TOWARDS A LANDSCAPE CONSERVATION STRATEGY : ANALYSIS OF JHUM LANDSCAPE AND PROPOSED CORRIDORS FOR MANAGING ELEPHANTS IN SOUTH GARO HILLS DISTRICT AND NOKREK AREA, MEGHALAYA

B.G. MARCOT*, A. KUMAR**, P.S. ROY***, V.B. SAWARKAR**
A. GUPTA** AND S.N. SANGMA****

Introduction

In India, Asian elephants (*Elephas maximus*) reach perhaps their highest density in Meghalaya, but recent censuses suggest a major decline in local numbers. In the South Garo Hills District and Nokrek area of Western Meghalaya, elephant habitat is being fragmented and altered from accelerated shifting cultivation or 'Jhum', which has eliminated old, native forests from nearly half of the landscape (Marcot *et al.*, 2001). Traditional travel lanes used by elephants are not in protected status, and annually many injuries and deaths occur when elephants encounter humans outside the few formal Protected Areas of the region.

Old native forests of the region consist of 81% community ownership and only 19% government ownership (Kumar *et al.*, 2001), the latter in 4 Reserved Forests (Emangiri, Rewak, Baghmara, Angratoli), 2 National Parks (Nokrek, Balpakram), and 2 Wildlife Sanctuaries (Siju, Baghmara Pitcher Plant) (Fig. 1). The total study area of South Garo Hills District and Nokrek area comprises about 2,458 km^2. The reserved forests, national parks, and wildlife sanctuaries, which are under control of the State Forest Department, cover about 362 km^2 or about 15% of the study area. The rest of the area belongs to the local Garo communities.

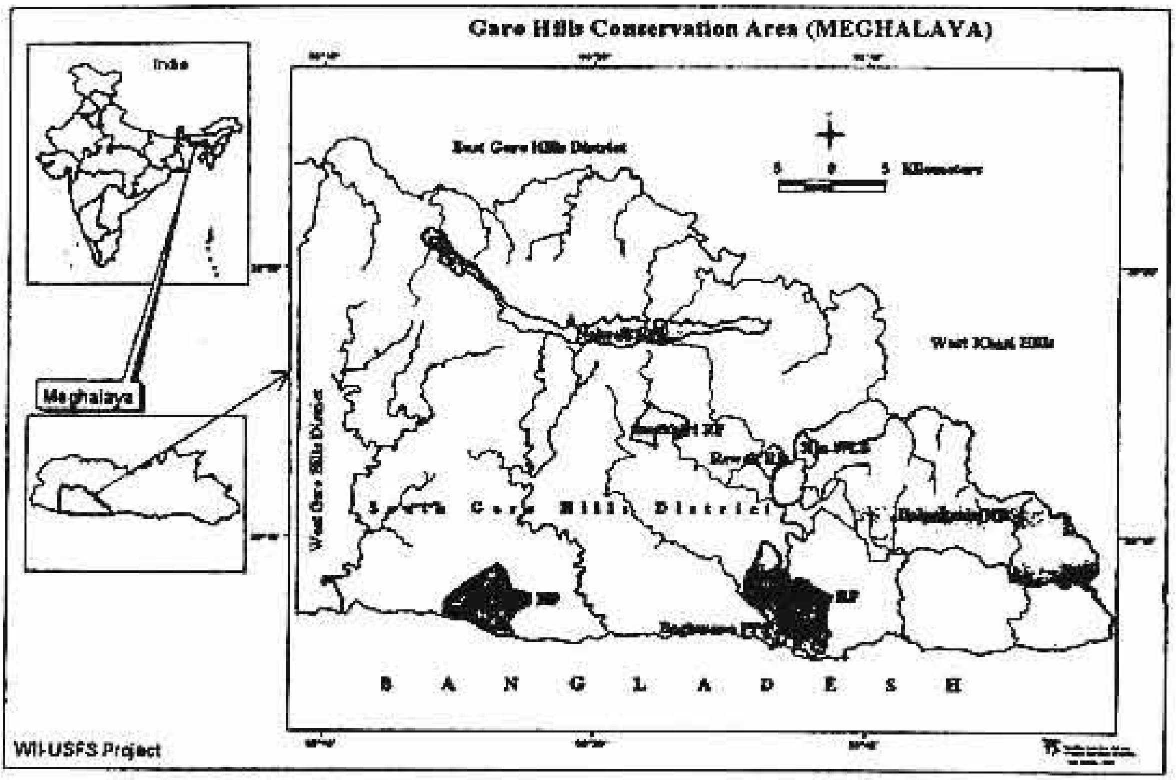
To aid management of elephants and their habitat, we conducted a statistical analysis to compare elephant density with vegetation and land cover conditions in the South Garo Hills District and Nokrek area. The objectives were to determine the major correlates with elephant numbers, the specific levels of land-altering conditions that might be adversely affecting elephants, and to suggest habitat corridors for reducing conflicts and helping ensure more stable elephant densities over time. Results could be used to craft new management guidelines for testing how best to maintain or restore habitat conditions for elephants of the area.

Analysis Methods

We used elephant census results from 1993 (Office of Divisional Forest Officer, East and West Garo Hills Wildlife Division, Tura, Meghalaya) and 1997-98 (Marak, 1998) to calculate elephant crude densities

*USDA Forest Service, Portland, Oregon (USA).
**Wildlife Institute of India, Dehra Dun (Uttaranchal).
***Indian Institute of Remote Sensing, Dehra Dun (Uttaranchal).
****East and West Garo Hills Division (Wildlife), Tura (Meghalaya).

Fig. 1

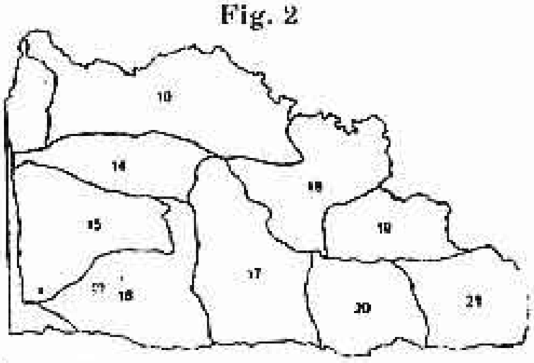


Location map of the South Garo Hills District and Nokrek study area in Meghalaya, showing boundaries of 8 government-administered protected areas of the region.

and per cent change in densities between the two periods, in each of the 9 census zones of the region (Fig. 2). Per cent change in elephant crude density, for each elephant census zone, was calculated as number of elephants counted in 1997-97 minus counts in 1993, divided by counts in 1993. In all, we used 5 response variables (Table 1). Table 2 lists the elephant densities.

Vegetation and land cover categories were mapped for the region using December 1998 remote sensing satellite data with a ground-truth accuracy likely exceeding 80%. Nine vegetation and land cover categories identified for the study area were: active jhum (0 to approximately 3 years old) and grassland; scrub and abandoned jhum (3-6 years old); which occurs mostly on degraded sites, bamboo brakes and secondary forest (6-10 years old); deciduous forest; semi-evergreen

Fig. 2



The 9 elephant census zones in the South Garo Hills District and Nokrek study area (Marak, 1998).
The two unnumbered zones on the West boundary are parts of areas not censused and are not included in the analysis

Table 1

The 5 response (Elephant) and 70 predictor (vegetation and lands cover)

Predictor (Vegetation and habitat) Variables :	Area (km^2)	Per cent of census zone	Total number of patches	Total area of patches	Av. patch size	Min. patch size	Max. patch size
Active jhum	c	c	c	c	c	c	c
Scrub and abandoned jhum	c	c	c	c	c	c	c
Bamboo brakes and secondary forest	c	R	c	R	c	R	R
Deciduous forest	c	R	c	c	R	c	R
Semi-evergreen forest	c	R	c	c	c	R	R
Evergreen forest	c	c	c	c	c	c	c
Permanent agriculture	c	c	c	c	c	c	c
Water bodies	c	R	c	c	c	c	c
Shadow	c	c	c	c	c	c	c
Deciduous, Semi-evergreen and evergreen forest combined	c	c	R	R	c	R	c

R = predictor variables used in correlation analyses and retained for linear regressions because of low correlation ($P>0.05$) with other predictor variables;

c = used in correlation but excluded from regression because of high correlations ($P<0.05$)

Response (elephant) variables :

Total no. of elephants from 1993 census, all age and sex classes combined

Total no. of elephants from 1997-1998 census, all age and sex classes combined

Crude density of no. elephants per census zone area, 1993 (n/km^2)

Crude density of no. elephants per census zone area, 1997-1998 (n/km^2)

Per cent change in total elephant numbers between 1993 and 1997-1998 censuses

forest (approxi-mately 15-30+ years old); evergreen forest; permanent agriculture; water bodies; and shadows. These were mapped at a resolution of 23.5 m x 23.5 m.

GIS was used to calculated area of each elephant census zoo, and the total area and per cent of each vegetation and land cover category in each elephant census zone. Other landscape metrics calculated for each vegetation and land cover category included total number of patches, and minimum, mean, and maximum size of patches. In total, some 70 predictor variables were generated (Table 1).

Simple Pearson correlations were calculated among the 70 predictor variables and excluding 56 of them (Table 1) from further analyses based on their high correlations ($P<0.05$). We then produced bivariate scatter diagrams of each of the 14 retained predictor variables (x) plotted against elephant crude density and change in density (y) among the elephant census zones, and calculated best-fit power regressions ($y = bx^m$, where b = a constant and m = slope coefficient). We also used

Table 2

Elephant census results from South Garo Hills District and Nokrek area, Western Meghalaya in 1993

Census zone number	Census zones name	Total area (km^2) (a)	Total no. elephs. 1993 (b)	Total no. elephs. 1998 (c)	% change (c-b)/b	Elephants/km^2 Crude density 1993 (b/a)	Crude density 1998 (c/a)
10	Nokrek-Samanda-Rongrenggiri	574.8	211	65	-69	0.37	0.11
14	Dana Adugre-Nengsranggre-Rongmagre	168.0	93	61	-34	0.55	0.36
15	Rongmagre-Dareng-Kakija-Warimagre	276.7	37	11	-70	0.13	0.04
16	Mibonpara-Ruga-Angratoli	333.4	138	10	-93	0.41	0.03
17	Rongdong-Tholegre-Rewak-jadigittim	364.6	141	78	-45	0.39	0.21
18	Rekmangre-Emangre-Chengbagre	357.5	102	84	-18	0.29	0.23
19	Siju-Rongchu-Rongcheng-Balpakram	182.3	240	116	-52	1.32	0.64
20	Baghmara-Halwa-Dambuk-Balpakram	193.4	248	156	-37	1.28	0.81
21	Mahadeo-Chimitap-Balpakram	214.3	223	216	-3	1.04	1.01
Total		2665	1433	797	-44	0.54	0.30
Mean		296.1	159.2	88.6	-47	0.64	0.38
S.D.		129.7	74.6	66.3	28	0.45	0.36

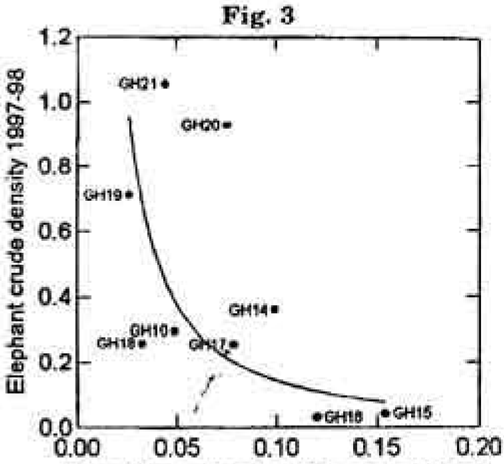
Source : Marak, 1998.
(Census zone areas calculated from GIS analysis. Crude density was calculated as total number of elephants/ total area).

stepwise multiple linear regression to determine the best model predicting elephant crude density in 1997-98 from the vegetation and land cover categories.

We compared results of correlating elephant density with vegetation and land cover categories, with actual counts of elephant sign (dung, tree breakage, and pugmarks) in the field (taken by A. Kumar). Counts of elephant sign in each vegetation and land cover category were compared with general availability (area sampled) of each category, by using Chi-square contingency analysis. This determined if elephants selected for particular categories.

Elephant habitat corridors were identified as the part of the landscape with a low degree of forest fragmentation that would link protected areas. To identify corridors, we used GIS to produce a map depicting 3 levels (low, medium, high) of forest fragmentation (Kumar *et al.*, 2001 for methods). We conducted two fragmentation analyses, one combining evergreen and semi-evergreen forest, and another combining these with deciduous forest, and used the latter analysis for the final delineation of corridors. We then compared the per cent of area, in each of the vegetation and land cover categories, in the proposed elephant habitat corridors with that in the entire South Garo Hills District and Nokrek area, using Chi-square contingency analysis, to determine if some categories were statistically more prevalent within the corridors.

Fig. 3



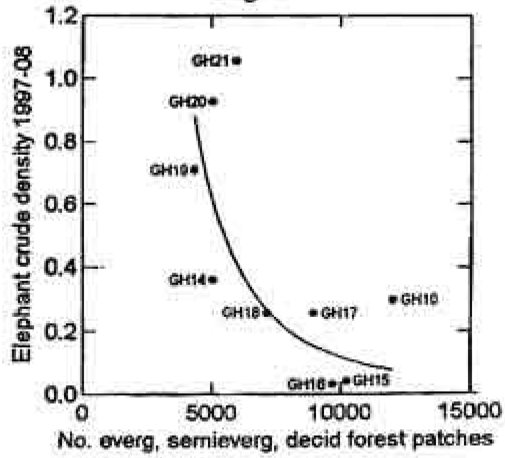
Elephant crude density (no. elephants of all sex and age classes/km^2) as a function of proportion of landscape in bamboo and secondary forest cover. Data points are individual elephant census zones in the South Garo Hills District and Nokrek study area (Fig. 2) and the curve is the best-fit power regression.

Results and Discussion

The 9 elephant census zones varied in size from 163.1 to 328.8 km^2. Numbers of elephants declined in all census zones between the two census periods of 1993 and 1997-98. Overall decline was a very alarming 44%. The question is, why ?

Elephant density in 1997-98 was significantly ($P<0.05$) and negatively correlated with total area ($r = 0.71$) and number of patches ($r = -0.71$) of bamboo brakes and secondary forest, and with number of patches of deciduous forest ($r = -0.75$) and of deciduous, evergreen, and semi-evergreen forest combined ($r = -0.70$). That is, elephant density clearly is lower with greater levels of forest fragmentation. These relations are also suggested by the scatter plots (Figs. 3, 4).

Fig. 4



Elephant crude density (no. elephants of all sex and age classes/km^2) as a function of number of mapped patches of native evergreen, semi-evergreen, and deciduous forest. Data points are individual elephant census zones in the South Garo Hills District and Nokrek study area (Fig. 2) and the curve is the best-fit power regression.

Per cent change in elephant crude

density between census periods was significantly and negatively correlated with number of deciduous forest patches ($r = -0.68$) and positively correlated with mean size of semi-evergreen patches ($r = 0.76$). Again, this suggests adverse effects on elephant numbers from fragmentation of native forest, and that higher elephant numbers correspond with larger and more contiguous forest patches.

Best-fit linear regression models predicted 1997-98 elephant density only at a marginal level of statistical significance ($F = 4.21$, $df = 4$, $P = 0.096$, with $R^2 = 0.81$). The model included 4 vegetation cover categories, all with negative coefficients: active jhum and grassland; per cent semi-evergreen forest; minimum patch size of deciduous, semi-evergreen, and evergreen forest; and maximum patch size of bamboo brakes and secondary forest. Most of the (negative) influence ($P \leq 0.05$) in the model was from active jhum and minimum forest patch size. These findings again suggest the adverse consequences on elephants from jhum and its effect of fragmenting native forest into small patches.

The best-fit linear regression model of per cent change in elephant crude density was highly significant ($F = 18.798$, $df = 3$, $P = 0.004$, $R^2 = 0.92$) and included three variables: per cent of the landscape in deciduous forest (negative influence); minimum patch size of deciduous, evergreen, and semi-evergreen forest (negative), and mean patch size of semi-evergreen forest (positive). That is, elephant crude density dropped the most in census zones where more of the landscape was in deciduous forest, where native forest was the most fragmented into tiny patches, and where patches of semi-evergreen forest were on average the smallest. These are also typical conditions resulting from jhum agriculture.

Marcot *et al.* (2001) conducted a similar analysis using the same elephant census data but different vegetation and land use data, for the entire Garo Hills region (East, West and South Garo Hills Districts that collectively comprise Western Meghalaya). Their findings were similar, also reporting negative correlations of elephant densities with proportion of land in current and abandoned jhum, and with village density; and positive correlations with deciduous forest cover and terrain complexity (topographic relief). They suggested that elephant densities might be maintained in landscapes with < 30% current and abandoned jhum, with < 20% in high forest patchiness (caused by jhum), and with village density < about 0.4/km^2, and that annual jhum rates should be < 2% of the land jhummed per year.

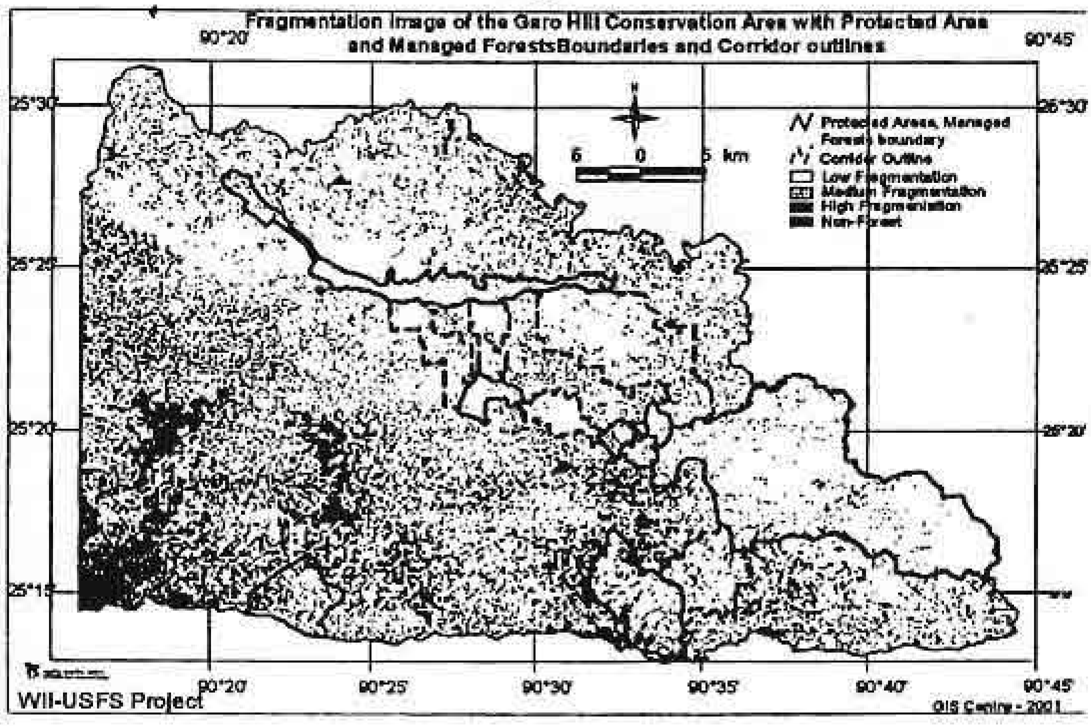
Our present findings for South Garo Hills District and Nokrek area also suggest higher elephant densities with <10% of the landscape in bamboo and secondary forest (Fig. 3) and with less fragmented, larger, and more contiguous patches of native forest (Fig. 4). We offer this as an ideal landscape design as a conservation strategy for maintaining elephants densities.

Analysis of the field data of elephant signs revealed only marginally significant selection for the individual vegetation and land cover categories (Chi-square = 10.92, $df = 6$, $0.05<P<0.10$), with bamboo brakes and semi-evergreen forest being used in slightly greater frequency by elephants than its availability, and deciduous forest and jhum used less. The greater use of bamboo somewhat contradicts the correlation analysis above which suggests that greater cover of bamboo is not correlated with greater elephant density. However, both deciduous forest and bamboo growth provide forage for the elephants. Deciduous forest is so fragmented that it does not provide cover value for elephants. Also, results of analyzing the field data on elephant sign should be taken with caution, as dung and other signs from the same animal were likely counted more than once, thus indicating as much the frequency of occurrence of individual elephants as well as the density of elephants.

We identified 7 potential elephant habitat corridors, consisting of largely unfragmented native forest, that would link most of the protected areas (Fig. 5). Some of these corridors also were previously identified by Williams and Johnsingh (1996) as being critical to maintaining elephant populations in the region. Our current analysis supports this, and provides specific locations and an analysis based on native forest condition.

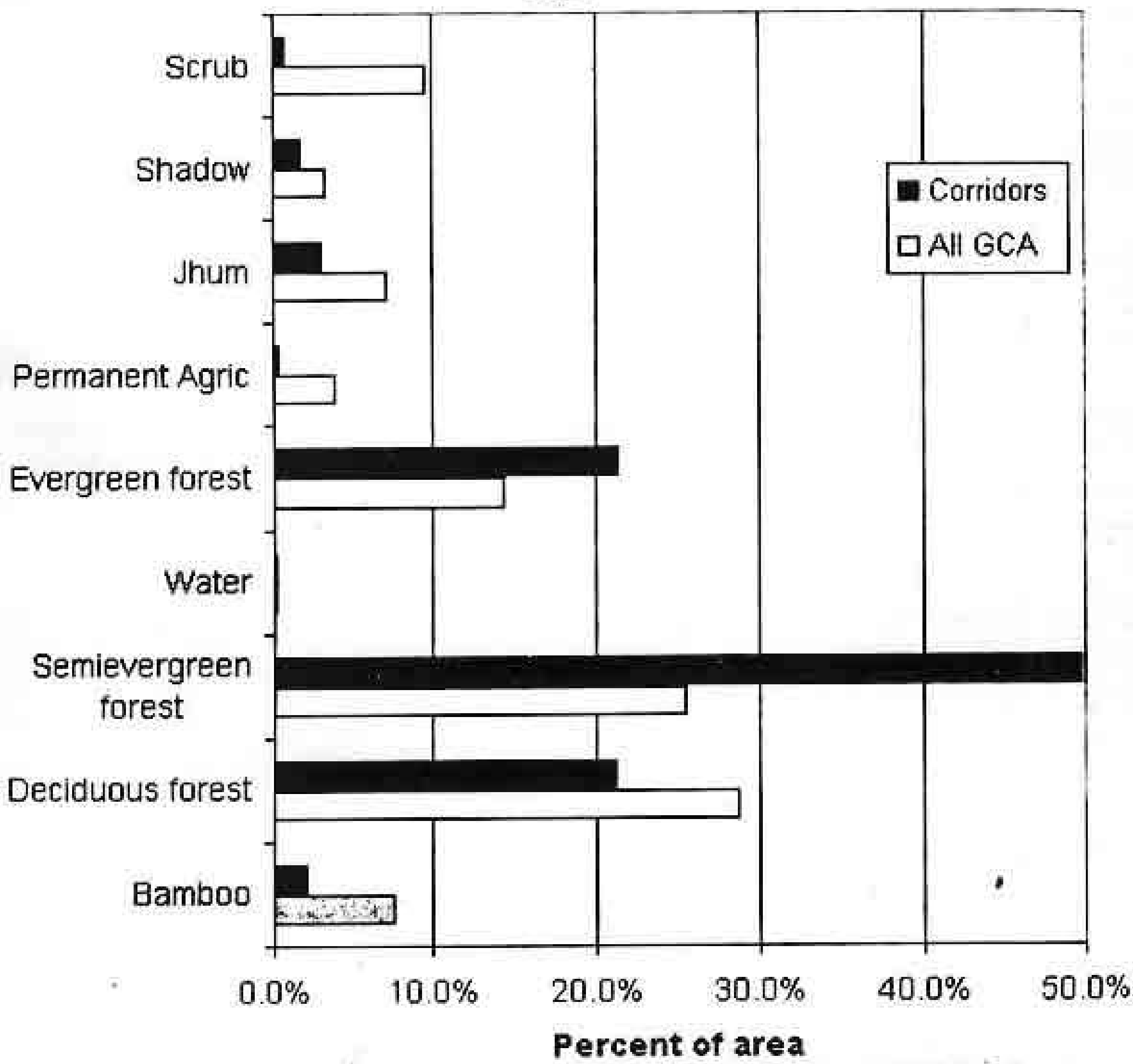
The area occupied by vegetation and land use categories differed significantly between the corridors, and the general South Garo Hills District and Nokrek area (Chi-square = 115.33, df = 8, $P<0.001$). The corridors have far greater proportions of semi-evergreen and evergreen forest cover,

Fig. 5



Fragmentation of native forest in South Garo Hills District and Nokrek area, showing the 7 protected areas (solid outlines) and 7 proposed elephant habitat corridors (dashed lines). Notice how the corridors include largely unfragmented native forest. Analysis of forest fragmentation was according to Kumar *et al.* (2001).

Fig. 6



Per cent coverage by 9 categories of vegetation or land cover within the South Garo Hills District and Nokrek area and within 7 proposed elephant habitat corridors.

and far less of jhum, agriculture, deciduous forest, and bamboo (Fig. 6). This result is not surprising, given that the corridors were delineated to encompass area of low forest fragmentation (although the lower occurrence and negative role of deciduous forest has been a little surprising). Further, the elephant corridors also have statistically significantly greater proportions (71%) of overall forest cover (combining semi-evergreen and evergreen forest) than in the South Garo Hills District and Nokrek area as a whole (40%). Thus, these specific corridors likely would serve well as elephant habitat, given results of the above analyses.

The community-owned forest lands play significant roles in providing forest habitat for elephants. Some 60% of evergreen forest and 80% of semi-evergreen forest, including some largely unfragmented forest outside protected areas, occur on community lands. The proposed elephant habitat corridors all occur on community lands. Obviously, if the elephant habitat corridors are to be somehow officially designated, community use of those lands and participation in their conservation need to be explicitly addressed and conflicts resolved.

Delineation and conservation of forest corridors for linking elephant movement among population centers are vital parts of a landscape-scale strategy for conserving elephants (Johnsingh and Williams, 1999). For example, elephant habitat corridors have been proposed to link Rajaji and Corbett National Park (Johnsingh *et al.*, 1990; Sunderraj *et al.*, 1995). Johnsingh *et al.* (1990) noted that such corridors also can link populations of other wide-ranging species, especially tigers (*Panthera tigris*), and that threats to corridors in the Rajaji-Corbett area include over-grazing by domestic livestock, weed proliferation, and lack of tree regeneration. Such threats can be dealt with using appropriate management tactics. Threats to old, native forest habitats in the elephant corridors of South Garo Hills largely pertain to excessive jhum agriculture. There too, appropriate management designation of the corridors, perhaps as wildlife sanctuaries, with diligent monitoring of incursion and forest use by local people, would help conserve their value for elephants and other wildlife species.

Acknowledgements

We thank S/Shri S.K. Mukherjee and A. Saxena of Wildlife Institute of India, Dehra Dun, Uttaranchal, for their kind support for the project. We thank Shri A.J.T. Johnsingh for a helpful review of the manuscript and Shri S.N. Sangma of East and West Garo Hills Division (Wildlife), Tura, State Forest Department, Meghalaya, for the elephant census data for 1993 and the census zone boundary map. Thanks are also due to Sh. T.T.C. Marak, IFS, Wildlife Wing, Forest and Environment Department, Shillong, Meghalaya, for conducting and reporting on elephant censuses in 1997-98, in Meghalaya.

SUMMARY

In the South Garo Hills District and Nokrek area of Western Meghalaya, statistical analyses suggest very low elephant densities and greatest declines of elephants in areas with >10% bamboo and secondary forest (6-10 years old) and >10% scrub and abandoned jhum fields (old fallow jhum 3-6 years old). Elephant densities are highest, and declines are the least, in areas with >25% semi-evergreen forest (old secondary forests 15-30+ years old). Data on elephant sign (use) in the field generally support these findings, with selection by elephants (ie., use significantly exceeding availability) for native semi-evergreen forest, and lack of selection (use significantly less than availability) for deciduous forests (including Sal forest, Teak, and Cashew plantations) and for scrub and abandoned jhum fields. To maintain elephant populations in the South Garo Hills District and Nokrek area, we suggest official delineation of 7 elephant habitat corridors that we mapped as having low degree of fragmentation of forest cover and a high proportion of contiguous, semi-evergreen and evergreen forest cover.

भूदृश्य संरक्षण समरनीति की ओर : झूम भूदृश्य का विश्लेषण तथा दक्षिण गारो पर्वतीय जिला और नोकरेक क्षेत्र, मेघालय में हाथियों का प्रबन्ध करने के लिए प्रस्तावित गलियारा

बी॰जी॰ मारकोट, ए॰ कुमार, पी॰एस॰ राय, वी॰बी॰ सावरकर, ए॰ गुप्त व एस॰एन॰ संगमा

सारांश

दक्षिण गारो पर्वतीय जिले और पश्चिमी मेघालय के नोकरेक क्षेत्र में किए गए सांख्यिकीय विश्लेषण > 10% बांस और द्वितीयक वन (6 - 10 वर्ष उम्र का) और > 10% क्षुद्र वन और परित्यक्त झूम खेतों (पुरानी परती झूमभूमि 3 - 6 वर्ष की) वाले क्षेत्रों में हाथियों की बहुत कम संख्या होने और वहां हाथियों की संख्या में सबसे अधिक कमी पड़ने का सुझाव देते हैं । > 25% अर्द्ध सदाहरित वन (पुराना द्वितीयक वन 15 - 30⁺ वर्ष उम्र का) क्षेत्रों में हाथियों की सघनता सर्वाधिक और उनकी संख्या में कमी पड़ना न्यूनतम है । क्षेत्र में हाथी चिह्नों (उपयोग) के आंकड़ों से सामान्यतः इस जानकारी का समर्थन होता है, जिसमें हाथी देशज अर्द्ध सदाहरित वन को चुनते (अर्थात् उसका उपयोग उपलभ्यता से काफी अधिक करते हैं) तथा पर्णपाती वनों (इसमें शाल वन, सागौन और काजू रोपवन सम्मिलित हैं) तथा क्षुद्र वनों और परित्यक्त झूम खेतों को चुनना छोड़ते (उसका उपयोग उपलभ्यता से काफी कम करते हैं) प्रतीत होते हैं । दक्षिण गारो पर्वतीय जिले और नोकरेक क्षेत्र में हाथी पूर्ववत् बने रहें, इसके लिए हमारा सुझाव है कि उन 7 हाथी गलियारों को, जिन्हें हमने मानचित्र पर वन वृक्षों के विखण्डित होने की कम मात्रा और साथ लगते, अर्द्ध सदाहरित और सदाहरित वन वृक्षों के अधिक समानुपात वाला बताते हुए दिखाया था, सरकारी तौर से वहां बनवा दिया जाए ।

References

Johnsingh, A.J.T., S.N. Prasad and S.P. Goyal (1990). Conservation status of the Chila-Motichur corridor for elephant movement in Rajaji-Corbett National Parks area, India. *Biological Conservation*, **51** : 125-138.

Johnsingh, A.J.T. and A.C. Williams (1999). Elephant corridors in India : lessons for other elephant range countries. *Oryx*, **33** (3) : 210-214.

Kumar, A., A. Saxena, B.G. Marcot, V.B. Sawarkar, P.S. Roy, P.K. Mathur and S.P. Singh (2001). Forest fragmentation in the tropical forest ecosystem of Garo Hills, Meghalaya, North-East India. *Proceedings of a workshop on Biodiversity and Environment : Remote Sensing and Geographic Information System Perspective* (P.S. Roy, S. Singh and A.G. Toxopeus, eds.). Indian Institute of Remote Sensing, National Remote Sensing Agency, Dehra Dun, India. pp. 174-196.

Marak, T.T.C. (1998). *The elephant census report for Meghalaya 1998.* Wildlife Wing, Forest and Environment Department, Shillong, Meghalaya. 22 pp.

Marcot, B.G., A. Kumar, P.S. Roy, V.B. Sawarkar, A. Gupta and G. Talukdar (2001). Elephants and landscapes : an assessment for the Garo Hills of Meghalaya. *National Symposium on Elephant Conservation, Management and Research*, 16-20 December. Rajaji National Park, India (submitted).

Sunderraj, S.F.W., B.K. Mishra and A.J.T. Johsningh (1995). Elephant use of Rajaji-Corbett Forest Corridor, North-West India. *A week with Elephants : Proc. Intl. Seminar on the Conservation of Asian Elephants* (June, 1993). (J.C. Daniel and H. Datye, eds). Bombay Natural History Society/Oxford University Press. pp. 261-269.

Williams, A.C. and A.J.T. Johnsingh (1996). Threatened elephant corridors in Garo Hills, North-East India. *Gajah*, **16** : 61-68.