dino S (2011) Resource wars and conflict ivory: the impact of civil conflict on elephants in the Democratic Republic of Congo—the case of the Okapi Reserve. PLoS ONE 6:e27129

Burnham KP, Anderson DR (2002) Model selection and multimodel inference: a practical information—theoretic approach. Springer, New York

Canty MJ, Nielsen AA (2008) Automatic radiometric normalization of multitemporal satellite imagery with the iteratively re-weighted MAD transformation. Remote Sens Environ 112:1025–1036
Chartier L, Zimmerman A, Ladle RJ (2011) Habitat loss and human–elephant conflict in Assam, India: does a critical threshold exist? Oryx 45:528–533
Datta A, Anand MO, Naniwadekar R (2008) Empty forests: large carnivore and prey abundance in Namdapha National Park, north-east India. Biol Conserv 141:1429–1435
Dávalos LM (2001) The San Lucas mountain range in Colombia: how much conservation is owed to the violence? Biodivers Conserv 10:69–78
de Merode E, Smith KS, Homewood K, Pettifor R, Rowcliffe M, Cowlishaw G (2007) The impact of armed conflict on protected-area efficacy in Central Africa. Biol Lett 3:299–301
DeFries R, Karanth KK, Pareeth S (2010) Interactions between protected areas and their surroundings in human-dominated tropical landscapes. Biol Conserv 143:2870–2880
Draulans D, Van Krunkelsven E (2002) The impact of wars on the Democratic Republic of Congo. Oryx 36:35–40
Dudley JP, Ginsberg JR, Plumptre JA, Hart JA, Campos LC (2002) Effects of civil war and strife on wildlife and wildlife habitats. Conserv Biol 16:319–329
FAO (1995) Forest resources assessment 1990: global synthesis. Food and Agriculture Organisation, Rome
Global Witness (2003) A conflict of interests: the uncertain future of Burma's forests. Oct 2003, Global witness. http://www.globalwitness.org/library/conflict-interest-english. Accessed 26 June 2013
Gureja N, Menon V, Sarkar P, Kyarong SS (2007) Ganesha to Bin Laden: human–elephant conflict in Sonitpur district of Assam. Occasional report no. 6. Wildlife Trust of India
Kushwaha SPS, Hazarika R (2004) Assessment of habitat loss in Kameng and Sonitpur Elephant Reserves. Curr Sci 87:1447–1453
Kushwaha SPS, Nandy S, Ahmad M, Agarwal R (2011) Forest ecosystem dynamics assessment and predictive modelling in Eastern Himalaya. In: International archives of the photogrammetry remote sensing and spatial information sciences, XXXVIII, ISPRS workshop, Bhopal
Laurance WF (2004) The perils of payoff: corruption as a threat to global biodiversity. Trends Ecol Evol 19:399–401
Laurance WF (2007) Forest destruction in tropical Asia. Curr Sci 93:1544–1550
Laurance WF (2013) Can research help to safeguard protected areas? Trends Ecol Evol 28:262–266
Le Billon P (2002) The political ecology of transition in Cambodia 1989–1999: war, peace and forest exploitation. Dev Chang 31:785–805
Mazoomdar J (2011) Where the forests have no trees. http://www.openthemagazine.com/article/nation/where-the-forests-have-no-trees/. Accessed 19 May 2013
McNeely K (2003) Conserving forest biodiversity in times of violent conflict. Oryx 37:142–152
McNeely J (2007) Addressing extreme conflicts through peace parks. In: Palo M, Uusivouri J, de Jong W (eds) Extreme conflicts and tropical forests. Springer, Netherlands, pp 159–172
Mittermeier RA, Myers M, Mittermeier, CG (2000) Hotspots: earth's biologically richest and most endangered terrestrial ecosystems. Conservation International, Mexico
Nag S (2000) Contesting marginality: ethnicity, insurgency and subnationalism in north-east India. Rawat Publications, New Delhi
Puyravaud J-P, Davidar P, Laurance WF (2010) Cryptic destruction of India's native forests. Conserv Lett 3:390–394
Richards P (2001) Are "forest wars" in Africa the case of resource conflicts? The case of Sierra Leone. In: Peluso NL, Watts M (eds) Violent environments. Cornell University Press, Ithaca
Saikia A (2011) Forests and ecological history of Assam, 1826–2000. Oxford University Press, New Delhi
Saikia AP, Ryakala VK, Sharma P, Goswami P, Bora U (2006) Ethnobotany of medicinal plants used by Assamese people for various skin ailments and cosmetics. J Ethnopharmacol 106:149–157
South Asia Terrorism Portal (2013) http://www.satp.org/satporgtp/countries/india/states/assam/terrorist_outfits/ndfb.htm. Accessed 15 Mar 2013
United Nations, Department of Economic and Social Affairs Population Division (2013) World population prospects: the 2012 revision, Vol II, demographic profiles (ST/ESA/SER.A/345)
Velho N, Karanth KK, Laurance WF (2012) Hunting: a serious and understudied threat in India, a globally significant conservation region. Biol Conserv 148:210–215
Vidal-Hall J (2006) "Naxalites". pp. 73–75 In Index of Censorship, Vol 35, number 4, quoted on pp 74