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Dr Ashish Kumar worked extensively in the forests of Garo Hills, Meghalaya, India for his doctoral research from the Forest Research Institute, Dehradun, India before joining Ministry of Environment, Forest and Climate Change, Government of India. He has represented Ministry as Project Coordinator for various national level projects.

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WILDLIFE CONSERVATION IN FRAGMENTED TROPICAL FORESTS

A case of South*Garo*Hills, Meghalaya, North East India[1]

ASHISH KUMAR

BRUCE G. MARCOT

ROHITKUMAR PATEL

[1] *This book is based on the work done for a long term (1996-2005) research and application project entitled, 'Management of Forests in India for Biological Diversity and Forest Productivity - A New Perspective' by the Wildlife Insitute of India, an autonomous institute of the Ministry of Environment, Forest and Climate Change, Government of India, in collaboration with the USDA Forest Service and the State Forest Department, Meghalaya.*

Contents

PREFACE AND ACKNOWLEDGMENTS

This volume presents findings on, and implications for, wildlife conservation in the tropical forests in *Garo* Hills of Megahlaya state in the North East India. A companion volume presented the findings on forest fragmentation due to practice of slash and burn agriculture in the region. Both of the volumes summarizes work completed over more than a decade on characterizing conditions of tropical forests in the *Garo* Hills of western Meghalaya State of North East India. This is essentially a compilation and compendium of findings presented in a Ph.D. Thesis of Ashish Kumar (Kumar 2005) and in related studies on forest fragmentation (Kumar et al. 2000, 2006a, 2008), forest management (Kumar et al. 2002), botanical diversity (Kumar et al. 2006b), and insights into habitat use and conservation of tigers (Kumar and Marcot 2010) and Asian elephants (Marcot et al. 2002, 2011). The work has led to innovations in suggestions for designing a protected area network for conservation planning in the region (Kumar et al. 2010).

We are grateful to a number of colleagues, advisors, reviewers, and co-workers over the course of these studies. Much of the early work was hosted by Wildlife Institute of India, Dehra Dun, under their program "Management of Forests in India for Biological Diversity and Forest Productivity" in collaboration with the United States Forest Service, and we gratefully acknowledge their support for our work in Garo Hills (Kumar et al. 2002). We also gratefully acknowledge support from the State Forest Department of Meghalaya; the Indian Institute of Remote Sensing, Dehra Dun; and the National Remote Sensing Agency, Hyderabad.

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1. LANDSCAPE, FORESTANDFRAGMENTATION: RECAP

We present an ecological assessment of a landscape spanning over 2459 km^2 area in the South *Garo* Hills of Meghalaya state in North East India (**Fig. 1.1**). The term 'landscape' in this volume denotes area encompassing entire South *Garo* Hills district and adjoining Tura Ridge area in the East and West *Garo* Hills districts. This landscape is a part of the *Garo* Hills representing the western-most hill ranges of Meghalaya state in northeast India. There are four out of five protected areas of state situated within the landscape, which offers excellent prospects of conserving native forest and associated biodiversity of the region. These protected areas sustain considerable portion of biological and cultural elements of ecological significance. The majority of land in these protected areas and surrounding unprotected areas are characterised by extremely rugged terrain, undulating hill ranges with deep gorges and several rivers/streams flowing across the north-south gradient.

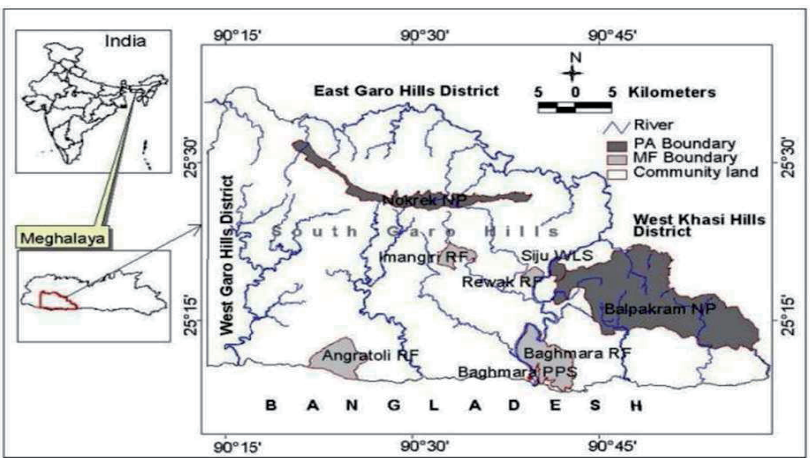

Fig. 1.1 Study area map with a geographical location within India and Meghalaya. Used with the permission of Current Science.*(PA = Protected Areas, NP = National Park, WLS = Wildlife Sanctuary, MF = Managed Forests, RF = Reserved Forests and PPS = Pitcher Plant Sanctuary)*

The land tenure system and land holding pattern in the *Garo* hills quite different from other parts of the country, since the majority of land base belongs to the native community. State government has control over 15% land, which is being managed as Protected Areas (PAs) and Reserved Forests (RFs). The shifting cultivation and unplanned land use activities have been recognised as major threats to the native biodiversity and natural wealth in this region. The objectives of the study were to (1) analyse landscape characteristics with special reference to forest fragmentation and evaluate the critical wildlife habitats; (2) assess diversity patterns and successional changes among tree communities in various forest landuse categories; and (3) develop models to identify wildlife area priorities for conservation and management targets.

In a companion volume, we presented the classification of the forest growth as tropical moist evergreen forests (14% of landscape), tropical semi-evergreen forests (26% of landscape) and tropical moist deciduous forests along with sal (*Shorea robusta*) plantations/forests (29% of landscape). The major landuse activities included habitation (10% of landscape), permanent agriculture (4% of landscape) and *Jhumming* (7% of landscape). Lower mean patch size and edge length of landuse patches suggested that fragmentation in the area is setting at its initial stages and the landscape still holds larger tracts of old forest cover. In recent decades, the increasing tendency of practising *Jhum* with shorter fallow period (3 years or less) consumed more and more forest tracts on regular basis.

The process of forest fragmentation was an outcome of prolonged practice of unplanned forestry activities, such as *Jhumming* and other associated developmental activities including road construction and mining. The developmental activities were comparatively slower in the region and absolute urban environment nowhere existed at the landscape. Like other parts of the *Garo* Hills, the use of land for residential and agricultural purposes was prominent in the landscape. Baghmara, the headquarter of South *Garo* Hills district is developing fast as township across the river Simsang and resembles semi-urban (or semi-rural) conditions, while rest of the landscape represented the rural environment. The old forest growth occupied a major portion of landscape and extensively used by the variety of wild animals.

The fragmentation analysis presented in the companion volume revealed that about 71% of landscape was under intact forest or low fragmentation level, while rest of the forested tract was under considerable influence of fragmentation. For management of some rare and secretive forest-dwelling wildlife such as gibbon and slow loris, conservation of "forest interior habitats" away from openings and edges is important. The seven corridors were identified as the major connectors between two successive PAs and referred to as the potential elements of Protected Area Network (PAN). The total area of corridors was 274 km^2, of which forests constitute 92%. The Elephant-Habitat Relationship analysis suggested that elephant densities are greater in landscapes with >40% evergreen, semievergreen, and moist deciduous forest cover, <30% *Jhum* (current *Jhum*<5%, abandoned *Jhum*<25%), <20% in high forest patchiness (caused by *Jhum*), village density <0.4 villages/km^2, <2% annual *Jhum* rate, <10% bamboo & young secondary forest.

About 1000 vascular plant species including more than 411 tree species were identified in the tropical forest ecosystem of this landscape. The frequency distribution of tree species suggested that most tree species had low frequency as would be expected in typical species-abundance distributions. *Artocararpus gomezians, Oroxylum indicum,* and *Rhus accuminata* had shown the most regular distribution (low abundance and high frequency) while *Shorea robusta, Boehmereahamiltoniana,* and *Saurauia nepaulensis* had shown the most clumped distribution (high abundance and low frequency) in various forest types. The diversity analysis revealed that the primary forests were the most tree-diverse, which was further confirmed through rarefaction analysis. Successional effects were examined on select tree species of wildlife and human uses, which revealed that middle aged secondary forests were very useful for both wildlife and human beings. One of the major food items, *Lepisanthes rubiginosa*, did not exist in seral stages and showed almost negligible importance in climax stage. Likewise *Artocarpus chaplasha* and *A. gomezianus* showed very little importance in all successional stages.

The elephant is a flagship and umbrella species of the region and conserving this species would entail the conservation of entire ecosystem including associated plant and animal species of conservation significance. Kumar *et al.* (2002) and Marcot *et al.* (2002 and 2011) provided a quantitative analysis of elephant-habitat-relationship for this landscape and precisely mapped the corridors and analysed the influences of increasing anthropogenic factors (settlements, road network and other developments) over landscape.

The landscape level analysis of the forests using Remote Sensing and Geographical Information System revealed that the Tropical Moist Evergreen Forest (TMEF) patches were mainly confined to the Nokrek and Balpakram areas in the relatively undisturbed forest. Most of the time such areas remained out of reach of society, hence could not be used for *Jhumming*by the native society. The Tropical Semi Evergreen Forest (TSEF) mainly buffered the TMEF and sometimes represented by very old *Jhum*, wherever their edges coincides with human settlements. A large belt of TSEF occurred in the south of Nokrek ridge, which spread between Imangiri village to the rewak village across river Simsang near Siju village. The TSEF areas formed the upper catchments Nareng, Bugi and Dareng rivers, while a few patches of TSEF in the central and southern portion of the landscape formed the middle and lower catchments of river Simsang. The Tropical Moist Deciduous Forest (TMDF) patches formed the mosaic of a large number of smaller sized patches, which are scattered all over the landscape in a matrix with the TSEF, land uses (habitation and agriculture) and non-forest vegetative patches. In the majority of cases, those represented the man-made forest types, which included the very old sal plantations.

In this volume, we have proposed a framework for potential Protected Area Network (PAN), which by extension may include the suggested corridors, forest patches within buffer zone and sacred groves as potential PAN elements. Overall findings and recommendations generated from the study could be used for landscapes scale conservation planning of wildlife in the tropical forests of the *Garo* Hills, Meghalaya, North East India.

2. WILDLIFE

2.1 Introduction

The State of Meghalaya contains some 5,538 species of vertebrates and invertebrates. This immense biological diversity (or biodiversity) is a significant proportion of the overall faunal diversity of India (ZSI, 1995). The ratio of numbers of invertebrate species to numbers of vertebrate species is about 5:1, although it is likely that many invertebrate species -- particularly arthropods and molluscs -- have yet to be discovered and scientifically described. To date, a total of 4,580 species of 2,094 genera of invertebrates have been recorded by ZSI (1995) from the state. Although the area of Meghalaya is less than one percent (1%) that of India, it is a home for more than 35% of the mammals and 50% of the birds of India (ZSI, 1995). A total of 958 species of 451 genera of vertebrates has been recorded from Meghalaya (**Fig. 2.1**).

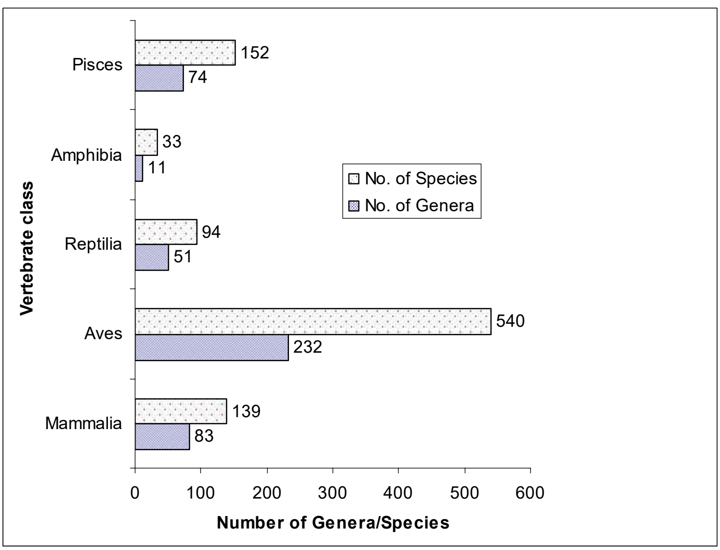

Fig. 2.1: Vertebrate fauna in Meghalaya (source: ZSI, 1995)

The *Garo* Hills cover 60% of the total forest area in Meghalaya. It is richly endowed by nature with some of the most exotic species of both flora and fauna. It is home to the largest number of Asian elephants in India, the Pitcher plant, the Himalayan panda or the Red panda, tigers, wild buffaloes, the only ape species found in India, the Hoolock Gibbon and various species of birds, reptiles, insects and other small mammals. *Garo* Hills is regarded as an ecological hotspot for biologists and zoologists. However, it is slowly degrading with the passage of time and developments taking place around it. Many of the lands here belong to the local communities that are engaged in logging, agriculture (*Jhum*) and also hunting. While a proposal for a major cement plant near Siju was shelved due to protest by environmental groups, there is a new proposal for a dam on the Simsang River which may include submergence of forest land if necessary. In the case of Balphakram tree cutting for fuel-wood is common while the lower slopes of the Tura range have degraded due to *Jhum* cultivation.

The *Garo* Hills consist of three districts namely East *Garo* Hills, West *Garo* Hills and South *Garo* Hills, which together constitute about one third of Meghalaya. The *Garo* Hills contain a rich faunal diversity with 859 vertebrate species recorded or expected (ZSI, 1995). The avifauna in the *Garo* Hills contributes about 60% of all vertebrate species found there, followed by fish, mammals, reptiles, and amphibians (**Fig. 2.2a**). There are a total of 85 mammal species in *Garo* Hills, which is 61% of the number of mammal species in all of Meghalaya. Rodents contribute 23% of all mammal species of the *Garo* Hills, followed by bats (Chiropters, 20%). Other mammalian groups such as insectivores, primates (apes and monkeys), canids, felids, bovids and viverids contribute less than 10% of the number of mammal species of the *Garo* Hills (**Fig. 2.2b**). The earliest detailed faunal assessment in *Garo* Hills was done in SijuCave by Kemp and Chopra (1924), who described various taxa (**Fig. 2.3**) and the cavernicolous (cave-adapted) animal life.

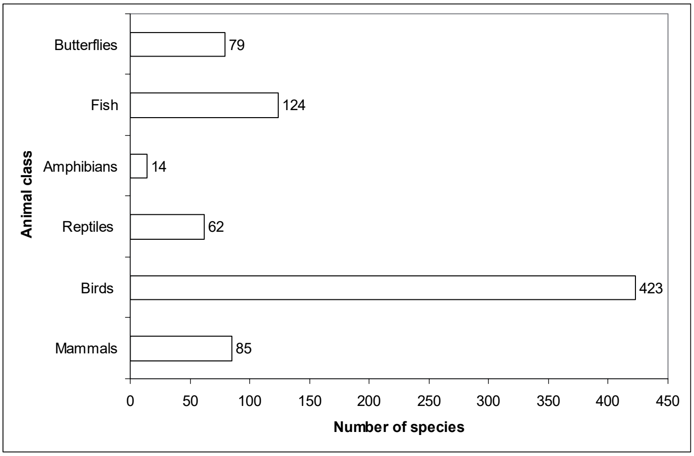

Fig. 2.2 a

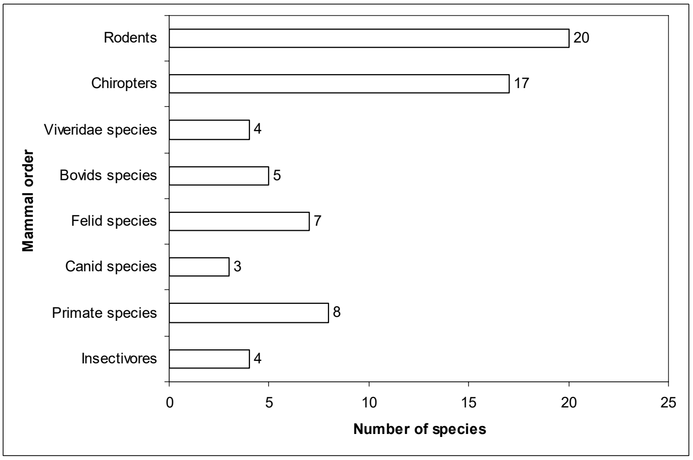

Fig. 2.2b

Fig. 2.2 a & b: Vertebrate fauna in *Garo* Hills (source: ZSI, 1995 for mammal and Fish; and Ghosh, 1984 for others)

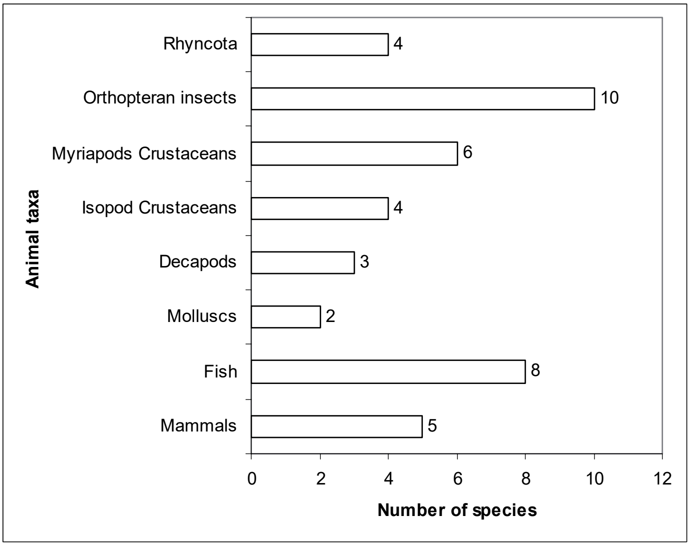

Figure 2.3: Fauna in the Siju cave (source: Kemp and Chopra, 1924)

A few ecological studies have been carried out in the adjacent northeast states of Arunachal Pradesh and Assam. The rest of northeast India, however, has remained largely unstudied mainly due to poor accessibility or underdeveloped transportation and communication infrastructures, although some authors have written on primates of Tripura (e.g., Gupta, 2000; Mukharjee, 1982) and northeast India (Srivastava, 1999). *Garo* Hills too, has been one of the least explored corners of northeast India in terms of ecological studies. Various state government departments including forest, agriculture, soil and water conservation, and ecodevelopment contributed such studies after statehood of Meghalaya was declared in 1972. In our present study, we collect this information and collate it with information we generated from other sources including interviews with local resident people and non -government organisations (NGOs) and our field research experience in the *Garo* Hills during 1997-2001. Most of the information we have on wildlife is for South *Garo* Hills, especially the Balpakram portion of South *Garo* Hills. Little information is available on wildlife of East *Garo* Hills and the plains of West *Garo* Hill.

2.1.1 Mammals

Ghosh and Biswas (1977) and Ghosh (1985) reported a number of mammalian species in the Balpakram portion of South *Garo* Hills. He recorded five species of primates *viz.* hoolock gibbon (*Bunopithecus hoolock*), rhesus macaque (*Macaca mulatta*), Assamese macaque (*Macaca assamensis*), capped langur (*Trachypithecuspileatus*) and slow loris (*Nycticebus coucang*) in the then Balpakram Wildlife Sanctuary (now National Park) with area of 120 km^2. Among the carnivores recorded there by Ghosh were tiger (*Panthera tigris*), leopard (*Panthera pardus*), jungle cat (*Felis chaus*), leopard cat *(Felis bengalensis*), wild dog (*Cuon alpinus*), large Indian civet (*Viverazibetha*), hog-badger (*Arctonyx collaris*), yellow-throated marten (*Martes flavigula*), Himalayan black bear (*Selenarctos thibetanus*) and jackals (*Canis aueius*). Other species he recorded were Indian bison (*Bos gaurus*), goral (*Nemorhaedus goral*), elephant (*Elephas maximus*), barking deer (*Muntiacus muntjak*), sambar (*Cervus unicolor*), porcupine (*Hystrix indica*) and Indian hare (*Lepus nigricollis*).

ZSI (1995) provided an inventory of 85 mammal species for the *Garo* Hills. Both of these studies reported only presence of mammal species and should be interpreted as a preliminary inventory of the larger-bodied mammals of the area, whereas Kumar and Rao (1985) had linked selected mammal species with broadly-defined habitat types (broad one) in the Balpakram area.

The report of an elephant census in the then proposed Balpakram Wildlife Sanctuary during 1981 also provided the approximate number and broad habitat-type associations of 20 mammal species as opportunistic count during their study on flora and fauna of the Balpakram National Park with the total area of 220 km^2 (Kumar and Rao 1985; **Table 2.1**). Evergreen forests in the interior hills, and limestone outcrop areas and grassland plateau form the major habitats for many native mammals in the Balpakram area (Kumar and Rao, 1985).

Table 2.1: Common wild mammals Balpakram area, South *Garo* Hills (1981)

Species	**Common Name**	**Habitat**	**Approx. No.**
Elephas maximus	Asian Elephant	EF (Evergreen Forest)	860
Panthera tigris	Tiger	EF at Lime stone	10
Panthera pardus	Leopard	Dense EF	7
Neofelis nebulosa	Clouded leopard	Dense EF	1
Felis bengalensis	Leopard cat	Dense EF	4
Felis Temmincki	Jungle cat	EF	6
Bos gaurus	India bison	EF near grassland	54
Bibos species	Mithun	EF near grassland	24
Bubalus bubalis	Wild buffalo	EF near grassland	2
Trachypithecus pileatus	Capped Langur	EF	193
Bunopithecus hoolock	Hoolock gibbon	EF	102
Selenarctasthibetanns	Himalayan black bear	EF	19
Sus scrofa	Wild pig	EF	102
Cervus unicolor	Sambar	All types of forest	79
Muntiacus muntjak	Barking deer	All types of forest	172
Cuon alpinus	Wild dog (Dhole)	EF	15
Capricornis sumatraensis	Serow	EF	23
Nycticebus coucang	Slow loris	EF	2
Petaurista candidatus	Flying squirrel	EF	21
Ratufa indica	Giant squirrel	EF	4
Source: SFD, 1981 and Kumar and Rao, 1985			

2.1.2 Birds

This study area, that is, South *Garo* Hills and adjoining Nokrek National Park and Biosphere Reserve, provides habitats for a large number of bird species but no systematic study of bird-habitat relations has been carried out in the *Garo* Hills. Ghosh (1984) provided a tentative list of 423 bird species in the *Garo* Hills, which was solely based on review of bird field guides coupled with few *in situ* observations. Kumar and Rao (1985) studied the quantitative ecology of selected bird species, in which they provided an imprecise estimate of abundance of nine bird species in the Balpakram National Park (220 km^2) (**Fig. 2.4**).

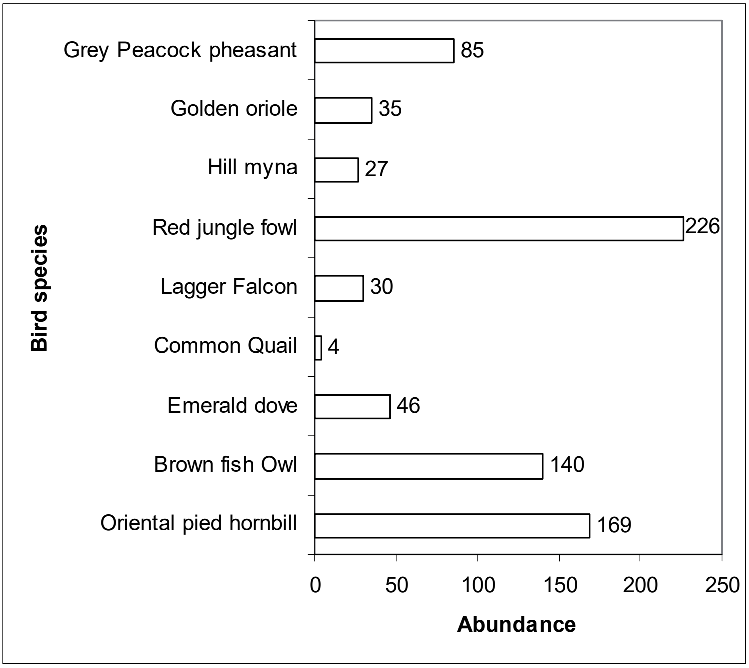

Figure 2.4: Abundance estimates of selected bird species of BNP (Source: Kumar and Rao, 1985)

A reliable inventory of birds in *Garo* Hills was conducted by the students of Wildlife Institute of India, Dehra Dun during a study tour in 1996-97. Manoj and Jayapal (personal communication, 1998) provided a checklist of selected species (see **Appendix 1** for detailed list) that the students observed in *Garo* Hills, most species of which were confirmed by us during field surveys for the present study. The students also provided information on habitat use by selected bird species, which was used to develop the bird-habitat-relationships of the region.

2.1.3 Reptiles

A total of 62 species of reptiles, including 8 species of turtles and tortoises, 18 species of lizards and 36 species of snakes, were reported from the *Garo* Hill regions by ZSI (1995).

2.1.4 Fishes

Fishes constitute a major natural resource used by local *Garo* people. A study conducted over seven years revealed 62 fish species from streams, rivers and water bodies of the area (Pillai and Yazdani, 1977). Of special interest is the finding of electric eels (*Electrophorus electricus*) in SimsangRiver (Ghosh, 1984). The detailed fish inventory is available in 'Fauna of Meghalaya' published by ZSI (1995).

2.1.5 Amphibians

Amphibians of *Garo* Hills include frogs. Out of a total of 40 amphibian species that ZSI (1995) reported from northeast India, 14 species (including several endemics) were from the *Garo* Hills region.

Endemic frogs of Garo Hills and Meghalaya

Four toad and frog species were reported by Pillai and Murhy (1989) to be endemic to Megahalya in general or to adjacent Khasi Hills, although there is no information on their presence in South *Garo* Hills per se:

i. *Garo* Hills Tree-Toad, *Pedostibes kempi* (family Bufonidae); rare species endemic to *Garo* Hills. Collected from Tura area of *Garo* Hills in 1919 - extremely rare. Expert tree climber, eats ants from tree trunks.

ii. *Bufoides meghalayana* (family Bufonidae), genus (and species) endemic to Meghalaya.

iii. *Leptobrachium hasselti* (family Pelobatidae), species endemic to Khasi Hills.

iv. *Hyla annectens* (family Hylidae), occurs in forests of Meghalaya. Calls loudly from tree canopy. Species endemic to Meghalaya.

2.1.6 Invertebrates

Of the invertebrates of *Garo* Hills, insects constitute the most diverse faunal component. Other numerous invertebrates of *Garo* Hills are annelids, molluscs, and arachnids. ZSI (1995) reported that almost 60% of the total aphid fauna in India is represented in the northeastern region and of these many species occur in *Garo* Hills. Some of the butterflies reported from South *Garo* Hills are given in **Table 2.2**. ZSI (1995) published a series of volumes on the invertebrate fauna of Meghalaya, ranging from primitive protozoan to more recently evolved species of insects.

Table 2.2: List of Butterflies in South *Garo* Hills (BNP = Balpakram National Park, RF = reserved forest)

Species	**Family**	**Common Name**	**Location**
Danus genutia	Danaidae	common tiger	Mahadeo
Danus chrysippus	Danaidae	plain tiger	Mahadeo
Euploeacore	Danaidae	common India crow	Mahadeo
Melanitis ledaismene	Satyridae	common evening brown	Mahadeo, Baghamara Road, Angratoli RF
Argynnis spp.	Nymphalidae	(no common name)	Mahadeo
Neptis spp.	Nymphalidae	(no common name)	Angaratoli RF
Precis atlites	Nymphalidae	grey pancy	BNP, Angratoli RF
Precis lemonias	Nymphalidae	lemon pency	Mahadeo, Siju, Baghmara RF
Papilio helenus	Papilionidae	red Helen	Baghmara-Siju-Tura
Papilio polytesromulus	Papilionidae	common mormon	Mahadeo. Siju, Baghamara
Papilio chaon	Papilionidae	yellow Helen	Baghamara-Tura
Troides Helena	Papilionidae	common birdwing	Baghamara-Tura
Catopsilia crocale	Papilionidae	common emigrant	Mahadeo, Baghamara-Tura
Eurema spp.	Papilionidae	(no common name)	Mahadeo, Baghamara-Tura
Ixias pyrene	Pieridae	yellow orange tip	Angratoli RF,
Pelopidas mathias	Hesperiidae	small banded swift	Tura
Udaspes folus	Hesperiidae	grass demon	Tura
Issoria sinha	Hesperiidae	Vagrant	Baghmara

2.2 Methods

We developed an information base on wildlife-habitat relationships (WHR) of selected species of mammals, birds, reptiles, fishes, amphibians, and invertebrates of *Garo* Hills. We used a variety of sources to develop the information base, including: (1) published and unpublished reports and articles, (2) survey data on wildlife from State Forest Department of Meghalaya, NGOs, and local wildlifers and researchers, and (3) interviews with local forest and wildlife staff personnel and local villagers. The animal species we included in the WHR database was based on Sawarkar and Marcot (2002). Methods for evaluating specific species groups or habitat relations included the following.

2.2.1 Mammal-habitat relations

The mammal species we included in the WHR database were tiger, macaques (rhesus, Assamese, stump-tailed and pig-tailed macaque), slow loris, serow, deer (sambar and barking deer), hoolock gibbon, squirrels (Malayan giant squirrel, hoary-bellied Himalayan squirrel and orangebellied Himalayan squirrel), capped langur, Indian bison, Himalayan yellow throated marten, wild pig, bats in general, Himalayan black bear, porcupine, civets (large, small and Himalayan palm civets) and Asian elephant. The local names of these species were used to gather the information on their habitat relations through interviewing local wildlife staff and villagers. The questions regarding local distribution, habits and use for habitats of selected species were asked while conducting interviews (Kumar *et al.* 2002).

2.2.3 Mammal-tree relations

During the background project (WII-USDA Forest Service collaborative project, 1996-2005; Kumar *et al.* 2002), a list of the scientific and *Garo* language names of 150 locally-occurring tree species (see **Appendix 2**) was used during interviews with local forest guards, foresters and permanently resident people, to help determine how selected mammal species used specific tree species as food sources. During the interviews, the interviewees identified which of the 150 tree species were used as food sources for each of the selected mammal species or group of species (macaques, deer, bats, civets). Once the forest staff and other locally resident people jointly agreed on use of a given tree species as a food item for a given mammal species or species group, the edible parts of the tree were identified and recorded, using the following list:

- B = Bark
- F = Fruit
- Fl = Flower
- S = Shoots
- Y = Young
- Blank = not used or information not available

Also, some of the favourite grass species were recorded along with tree species because grasses constitute a major part of some animals' diet.

2.2.4 Bird-habitat relations

We used inventories of selected birds conducted by Manoj and Jayapal (personal communication) to determine bird-habitat relationships.

2.3 Results

In this section, we present results of information on wildlife-habitat relationships in the form of individual species accounts. Local names refer to animal names in the *Garo* language.

Additional, specific information on mammal-tree relations, and bird-habitat relations follow the species accounts below.

2.3.1 Mammal-habitat relations

2.3.1.1 Tiger (***Panthera tigris***)

Local name**:** Matcha.

Prey species are sambar, barking deer, wild pig, Indian bison, wild pig, hare, goat, fowl, langur, hoolock, macaques and other species.

Local distribution**:** Forests that provide suitable habitat for tigers occur near villages in the Balpakram area, the Sinaru area, and near Agal-chongoppa in the way of Rongcheng from Balpakram plateau, and include forests near the villages of Pindengru, Maogipeng, Penda, Marakabari, Pusulchiring, Deoban area, Dogepchiring, Teptepa area, Ailatoli area, Maheshkola, Bellibari, Narangbari, Sochetchiring, Rongdi-bisik, Nowa chiring, Ronsu-agal, Chutmang, Ampangiri, Hatitia, Passgaon, Bonbera, Nadankol, Atambing, Rongsu, and Rewak villages.

Habitat**:** Dense Primary Forest, Bamboo forest, Grassland.

State Forest Department of Meghalaya conducted a tiger census during 1992-93. The census covered 9676 km^2 area (43%) of Meghalaya, although there is no published information on how the census was conducted and how the census routes and areas were chosen. The total number of tigers counted in the Meghalaya tiger census was 63, of which 34 (54% of total in Meghalaya) were present in the *Garo* Hills. The densest population was found in district South *Garo* Hills, which consists of only 16% of census area with 27% of all tigers counted (**Fig. 2.5**).

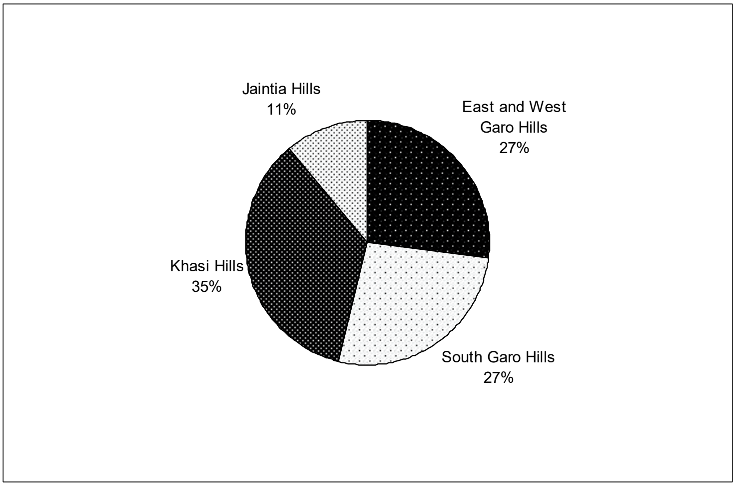

Fig. 2.5: Tiger population in Meghalaya (source: State Forest Department, Meghalaya)

***<u>2.3.1.2 Macaques</u>* (*Macaca mulatta, Macaca arctoides, Macaca assamensis, Macaca nemestrina*)**

***Local names*:** Rhesus (Makri-chiran), Assamese (Makri-ugong), Stump-tailed (Makri-dalgappa) & Pig-tailed Macaques.

Local distribution: Rhesus macaque occurs throughout *Garo* Hills (or study area). Assamese macaque is more difficult to see but is said to be abundant in undisturbed forest areas. Stump-tailed and pig-tailed macaques are very rare in South *Garo* Hills and are mainly confined to the interior of BNP.

***Habitat*:** Rhesus macaque is found in every type of forest and in villages near forests, usually large groups also found near river plains in valleys. Assamese macaque can be seen in dense forests in limestone areas of Balpakram National Park and Siju Wildlife Sanctuary. Stump-tailed and pig-tailed macaques use undisturbed primary forest (mainly Evergreen and sometimes Semi-evergreen forests), occurring very rarely near human habitations and open areas.

2.3.1.3 Slow loris **(*Nycticebus coucang*)**

Local name**:** Gilbe

Local distribution**:** In the old forest growth near villages namely Hatitia, Teptepa, Kanai, Rompa, Rongmenchiring, Passgaon, Ranthangri, Rongcheng, Siju, Rewak, Rongsu, Chimitab, Maheshkola, Shooling, Pindengru, Maogipeng, Chutmang and other villages.

Habitat**:** Sometimes seen near 3-4 years old *Jhum* (slash-and-burn shifting cultivation) fallows, as reported by local people, but likely more closely associated with older forests including dense primary forest and riparian forests.

2.3.1.4 Serow **(*Capricornis sumatraensis*)**

Local name**:** Matrong

Local distribution**:** Forests and Gorge area near Rompa Dare ("Dare" means gorge in the *Garo* language), Chidokthak Dare, Hamdangi Dare, Kundulgop Dare, Rongdibisek Dare, Nowa Dare, Maogapeng Dare, Sprichiring Dare, Ranthangsora chiring Dare, Deoban Dare, Kanai Dare, Chutnmang Dare. *Dare* (Gorges) are named after villages where they occur.

Habitat**:** Thickly wooded gorges with boulders, in hilly terrain.

2.3.1.5 Sambar **(*Cervus unicolor*) and *Barking deer* (*Muntiacus muntjak*)**

Local names: Sambar (Matchok) and Barking deer (Balgitchok)

Local distribution**:** Throughout *Garo* Hills.

Habitat: Serow visit new *Jhums* and cultivated fields frequently to forage, as well as grasslands and all types of forests except the forests in limestone areas.

***2.3.1.6 Hoolock gibbon* (*Bunopithecus hoolock*)**

***Local Name*:** Huru,

***Local distribution*:** Forest near villages or streams such as Rokpa chiring/Rompachiring (Chiring means stream), Hamdangi chiring, Narang chiring, Nongal gat, Kundulgop, Rongchun area, Panda area, Pindengru, Nawa chiring, Chutmang, Rongcheng, Rongsu, Chimitab, Shooling, Siju, Rewak, Balpakram area, Maheshkola, Bellibari area, Kanai-Rongtherasrea area, Rongra area, Taidang area, Kunchung area, Dambuk-Jongkol area, Teptepa.

Group size varies from 2 to 6 individuals (A. Kumar, personal observation; this observation confirms the findings of Alfred and Sati, 1990).

***Habitat*:** Undisturbed old primary forest with closed tree canopies. Sometimes seen in the dense forests with tall trees near villages in the interiors hills.

Alfred and Sati (1990) surveyed 200 localities (covering 5075 km^2 area of South and West *Garo* Hills districts), which were reported as gibbon habitats, and observed 130 gibbons in only 32 of these localities (812 km^2). Out of these 130 (126 in groups+ 4 floating individuals) gibbons about two-thirds were adult (> 7 years of age). The populations of sub-adults (4-7 years), juveniles (2-4 years) and infants (< 2 years) were 6%, 12% and 15%, respectively (**Table 2.3**).

Table 2.3: Population status of Gibbons in the South and part of the West *Garo* Hills districts

<table>
<tr><th colspan="3">Parameter</th><th colspan="2">Estimate</th><th>% of total individuals(N=126)</th></tr>
<tr><td colspan="3">Number of localities</td><td colspan="2">32</td><td>---</td></tr>
<tr><td colspan="3">Area surveyed (km^2)</td><td colspan="2">812</td><td>---</td></tr>
<tr><td colspan="3">Territory size (km^2)</td><td colspan="2">14</td><td>---</td></tr>
<tr><td colspan="3">Number of groups</td><td colspan="2">42</td><td>---</td></tr>
<tr><td rowspan="6">Number of individuals</td><td rowspan="2">Adult</td><td>Male</td><td>42</td><td rowspan="2">85</td><td>33</td></tr>
<tr><td>Female</td><td>43</td><td>33</td></tr>
<tr><td rowspan="2">Sub-adult</td><td>Male</td><td>6</td><td rowspan="2">11</td><td>4</td></tr>
<tr><td>Female</td><td>5</td><td>2</td></tr>
<tr><td colspan="2">Juvenile</td><td colspan="2">15</td><td>12</td></tr>
<tr><td colspan="2">Infants</td><td colspan="2">19</td><td>15</td></tr>
<tr><td colspan="3">Total</td><td colspan="2">130 (126 + 4 floating individuals)</td><td></td></tr>
<tr><td colspan="6">Source: Alfred and Sati, 1990</td></tr>
</table>

Group size reported by Alfred and Sati (1990) varied from two to six individuals per group. They observed an average of three groups and nine individuals of gibbons per km^2. Only one group was observed with 6 individuals. Most groups had 3 individuals, and only one group had 6 individuals. Some 50% of all gibbons were reported with 21 groups each with 3 individuals (**Table 2.4**).

Table 2.4: **Hoolock gibbon group counts**

Group size	Frequency	No. of individuals
6	1	6
5	3	15
4	4	16
3	21	63
2	13	26
Total		**126**
Source: Alfred and Sati, 1990		

Territory size of groups varied from 14 ha to 55 ha (Alfred and Sati, 1990), whereas a study in Tripura (India) reported far larger territory sizes of 300-400 ha (**Table 2.5**).

Table 2.5: Territory size and density of Hoolock gibbons compared with other studies

Location		Assam (India)	Tripura (India)	Sylhet (Bangla Desh)	West *Garo* Hills (India)
Area surveyed (km^2)		8	11	162	812
Territory size (ha)	Range	18-30	300-400	3.2-?	14-55
	Mean	22	300	23	31
No. of groups		7	6	6	42
Total gibbons		26	16	21	130
Av. group size		3.4	3.2	3.5	3
Group per km^2		2.2	0.55	4.4	3.01
Gibbons per km^2		7.55	1.45	5.25	9.03
Source		*Tilson (1979)*	*Mukharjee (1982)*	*Gittins and Tilson, (1984)*	*Alfred & Sati (1990)*

Out of 200 localities studied by Alfred and Sati (1990) as potential gibbon habitats (presumed based on forest cover or confirmed by local residents as having gibbons present), gibbons were observed at only 32 localities,. The other 168 localities had similar vegetation types and the local villagers had confirmed the existence of gibbons during the late 1970s and early 1980s, but these sites lacked continuous dense forest canopy, which is a critical part of hoolock gibbon habitat. The area of 32 localities with observed gibbon varied from 300 to 41,500 ha with forest area of 14 to 277 ha, although no information was given on how such areas were delineated. Approximately 75% of all gibbons seen were observed near village sacred forests, where cultivated fruit trees such as mango, jackfruit, orange and guava were grown. The 32 localities also were surrounded by forested hills with potentially suitable gibbon forest habitat (Alfred and Sati, 1990).

According to Hazarika (1988), *Jhumming* had destroyed about 550 km^2 forest area per year in Meghalaya. The population of gibbons in the *Garo* Hills region was found to be under great threat at that time and Alfred and Sati suggested the need for immediate attention for proper conservation in those 32 localities. Now, almost a decade after of Alfred and Sati's survey, it is timely to re-inspect the gibbon population in those 32 localities and assess the existing status of gibbons. This is vital for the preparing proper conservation strategies for protecting gibbons and their habitats in the region.

2.3.1.7 Squirrels (*Ratufa bicolor, Dremomys lokriah* and *Callosciurus pygerythrus*)

Local name: Math (Malayan giant squirrel, Hoary bellied Himalayan squirrel and orange bellied squirrel)

***Local distribution*:** Rompa-bisek, Limestone area, Deoban, Kundulgop, Rongcheng, Nowa area, Chimitab, Siju and Shooling area.

Habitat: Higher reaches of tall trees in denser forests, very rarely on ground.

2.3.1.8 Capped langur (***Trachypithecus pileatus***)

Local name: Rangol

***Local distribution*:** Forest area near villages including Rompa chiring, Hamdangi chiring, Ronthersea, Pindengru, Narang chiring, Maogipeng, Narangbari area, chimitab, Taidang, Nowa, Rongcheng, Kundulgop, Rangthangsora, chiring, Deoban area, Kala Paharh (Paharh means Hill), area, Rongsu area, Penda area, Maheshkola, Shooling, Siju, Kanai, Marakabari, Dogepchiring, Teptepa, Chutmang.

Habitat: Undisturbed primary forests with dense canopied trees.

2.3.1.9 Indian bison (***Bos gaurus***)

Local name: Matle

***Local distribution*:** Forest near villages or locations such as Balpakram, Sochet chiring, Atambing, Pindengru, Nowa chiring, Maogipeng, Penda area (mainly during May-June), Hamdangi area, Roncheng, Chimitab.

Habitat: Grasslands, Bamboo area, Secondary Forests in the interior of BNP.

2.3.1.10 Himalayan Yellow-throated martin (***Martes flavigula***)

***Local name*:** Gredong

***Local distribution*:** In the forests near villages including New Rongmenchiring, Kundulgop, Deoban, Rompa chiring, Rongcheng, Nowa area, Chtmang, Rongsu, Siju, Shooling, Narangbari, Hamdangi, Pindengru, Narang chiring and other such areas.

Habitat: Occurs on trees mainly in old forests. Sometimes seen near roads in relatively undisturbed areas.

***2.3.1.11 Wild pig* (*Sus scrofa*)**

Local name: Wak-burung

Local distribution: Throughout study area.

Habitat: In the surroundings of limestone areas nearby habitation, very old secondary forests. Visits *Jhum* fields regularly.

***2.3.1.12 Bats* (*Cynopterus sphinx* and other speccies)**

Local name: Dobak for all species of bats

Local distribution: Nongalgat, Rompa dare, Kundulgop, Rongthrasea Dare, Siju Dobak-kol, Nowa Dare, Rongdi-bisek Dare, Maogipeng Dare, Chutmang, Ranghtansora Dare, Kanai Dare, Deoban Dare, Spruchiring Dare, Chidokthak Dare. Probably more widely distributed throughout the *Garo* Hills.

Habitat: Caves, trees near caves, Ficus trees. Sometimes found on abandoned man-made structures such as ceilings of bridges, culverts and old buildings.

***2.3.1.13 Himalayan black bear* (*Selenarctas thibetanus*)**

Local name: Makbil-bak

Local distribution: Old forest near villages and places including Rokpa chiring area, Rongtherasea, Hamdangi, Deoban area, Kundulgop, NBalpakram plateau, Nowa area, Roncheng, Chimitab, Chutmang, Kunchung, Maogapeng, Rangthansora, Rompa, Kanai.

Habitat: Old *Jhum* fallows, limestone areas in dense evergreen forests, visits new *Jhum* areas for paddy, potato and tapioca. Also feeds on rotten meat of dead animals, honey and insects. During rains builds bed on tree branches and leaves to rest and sleep.

***<u>2.3.1.14 Porcupine</u>* (*Hystrix indica*)**

Local name: Okchigipu

***Local distribution*:** Forest near villages including Rompa ading, Hatitia, Dulbeta, Teptepa, Ranthagsora, Chimitab, Deoban, Kundulgop, Balpakram plateau, Maheshkola, Atambing, Siju, Rongsu, Rongcheng, Nowa, Ampangiri, Rewak.

Habitat: Small holes in rocks, burrows in soil.

***<u>2.3.1.15 Civets</u>* (*Vivera zibetha* and other species)**

Local name: Matchuri

***Local distribution*:** Forest near villages including Hatitaia, Rompa, Kanai, Teptepa, Rangthansora, Passgaon, Balpakram plaeau, Rongcheng, Maogapeng, Chimitab, Rongsu, Siju, Rongra, Shooling, Deoban, Kundulgop, Chinaru.

Habitat: Primary and secondary forests. Sometimes seen nearby habitation and roadsides during evening time.

***2.3.1.16 Elephant* (*Elephas maximus*)**

Local Name: Mongma

***Local distribution*:** Higher densities inside BNP including Kanai, Rongra, Siju, Gaobari, Teptepa, Pindengru, Balpakram, Rongcheng nowa, Narang chiring, Kundulgop, Deoban, Rangthansora chiring, Dogeochiring, Shooling, Chimitab, and Chutmang. Also, the Nokrek area, in and around the Nokrek National Park (NNP). Elephant can be seen roaming all over the *Garo* Hills.

Habitat: Primary forests. Visit secondary forests and habitation during Jan-Feb. Seen on hill slopes, valleys. During Jan-Feb seen along streams for water.

IUCN's Species Survival Commission's Asian Elephant Specialist Group, during the year 2000 estimated a population of *c.* 35,000 to 51,000 Asian elephants in world, with *ca.*19,100 to 29,450 in India and *ca.*7,200 to 11, 300 in Northeast India (WWF, 1996).

A total of 2872 elephants were recorded in the Meghalaya, of which 1850 elephants were found in the *Garo* Hills during a 1993 census (**Table 2.6**). Out of these 1850 elephants, 1460 individuals were recorded through direct sighting and 390 were estimated on the basis of indirect evidences. The population estimate of elephants in the South *Garo* Hills district was 910, with 591 of these occurring the BalpakramNational Park. Kumar and Rao (1985) reported 860 elephants in Balpakram National Park based on elephant census data from State Forest Department taken during 1981. Numbers of elephants sighted during the 1993 census, by age, sex, and tusker class, are presented in **Table 2.6**.

Table 2.6: Elephant Population structure in *Garo* Hills (1993)

Elephant group	Male		Female	Unsexed	Total
	Tusker	Makna			
Adult	164	31	432	189	716
sub-adult	96	13	84	208	401
Calf	9		2	204	215
Total	313		518	601	1432
Solitary	18	2			28
	20				
Maljuria	6	2			
	8				
Total Direct sighting					1460
Indirect Sighting					390
Grand total					**1850**
Source: SFD, Meghalaya, 1993					

Elephants were censused in *Garo* Hills in 1993 over 5909 km^2 (72% of the entire *Garo* Hills). Of this, about 2636 km^2 land is under private forest on which 307 elephants were found, whereas the rest of 1153 individuals were found over the remaining 3273 km^2 area which includes government owned forests in the form of Protected Areas and Reserved Forests and their adjoining forest land (**Table 2.7**).

Table 2.7: Elephant bearing areas in the *Garo* Hills

S. No.	Name of the forests	Location	Approximate area of Forests (sq. km.)	No. of Elephants
A.	Government owned Forests and adjoining forest land			
1.	Balpakram NP	South GH	538	591
2.	Nokrek NP	West GH and part of East GH	516	161
3.	Rewak-emangiri RF	South GH	657	172
4.	Angratoli RF	South GH	307	98
5.	Dibru Hills RF	West GH	180	27
6.	Songsak RF	East GH	434	51
7.	Dambu-Darungiri RF	East GH	398	17
8.	Dhima-Rajasimla-Ildek RF	East GH	243	36
	Total		*3273*	*1153*
B.	**Purely unclassed Private Forests**			
1.	Rongchugre-Chesingre RF	South GH	1069	87
2.	Moranga RF	South GH	279	4
3.	Rangira-damalgre RF	West GH	586	83
4.	Kherapera-Dana-Adugre- Rongmagre	West GH	702	133
		Total	*2636*	*307*
		GRAND TOTAL	**5909**	**1460**
Source: SFD, Meghalaya, 1993				

According to Gogoi and Chowdhary (1982), the proposed Balpakram wildlife sanctuary (292 km^2) and its buffer zone (292 km^2) harboured 580 (including three solitary individuals) and 280 elephants, respectively (**Table 2.8**). The ratios among adults, sub-adults and calves in the total census area and the proposed Balpakram Sanctuary are 3.14: 1.57: 1 and 2.87: 1.73: 1, respectively.

Table 2.8:Elephant population in 1981 in proposed Balpakram Wildlife Sanctuary and its surroundings

Population structure	Proposed Balpakram WLS	Buffer zone	Total Census Area
Adult	296+3 solitary	115	471
Sub-adult	178	58	236
Calf	103	47	150
Total	577+3=580	280	860
Source: Gogoi and Chowdhary, 1982			

According to IUCN's Species Survival Commission's Asian Elephant Specialist Group (WWF, 1996), "the population of elephants in *Garo* Hills i.e. West Meghalaya is probably the most threatened population of its size throughout the entire range of the Asian elephant". The 1993 elephant census estimated the population of elephants in *Garo* Hills to be 1,850 elephants (SFD, 1993). The latest census, in 1998, however, revealed only 1,306 elephants in *Garo* Hills; this is about 71% of the total elephant population of Meghalaya (Marak, 1998). In *Garo* Hills, there appears to be a decline in the elephant population of about 30% over a five-year period, although it is unclear whether this decline in censused numbers reflects true population trend or differences in census methods. However, Marak (1998) reported that the death of 46 elephants was due to both natural and unnatural causes during 1994 to 1999, of which poaching accounted for 46% of the cases.

2.3.2 Mammal-tree relations

Trees are an integral part of forest wildlife habitats. Local environmental and anthropogenic factors affect the distribution of various tree species. Tree species are distributed according to environmental factors and also comprise forest and woodland vegetation communities. Trees also significantly provide wildlife with food, shelter and cover. Kumar (2002 and 2006b) describes the distribution of various tree species in among forest types and habitats.

Out of a total of 150 tree species identified in *Garo* Hills, the selected mammal species used 56 species (**Fig. 2.7**). Macaques (rhesus, Assamese, pig-tailed and stump-tailed macaques), slow loris, serow and deer (sambar and barking deer) had a wide range of food used for tree species by consuming various body parts of 28, 27, 25 and 25 tree species, respectively (**Appendix 2**). Squirrels, hoolock and capped langur had the next most diverse use of trees, feeding on 21, 20 and 20 tree species, respectively.

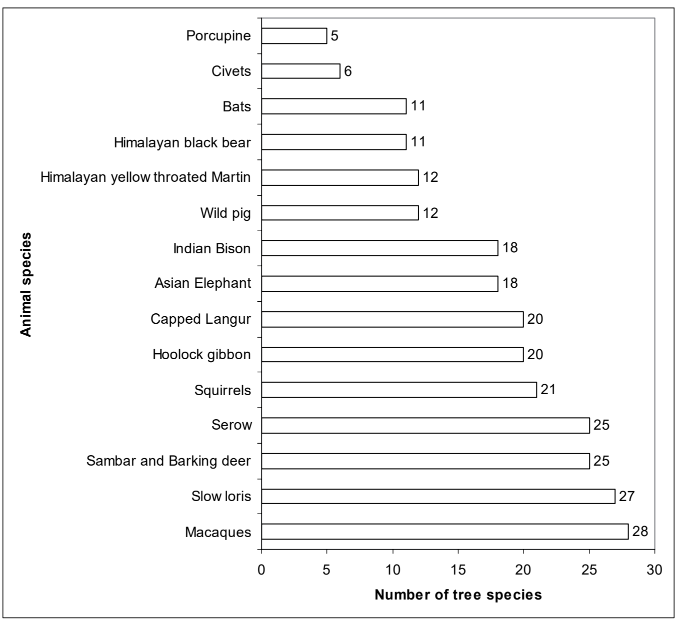

Fig. 2.7: Selected mammals*Vs*. tree species (no) in the study area (source: this study)

The *Grewia microcos, Artocarpus chama, Syzygium cumini, Lapisanthusrubiginosa, Artocarpus gomezianus, Ficus semicordata* and *Lannea grandis* are the tree species used by the most number of the 15 mammal species assessed. Ten or more wildlife species consume fruits, leaves, flowers, or bark of these tree species. All 15 selected mammal species use Grewia microcos as food. The fruits of this tree species are also used by many other mammals and bird species of Garo Hills. The interviews conducted suggested that there were 16 tree species that are used as food sources by only one of the mammal species out of the set of 15 assessed here, 6 tree species are used by 2 mammal species, and 6 tree species are used by 3 mammal species (**Appendix 2**).

The trees *Arundinella bengalensis, Neyraudia reymendiana, Calamus sp.,* leaves and fruits of *Trema orientalis, Bauhinia purpurea, Rhus javanica, Dillenia indica, D. pentagyna, Artocarpus chaplasha, Sterculia roxburghii, Stereospermum chelonoides* and *Litsea polyantha* and many species of wild banana and bamboo were the major food items of elephants. Elephants visited nearby villages and jhum fields during the dry season in search of food. The jhum and cash crops of tapioca, sweet potato, pineapple, banana and other cultivated plants were the preferred food of elephants. Considerable damage was done to jhum fields and horticultural bagans (gardens around homes or villages) by elephant herd raids.

Sambar and barking deer used thick undergrowth and sometimes also were seen in open areas, in jhum fields and on roadsides. The fruits of *Dillenia indica, Olea dentata, Emblica officinalis, Semicarpus anacardium, Spondius pinnata, Terminalia bellirica, T. chebula, Vitex peduncularis, Solanum sp.* and *Convolvulaceae* climbers along with sweet potato and some crop plants in the jhums were used food items of sambar and barking deer (Kumar and Rao, 1985).

Large herbivores including Indian bison and wild buffalo were confined to the grasslands of Balpakram plateau and in the nearby evergreen and mixed evergreen patches of undisturbed forests. The grass species consumed by these animals were *Alloteropsis semialata, Arundinella bengalensis, Centotheca* *lappacea, Cymbopogon khasianum, Echinochloa colonum* and *Ischaemum geobelli*.

Hoolock gibbons were mostly confined to undisturbed evergreen forest with tall and contiguous canopied trees. Hoolock generally ate fleshy fruits of *Ficus, Spondiuspinnata, Garcinia cowa, Terminalia bellirica* and *T. chebula*.

2.3.3 Bird-habitat relations

Manoj and Jayapal (personal communication, 1998) provided a checklist of 184 bird species from BNP and its surrounding areas. Manoj and Jayapal also described the habitats of 110 of these species (**Appendix 2**). They also reported that 26 bird species were restricted to primary forests, and a total of 51 bird species used primary forest habitat and at least one other habitat. The species restricted to, or that use, primary forest may be of focal conservation interest, because the conversion of old primary forests to secondary forest may greatly reduce available habitat of these specialist species.

Manoj and Jayapal also reported that 55 bird species were associated with secondary forests of BNP, of which 18 bird species were restricted to secondary forests only. Out of 36 birds that Manoj and Jayapal recorded from *Jhum* areas, 10 were completely restricted to *Jhum* patches, an additional bird species we observed in the BNP area (during March-April 1998) that was not included in Manoj and Jayapal's list was Large Niltava (*Niltava grandis*), seen by us in secondary forest. Additionally, we observed Fairy Bluebird in secondary forest, and Large-billed (Jungle) Crow (*Corvus macrorhynchos*), White-bellied Yuhina (*Yuhina zantholeuca*), Peacock pheasant, Kalij pheasant (*Lophura leucomelanos*), and Pale-capped (Purple Wood) Pigeon (*Columba punicea*) on the slopes of Balpakram Plateau. We also confirmed presence in BNP of other bird species reported by Manoj and Jayapal.

2.4 Discussion

Here we present nearly all the available literature collected by several agencies and individuals on faunal diversity of the region. The researchers and managers did several surveys, inventories and research studies using various methods and field techniques, which were popular in particular timeframe. We observed some uncertainty of some of the findings and the variation in methods used while scanning these studies. One example is the elephant census studies, which combined information from field observations with local interviews of villagers to determine numbers of elephants. Such methods result in some uncertainty of total numbers, double-counting elephants, use of sign (e.g., tracks) in making counts, reliability of interviewees' observations, etc. In this example, it was not possible to calculate how errors might combine, nor to calculate confidence intervals of elephant population estimates.

Information presented here is based on our direct observations in *Garo* Hills and largely on information available from various published and unpublished research papers, official documents, elephant census results, work of local NGOs, interviews with individuals, and observations from several visiting researchers. Zoological Survey of India, Shillong was also the source of intensive inventories of the faunal resources of *Garo* Hills. However, much information and research on the ecology of animals are lacking in the *Garo* Hills. *Garo* Hills harbours more than 600 vertebrate animal species, which is a significant fraction of the total of 958 animal species in Meghalaya.

Information, we provide here, is from many sources, including inventories, surveys, and research. In most cases, the ecological relationship of animals with their habitat is not available. Manoj and Jayapal (person communication) suggested a few birds from broad habitats including primary forests, secondary forests, shifting cultivation (*Jhum*) area and the Balpakram plateau area. Hopefully, such initial studies could serve as a prelude to more extensive wildlife inventories and research projects.

We summarize surveys and population estimates of tiger (Kumar and Marcot 2010), elephant and hollock gibbon done by state forest department, and rates of elephant mortality reported by the wildlife divisions of *Garo* Hills. We describe wildlife-habitat relationships of selected mammal and bird species, including specifically elephants (will be discussed in length in following chapters). Local villagers and field staff were interviewed as sources of information on species-habitat relationships. Information on mammal species' use of tree species and tree parts suggests that the *Grewia microcos, Artocarpus chama, Syzygium cumini, Lapisanthus rubiginosa, Artocarpus gomezianus, Ficus semicordata* and *Lannea grandis* are the most used tree species out of 150 tree species assessed for *Garo* Hills. *Grewia microcos* is the common food source for all 15 mammals species that we specifically evaluated. The fruits of this tree species are also preferred by many other mammals and bird species in *Garo* Hills.

Information on bird-habitat relationships includes a list of 184 bird species observed in *Garo* Hills, with habitat relationships shown for 110 of these species. Twenty-six bird species are restricted to primary forests, although a total of 51 species use primary forest habitat and other habitats. Secondary forests form important habitats for many bird species. Out of 36 birds recorded from *Jhum* areas, 10 are completely restricted to *Jhum* patches only. Out of 36 bird species recorded from Balpakram plateau, 10 species were not seen anywhere else in *Garo* Hills.

We realize the urgent need of field inventories by habitat types of all taxonomic groups of vertebrate and invertebrate fauna of the region. The autecological studies of wildlife species, their life histories including population status and trend especially for endemics, habitat specialists and rare species are very important for helping set proper management goals and for aiding conservation planning of wildlife.

We also suggest initiating some studies to assess the use of key environment correlates for wildlife species of conservation importance especially for species closely associated with old primary forests. This will help develop our understanding of wildlife habitat relationships and, in particular, which elements of old forests could be provided in various portions of the landscape such as habitat corridors, recovered *Jhum* fields, protected area buffers, and reserved forests, to help provide for old-forest wildlife. Likewise, understanding key ecological functions, especially of keystone species is vital for their management and these should be included in decision making for wildlife management and conservation planning.

3. ELEPHANT HABITAT RELATIONS

3.1 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., 2011). 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.

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, to determine 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. Our results could be used to craft new management guidelines for testing how best to maintain or restore habitat conditions for elephants of the area.

3.2 Methods

We used elephant census results from 1993 (Office of Divisional Forest Office, East and West *Garo* Hills Wildlife Division, Tura, Meghalaya) and 1997-98 (Marak 1998) to calculate elephant crude densities and percent change in densities between the two periods, in each of the 9 census zones of the region (**Fig. 3.1**). We calculated percent change in elephant crude density, for each elephant census zone, as number of elephants counted in 1997-97 minus counts in 1993, divided by counts in 1993. In all, we used 5 response variables (**Appendix3**). **Appendix 4** lists the elephant densities.

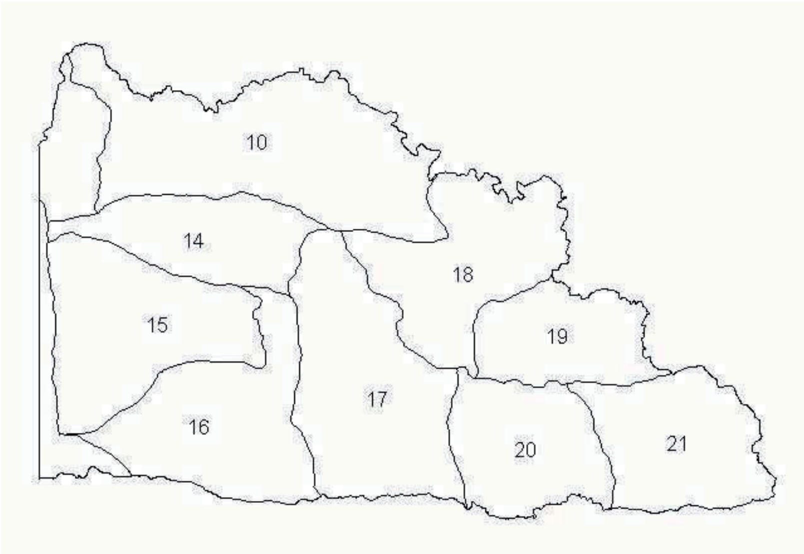

Fig. 3.1. The 9 elephant census zones in the South *Garo* Hills District and Nokrek study area (Marak 1998). The two unnumbered zones on the west boundary are parts of areas not censused and are not included in the analysis.

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 forest (approximately 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.

We used GIS to calculate area of each elephant census zone, and the total area and percent 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 (**Appendix 3**).

We calculated simple Pearson correlations among the 70 predictor variables and excluded 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 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 (see Kumar et al. 2002 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 percent 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.

3.3 Results and Discussion

The 9 elephant census zones varied in size from 163.1 to 328.8 sq km. 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. 3.2 and 3.3**).

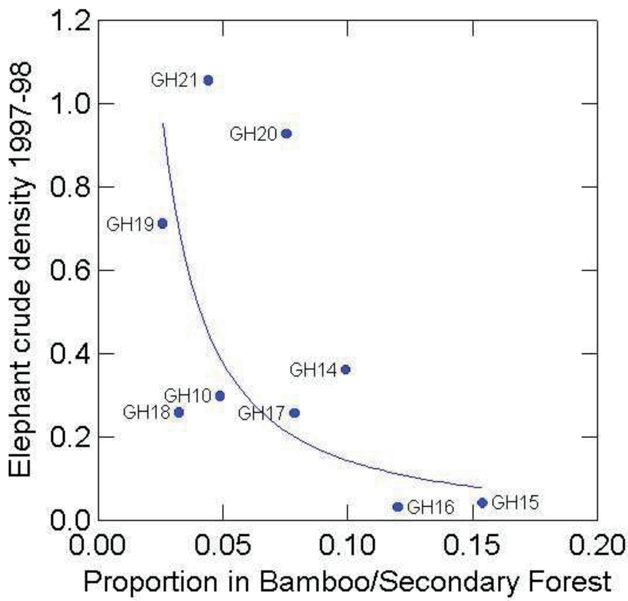

Fig. 3.2. Elephant crude density (no. elephants of all sex and age classes / sq km) as a function of proportion of landscape in bamboo and secondary forest cover. Data points are individual elephant census zones in the South *Garo* Hills District and Nokrek study area (see Fig. 2.1) and the curve is the best-fit power regression.

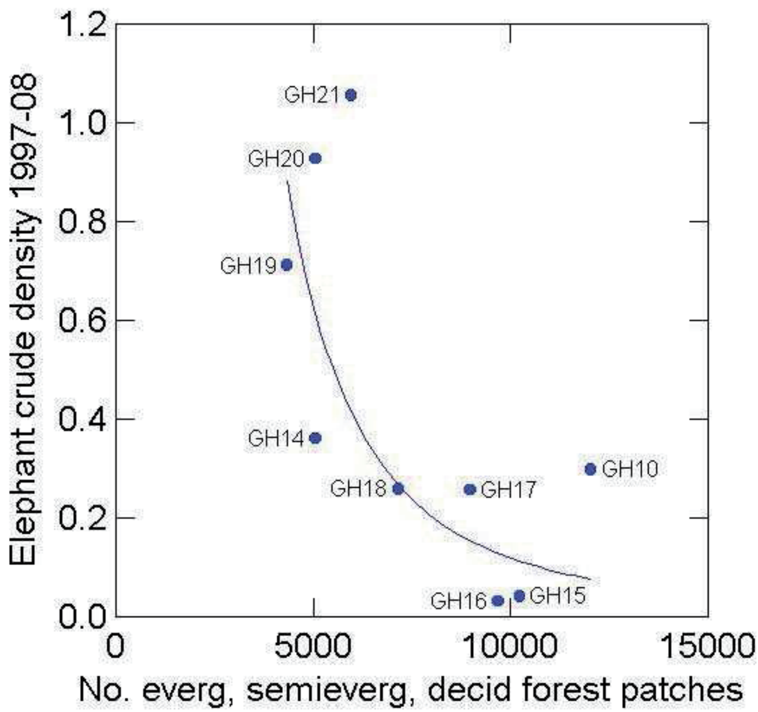

Fig. 3.3. Elephant crude density (no. elephants of all sex and age classes / sq km) as a function of number of mapped patches of native evergreen, semi-evergreen, and deciduous forest. Data points are individual elephant census zones in the South *Garo* Hills District and Nokrek study area (see Fig. 2.1) and the curve is the best-fit power regression.

Percent 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; percent 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 percent change in elephant crude density was highly significant ($F = 18.798$, $df = 3$, $P = 0.004$, $R^2 = 0.92$) and included three variables: percent 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. (2011) 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* Hill 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 / sqkm, and that annual *Jhum* rates should be < 2% of the land *Jhum*med 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. 3.2**) and with less fragmented, larger, and more contiguous patches of native forest (**Fig. 3.3**). We offer this as an ideal landscape design as a conservation strategy for maintaining elephants densities.

Analysis of the field data of elephant sign 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. 3.4**). 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.

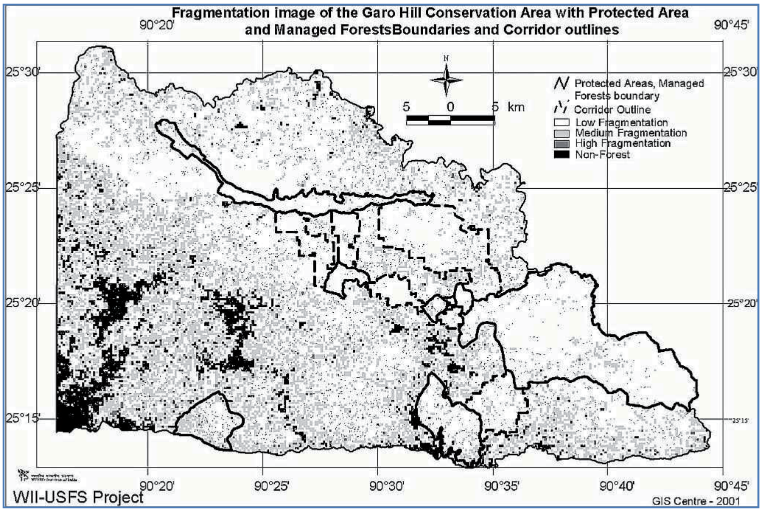

Fig. 3.4. Fragmentation of native forest in South *Garo* Hills District and Nokrek area, showing the 7 protected areas (solid outlines) and 7 proposed elephant habitat corridors (dashed lines). Notice how the corridors include largely unfragmented native forest. Analysis of forest fragmentation was according to Kumar et al. (2002).

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, and far less of *Jhum*, agriculture, deciduous forest, and bamboo (**Fig. 3.5**). This result is not surprising, given that the corridors were delineated to encompass areas 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.

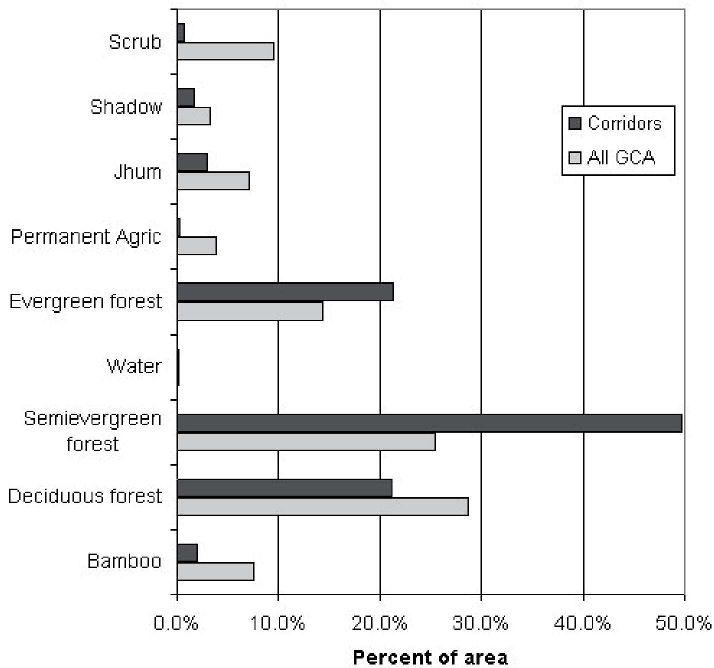

Fig. 3.5. Percent coverage by 9 categories of vegetation or land cover within the South *Garo* Hills District and Nokrek area and within 7 proposed elephant habitat corridors.

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 Parks

(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 overgrazing 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.

In the South *Garo* Hills District and Norkrek 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 (i.e., 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.

4. PROTECTED AREA NETWORK

4.1 Introduction

More than 90% of Meghalaya's protected area coverage is within the confines of the landscape under present investigation. These protected areas includes the Balpakram National Park (BNP) (220 km^2, later extended to 353 km^2 by further land acquisition), Nokrek National Park (NNP) (47.48 km^2, later extended to 80 km^2 and declared as Biosphere Reserve), Siju Wildlife Sanctuary (SWS) (5.18 sq km^2), Baghmara Pitcher Plant Sanctuary (BPPS) (2.7 ha). Also, the four reserved forests within the boundary of landscape were regarded as protected areas due to absence of any dependency of native *Garo* community (Kumar *et at.* 2002). These reserved forests included the Baghamara Reserved Forests (BRF) (44.29 km^2), Rewak Reserved Forests (RRF) (6.48 km^2), Emangiri Reserved Forests (ERF) (8.29 km^2), and Angratoli Reserved Forests (ARF) (30.11 km^2).

All the protected areas and reserved forests were considered and referred as the elements of potential protected area network for present study. These elements constituted 15% (20% after adding subsequent acquisition) geographical area of landscape. The present study examined the 15% area, since subsequent land was acquired after 1996-97, when the baseline work for mapping protected area coverage of landscape was carried out for the present study.

The community land outside these elements of protected area network affects various processes and functions happening within the protected areas and reserved forests, and imposes direct or indirect influences over the protected area network, which had never been studied for Meghalaya or other states of northeast India. So far, not much work has been done to evaluate the efficacy of existing protected area network in Meghalaya (or northeast India) except for a study conducted to assess the effectiveness of existing protected area network using non-spatial databases, in which the need for expanding protected area coverage was suggested due to inadequate representation of most biodiversity element of *Garo* Hills, which remained lying outside the boundaries of existing protected areas and reserved forests (Khan *et al.* 1997).

The connectivity among various protected area elements is an integral part of any protected area network, which does exist among various elements of protected area network of this landscape in *Garo* Hills, but definitely need formal protection (official designation) without which it may be disappearing soon due to widespread influence of *Jhum*. In such circumstances, it would be necessary to spatially evaluate the existing forest cover outside the protected area coverage, which would help identify spatial distribution of large, but unprotected forest tracts from community land to help direct the process of land acquisition or *Jhum* regulations to enhance the conservation status of land in the *Garo* Hills. Such findings could be used to model landscape scale conservation strategies for *Jhum* influenced landscapes in the tropics of northeast India and adjoining countries of Indo-Malayan and Indo-Chinese biogeographic zones.

4.2 Methods

The boundaries of existing elements of protected area network were obtained from various sources and got digitised at uniform scale using standard techniques. The specific zones of influences were identified within the community land by buffering the existing elements of protected area network. The connectivity among several elements of protected area network was identified through fragmentation analysis (as discussed in the companion volume), which helped in delineating the boundaries of potential wildlife habitat corridors in community land. Then land use land cover map generated during present study was integrated with the boundary maps of elements of protected areas and reserved forests; potential elements of protected area network, such as identified corridors; and various zones of influences with widely distributed patches of old forest growth, a few of which could be identified as potential elements of protected area network and may be considered for updating the priority list of areas officially proposed for future land acquisition in the state.

3.2.1 Elements of protected area network and zones of influences

The boundaries of protected areas including Balpakram, Nokrek National Parks and Siju Wildlife Sanctuary were taken from the maps available from Balpakram National Park Division, Baghmara (South *Garo* Hills district) and East and West *Garo* Hills Wildlife Division, Tura (West *Garo* Hills district). The BPPS is a small sanctuary (0.27 km^2) and located in the middle of Baghmara town; but did not consider for spatial analysis. The boundaries of four reserved forests including BRF, RRF, ERF and ARF were taken from maps available from the *Garo* Hills (Territorial) Division, Tura (West *Garo* Hills district). All maps collected from various offices of State Forest Department of Meghalaya were originally prepared at varying scales ranging from 1:10 000 to 1:250 000. All of the maps were digitised in GIS domain at a uniform scale of 1:50 000 to maintain consistency in mapping efforts (**Fig. 2.1**). The two zones around elements of protected area network buffering 2 km and 5 km were considered to represent the specific zones of influences and referred as 2 km Zone of Influence (2 km ZI) and 5 km Zone of Influence (5 km ZI), respectively.

4.2.2 Connectivity and potential wildlife habitat corridors

The nearest distances among several protected areas and reserved forests were computed to reveal the proximity and potential connectivity among these elements of protected area network of the landscape. The wildlife corridor can be defined as a linear two dimensional landscape element that connects two or more patches of wildlife (animal) habitat that had been connected in historic times (Soule and Gilpin, 1991). The potential wildlife corridors were identified on the basis of fragmentation image outputs during present study. Those pixels within the least fragmented categories in the community land connecting various protected areas and reserved forests were delineated through sketching the boundaries around such least fragmented areas. These boundaries were designated as the corridor boundaries, which were integrated with land use land cover map for further analysis and ecological interpretation for important biodiversity elements within.

4.2.3 Analysis of spatial attributes

The spatial indices discussed in this volume includes the mean patch size, patch size standard deviation, mean edge length, edge length standard deviation, patch and edge densities, while the list of all calculated indices for all bigger size patches (≥ 0.01 km^2 or 1 ha area) were appended to the end (**Appendix 5**). Some of the patch indices including total number, area, standard deviation and largest area were computed for all protected areas and reserved forests individually (**Appendix 6**) in order to provide ready reference for comparing individual units by managers depending on the objective of management.

4.2.4 Analysis of non-spatial attributes

The tree species sampled and analysed in companion volume were used to describe the non-spatial attributes of landscape. The number of tree species, mean tree density, mean basal area per ha, species richness (Menhinick index), species diversity (Shannon-Wiener index) and species evenness (modified Hill's ratio) were computed for various segments of landscape included the protected areas (n = 17 belt-transects), reserved forests (n = 11) and surrounding unprotected forest cover over community land (n = 7). The analysis of variance (ANOVA) was done to compare various segments of landscape for all these six tree species variables. The phyto-sociological analysis of all tree species was done to rank order them within various segments of landscape. The 10 most important (showing highest SIVs) and least important species (showing lowest SIVs) were identified and provided for ready reference in this volume. The detailed phyto-sociological characteristics of these tree species within various kinds of old forest growth and forest types have already been discussed in the companion volume.

4.2.5 Comparing landscape segments for broad scale assessment

The landscape segments including elements of protected areas, reserved forests, corridors and various zones of influences were compared on the basis of total area of all patches. The protected areas and reserved forests were combined together for chi-square analysis. In case of zones of influences, the area of distinct forest types in various zones within community land were computed for 2 km ZI (ZI1), 5 km ZI exclusive of 2 km ZI (ZI2) and rest of the community land (ZI3) to avoid the biasness due to overlapping of various segments of landscape. Specifically, these segments included the elements of existing protected area network, *i.e.*, all protected areas and reserved forests combined (hereinafter referred as PARF); potential elements of protected area network, *i.e.*, proposed wildlife habitat corridors (referred as Corridors); three zones of influences (referred as ZI1, ZI2 and ZI3). The chi-square analysis (α = 0.05) was done to test following research hypotheses:

- Ho: All landscape segments including PARF, corridors, ZI1, ZI2 and ZI3 were independent of three forest types;
- Ho: All zones of influences including ZI1, ZI2 and ZI3 were independent of three forest types; and
- Ho: All zones of influences including ZI1, ZI2 and ZI3 were independent of three land uses.

The null hypotheses tested for significance of differences using chi-square test were:

- Ha: All landscape segments including PARF, corridors, ZI1, ZI2 and ZI3 were not independent of forest types;
- Ha: All zones of influences including ZI1, ZI2 and ZI3 were not independent of three forest types; and
- Ha: All zones of influences including ZI1, ZI2 and ZI3 were not independent of three land uses.

4.3 Results

4.3.1 Protected areas

The old forest growth including TMEF, TSEF and TMDF constitute majority of area within protected areas and occupying 7%, 4% and 1% of entire landscape area, respectively. The mean patch size ± standard deviation of patches of these three forest type were 0.62 ± 5.20 km^2, 0.17 ± 0.95 km^2 and 0.06 ± 0.19 km^2, respectively, while the mean edge lengths were 6 ± 3 km, 4 ± 14 km and 2 ± 4 km, respectively. The patch densities for three forest types were 2, 6, and 16 patches per km^2, respectively, while edge densities were 10, 22 and 32 km per km^2, respectively. The evidences of land uses and bamboo patches were recorded for 5and 1 km^2 of land within protected areas. Some of the indices representing number, area, mean area, standard deviation, and the largest patch area for individual protected area are provided in **appendix 6**.

The 10 most important species (decreasing order of SIV) were The 20 most important species (decreasing order of SIV) were; *Polyalthia simiarum, Schimawallichii, Castonopsispurpurella, Grewia microcos, Walsura tubularis, Syzygium cuminni, Syzygium operculatum, Aphanamixis polystachya,* and *Aporusa dioica*, while the 10 species showing least importance values (SIV in increasing order) were *Anacardium occidentale, Cassia fistula, Bauhinia* spp., *Hodgsonia macrocarpa, Ochna integerrima, Disoxylum hamiltonii, Garuga pinnata, Aristolochia tagala, Bredelia tomentosa* and*Glycosmis arborea*.

4.3.2 Reserved forests

The TMEF was recorded for three patches covering area of 0.06 km^2 of landscape, which is almost negligible. The old forest growth included TSEF and TMDF, which constituted 1.6% and 1.7% area of landscape, respectively. The mean patch size ± standard deviation of patches of these two forest type were 0.31 ± 1.02 km^2 and 0.21 ± 0.69 km^2, respectively, while the mean edge lengths were 6 ± 18 km for both, TSEF and TMDF. The patch densities for two forest types were 3 patches per km^2 and 5 patches per km^2, respectively, while edge densities were 19 km per km^2 and 28 km per km^2, respectively. The evidences of land uses and bamboo patches were recorded for 5 km^2 and 2 km^2 of land within the reserved forests. Some of the indices representing number, area, mean area, standard deviation, and the largest patch area for individual reserved forests are provided in **appendix 6**.

The 10 most important species (decreasing order of SIV) were *Shorea robusta, Castonopsispurpurella, Schima wallichii, Tectona grandis, Syzygium cuminni, Grewia microcos, Aporusa dioica, Glycosmis arborea, Sapium baccatum,* and *Dillenia pentagyna*, while the 10 species showing least importance values (SIV in increasing order) were *Polyalthia* spp*., Phoebe* spp*., Aesculus assamica, Ardisia* spp*., Citrus* spp*., Vitex glabrata, Wendlandia excelsa, Ficus lamponga, Abrus precatorius,* and *Syzygium operculatum*.

4.3.3 Community land

The old forest growth including TMEF, TSEF and TMDF occupied 10%, 22% and 28% of landscape area, respectively. The mean patch size ± standard deviation of patches of these three forest type were 0.26 ± 3.19 km^2, 0.19 ± 2.24 km^2 and 0.13 ± 0.94 km^2, respectively, while the mean edge lengths were 3 ±28 km, 4 ±36 km and 4 ±23 km, respectively. The patch densities for three forest types were 4 patches per km^2, 5 patches per km^2 and 8 patches per km^2, respectively, while edge densities were 13 km per km^2, 23 km per km^2 and 32 km per km^2, respectively. The land uses and bamboo patches were extensive within community land and recorded for 343 km^2 (17% of landscape) and 99 km^2 (5% of landscape). The 10 most important species (decreasing order of SIV) were *Shorea robusta, Schimawallichii, Castonopsis purpurella, Eurya accuminata, Dillenia pentagyna, Diospyros variegata, Castonopsis* spp*., Syzygium cuminni, Macaranga denticulata,* and *Sapium baccatum*, while the 10 species showing least importance values (SIV in increasing order) were *Polyalthia* spp*., Phoebe* spp*., Aesculus assamica, Ardisia* spp*., Citrus* spp*., Vitex glabrata, Wendlandia excelsa, Ficus lamponga, Abrus precatorius,* and *Syzygium operculatum*.

Analysis of patch statistics revealed that habitation, permanent agriculture and *Jhumming* occupied 9%, 4% and 4% of landscape area, respectively. The mean patch size ± standard deviation of patches of these three land uses were 0.07 ± 0.39 km^2, 0.06 ± 0.16 km^2 and 0.03 ± 0.04 km^2, respectively, while the mean edge length 2 ± 10 km, 4 ± 36 km and 1 ± 1 km, respectively. The patch densities for three land uses were 4 patches per km^2, 5 patches per km^2 and 8 patches per km^2, respectively, while edge densities were 34 km per km^2, 28 km per km^2 and 48 km per km^2, respectively.

The protected areas and reserved forests all together constitute 15% of landscape, while rest of the land belongs to local community. The mean patch size ± standard deviation for all patches within three components of landscape including protected areas, reserved forests and unprotected community land were 0.18 ± 2.17 km^2, 0.14 ± 0.59 km^2 and 0.09 ± 1.14 km^2, respectively, while the mean edge lengths were 3 ±18 km, 4 ±13 km and 3 ±18 km, respectively. The patch densities for three forest types were 5 patches per km^2, 7 patches per km^2 and 11 patches per km^2, respectively, while edge densities were 17 km per km^2, 26 km per km^2 and 29 km per km^2, respectively. The land uses and bamboo patches were extensive within community land and recorded for 343 km^2 (17% of landscape) and 99 km^2 (5% of landscape). The community land supported the majority of old forest growth, which constituted 60% of entire landscape area (see **Appendix 5** for details of patch indices).

Several patch and edge indices mentioned above were used to compare the landscape characteristics (based on patch characteristics) of various landscape segments including protected areas, reserved forests and community land. The analysis of variance revealed that of all spatial indices (**Appendices 5** and **6**) patch area, patch numbers, patch size coefficient of variation, edge length, and edge length coefficient of variation varied significantly across three landscape segments mentioned above, while others did not (**Table 4.1**).

Table 4.1 Results of Analysis of Variance (ANOVA) comparing the landscape segments on the basis of patch characteristics of landscape (df = 2)

Spatial indices	F	Sig.
Total area of patches 0.01 km^2	7.329	.006
Per cent of total landscape area	1.168	.338

Spatial indices	F	Sig.
Largest patch index (%)	.509	.611
Number of patches	18.960	.000
Patch density (no./ km^2)	.847	.448
Mean patch size (km^2)	.147	.865
Patch size Standard Deviation - PSSD (km^2)	.658	.532
Patch size Coefficient of Variation - PSCV (%)	4.013	.040
Total edge length (km)	7.213	.006
Edge density (km/ km^2)	1.136	.347
Largest edge length (km)	3.307	.065
Mean edge length (km)	.027	.973
Edge length Standard Deviation (km) – ELSD (km)	2.677	.101
Edge length Coefficient of Variation - ELCV (%)	5.208	.019

The ANOVA results for comparing the tree communities among protected areas, reserved forests and non-protected forest cover from community land did not show any significant difference for any of six variables used for analysis. These six variables included the number of tree species (F=0.60, df=2 and p>0.05), tree density (F=1.26, df=2 and p>0.05), basal area per ha (F=1.03, df=2 and p>0.05), Menhinick index for species diversity (F=1.25, df=2 and p>0.05), Shannon-Wiener index for species diversity (F=1.03, df=2 and p>0.05) and modified Hill's ratio for species evenness (F=2.83, df=2 and p>0.05) (**Table 4.2**).

Table 4.2 Summary statistics showing vegetation characteristics in various landscape segments

Vegetation characteristics	Protected areas (n = 17 belt transects)	Reserved forests (n = 11)	Community forests (n = 7)
No. of species	46 – 81	26 – 84	37 – 87

Vegetation characteristics	Protected areas (n = 17 belt transects)	Reserved forests (n = 11)	Community forests (n = 7)
Mean tree density (± SD)	816 ± 215	856 ± 107	938 ± 120
Mean basal area (m^2/ha) (± SD)	56 ± 42	47 ± 13	17 ± 45
Species richness (Menhinick index)	1.48 – 3.22	0.97 – 2.82	1.24 – 3.26
Species diversity (Shannon index)	2.64 – 3.69	1.72 – 3.61	2.26 – 3.72
Species evenness (modified Hill's ratio)	0.39 – 0.70	0.25 – 0.70	0.29 – 0.71

4.3.4 Zones of Influence

The zones of influence within landscape represent the zones under the influence of biotic communities of protected area network and the biotic as well as cultural communities from surrounding community land. During present study two zones of influence at specified distances of 2 km and 5 km for further assessment of various land uses and forest types. Specifically, these two zones referred as 2 km ZI (zone of influence at 2 km distance) and 5 km ZI (at the distance of 5 km).

4.3.4.1 Zone of influence at 2 km (2 km ZI)

The ZI defined by a 2 km distance from PA boundaries (with the exception of ARF) contained more old forest growth (TMEF, TSEF and TMDF) than non-forest. Even in the case of combined ZI for three PAs, the forested areas were greater in the ZI than non-forested areas. The most redeeming feature of ZI at a 2 km distance was the low proportions of agricultural, *Jhum* and scrubland areas, suggesting that biotic pressures within the ZI at 2 km were not very high (**Table 4.3**). The ZIs of BNP, SWS, and RRF overlapped when ZI was considered at 2 km distance (total area 135 km^2). Therefore, a combined ZI was calculated (**Fig. 4.1 and Table 4.3**). The TSEF comprised 39% of total area, followed by the TMDF comprising 31% of total area under 2 km ZI. The proportion of TMEF is very low (about 7%) with overall land use covering 13% of total area under various land use categories.

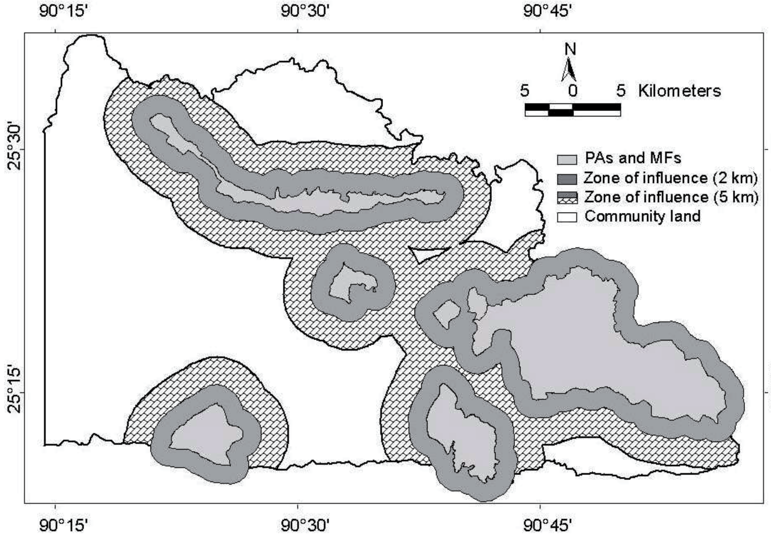

Fig. 4.1 Specified zones of influences (ZI); PAs = Protected Areas, & MFs = Managed Forests, which are designated as Reserved Forests in the *Garo* Hills

Table 4.3 Area (km^2) of forest and non-forest types in the 2 km zone of influence around protected areas and reserved forests

Forest and Non-forest types	**ARF**	**BRF**	**ERF**	**RRF**	**BNPSWS**	**NNP**	**Combined ZI**
Evergreen forest	0	3	17	3	3	5	9
Semi-evergreen forest	3	10	1	2	4	52	52
Deciduous forests	16	8	1	2	36	3	42
Habitation/Scrub/Abandoned	7	5	0	0	1	0	5

Forest and Non-forest types	ARF	BRF	ERF	RRF	BNPSWS	NNP	Combined ZI
Jhum fields							
Permanent Agriculture	2	7	0	1	7	2	4
Shifting Cultivation/ grasslands	4	1	1	0	9	78	9
Bamboo/Secondary forest (6-10 years)	6	19	22	13	48	24	8
Plateau grassland	0	0	0	0	0	0	0
Waterbodies	0	8	3	9	8	7	1
Shadow	1	0	0	1	3	1	5

ARF = Angratoli RF, BRF = Baghmara RF, ERF = Emangiri RF, RRF = Rewak RF, BNPSWS = Balpakram National Park and Siju Wildlife Sanctuary, NNP = Nokrek National Park.

4.3.4.2 Zone of Influence at 5 km (5 km ZI)

The 5 km ZI had much overlaped among the zones around BNP, NNP, SWS, BRF, RRF and ERF. Accounting for this overlap (**Fig. 4.1**), within the combined 5 km ZI the overall forest area was much greater than the overall area in non-forest (**Table 4.4**). Total area under this particular ZI increased greatly (seven times larger compared to that of 2 km ZI), however, the proportion of forest and non-forest is same as 2 km ZI. *i.e.,* almost 80% of the total 5 km ZI area was under old forest growth (TMEF, TSEF, TMDF) (**Table 4.4**).

In the 5 km ZI around some individual PAs (*i.e.*, ARF, BRF, BNP, and SWS) however, the area under *Jhum* was quite substantial. BNP and SWS, with an area of about 130 km^2 under TMEF and TSEF had the most forested and the least disturbed 5 km ZI. The overall land uses in this ZI comprised about 13% of land area of 5 km ZI.

Table 4.4 Area (km^2) of forest and non-forest types in the 5 km zone of influence around PA and RF.

Forest and Non-forest types	ARF	BRF	IRF	RRF	BNPSWS	NNP	Combined ZI
Evergreen forest	0	1	1	6	21	155	178
Semievergreen forest	10	38	0	1	108	152	327
Deciduous forests	47	50	66	40	93	76	248
Habitation/Scrub/Abandoned *Jhum* fields	25	19	0	0	12	7	37
Permanent Agriculture	8	12	10	9	9	2	21
Shifting Cultivation/ grasslands	10	18	3	3	23	20	66
Plateau grassland	0	0	0	0	0	0	0
Bamboo/Secondary forest (6-10 years)	17	15	52	41	19	14	49
Waterbodies	0	1	12	8	1	0	2
Shadow	3	6	6	6	12	14	31

ARF = Angratoli RF, BRF = Baghmara RF, ERF = Emangiri RF, RRF = Rewak RF, BNPSWS = Balpakram National Park and Siju Wildlife Sanctuary, NNP = Nokrek National Park.

4.3.5 Connectivity among existing elements of protected area network

All of these elements were not at all connected with each other, however, connectivity among the elements is must for any kind of networking including the protected area network. The proximity among these elements provided the idea on feasibility of performing the corridor's its function of providing migration route to the wide ranging wildlife species. Moreover, the results from assessment of landscape scale fragmentation could be interpreted to get the connectivity routes, which would be linking existing elements of protected area network of the landscape.

4.3.5.1 Proximity among elements of protected area network

The existing protected areas and reserved forests comprising 15% of landscape, constituted the major elements of the protected area network of not only *Garo* Hills, but for entire Meghalaya state. BNP being the largest protected area (220 km^2) of state is one of the largest protected area of landscape. SWS at the northern boundary of BNP forms a *de facto* part of the national park by sharing common boundary at some places. RRF and BRF were the nearest neighbours of BNP with the nearest edge-to-edge distance of 2 km and 5 km, respectively. The NNP is situated in the northwest of BNP at the distance of 10 km. ERF is the closest neighbour of Nokrek NP at a distance of 6 km. ARF is the farthest at a distance of 27 km from BNP, hence did not have any connecting corridors like other reserved forests of the landscape and has the least probability of connectivity with any of them (**Table 4.5**).

Table 4.5 Minimum edge-to-edge distance (km) among various protected areas and reserved forests

	BNP	NNP	SWS	BRF	ARF	ERF	RRF
Balpakram NP	0						
Nokrek NP	12	0					
Siju WLS	0	10	0				
Baghmara RF	5	20	8	0			
Angratoti RF	27	22	28	20	0		
Emangiri RF	11	6	10	13	20	0	
Rewak RF	2	11	1	6	24	7	0

ARF = Angratoli RF, BRF = Baghmara RF, ERF = Emangiri RF, RRF = Rewak RF, BNP = Balpakram National Park, SWS = Siju Wildlife Sanctuary, and NNP = Nokrek National Park.

4.3.5.1 Potential wildlife habitat corridors

Habitat corridors can play an important role in the dispersal of some biota as well as facilitating gene flow between populations, thereby maintaining or increasing the heterozygosity within taxa and the biodiversity of the region (Hobbs *et al.* 1989; and Norton and Nix, 1991). Remotely sensed data is useful in identification and mapping of forest habitat corridors (Gulinck *et al.*, 1991).

The fragmentation analysis helped identifying seven connectivity routes among these protected areas and reserved forests were shown over the re-classed fragmentation image (**Fig. 4.2**).

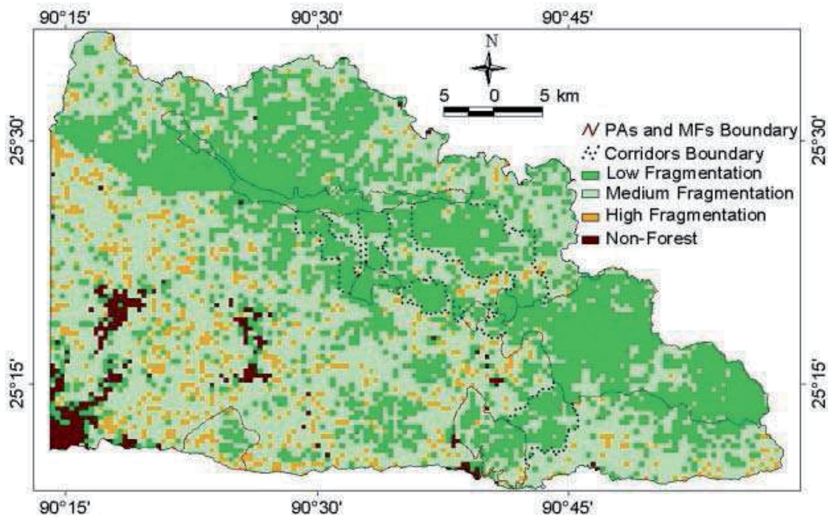

Fig. 4.2 Potential wildlife habitat corridors

A total of 14340 patches were recorded within the corridor boundaries, of which 6944 patches (48% of all patches in corridors) constituted 92% of total corridor area (**Table 4.6**) with mean patch size (± standard deviation) 0.04 ± 0.63 km^2, however, the mean patch size (± standard deviation) was 0.003 ± 0.008 km^2 for all 7396 non-forest patches within the corridor boundaries. All of these corridors linked all the protected areas and reserved forests of landscape with each other except the Angratoli Reserved Forests, which is farthest of all other protected areas and reserved forests (**Table 4.5**) and located in the highly fragmented south western portion of landscape. All seven potential corridors linked the Balpakram National Park in the south to the Nokrek National Park in the northern most range of landscape along with three reserved forests via one or more routes.

These Corridors can help connect Balpakram National Park (BNP) with Nokrek National Park (NNP) in the northwest, Rewak Reserved Forest (RRF) in the west and Baghmara Reserved Forest (BRF) in the southwest. The corridors also connect the adjoining Siju Wildlife Sanctuary (SWS) with NNP and RRF, respectively. The smallest corridor had forest area of 1 km^2 and connected SWS and RRF. A corridor connecting RRF with ERF was 15 km^2, of which 95 % was forested. NNP was linked with ERF with two corridors, covering an area of 23 km^2 and 16 km^2, containing 93 % and 96 % of forest cover, respectively.

Table 64.6 Forest and non-forest in the identified corridors

Corridors	Forest area (km^2)	Non-forest area (km^2)	Total area (km^2)
BNP/SWS-NNP3	167	14	181
BNP-BRF	30	3	33
ERF-NNP1	22	2	23
ERF-NNP2	15	1	16
RRF-ERF	14	1	15
BNP/SWS-RRF	4	1	5
SWS-RRF	1	0	1
Total	**253**	**22**	**274**

ARF = Angratoli RF, BRF = Baghmara RF, ERF = Emangiri RF, RRF = Rewak RF, BNPSWS = Balpakram National Park and Siju Wildlife Sanctuary, NNP1 = Nokrek National Park. Corrodor no. 1, NNP2= Nokrek National Park. Corrodor no. 2,and NNP3 = Nokrek National Park. Corrodor no.3.

The total area of these all corridors was 274 km^2, with old forest growth in the form of TMEF, TSEF and TMDF, constituting 23 %, 54 % and 23 %, respectively, of old forest growth within the corridors. Most corridors comprised TSEF and TMDF with least proportion of TMEF. A corridor connecting BNP, SWS and NNP comprised the maximum area, however, its actual importance to the native wide ranging wildlife need to be evaluated after considering topographic features of corridor area within landscape (**Tables 4.7**).

Table 4.7 Distribution of forest types within the potential corridors

Corridors	TMEF area (km^2)	TSEF area (km^2)	TMDF area (km^2)	Total area (km^2)
BNP/SWS-NNP3	49	81	35	167
BNP-BRF	1	19	10	30
ERF-NNP1	1	17	4	22
ERF-NNP2	7	7	1	15
RRF-ERF	0	10	4	14
BNP/SWS-RRF	0	0	4	4
SWS-RRF	0	0	0	1
Total	58	136	58	253

ARF = Angratoli RF, BRF = Baghmara RF, ERF = Emangiri RF, RRF = Rewak RF, BNPSWS = Balpakram National Park and Siju Wildlife Sanctuary: NNP1 = Nokrek National Park. Corrodor no. 1, NNP2= Nokrek National Park. Corrodor no. 2,and NNP3 = Nokrek National Park. Corrodor no.3: TMEF= Tropical Moist Evergreen Foersts, TSEF= Tropical Moist Evergreen Forests; and TMDF= Tropical Moist Deciduous Foersts.

4.3.6 Comparing various landscape segments

The results of chi-square analysis for testing the significance of difference among various segments of landscape for distinct forest types and land use activities (**Fig. 4.3**) revealed that:

- All landscape segments including PARF, Corridors, ZI1, ZI2 and ZI3 are not independent of three forest types (likelihood Chi square ratio = 411.472,
  df = 8 and p<< 0.001). The old forest growth area varied significantly among various landscape segments with the highest proportion of area within ZI2.
- All Zones of influences including ZI1, ZI2 and ZI3 (**Table 4.8**) are not independent of three forest types (likelihood Chi square ratio = 180.260, df = 4 and p<< 0.001).
- Zones of influences including ZI1, ZI2 and ZI3 are not independent of three land uses (likelihood Chi square ratio = 28.920, df = 4 and p< 0.001). In consideration of land use activities, all landscape segments varied significantly with the highest proportion of within ZI3.

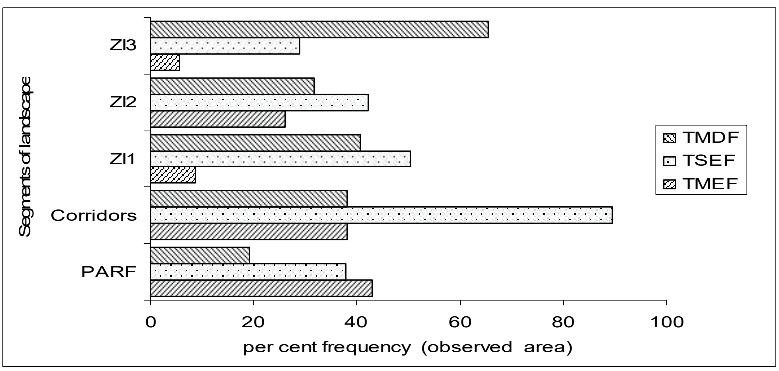

Fig 4.3 Observed per cent area of various forest types among various landscape segments

4.4 Discussion

The study was undertaken to define the elements of protected area network and analyse various landscape level spatial patterns in relation with the patches of old forest growth (i.e., TMEF, TSEF and TMDF) and land use activities (i.e., habitation, permanent agriculture and *Jhumming*), which directly or indirectly affect the biodiversity within the landscape. Also, the tree species were examined for stand level assessment and comparing various segments of landscape including protected areas, reserved forests and community forests. Several indices were computed and provided for comparing various forest types and land uses among several combinations of landscape segments, such as protected areas, reserved forests and community land. The managers can use these indices, either independently or in combination for comparing various segments of landscape, for example, among several protected areas and reserved forests along with surrounding community land; between or within overall land uses and forest cover; several land uses or forest cover within any of them; between two protected areas, such as Balpakram and Nokrek National Parks; or other combinations of subsets of larger landscape, depending on the objectives of proposed management activities (**Appendices 5** and **6**).

The landscape and fragmentation analyses presented in the companion volume revealed that 21% area of landscape was subjected to medium to high degrees of fragmentation, while 8% area was completely devoid of any forest growth. Unfortunately, the intact forest cover with low fragmentation area in *Garo* Hills decrease at faster pace than ever. The fact is well illustrated in a study, which revealed the significant reduction in the forest cover area from 51% to 17% between 1980 and 2000 (Talukdar 2004). With this rate of forest recession, the 71% low fragmentation area (along with intact forest cover) within the landscape may reduce drastically in coming years. The existing coverage of protected area covering only 15% of landscape, obviously does not seem adequate to conserve the rich biodiversity within these old forest growth of landscape. The higher mean patch size and lower patch density among protected areas suggested that low fragmentation level within protected areas compared to reserved forests and community land, however, majority of forest cover (60% of landscape) was confined within community land. The ANOVA results suggested that these community forests were equally rich and diverse as far as the tree communities are concerned, at least for the given sampling efforts during present study.

Also, the mean patch sizes and patch densities of various forest types and land uses within the confines of community land suggested that the patches of old forest growth were dominant over landscape. The fragmentation analysis helped delineating a few wildlife habitat corridors for linking various elements of existing protected area network (all protected areas and reserved forests), which could be placed at priority list of areas proposed to bring under the process of official land acquisition in the state. Williams and Johnsingh (1996) had earlier identified three elephant habitat or elephant travel corridors in the study area based on a short-term field survey. These corridors were named as Siju-Rewak, Balpakram-Baghmara and Emangiri-Nokrek covering the area of 8 km^2, 31 $km^2$and 48 km^2, respectively.

The seven corridors identified in present study encompass these three earlier identified corridors. It was observed that Angratoli Reserved Forest was the farthest amongst all elements of existing protected area network and did not have any connectivity with any other such elements now, however the evidences of historic connectivity between Angratoli Reserved Forest and Emangiri Reserved Forest were recorded in the field which once facilitated the movement of elephants across Nokrek National Park in the north and plains of Bangladesh in the south. Such migratory routes could be restored with timely management interventions. Additionally, the Angratoli Reserved Forest is situated along sensitive and porous international border, which make this comparatively larger reserved forest more vulnerable from conservation point of view. Additional strategic measures along with adequate protection (for example, from direct hunting) would be one of the most urgent conservation need under *Garo* Hills for the successful conservation of native biodiversity in the region.

The Chi square analysis was done for comparing various segments of landscape including PARF, Corridors, ZI1, ZI2, ZI3, which suggested that all of these segments were independent for forest area, represented by TMEF, TSEF and TMDF. The findings revealed that ZI2 and ZI3 have extensive cover of old forest growth, which may either require protection or sometimes (very rarely) restoration measures. When three ZIs (ZI1, ZI2 and ZI3) were compared exclusively for the proportion of forest areas, it confirmed the above interpretation. Various land use activities including habitation, permanent agriculture and *Jhumming* were found significantly different among three ZIs with the highest proportion in ZI3, where habitation was the most prevalent activity followed by shifting cultivation and permanent agriculture. These findings suggest that the ZI1 supported lower proportion of old forest growth with almost negligible area under various land use activities, while ZI2 supported the highest proportion of various forest types and the moderate land use activities, however, ZI3 was observed for the least proportion of TMEF and majority of TMDF, which represented more or less open/disturbed from of the old forest growth with highest proportional area of land use activities mainly represented by residential and agricultural (settled or *Jhumming*) areas.

Thus, conservation efforts in this particular ZI should focus more on restoration activities, which may be coupled with additional protection measures to help protect larger forest tracts within the community land, however, the ZI2 may just require the protection measures, since majority of land within this zone sustained the TMEF and TSEF growths with moderate proportion of TMDF with low land use activities. These findings suggest that the successful conservation of biodiversity within this zone (and landscape as well) could be achieved by just maintaining existing protection level and discouraging the native community for further large scale clear felling, while practising *Jhum* agriculture especially around reserved forests like Angratoli Reserved Forest and Emangiri Reserved Forest, which could be set up as the priority areas for implementing immediate conservation measures to help protect the fast disappearing biodiversity in these sundry wildlife habitats of the landscape.

The effects of landscape fragmentation on biotic community including several wildlife species can be examined in three ways (Kufper *et al.* 2004); (1) effects on movement and pattern of habitat use (both within individual remnant and among group of remnant patches, (2) effects of population and community dynamics in heterogeneous landscapes and (3) changes in ecological processes at forest edges (Berrett & Peles 1999). The present study addresses comparatively larger landscape, which is a mosaic of large number of varying sized patches, hence, more concrete efforts would be required to evaluate all of the above mentioned effects of forest fragmentation over landscape and several wildlife populations and communities. Instead, the attempts were made to use fragmentation analysis to identify the potential wildlife habitat corridors among existing protected areas and reserved forests of the landscape.

The elephant habitat corridors suggested by Williams & Johnsingh (1996) included much secondary forest and some *Jhum* cover, particularly in the corridor linking Siju Wildlife Sanctuary and Rewak Reserved Forest, and the corridor linking Balpakram National Park and Baghmara Reserved Forest. The authors reported low values of their corridor suitability index for these two corridors despite high elephant sign encounter rates. Their results could be interpreted as meaning that elephants have been habitually using these movement areas despite degradations in forest cover. However, the authors also acknowledged that continued use by elephants may be in question if human use increases, such as by creation of a cement factory in the first of these corridors. The authors also reported that a third corridor linking Emangiri Reserved Forest and Nokrek National Park is dominated by tropical evergreen forest and moist deciduous forest with patches of degraded secondary forest. These authors, however, did not analyze percent of each cover type in each corridor, nor compare elephant densities to cover types outside their proposed corridors, as presented here. It is suggested that these findings provide at least a testable management hypothesis for the kinds, ages, and fragmentation patterns of forest cover that may be more useful to sustain elephant and other wildlife populations over the longer term.

5. WILDLIFE MANAGEMENT FOR BIODIVERSITY CONSERVATION

5.1 Introduction

In this concluding chapter we present the overall analysis and synthesis of information presented in both volumes. The *Garo* Hills in Meghalaya is probably one of the least explored regions of northeast India from biodiversity point of view. There a few studies were conducted by the Botanical Survey of India, Zoological Survey of India and some other scientists, however, most of these studies were confined to the taxonomic evaluation of various plant and animal taxa to identify the immense species richness of the region. The notable studies on the plant taxonomy included the Kanjilal *el al. (*1934-40), Kumar & Rao 1985, Haridasan & Rao (1988) and Tiwari *et al*. (1999), while the animal taxonomy included Kemp & Chopra (1924), Pillai & Yazdani (1977), Ghosh & Biswas (1977), Ghosh (1984), Kumar & Rao (1985), Pillai & Murhy (1989).

Additionally, Alfred & Sati (1990) and Marak (1998) provided the distribution of hoolock gibbons and elephants of the *Garo* Hills, respectively, however, no ecological study has ever been conducted to understand the wild fauna of the *Garo* Hills in relation with their habitats except for a study by Kumar & Rao (1985), which mentioned the preliminary level association of selected mammal species with the broad vegetation categories reported in the Balpakram National Park area. It could be treated as the start of wildlife habitat relationship assessment in the region; however, next attempts were made after a long gap by Kumar *et al.* (2002), Mathur *et al.* (2002) and Marcot *et al.* (2011).

The only study attempting the evaluation of effectiveness of protected area network of Meghalaya was conducted by the Khan *et al.* (1997) using databases containing information on plant species (including habit, altitudinal distribution, endemism of species) and existing protected areas (including type, extent and altitudinal representation of area). They did not use spatial data sets while evaluating the effectiveness of existing protected area network, which could be one of the most vital parameters for such evaluations. The present study performed landscape level mapping and identify broad forest types and land uses to discuss the landscape characteristics as well as the effectiveness of protected area network. The modern ecological principles including the well established maxims of landscape ecology (for example, spatial indices on patch characteristics) were evaluated to discuss the patch characteristics and spatial pattern of landscape.

Earlier studies on mapping and analysis of landscape were done at 1:2 50 000 scale at medium resolution satellite data (62 m x 62 m) (Roy & Tomar 2001, and Talukdar 2004), however, present study used the finer resolution satellite data (23.5 m x 23.5 m) and performed mapping at 1:50 000 scale. The connectivity among various wildlife habitat centres (protected areas and reserved forests) was evaluated by Williams & Johnsingh (1996), which mentioned three wildlife habitat corridors. The present study suggested the seven corridors from same area (*i.e.*, landscape) with precise mapped locations using more scientific fragmentation analysis.

We also discuss the important wildlife issues and concerns of national (and global) significance with the examples of one of the most important species of the ecosystem, *i.e.*, tiger. The overall analyses at landscape (broad scale) and stand levels (finer scale) presented in this these have much wider implications for wildlife management and biodiversity conservation in the regions, which will be discussed in the following sections.

5.2 Successional Stages and Tree Species

The present study identified more than 1000 vascular plant species including more than 400 tree species in the tropical forest ecosystem of the landscape. Many of these species are rare, endangered, endemic and thus are of great conservation importance. The major forest vegetation types are primary and secondary forests, which occupy most of the landscape. Forest stand density and vigour compare well with the densest tropical rain forests anywhere in the world. These forests have the highest tree basal area ever reported from tropical forests anywhere in the world. The study compared tree species diversity between the primary and secondary forests as well as within various forest formations of primary forests and successional stages of secondary forests. The cluster analysis identified the PF into three distinct forest formations located in different altitudinal zones including low (less that 400 m elevation), mid (400 – 800 m elevation) and high (more than 800 m elevation) formations. At the same time, it clustered the SF into three successional stages including young (under fifteen years old), mature (between fifteen and thirty years) and old (over thirty years old) seral stages.

The phyto-sociological analysis revealed the forest structure in terms of tree species and revealed the relative frequency, abundance, dominance and importance values of 165 species sampled (n = 35 belt transects). The standard indices of Menhinick index, Shannon index and Hill's ratio compared the primary and secondary forests for species richness, diversity and evenness, respectively. The diversity analysis also revealed that the primary forests are the most tree-diverse, which is further confirmed through rarefaction analysis by plotting the number of cumulative tree species as a function of the cumulative number of samples in primary forests (n = 21 belt transects) and secondary forests (n = 10 belt transects). The ten most important species of primary forests are *Polyalthia simiarum, Schimawallichii, Castanopsis purpurella, Syzygium cumini, Grewia microcos, Drimycarpus racemosus, Dillenia pentagyna, Cynometra polyandra, Aphanamixis polystachya,* and *Walsura tubulata*, whereas the ten most important species of secondary forests are *Schimawallichii, Castanopsis purpurella, Shorea robusta, Macaranga denticulata, Grewia microcos, Syzygium cumini, Aporusa dioica, Euryaacuminata, Dillenia pentagyna,* and *Callicarpa arborea* (see companion volume for detailed phytosociological features of all tree species in various forest growths, derived forest types and formations). The concentration areas for specific tree species could be mapped to understand the occupancy and abundance patterns of species in the region. This would help in developing wildlife habitat relation databases for select herbivores including several larger mammals and prey species for promoting selective wildlife species and sustainable use of tree resources in a planned manner.

Though the findings of present study reveal that secondary forests are less tree-diverse, however, one should not undermine the values of secondary forests, since they are of utmost importance to the native wildlife and cultural societies in variety of ways. Hence, attempts in present study were made to describe distinct successional stages of secondary forests for their tree species by plotting the SIV of selected tree species as a function of successional stages (age classes) of secondary forests to find out the process of invasion of forest tree species from the young seral stage to the old forest growth where it resembles the primary forests.

The criteria for selecting the species include (i) the species importance value, (ii) the use of species by native wildlife and (iii) the use of species by native people. This gave the idea of arresting desired successional stages and identifying the scientifically sound fallow period with longer *Jhum* cycle. This would help implementing adequate silvicultural treatment to the stand as per the needs of native wildlife and society. Further silviculture of these primary forest tree species coupled with analysis of various forest formations of primary forests, successional stages of secondary forests and response by individual tree species would provide information useful in recovering primary forests following clearing and developing a scientific foundation for forest management and biodiversity conservation. It would recommend a better form of regulated *Jhum* to ensure that at least some patches and elements of primary forests could be restored and retained throughout the region to reduce the impact of forest fragmentation, which frequent *Jhumming* is posing over the landscape now.

5.3 Using key functions of species for management purposes

The stand level assessment of forest growth with special reference to tree species suggest the need for designing further research studies to assess the use of 'key environmental correlates (KECs)' for wildlife species of conservation importance especially for species closely associated with old primary forests (Morrison *et al*. 2006). The term KECs refers to wildlife habitats, habitat elements, and other non-habitat influences on the distribution and abundance of organisms. This would help in developing our understanding of wildlife habitat relationships and, in particular, which elements of old forests could be provided in various portions of the landscape such as habitat corridors, recovered *Jhum* fields, protected area buffers, and reserved forests, to help provide for old-forest wildlife. Likewise, understanding key ecological functions, especially of keystone species is vital for their management, and these should be included in decision making for wildlife management and conservation planning. The term 'key ecological functions (KEFs)' refers to the principal set of ecological roles performed by a species in its ecosystem and the main ways organisms use, influence, and alter their biotic and abiotic environments (Morrison *et al*. 2006).

The study area, as described above, contains a wealth of natural resources and cultural heritage. Several scientists studied the biological, geological, anthropogenic features of *Garo* Hills and tribes; however, very few of them have been linking the native natural resources with their use by native cultural society. It is important to assess the key cultural functions (KCFs) of native wild plants and animals, including determining how various resources are used and valued, and rates of extraction. KCFs refer to the principal set of cultural roles performed by a species in the culture and society of the native *Garo* population (idea introduced by Bruce G. Marcot). Such information would help provide a basis for improving resource management and sustainable development in the area. The understanding of such cultural roles is imperative to developing any conservation strategy that will be acceptable to the *Garo* people and *Nokma*s.

Some of the KCFs are unique to *Garo* tribes, and differ substantially from how plants and animals are used by other people of Meghalaya or Northeast India. Jadorang represents the Psycho-cultural religion/philosophy of the *Garo*s. It involves the rather startling, animistic-like beliefs of this religion. The *Garo*'s use of plants and animals in Jadorang is far different from usual ethnobotany or ethnozoology (terms Coined by Bruce G. Marcot). Some plants play psychotropic roles; others are used as ritual or metaphorical symbols. Others, including some plants and animals, are believed to wield great animistic power of various specific natures. The terms 'psychobotany' and 'psychozoology' refer to a culture's use of plants and animals, respectively, for specific rites, rituals, religious interests, and other KCFs of organisms. These terms refer to the use of plants and animals that include, but extend well beyond, the traditional concept of 'ethnobotany' (for plants) that depicts the use of organisms for medicines and trade. The examples of key cultural functions of plants and animals used by the *Garo* people in the *Garo* Hills of western Meghalaya for religious rites and rituals are provided in **appendix 7**.

Once the KCFs are described, it is simple matter to query the relational databases of KCFs and KEFs to ask some rather profound things, for example, asking such questions as, what are the species of wildlife important to *Garo* tribes used as ritual sources of sustenance, and what habitats and KECs do such species use? It would help managers and planners to link the species geographically; map out concentration areas of species or populations having specific KCFs; and project their distribution over time under different management options. Furthermore, managers can link the species to their KEFs as well, and thereby – perhaps for the first time – ask joint questions about their specific cultural and ecological roles in the ecosystem. Managers can map the answers and project the effects of historic and potential future land use practices on them. Describing both the cultural and ecological roles of native organisms, and determining (in a very general way) what potential management activities influence them, is a major step forward in integrating (and, in a sense, "equalizing") the natural ecological with human ecological (cultural anthropological) dimensions.

The KCFs provide for social or cultural integrity of the human system, that is, they influence (at least in part) the social and cultural diversity and the quality of life of the human community. Likewise, KEFs of the species influence the ecological integrity of the ecosystem, that is, they affect (at least in part) the biodiversity, productivity, and sustainability of the system. Specific management goals and objectives, both ecological and cultural in nature, might describe the degree of social/cultural integrity and ecological integrity desired. In turn, achieving these goals of social/cultural integrity and ecological integrity means specifying a set of land and resource management activities, which directly influence various environmental features of the land, which in turn serve as habitats for the species of interest. This is a species- or organism-centric approach, to be sure, although the 'species' can equally well be described with functional or taxonomic groups of organisms, not just single species. Therefore, this can be a multi-species 'systems' approach as well.

The information on key function presented in the volume, has been supplemented through a few focus group interviews in selected villages to better understand and record the indigenous knowledge. The focus groups comprised the groups of experienced and old tribes from interior hills and staff members of forest/wildlife departments of the *Garo* Hills. Following paragraphs discuss the results of focus group interviews.

5.3.1 Trees as potential food for native wildlife

Trees in a forest ecosystem are one of the major food sources to wildlife especially terrestrial and arboreal mammals, and in majority of cases such wildlife species are the focus of conservation. The selected mammals to represent wildlife use of tree species in present study included the hoolock gibbons (*Bunopithecus hoolock*), Assamese macaque (*Macaca assamensis*), rhesus macaque (*Macaca mulatta*), stump-tailed macaque (*Macaca arctoides*), pig-tailed macaque (*Macaca nemestrina*), slow loris (*Nycticebus coucang*), capped langur (*Trachypithecus pileatus*), serow (*Capricornis sumatraensis*), sambar (*Cervus unicolor*), barking deer (*Muntiacus muntjak*), Malayan giant squirrel (*Ratufa bicolor*), hoary-bellied Himalayan squirrel (*Dremomys lokriah*), orange-bellied Himalayan squirrel (*Callosciurus pygerythrus*), Indian bison (*Bos gaurus*), Himalayan yellow-throated marten (*Martes flavigula*), wild pig (*Sus Scrofa*), bats in general (*Cynopterus sphinx* and other species), Himalayan black bear (*Selenarctos thibetanus*), porcupine (*Hystrix indica*), civets (Viverradeae) other civets and Asian elephant (*Elephas maximus*).

During the interviews, the interviewees identified the tree species used as food for each of the selected mammal species or group of species (macaques, deer, bats, civets). Once the forest staff and other locally resident people jointly agreed on use of a given tree species as a food item for a given mammal species or species group, the edible parts of the tree were identified and recorded (**Appendix 8**). The edible portions of tree species included the bark (B), fruit (F), flower (Fl), shoots (S), mature leaves (L) and young leaves (YL).

Out of a total of 150 tree species, all fifteen mammal (group) species used 56 tree species (**Fig. 7.1** and **Appendix8**). The macaques (rhesus, Assamese, pig-tailed and stump-tailed), slow loris, serow and deer (sambar and barking deer) had a wide range of food use for tree species by consuming various phenological parts of 50, 48, 45 and 45 per cent of used tree species, respectively **(Appendix 8**). Squirrels, hoolock and capped langur had the next most diverse use of trees, feeding on 21, 20 and 20 tree species, respectively.

The tree species like *Grewia microcos, Artocarpus chaplasha, Syzygium cumini, Lapisanthusrubiginosa, Artocarpus gomezianus, Ficus semicordata* and *Lanneagrandis* were the more used tree species. Ten or more wildlife species consume fruits, leaves, flowers, or bark of these tree species. All fifteen selected mammal species use *Grewia microcos* as food. The fruits of this tree species are also used by many other mammals and bird species of the *Garo* Hills. There were sixteen tree species that are used as food sources by only one of the mammal species assessed here, six tree species are used by two mammal species, and six tree species are used by three mammal species **(Appendix 8**). These wildlife uses of tree species represent the important key ecological functions of tree species.

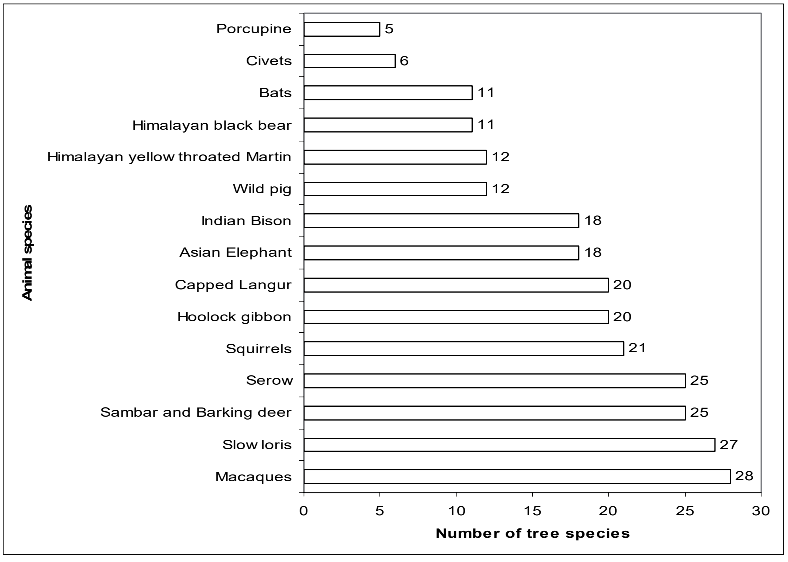

Fig. 5.1 Use of tree species as food by selected wildlife species based on the results of focus group interviews

5.3.2 Trees providing services to human society

In all, 108 out of 150 tree species were reported to be used by society in different ways (**Appendix 9**). Specific services considered to rate the uses of tree species by native people include their use as food, medicine, timber, fuelwood and raw material for boat construction, and the number of species recorded for such uses were 31, 19, 50, 91 and 40 per cent of used tree species, respectively. Two tree species *Dillenia pentagyna* and *Terminalia citrina* were the most versatile species and used for all of the five purposes. These cultural uses of tree species represent the key cultural functions of tree species.

The findings suggested that forest fragmentation has resulted in the loss of intensive forest cover by changing dense forest cover (TMEF and TSEF) into open forest cover (TMDF) resulting into decline in tree species diversity as revealed by the phyto-sociological and diversity analyses during present study. The TMDFs have shown the least tree species diversity compared to the TMEF and TSEF, though not proven significantly different by statistical analyses. This ultimately influenced the quality of wildlife habitat available in the study area. The study also identified certain tree species with low Species Importance values. Such species could be considered as rare species and require immediate conservation interventions to protect the immense wildlife and biodiversity values of landscape in the *Garo* Hills.

5.4 Wildlife

The old records of State Forest Department of Meghalaya revealed a considerable proportion of tiger population from the community owned forestland in the state. The 1992 – 93 census suggested a population of 63 tigers, with various sub-populations widely distributed in the forests of the *Garo*, *Khasi* and *Jaintia* Hills of Meghalaya, although there is no published information on how the census was conducted, how the census routes and areas were chosen, and the degree of uncertainty or error around the population value. The *Garo* Hills (8167 km^2) with 54% of state's tiger population harbours some of the most suitable tiger habitats in western Meghalaya. As per official records, the small South *Garo* Hills district (1850 km^2) housed 27% of all tigers counted while the equal numbers of tigers were reported from the rest of the *Garo* Hills including East and West *Garo* Hills districts covering 77% of the *Garo* Hills area (**Fig. 5.3**).

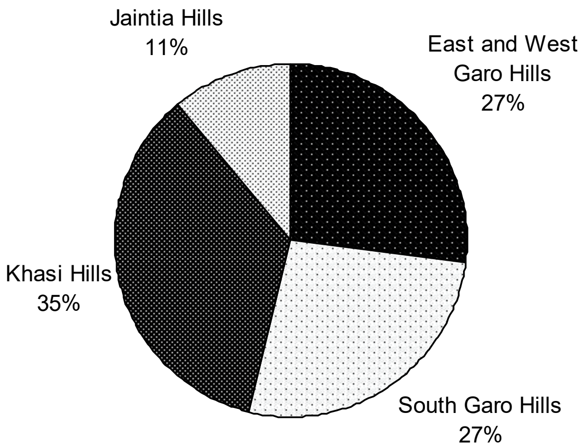

Fig. 5.3 Tiger census statistics (1992-93) in the Meghalaya (*Source: State Forest Department of Meghalaya, 1995)*

Surprisingly, in Meghalaya's first official tiger census during 1981, a population of ten tigers was reported from the core of Balpakram National Park, then Wildlife Sanctuary (120 km^2) with a crude density of one tiger per 12 km^2. In the same year, the population estimates of some tiger prey species especially wild pig (*Sus scrofa*), sambar (*Cervus unicolor*) and barking deer (*Muntiacus muntijak*), revealed the small populations of 102, 79 and 172 individuals from same area, however, the figures may need to be verified with the new census operations. There is need to monitor the population dynamics of tigers and other prey species using more precise and accurate census operations and consistent monitoring efforts using statistically-based sampling.

The results of focus group interviews involving senior wildlife officials along with frontline staff, local residents and other concerned individuals suggested the presence of tigers (direct sighting or indirect evidences) from more than 20 localities in remote hills of landscape. There are possibilities that many of these localities would be shared by the same tiger and the actual abundance might be much lower, however, the evidences of tiger presence were rather more common in this part of the *Garo* Hills. The *Aking* tracts (villages) like *Balpakram, Sinaru, Agal-chongoppa, Pindengru, Maogipeng, Penda, Marakabari, Pusulchiring, Deoban area, Dogepchiring, Teptepa, Ailatoli, Maheshkola, Bellibari, Narangbari, Sochetchiring, Rongdi-bisik, Nowa chiring, Ronsu-agal, Chutmang, Ampangiri, Hatitia, Passgaon, Bonbera, Nadankol, Atambing, Rongsu,* and *Rewak* are located within the core tiger habitats in the South *Garo*Hills district. More such areas could be identified and designated as the tiger monitoring points, which may be used to conduct further demographic studies for adequate conservation planning in the region.

The protected areas include Nokrek Biosphere Reserve and National Park, Balpakram National Park and Siju Wildlife Sanctuaries, while the managed forests designated as reserved forests include Baghmara, Rewak, Imangiri and Angratoli Reserved Forests. These protected areas and reserved forests all together covers about 20% of landscape area and constitute the major elements of protected area network in Meghalaya. The dense old forest growth comprising the tropical moist evergreen forests (TMEF), tropical semi-evergreen forests (TSEF) occupied about 40% of landscape, while the open forest growth comprising the tropical moist deciduous forests (TMDF) and sal (*Shorea robusta*) plantations comprised about 29% of landscape. The Bamboo growth and grassland patches along with associated young secondary forest patches and non-forest areas occupied nearly 10% of landscape area, while rest of the land is being used for various land use activities by native people. The habitation, covering about 10% of landscape area was the major land use activities and all settlements within the landscape belong to the four Community Development Blocks (CDBs), namely Chokpot, Baghmara, Rongra (all three in South *Garo* Hills district) and Samanda (East *Garo* Hills district). A small portion occupying only 4% of landscape was used for cultivating paddy and other crops through settled or permanent agriculture, most of which was confined in the valley plains or lower hills at gentle slopes around habitation. The land under shifting cultivation was much higher compared to settled agriculture and occupied about 7 % of landscape area.

A total population of 107,167 people (6703 families) inhabited the 712 small to large human settlements or villages (locally known as *Aking*) in these four CDBs, of which about 20% are engaged in *Jhumming* for their survival (DSWC 1995). TheRongra CDB, in the southeast of landscape is one of the least used areas with the lowest human density of 25 persons/km^2 (DSE 1995) among all four CDBs of landscape. This area holds much better opportunity for implementing conservation actions due to low anthropogenic influences and could be used for demonstrating the approaches towards guiding and allocating the ecologically acceptable *Jhum* activities and predicting desired land use pattern for sensible land use planning to ensure the long term conservation of tiger habitats and overall native biodiversity.

There is urgent need for adopting landscape scale ecological considerations, such as considerations of connectivity amongst various wildlife habitats for conserving this species. A new approach for determining the broader scale distribution and abundance of tigers and associated prey species needs to be adopted for successful conservation of this species. The additional floristic studies among various forest communities would help determine the habitat quality for herbivores especially wild pig, sambar, barking deer and other prey species in the region. There is need to understand the tiger habitat relations at landscape level for wider geographical coverage in their natural habitats.

The tiger population in the *Garo* Hills has a better chance of survival than in other parts of Meghalaya due to existence of connectivity among various old forest growth patches forming key tiger habitats. Some of such connectivity routes were identified as the potential wildlife habitat corridors by Williams & Johnsingh (1996) and Kumar *et al.* (2002). Such corridors likely would facilitate the movement of tigers and exchange of breeding individuals among subpopulations of larger landscapes in Meghalaya especially *Garo* Hills.

Conservation of the more intact, older native forest habitats buffering existing protected areas and providing habitat corridors to connect such areas would likely help conserve not just elephants but also tigers and their prey. In this way, a multi-species approach to conservation of the wildlife community can be taken. Other species of conservation significance in the *Garo* Hills needing immediate management interventions may include the clouded leopard (*Neofelis nebulosa*), hoolock gibbon (*Bunopithecus hoolock*), slow loris (*Nycticebus coucang*) and many other species. The old forest growths in the South *Garo* Hills district and adjoining Nokrek Biosphere Reserve (National Park) along with surrounding community land probably provide one of the best tiger habitats in northeast India and need to be protected on the priority basis for conserving the native biodiversity of Meghalaya.

5.5 Modelling elephant habitat relations in the *Garo* Hills

Most elephant populations were concentrated in Balpakram, Mahadeo, Chimitab, Siju, Baghmara, Nokrek and Samanda areas, however, a few noticeable meta-populations of this wide ranging species were observed inhabiting other parts of *Garo* Hills, for example, Dambu, Dagal, Kherapara, Adugre, Ranggira and other areas (Marak, 1998). Therefore, examining such widely distributed species within the confines of specific study area would not be appropriate from landscape perspective, which essentially needs to be appropriately defined in terms of species of the interest or target of management options.

Given these rationales, Marcot *et al.* (2002 and 2011) analysed the data from elephant censuses during last decade (1993 and 1998) and suggested a few statistical models using percent change of populations and crude densities of elephants, which established the use of census results as effective tool for management purposes. It would be appropriate to provide this useful analysis here, since it could be effectively incorporated in management and conservation of other wildlife species also. Marcot *et al.* (2002 and 2011) prepared a few models using elephant census records of the State Forest Department of Meghalaya. The dependent and independent variables were computed for the specific census zones (**Fig. 5.5**) in the *Garo* Hills and following models were suggested.

Fig. 5.5 Elephant census zones in the *Garo* Hills (GH), western Meghalaya. The All *Garo* Hills area included all labeled census zones; the South *Garo* Hills area included zones marked with an asterisk (*). Source: Marak (1998), as digitized into ArcInfo GIS

For All *Garo* Hills, the best-fit simple linear regression model of elephant-people-habitat relationships was:

Crude density (n/km^2) = 0.222 - 0.463(NVILDENS) + 0.005(TERRHIPC) + 0.076(MMDECID)

where NVILDENS = density of villages (n/km^2), TERRHIPC = percent cover of elephant census zones in high terrain complexity, and MMDECID = percent cover of elephant census zones in deciduous forest. This is a highly significant model (adjusted multiple R^2 = 0.65, F = 13.52, df = 3, P < 0.001). Further, combining percent cover in evergreen, semi-evergreen, and mixed moist deciduous forest also yielded a significant, single-variable regression model (F = 0.008, df = 1, P = 0.008).

For South *Garo* Hills, the best-fit model was:

Crude density (n/km^2) = 2.785 – 0.037(SHIFT) – 0.076(PCSEMIEV) – 22892.794(B3_MINA) – 0.374(BA_MAXA)

where SHIFT = area in km^2 of Jhum, PCSEMIEV = percent cover in semi-evergreen forest, B3_MINA = minimum patch size of evergreen, semi-evergreen, and deciduous forest combined, and BA_MAXA = maximum patch size of bamboo forest. This was a marginally significant model (adjusted multiple R^2 = 0.62, F = 4.214, df = 4, P = 0.096).

The two models told a similar story – that elephant density was related positively to areas with intact native forest and high topographic relief (steep hills away from villages and *Jhum* sites), and negatively to areas with high village density, extensive *Jhum* and secondary bamboo forest, and high fragmentation of native forest. The results of the linear regressions suggested the following critical values of specific habitat variables affecting elephant density at the two scales.

In All *Garo* Hills, elephant densities are greater in landscapes with:

- < 30% current and abandoned *Jhum* (current *Jhum*< 5%, abandoned *Jhum*< 25%)
- < 20% in high forest patchiness (caused by *Jhum*)
- village density < about 0.4 villages/km^2
- annual *Jhum* rates < 2% of the land *Jhummed*/year
- evergreen, semievergreen, and mixed moist deciduous forest cover is > 40%

In South *Garo* Hills, elephant densities are greater in landscapes with:

- < 10% in bamboo and secondary forest
- less fragmented, larger, and more contiguous patches of native forest

Results at the two scales were consistent although the independent (habitat) variables used in the analyses were different. The forest manager could use these findings to help direct habitat conservation or restoration measures for maintaining elephants in the *Garo* Hills, at least as working hypotheses. Further, the conservation of a set of seven elephant habitat corridors identified in this study consist of largely intact native forest and conditions suggested by the above summary that correlate with high elephant density in both scales of analysis. Behavioural studies could help validate these initial findings of elephant-people-habitat relations.

5.6 Land use planning for Biodiversity Conservation

The landscape still holds many large forest tracts, but most of them are situated in the unprotected community land and open for all kind of resource use by native society. The Balpakram and Nokrek areas of landscape with the protected areas and sundry reserved forests are the real biodiversity gems of regional and global conservation significance. These areas hold far greater forest cover, and are less densely inhabited by people, than other landscapes from adjoining districts of India and Bangladesh.

The major stressor to native biodiversity in *Garo* Hills is the increasing anthropogenic conversion of nature and primary forests to human land. *Jhum* had a more extensive influence on loss of old forest habitat and associated wildlife, both plants and animals, and on loss of soil fertility and increase in soil erosion. However, it is not *Jhum* agriculture *per se* that is to blame for this reduction, but rather the increasing intensity of its application across the landscape of *Garo* Hills. *Jhum* agriculture is central to the social structure, beliefs, and even language of the *Garo*s (Kar 1982, Playfair 1998). When applied with appropriate fallow periods (especially 20 years or longer), *Jhum* agriculture has the potential of providing for both older forest communities as well as for the agricultural needs of the local peoples, at different stages of growth of the vegetation on the same site. It is the great reduction in the fallow period (Jha 1997) that has sacrificed soil fertility and that has truncated forest growth cycles and caused the loss of older forests and their wildlife.

With proper guidance on *Jhum* allocations and fallow periods, in specific areas, much of the old-forest community can likely be restored at least in selected sites of highest biological conservation interest and importance. Without such proper guidance, some species will likely become imperiled or locally extinct. Wildlife closely associated with old forests with contiguous tree canopy cover includes tiger (*Panthera tigris*), clouded leopard (*Neofelis nebulosa*), golden cat (*Felis temminki*), slow loris (*Nycticebus coucang*), hoolock gibbon (*Bunopithecus hoolock*), capped langur (*Trachypithecus pileatus*), pigtailed macaque (*Macaca nemestrina*), stumptailed macaque (*M. speciosa*), flying squirrel (*Petaurista petaurista*), binturong (*Arcticus binturong*), and many other species. These species likely have suffered reductions in distribution and numbers over historic times from changes in their old, primary forest habitat to younger forests with dis-contiguous canopy cover and to non-forest agriculture conditions.

Since most of the land base in *Garo* Hills belongs to the native *Garo* community, the state government had to put extra efforts in maintaining the existing protected area network and expanding it. Long after initial acquisition of 220 km^2 (Balpakram Narional Park) and 47 km^2 (Nokrek National Park) during 1985-86, additional 132 km^2 area was acquired **(Fig. 5.2)** and added to these two protected areas, while further 359 km^2 of land was proposed for further acquisition with the joint funding efforts of state and central governments.

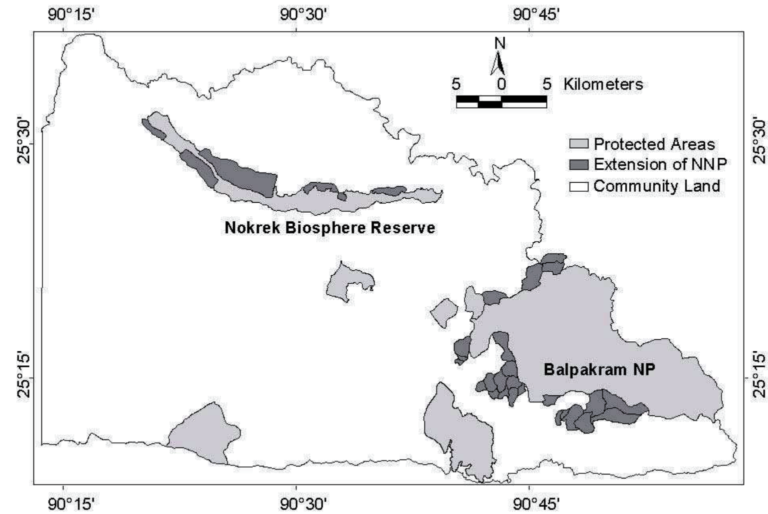

Fig. 5.2 An example of extending two protected areas of South *Garo* Hills, Nokrek National Park and Balpakram National Park.

The analyses of zones of influences around protected areas and reserved forests revealed that large tracts of forest cover exist over much of community land. Additionally, the four reserved forests along with other reserved forests including Rongrengiri, Songsek and Darugiri Reserved Forests (60 km^2) in the *Garo* Hills, outside the boundaries of landscape were also proposed for designating as wildlife sanctuaries (SFD, 1995).

Among the important wildlife habitats needing more formal protection are sacred groves having older forest cover. Even sacred groves of the smallest size, just a few hectares or less, provide valuable habitats with fruiting trees, cavity trees, canopies for cover, and other habitat values (Tiwari *et al.* 1999). Some 133 plant species are restricted to sacred groves of Meghalaya, and of these, 96 are endemic to Meghalaya (Khan *et al.* 1997). Further, a new subset of biodiversity rich locations including sacred groves could be identified as key wildlife habitats and considered for further extension of protected area network of the region. Such areas may include several forest patches with sufficient enough core areas, especially within the corridor boundaries and the various zones of influences. The suggested framework for expanding the existing protected area network may include the following categories of elements of protected area network in the *Garo* Hills, which could be used as model demonstration sites for other *Jhum* influenced landscapes in the tropics of northeast India and Indo-Malayan and indo-Chinese biogeographic regions. The state government may select the identified critical areas for targeting their conservation efforts, and arrange the structure of protected area network in the *Garo* Hills (or other part of Meghalaya) in following four categories.

- Government-designated national parks, wildlife sanctuaries for conserving biodiversity.
- Reserved forests for sustainable resource use (though now proposed to provide complete protection by converting their status as wildlife sanctuaries).
- Zones, buffers, corridors around above categories within various zones of influencesfor local protection, and for the connectivity of habitats and plant and animal populations. This particular category should consider the sacred groves of *Garo* Hills on priority basis.
- Specific substrates and vegetation elements within the croplands, managed forests, and other high-use areas for providing specific habitat elements (see **appendix10** for details of select specific substrates).

The most centres of wildlife habitat in the landscape are well connected with each other, which provided opportunity to wide ranging wildlife species (especially Asian elephants, the *Elephas maximus*) to move across the region (between Brahmaputra valley in Assam, India towards north and Surma valley in Bangladesh towards south) to facilitate the gene flow among several populations (including meta-populations) of landscape to ensure long term survival of the species. These potential corridors are performing valuable ecological functions of facilitating the movement of several populations of native wildlife species especially the large mammals. The state government could manage these corridors as actual or *de facto* wildlife sanctuaries, the purpose being to protect the old forest stands from excessive *Jhum* and enhance the conservation status by protecting and monitoring them. Other such linkages between major wildlife centres could be mapped and evaluated for the extent of old forest growth (representing wildlife habitat conditions) beyond the boundaries of landscape. The state government has already proposed following areas as potential wildlife habitat corridors for official acquisition in the Meghalaya, most of which are confined to the *Garo* Hills.

Within *Garo* Hills

- Nokrek – Rongrengiri – Songsak (55 km^2)
- Rewak – Emangiri – Rugapara – Nokrek (96 km^2)
- Balpakram – Baghmara (31 km^2)
- Siju – rewak (0.25 km^2)

Out side *Garo* Hills

- Balpakram – Umbitt – Pormodar – Rengdim (70 km^2)
- Khri Catchment – Nongkhyllem (50 km^2)

All these routes are vital for maintaining efficient gene exchange and smoother movement of wide ranging mammal, especially Asian elephants, which is the most dominant among all animal life forms by virtue of being the largest terrestrial mammal on earth. The logn term survival of this particular species could not be expected without maintaining these corridors.

5.7 Demonstration Projects

The formation of a few demonstration projects was one of the most important implications of present study for testing and implementing modifications to *jhum* agriculture (shifting cultivation) in *Garo* Hills. The suggested demonstration projects base on the following three themes (**Appendix 11**):

- Additions to protected areas
- Protection of primary and mature forests in wildlife corridor habitat areas.
- Provision of older secondary forests (as wildlife habitat) in heavily *jhummed* areas.

5.8 Proteted Area Network

We identified a series of 7 potential forest corridors that could help link the PAs and, as such, would constitute a true PA network or PAN. To date, most PAs are identified and designated independent of other PAs, the broader landscape, and major conservation goals. The PAN approach also focuses on conditions among the PAs within the broader landscape, and delineates corridors based on high proportion of native forest cover, large average forest patch size, low levels of forest fragmentation, and low occurrence of anthropogenic land use, principally habitations, permanent agriculture and *Jhum*. The PAN approach also provides clearly delineation of lands more suited for human activities outside PAs and connecting corridors. As part of the PAN framework, we also evaluated forest conditions with three zones of influence surrounding PAs, and suggested potential restoration or preservation priorities within each zone, that would significantly add to the effective area of PAs and likely enhance the functionality of the connecting corridors.

Expanding the traditional conservation focus on PAs to include landscape-wide assessments and delineations of zones of influence and networks of connecting corridors could be usefully applied to other parts of the country where isolation of parks and wildlife reserves are proving problematic to maintaining at-risk species. The biodiversity within PAs in *Garo* Hills is influenced not only by the forest conditions protected within the PAs, but also by the traditional practice of shifting cultivation or *Jhumming* in their surrounds. Our spatial analysis revealed that a substantial proportion of old native forest is still present outside existing PAs. However, unless, such sites brought within the modified and improved framework of PAN, it would be difficult to conserve biodiversity in the actively-managed community or privately-owned forest land in *Garo* Hills.

The Forest Rights Act of 2006 provides immense authorities to native tribal communities, empowering them to exploit natural resources including forests and wildlife to such extent that can gravely compromise native forest cover and associated biodiversity. The corridor system in our proposed PAN framework would likely provide for at least some successful, continued interchange, among

PAs, of native, wide-ranging wildlife of the region including elephants, tigers, ungulates, and other large predators and herbivores. The PAN approach could include protection of selected, intact forests within zones of influence (ZI1, ZI2) and active restoration of selected sites (ZI3). Mathur and Sinha (2008) have also emphasized on additions to the PAs of the region, or designations of corridors and linkages to serve as a PAN, should also account for social and economic issues and resource needs of the *Garo* people.

5.9 Conclusion

Our analysis suggests that, although most of the land area in *Garo* Hills is forested, residential and agricultural use by the *Garo* community is widely dispersed throughout the area. Also, most of the area around human settlements is extensively used for *jhumming* until the recent past. Past *jhumming* has left degraded scrub areas concentrated around villages or settlements. Mostaerable land is being used either for settled permanent agriculture or *jhumming*, and other forest resource uses such as firewood gathering (Bhatt and Sachan 2004) are also having a toll on native forests of the region.

Lower mean patch size and smaller edge length of patches with intense human use, as compared to those of forest cover patches, suggested that forest cover is being fragmented by human use. This is also suggested by patches with intense human use having a higher patch density and edge density as compared to those of forest cover patches. However, the landscape still holds larger tracts of old forest cover. Several large forest patches in the PAs and in BRF and ARF are the best examples, as these forest patches provide promising habitat for hoolock gibbons (*Bunopithecus hoolock*), which have gradually disappeared during the past two decades and have become locally extinct from these areas mainly due to increasing human disturbances in their habitats. Forest managers may consider protecting large patches of native forests that occur outside but adjacent to the PAs and RFs as part of restoration programmes for locally extirpated wildlife species.

Jhum has had an obvious impact on reducing native forest cover of the area. During 2000, a total of 7900 families (39 500 people) used 68 km^2 land for *jhumming*, at an annual rate of *jhumming* was 3.67% in South *Garo* Hills (DSWC 2001). Such rates of converting forest to *jhum* likely have adversely impacts some habitats and populations of wildlife species of the area. The impact of *jhum* can be described by identifying the levels of fragmentation of native forests and the dispersion of *jhum* patches over the landscape. Fortunately, 71% of the landscape area was at a low level of fragmentation, whereas most of the medium or high fragmentation areas were concentrated in the south-west corner of the landscape. This portion lies on the flat land south and away from Nokrek Ridge and far from BalpakramNational Park. Nokrek and Balpakram are important protected areas of the region, and both seem have mostly retained extensive cover of native old forests.

Unfortunately, such intact forest cover in *Garo* Hills is suffering an increased rate of fragmentation from *jhum* and other human use. The seven wildlife habitat corridors we identified encompass three corridors identified previously by Williams and Johnsingh (1996). We observed that ARF is the most isolated of all PAs and RFs in the landscape, and has lacked forest connectivity with any other such elements, although evidence suggests that it was historically connected with ERF by a corridor of old native forest cover. This historic corridor once facilitated movement of elephants across NNP in the north and the plains of Bangladesh in the south. Such migratory routes could be restored with timely management interventions.

It is unclear the degree to which the existing PAs, which constitute over 15% of the landscape, will conserve the rich biodiversity of these old forests. Our finding of higher mean forest patch size and lower mean forest patch density within the PAs as compared with outside the PAs reflects the lower degree of forest fragmentation within PAs as compared to RFs and community land, and we speculate that fragmentation might sacrifice some biodiversity elements. However, most forest cover (60% of landscape) is found in community land. However, in a companion analysis, Kumar (2005) reported that most community forests had high tree species diversity, but some tree species were found only with, or at least more dominant within, the PAs.

Our findings included that the 2-km ZIs had lower proportions of TMEF forest and with negligible area under various land use activities, whereas the 5-km ZIs contained a higher proportion of forest and a moderate proportion of land use activities. The community forest land area beyond the 5-km ZIs contained the lowest proportion of TMEF but most of TMDF and the highest proportion of residential and agricultural (settled or *jhumming*) areas. The area of TMDF represented more or less open or disturbed forest growth. Thus, efforts to conserve wildlife habitat and tropical evergreen forest in the 2-km ZI could focus on preservation and perhaps enlargement of PA boundaries or designation of intact forests as parts of corridors. Forest conservation in the 5-km ZI could focus on additional protection measures because most of this ZI contains TMEF and TSEF native forest with only low levels of land use activities. And forest conservation in the land area beyond the 5-km ZI could focus more on restoration (rather than preservation) activities, which may be coupled with additional protection measures to help protect at least some of the remaining, larger forest tracts within community land.

As reported by Marcot et al. (2002 and 2011), elephant populations were most dense in Balpakram, Mahadeo, Chimitab, Siju, Baghmara, Nokrek and Samanda areas, but were also dispersed in lower densities in other parts of *Garo* Hills, for example, Dambu, Dagal, Kherapara, Adugre, Ranggira and other areas (Marak, 1998). Therefore, examining the requirements of such a widely distributed species as elephant within the South *Garo* Hills study area should also entail understanding its distribution and habitat associations in a broader geographic context. For example, using spatial information from Talukdar (2004), Marcot et al. (2002 and 2011) analysed elephant-habitat relationships across all of *Garo* Hills, by using elephant censuses from 1993 and 1998. They presented a statistical models suggesting the following critical values of specific habitat variables significantly correlating with elephant density. Across the entire *Garo* Hills, elephant densities were reported to be greater in landscapes with:

- < 30% current and abandoned *jhum* (current *jhum*< 5%, abandoned *jhum*< 25%),
- < 20% in high forest patchiness (caused by *jhum*),
- village density < about 0.4 villages/km^2,
- annual *jhum* rates < 2% of the land *jhummed*/year, and

- evergreen, semi-evergreen, and mixed moist deciduous forest cover is > 40%.

These correlations, along with the wildlife habitat corridors, could also be used to help guide conservation or restoration of elephant forest habitat in *Garo* Hills. In addition, activities for maintaining or restoring overall forest biodiversity could also use our findings for conserving intact blocks of native forest, especially of TSEF, in the 2- and 5-km ZIs, and encouraging rates of *jhum* in the land areas beyond the 5-km ZIs to allow for some degree of forest regrowth and restoration.

The 2003 amendments in the Wildlife Protection Act (1972) of Government of India bestowed the State Governments and Forest Departments with a strong tool through designating some forests on private non-government lands (*Garo* community land in present study) as 'Community Reserves,' whereas government lands may be designated as 'Conservation Reserves.' The landscape under investigation during present study offers excellent prospects for declaring both community reserves and conservation reserves for the purpose of conserving or restoring elephant populations and overall forest biodiversity.

Results of our study support similar findings of adverse effects on native forest cover and diversity from intensive and accelerated shifting cultivation in India and elsewhere. For example, studies in the Chittagong Hills of Bangladesh, which borders the *Garo* Hills to the south, have shown that shifting cultivation had little affect on forests until it accelerated at the beginning of the colonial period (Thapa and Rasul 2006). Together with dam construction, expansion of permanent plot agriculture, commercial and clandestine logging, and population migration and increase, shifting cultivation in Chittagong Hills has caused loss of native forests and reduction in soil productivity (Gafur et al. 2003). Changing the course of this tide has been impeded there by policy problems in land rights and trade, and lack of infrastructures and support services (Thapa and Rasul 2006). Agroforestry -- the mixing of semi-permanent crops with different harvest cycles and life forms on the same plot of land -- has been suggested as an alternative to shifting cultivation in this area (Rasul and Thapa

2006), and indeed in many areas of the world such as in Amazonia (Mcgrath et al. 2000).

In other examples, studies by Lawrence (2004, 2005) of 10-200 years of shifting cultivation in rainforests of Borneo suggested that, over many cultivation cycles, tree diversity and regeneration has shifted from seed-banking species to resprouting species, and that the overall carbon sequestration capacity of the secondary forests may become compromised. In Peru, Naughton-Treves et al. (2003) reported that hunting had an additional impact on persistence of mammals in shifting cultivation forest landscapes. In Arunachal Pradesh, India, Arunachalam and Arunachalam (2002) found that degraded soil of *jhum* fallows, particularly soil microbial carbon, nitrogen, and phosphorous, could be rehabilitated by planting of *Bambusa nutans* bamboo. Tawnenga et al. (1996) suggested that second-year cropping and use of fertilizers could maintain yields in *jhum* fields in Mizoram, North East India, and that shorter cycles (6 years vs. 20 years) of traditional *jhum* methods result in declines in primary productivity and economic yield of rice crops.

However, as our case study also revealed, *jhum* cannot be singled out as the villain, nor easily altered or replaced wholesale with other less-extensive forms of agriculture and land use, without considering the tapestry of fuller cultural traditions, society norms, and even religious beliefs in which old forms of forest agriculture have arisen. Moreover, it is not *jhum* per se that is the concern, but rather the unimpeded expansion of human populations into forest landscapes with fragile or erodable tropical and subtropical soils. Strategies for changing such long-standing traditions as well as ameliorating adverse effects of human density and occupation of forest landscapes must integrate consideration for nutrition, health, education, access to economic trade, and effects on traditional lifestyles.

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Appendix 1

Habitats of selected bird species in and around BalpakramNational Park . 1 = reported to occur; blank = reported to not occur or no information

S. No.	Common name	Scientific name	Primary Forest	Secondary Forest	*Jhum*Areas	Balpakram Plateau
1	Red Jungle Fowl	*Gallus gallus*	1	1	1	1
2	Brown shrike	*Lanius cristatus*		1	1	1
3	Red whiskered bulbul	*Pycnonotus jocosus*		1	1	1
4	Red vented bulbul	*Pycnonotus cafer*		1	1	1
5	Yellow browed leaf warbler	*Phylloscopus inornatus*	1	1		1
6	Grey headed flycatcher warbler	*Seicercus xanthoschistos*	1	1		1
7	Franklin's wren warbler	*Prinia hodgsoni*		1	1	1
8	Yellow backed sunbird	*Aethopyga siparaja*	1	1		1
9	White-eye	*Zosterops palpebrosus*	1	1		1
10	Sparrow Hawk	*Accipiter nisus*		1		1
11	Kestrel Falco	*Falco tinnunculus*			1	1
12	Kaleej Pheasant	*Lophura leucomelana*	1	1		
13	Thickbilled green pigeon	*Treron curvirostra*	1	1		
14	Rufous turtle dove	*Streptopelia orientalis*			1	1
15	Emerald dove	*Chalcophaps indica*	1	1		
16	Lorikeet	*Loriculus vernalis*	1	1		
17	Common hawk cuckoo	*Cuculus varius*		1		1

S. No.	Common name	Scientific name	Primary Forest	Secondary Forest	*Jhum*Areas	Balpakram Plateau
18	Coucal	*Centropus sinensis*		1	1	
19	Palm swift	*Cypsiurus parvus*			1	1
20	Great hill barbet	*Megalaima virens*	1	1		
21	Large green barbet	*Megalaima zeylonica*	1	1		
22	Golden oriole	*Oriolus oriolus*		1		1
23	Maroon oriole	*Oriolus trailii*	1	1		
24	Blackheaded oriole	*Oriolus xanthornus*	1	1		
25	Greybacked shrike	*Lanius tephronotus*			1	1
26	Grey drongo	*Dicrurus leucophaeus*		1		1
27	Bronzed drongo	*Dicrurus aeneus*	1	1		
28	Lesser rackettailed drongo	*Dicrurus remifer*	1	1		
29	Greater rackettailed drongo	*Dicrurus paradiseus*	1	1		
30	Ashy swallow shrike	*Artamus fuscus*			1	1
31	Greyheaded myna	*Sturnus malabaricus*		1		1
32	Pied flycatcher shrike	*Hemipus picatus*		1		1
33	Scarlet minivet	*Pericrocotus flammeus*	1	1		
34	Common iora	*Aegithinia tiphia*	1	1		
35	Goldmantledchloropsis	*Chloropsis cochinchinensis*		1		1
36	Olive bulbul	*Hypsipetes viridiscens*	1	1		
37	Brown eared bulbul	*Hypsipetes flavalus*	1	1		

S. No.	Common name	Scientific name	Primary Forest	Secondary Forest	*Jhum*Areas	Balpakram Plateau
38	Spotted babbler	*Pellorneum ruficeps*	1	1		
39	Slatyheaded scimitar babbler	*Pomatorhinus horsfieldii*	1	1		
40	Nepal babbler	*Alcippe nipalensis*	1			1
41	Greyheaded flycatcher	*Culicicapa ceylonensis*	1	1		
42	Blyth's reed wabbler	*Acrocephalus dumetorum*			1	1
43	Dull green leaf warbler	*Phylloscopus trochiloides*	1	1		
44	Dark grey bush chat	*Saxicola ferrea*			1	1
45	Indian tree pipit	*Anthus hodgsoni*			1	1
46	Purple sunbird	*Nectarinia asiatica*		1		1
47	Crested surpent eagle	*Spilornis cheela*				1
48	Buzzard spp	*Buteo spp*				1
49	Blackcrested Baza	*Aviceda leuphotes*			1	
50	Short-Toed Eagle	*Circaetus gallicus*				1
51	Oriental hobby	*Falco severus*			1	
52	Lesser Kestrel	*Falco naumannii*			1	
53	Peacock Pheasant	*Polyplectron bicalcaratum*	1			
54	Indian cuckoo	*Cuculus micropterus*		1		
55	Drongo cuckoo	*Surniculus lugubris*	1			
56	Large green billed malkoha	*Rhopodytestristis*	1			

S. No.	Common name	Scientific name	Primary Forest	Secondary Forest	*Jhum*Areas	Balpakram Plateau
57	Longtailed nightjar	*Caprimulgus macrurus*		1		
58	Red headed trogon	*Harpactes erythrocephalus*	1			
59	Himalayan swiftlet	*Collocalia brevirostris*				1
60	Whitebreasted kingfisher	*Halcyon smyrnensis*				1
61	Chestnut headed bee-eater	*Merops leschenaultii*		1		
62	Indian roller	*Coracias benghalensis*				1
63	Indian pied hornbill	*Anthracoceros coronatus*	1			
64	Bluethroated barbet	*Megalaima asiatica*		1		
65	Speckled piculet	*Picumnus innominatus*	1			
66	Rufous piculet	*Sasia ochrasia*		1		
67	Rufous woodpecker	*Micropternus brachyurus*	1			
68	Longtailed broadbill	*Psarisomus lunatusdalhousiae*	1			
69	Swallow	*Hirundo rustica*				1
70	Sand Martin	*Riparia riparia*				1
71	Refousbacked shrike	*Lanius schachtricolor*		1		
72	Hill myna	*Gracula religiosa*	1			
73	Large wood shrike	*Tephrodornis virgatus*		1		

S. No.	Common name	Scientific name	Primary Forest	Secondary Forest	*Jhum*Areas	Balpakram Plateau
74	Large cuckoo shrike	*Coracina novaehollandie*		1		
75	Smaller grey cuckoo shrike	*Coracina melaschistos*		1		
76	Longtailed minivet	*Pericrocotus ethologus*		1		
77	Goldfrontedchloropsis	*Chloropsis aurifrons*	1			
78	Orange belliedchloropsis	*Chloropsis hardwickii*	1			
79	Fairy bluebird	*Irene puella*	1			
80	Finchbilled bulbul	*Spizixos canifrons*	1			
81	Blackheaded yellow bulbul	*Pycnonotus melanicterus*	1			
82	Black bulbul	*Hypsipetes madagascariensis*	1			
83	Whitethroated bulbul	*Criniger flaveolus*	1			
84	Redfronted babbler	*Stachrisruficeps*			1	
85	Blackchinned babbler	*Stachyris pyrrhops*		1		
86	Yellow breasted babbler	*Macronous gularis*			1	
87	Redcapped babbler	*Timalia pileata*			1	
88	Necklace laughing thrush	*Garrulax moniligers*		1		
89	Blackgorgetted laughing trush	*Garrulax pectoralis*		1		
90	Blackcapped sibia	*Heterophasia capistrata*	1			
91	Little pied flycatcher	*Ficedula westermanni*		1		

S. No.	Common name	Scientific name	Primary Forest	Secondary Forest	*Jhum*Areas	Balpakram Plateau
92	Redbreasted flycatcher	*Ficedula parva*			1	
93	Pygmy blue flycatcher	*Muscicapella hodgsonii*				1
94	Bluethroated flycatcher	*Cyornis rubeculoides*	1			
95	Whitethroated fantail flycatcher	*Rhipidura albicollis*		1		
96	Blacknaped blue flycatcher	*Hypothymis azurea*				1
97	Large billed leaf warbler	*Phylloscopus magnirostris*	1			
98	Large crowned leaf warbler	*Phylloscopus coronatus*	1			
99	Allied flycatcher wabler	*Seicercus affinis*		1		
100	Sultat tit	*Melanochlora sultanea*	1			
101	Scarlet backed flowerpecker	*Dicaeum cruentatum*	1			
102	Rubycheek	*Anthreptes singalensis*	1			
103	Nepal yellowbacked sunbird	*Aethopyga nipalensis*		1		
104	Little spider hunter	*Arachnothera longirostris*	1			
105	Streaked spider hunter	*Arachnothera magna*	1			
106	Blackbreasted sunbird	*Aethopyga saturata*	1			
107	Tree sparrow	*Passer montanus*		1		
108	House sparrow	*Passer domesticus*			1	

S. No.	Common name	Scientific name	Primary Forest	Secondary Forest	*Jhum*Areas	Balpakram Plateau
109	Whitebacked munia	*Lonchura striata*			1	
110	spotted munia	*Lonchura punctulata*			1	
	Total		51	55	24	36
Source: Manoj and Jayapal, personal communication, 1998						

Appendix 2

Tree species and parts used as food items by 15 selected mammal species of *Garo* Hills. B = bark, F = fruit, Fl = flower, S = shoots, Y = young, blank = not used or information not available.

Tree species	Macaques	Slow loris	Sambar and Barking deer	Serow	Squirrels	Hoolock gibbon	Capped Langur	Asian Elephant	Indian Bison	Wild pig	Himalayan yellow throated Martin	Himalayan black bear	Bats	Civets	Porcupine	Total
Grewia microcos	B	F	F,L	F,L	F	YL	L	F, L	F	F	F	F	F	F	F	15
Artocarpus chama		F	F	F	F	F,L	F,L	F, L	F	F	F	F	F		F	13
Syzygium cumini		F		F,L	F	F		F	F	F	F	F	F	F	F	12
Lepisanthes rubiginosa		F	F	F,L	F	L	F,L	L		F		F	F		F	11
Artocarpus gomezianus	B, L		F		F	F	L	L	F		F	F	F			10
Ficus semicordata	B, L		F		F	L	L	L	F		F		F	F		10
Lanneagrandis		F	F,L	F,L	F	L		F,L	F			F	F	F		10
Bursera serrata	B, L	F	F		F	F,L	L	F		F	F	F				9
Dillenia pentagyna		F	F	L	F	F,L	F,L	F,L			F	F				9
Ficus subulata	B, L			F,L		F,L	L	F,L	F		F	F		F		9
Garcinia lancifolia		F	F	F	F	F		F				F	F		F	9
Ilex umbellulata		F	F	F,L	F			F	F	F			F			8
Syzygium	B,		F			F,L	F,L	L	F		F		F			8

Tree species	Macaques	Slow loris	Sambar and Barking deer	Serow	Squirrels	Hoolock gibbon	Capped Langur	Asian Elephant	Indian Bison	Wild pig	Himalayan yellow throated Martin	Himalayan black bear	Bats	Civets	Porcupine	Total
balsameum	L,F															
Alangium chinense		F	F	F	F					F		F	F			7
Bauhinia stipularis		Y. L, Fl	F	F,L	Fl	L,Fl	F,L	F,L								7
Garcinia kydia		F	F		F	F	F,L			F			F			7
Macaranga indica		F	F	F,L		L				F			F			6
Mangifera indica	F		F			F			F		F		F			6
Mangifera sylvatica	F		F			F			F		F		F			6
Trema orientalis	B, L		F	L		L	L	L								6
Callicarpa arborea		F	F	F,L			L			F						5
Flacourtia jangomas		F	F	F	F							F				5
Abrus precatorius			F			F,L	F,L	F,L								4
Ficus foveolata						L	F,L	L					F			4
Garcinia tinctoria	B, L	F	F		F											4
Gmelina arborea				L		F, YL	F,L	F,L								4
Morinda		F	F	F	F											4

Tree species	Macaques	Slow loris	Sambar and Barking deer	Serow	Squirrels	Hoolock gibbon	Capped Langur	Asian Elephant	Indian Bison	Wild pig	Himalayan yellow throated Martin	Himalayan black bear	Bats	Civets	Porcupine	Total
augustifolia																
Pterigotaalata	B, L			F	F			F,L								4
Aporusa dioica				F	F								F			3
Emblica officinalis						F, YL		F					F			3
Eurya accuminata		F		F				F								3
Maesa sarmentosa		F	F					L								3
Syzygium operculatum			F, YL		F						F					3
Wendlandia excelsa						L	L	L								3
Bridelia retusa			F					F,L								2
Croton joufera				F,L									F			2
Hodgsonia macrocarpa	F						F,L									2
Holarrhena antidysenterica				L		L										2
Pterospermum acerifolium	B		F													2
Vitex peduncularis						B, L				F						2

Tree species	Macaques	Slow loris	Sambar and Barking deer	Serow	Squirrels	Hoolock gibbon	Capped Langur	Asian Elephant	Indian Bison	Wild pig	Himalayan yellow throated Martin	Himalayan black bear	Bats	Civets	Porcupine	Total
Aesculus assamica				L												1
Albizia chinensis				L												1
Albizia odoratissima				L												1
Anthocephalus chinensis														F		1
Aristolochia tagala				F												1
Bridelia monoica		F														1
Careya arborea								L								1
Dalbergia paniculata				L												1
Elaeocarpus rugosus	B, L															1
Erythrina stricta	B															1
Glochidion spharogynum													F			1
Mallotus roxbughianus	B, L															1
Ostodes paniculata													F			1
Polyalthia simiarum			F													1
Pterospermum	B,															1

Tree species	Macaques	Slow loris	Sambar and Barking deer	Serow	Squirrels	Hoolock gibbon	Capped Langur	Asian Elephant	Indian Bison	Wild pig	Himalayan yellow throated Martin	Himalayan black bear	Bats	Civets	Porcupine	Total
lancifolium	L															
Tetrameles nudiflora	B															1
Total species used	28	27	25	25	21	20	20	18	18	12	12	11	11	6	5	

Appendix 3

The 5 response (elephant) and 70 predictor (vegetation and lands cover) variables. 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 correlations but excluded from regressions 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 / sq km)

Crude density of no. elephants per census zone area, 1997-98 (n / sq km)

Percent change in total elephant numbers between 1993 and 1997-98 censuses

Predictor (vegetation and habitat) variables:

	Area (sq km)	Percent of census zone	Total number of patches	Total area of patches	Average patch size	Minimum patch size	Maximum patch size
Active *Jhum*	c	c	c	c	c	c	c
Scrub & abandoned *Jhum*	c	c	c	c	c	c	c
Bamboo brakes & 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, & evergreen forest combined	c	c	R	R	c	R	c

Appendix 4

TABLE 1. Elephant census results from South *Garo* Hills District and Nokrek area, western Meghalaya, in 1993 (Wildlife Wing, Forest & Environment Department, Shillong, Meghalaya) and 1997-98 (Marak 1998). Census zone areas calculated from GIS analysis. Crude density was calculated as total number of elephants / total area.

						Elephants / sq km	
Census zone number	Census zone name	Total area, sq km (a)	Total no. elephs. 1993 (b)	Total no. elephs. 1998 (c)	Percent change (c-b)/b	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

Appendix 5

Analysis results showing various spatial (landscape) indices calculated for all patches with 0.01 sq km (1 ha) area or above for providing ready reference to the managers planners for comparing various combinations of landscape segments in the *Garo* Hills.

(Note: The largest patch indices in following tables were calculated by considering the total area of particular landscape segment, for example, in case of combined protected area and reserved forests, the largest patch index was computed using 362 km² as total area, while for protected areas, reserved forests and community land it considered 272 km², 90 km² and 2097 km², respectively.)

A	**Land stewardship**				
A1	**Overall Statistics**				
	Spatial indices	**Landscape**	**PA**	**RFs**	**Community land**
	Total area of patches >=0.01 km²	2070.58	254.98	76.74	1738.86
	% of total landscape area	100.00	12.31	3.71	83.98
	Largest patch index (%)	4.12	2.80	0.29	4.12
	No. of patches	20914.00	1384.00	560.00	18970.00
	Patch density (no./ km²)	10.10	5.43	7.30	10.91
	Mean patch size (km²)	0.10	0.18	0.14	0.09
	Patch size Standard Deviation - PSSD (km²)	1.23	2.17	0.59	1.14
	Patch size Coefficient of Variation - PSCV (%)	1239.08	1177.21	433.91	1246.32
	Total edge (km)	57061.49	4410.12	1993.98	50657.39
	Edge density (km/ km²)	27.56	17.30	25.98	29.13
	Largest edge (km)	1545.48	538.58	156.74	1545.48
	Mean edge length (km)	2.73	3.19	3.56	2.67
	Edge length Standard Deviation (km)	18.30	18.98	12.72	18.39
	Edge length Coefficient of Variation (%)	670.76	595.69	357.38	688.64
B	**Within Protected areas + Reserved forests**				

B1	**Overall land cover**				
	Spatial indices	**Land uses**	**Forest cover**	**Bamboo**	**Cloud/shadow**
	Total area of patches >=0.01 km^2	9.55	311.61	2.67	4.66
	% of total landscape area	0.46	15.05	0.13	0.22
	Largest patch index (%)	0.06	19.03	0.02	0.06
	No. of patches	343.00	1315.00	129.00	132.00
	Patch density (no./ km^2)	35.92	4.22	48.38	28.35
	Mean patch size (km^2)	0.03	0.24	0.02	0.04
	Patch size Standard Deviation - PSSD (km^2)	0.03	2.26	0.01	0.04
	Patch size Coefficient of Variation - PSCV (%)	101.15	951.65	70.53	112.26
	Total edge (km)	428.16	5582.26	148.16	163.83
	Edge density (km/ km^2)	44.84	17.91	55.56	35.18
	Largest edge (km)	5.78	538.58	3.85	6.15
	Mean edge length (km)	1.25	4.25	1.15	1.24
	Edge length Standard Deviation (km)	0.91	21.08	0.64	0.95
	Edge length Coefficient of Variation (%)	72.52	496.49	55.97	76.65
B2	**Land use**				
	Spatial indices	**Habitation**	**Permanent agriculture**	**Shifting agriculture**	
	Total area of patches >=0.01 km2	3.93	1.71	3.91	
	% of total landscape area	0.19	0.08	0.19	
	Largest patch index (%)	0.05	0.06	0.03	
	No. of patches	126.00	48.00	169.00	
	Patch density (no./ km2)	32.03	28.11	43.27	
	Mean patch size (km2)	0.03	0.04	0.02	
	Patch size Standard Deviation -	0.03	0.04	0.02	

	PSSD (km2)				
	Patch size Coefficient of Variation - PSCV (%)	104.22	112.02	79.01	
	Total edge (km)	166.69	62.28	199.19	
	Edge density (km/ km2)	42.37	36.47	51.00	
	Largest edge (km)	5.78	5.73	5.75	
	Mean edge length (km)	1.32	1.30	1.18	
	Edge length Standard Deviation (km)	1.02	1.02	0.77	
	Edge length Coefficient of Variation (%)	77.19	78.56	65.26	
B3	**Forest cover**				
	Spatial indices	**TMEF**	**TSEF**	**TMDF**	
	Total area of patches >=0.01 km^2	137.99	117.95	55.67	
	% of total landscape area	6.66	5.70	2.69	
	Largest patch index (%)	19.02	4.28	1.59	
	No. of patches	226.00	593.00	496.00	
	Patch density (no./ km^2)	1.64	5.03	8.91	
	Mean patch size (km^2)	0.61	0.20	0.11	
	Patch size Standard Deviation - PSSD (km^2)	5.17	0.96	0.43	
	Patch size Coefficient of Variation - PSCV (%)	845.94	483.10	385.56	
	Total edge (km)	1430.56	2505.63	1646.08	
	Edge density (km/ km^2)	10.37	21.24	29.57	
	Largest edge (km)	538.58	211.05	150.45	
	Mean edge length (km)	6.33	4.23	3.32	
	Edge length Standard Deviation (km)	41.67	14.97	10.91	
	Edge length Coefficient of Variation (%)	658.29	354.25	328.89	

C1	**Within Protected areas**				
	Overall land cover				
	Spatial indices	**Land uses**	**Forest cover**	**Bamboo**	**Cloud/shadow**
	Total area of patches >=0.01 km^2	4.51	242.95	1.11	3.75
	% of total landscape area	0.22	11.73	0.05	0.18
	Largest patch index (%)	0.04	25.31	0.02	0.08
	No. of patches	171.00	1037.00	52.00	106.00
	Patch density (no./ km^2)	37.92	4.27	46.70	28.30
	Mean patch size (km^2)	0.03	0.23	0.02	0.04
	Patch size Standard Deviation - PSSD (km^2)	0.02	2.50	0.01	0.04
	Patch size Coefficient of Variation - PSCV (%)	88.56	1068.46	66.32	106.43
	Total edge (km)	204.29	3955.17	60.50	128.73
	Edge density (km/ km^2)	45.30	16.28	54.33	34.37
	Largest edge (km)	5.75	538.58	2.87	5.88
	Mean edge length (km)	1.19	3.81	1.16	1.21
	Edge length Standard Deviation (km)	0.85	21.87	0.59	0.87
	Edge length Coefficient of Variation (%)	71.19	573.37	50.88	71.26
C2	**Land use**				
	Spatial indices	**Habitation**	**Permanent agriculture**	**Shifting agriculture**	
	Total area of patches >=0.01 km^2	1.63	0.39	2.49	
	% of total landscape area	0.08	0.02	0.12	
	Largest patch index (%)	0.04	0.02	0.04	
	No. of patches	54.00	18.00	99.00	
	Patch density (no./ km^2)	33.10	46.11	39.79	
	Mean patch size (km^2)	0.03	0.02	0.03	

	Patch size Standard Deviation - PSSD (km^2)	0.03	0.01	0.02	
	Patch size Coefficient of Variation - PSCV (%)	93.20	59.60	86.70	
	Total edge (km)	67.08	16.13	121.07	
	Edge density (km/ km^2)	41.12	41.33	3.04	
	Largest edge (km)	4.32	1.74	5.75	
	Mean edge length (km)	1.24	0.90	1.22	
	Edge length Standard Deviation (km)	0.87	0.35	0.90	
	Edge length Coefficient of Variation (%)	69.86	0.40	73.47	
C3	**Forest cover**				
	Spatial indices	**TMEF**	**TSEF**	**TMDF**	
	Total area of patches >=0.01 km^2	137.93	84.02	21.00	
	% of total landscape area	6.66	4.06	1.01	
	Largest patch index (%)	25.31	5.70	1.02	
	No. of patches	223.00	484.00	330.00	
	Patch density (no./ km^2)	1.62	5.76	15.72	
	Mean patch size (km^2)	0.62	0.17	0.06	
	Patch size Standard Deviation - PSSD (km^2)	5.20	0.95	0.19	
	Patch size Coefficient of Variation - PSCV (%)	840.64	545.58	302.32	
	Total edge (km)	1428.11	1856.03	671.03	
	Edge density (km/ km^2)	10.35	22.09	31.96	
	Largest edge (km)	538.58	211.05	49.57	
	Mean edge length (km)	6.40	3.83	2.03	
	Edge length Standard Deviation (km)	2.81	14.16	4.06	
	Edge length Coefficient of Variation (%)	43.86	369.38	199.57	

D	**Within Reserved forests**				
D1	**Overall land cover**				
	Spatial indices	**Land uses**	**Forest cover**	**Bamboo**	**Cloud/shadow**
	Total area of patches >=0.01 km^2	5.04	68.66	1.55	0.91
	% of total landscape area	0.24	3.32	0.08	0.04
	Largest patch index (%)	0.24	7.83	0.10	0.29
	No. of patches	172.00	278.00	77.00	26.00
	Patch density (no./ km^2)	34.14	4.05	49.58	28.53
	Mean patch size (km^2)	0.03	0.25	0.02	0.04
	Patch size Standard Deviation - PSSD (km^2)	0.03	0.83	0.01	0.05
	Patch size Coefficient of Variation - PSCV (%)	110.05	335.91	73.88	136.19
	Total edge (km)	223.88	1627.09	87.66	35.10
	Edge density (km/ km^2)	44.44	156.74	56.44	38.51
	Largest edge (km)	5.78	2.28	3.85	6.15
	Mean edge length (km)	1.30	5.85	1.14	1.35
	Edge length Standard Deviation (km)	0.96	17.76	0.68	1.26
	Edge length Coefficient of Variation (%)	73.45	303.38	59.61	93.16
D2	**Land use**				
	Spatial indices	**Habitation**	**Permanent agriculture**	**Shifting agriculture**	
	Total area of patches >=0.01 km^2	2.30	1.32	1.42	
	% of total landscape area	0.11	0.06	0.07	
	Largest patch index (%)	0.22	0.24	0.07	
	No. of patches	72.00	30.00	70.00	
	Patch density (no./ km^2)	31.27	22.77	49.37	
	Mean patch size (km^2)	0.03	0.04	0.02	

	Patch size Standard Deviation - PSSD (km^2)	0.04	0.05	0.01	
	Patch size Coefficient of Variation - PSCV (%)	111.47	108.84	54.88	
	Total edge (km)	99.61	46.15	78.12	
	Edge density (km/ km^2)	43.25	35.03	55.09	
	Largest edge (km)	5.78	5.73	3.51	
	Mean edge length (km)	1.38	1.54	1.12	
	Edge length Standard Deviation (km)	1.12	1.20	0.54	
	Edge length Coefficient of Variation (%)	81.31	78.28	48.05	
D3	**Forest cover**				
	Spatial indices	**TMEF**	**TSEF**	**TMDF**	
	Total area of patches >=0.01 km^2	0.06	33.92	34.68	
	% of total landscape area	0.00	1.64	1.67	
	Largest patch index (%)	0.03	7.84	6.38	
	No. of patches	3.00	109.00	166.00	
	Patch density (no./ km^2)	48.50	3.21	4.79	
	Mean patch size (km^2)	0.02	0.31	0.21	
	Patch size Standard Deviation - PSSD (km^2)	0.01	1.02	0.69	
	Patch size Coefficient of Variation - PSCV (%)	43.30	326.65	329.57	
	Total edge (km)	2.44	649.60	975.05	
	Edge density (km/ km^2)	39.51	19.15	28.12	
	Largest edge (km)	1.08	156.74	150.45	
	Mean edge length (km)	0.81	5.96	5.87	
	Edge length Standard Deviation (km)	0.23	18.09	17.74	
	Edge length Coefficient of Variation (%)	28.46	303.49	302.01	
E	**Within community land**				

E1	**Overall land cover**				
	Spatial indices	**Land uses**	**Forest cover**	**Bamboo**	**Cloud/shadow**
	Total area of patches >=0.01 km^2	343.28	1241.79	98.63	53.33
	% of total landscape area	16.58	59.97	4.76	2.58
	Largest patch index (%)	0.62	4.83	0.07	0.08
	No. of patches	7118.00	7606.00	2692.00	1497.00
	Patch density (no./ km^2)	20.74	6.13	27.29	28.07
	Mean patch size (km^2)	0.05	0.16	0.04	0.04
	Patch size Standard Deviation - PSSD (km^2)	0.25	1.78	0.07	0.07
	Patch size Coefficient of Variation - PSCV (%)	525.38	1092.92	197.90	188.83
	Total edge (km)	12488.48	31687.51	4439.76	1956.76
	Edge density (km/ km^2)	36.38	25.52	45.02	36.69
	Largest edge (km)	303.62	1545.48	37.41	38.92
	Mean edge length (km)	1.75	4.17	1.65	1.31
	Edge length Standard Deviation (km)	6.34	28.28	2.21	1.58
	Edge length Coefficient of Variation (%)	361.31	678.86	133.85	120.75
E2	**Land use**				
	Spatial indices	**Habitation**	**Permanent agriculture**	**Shifting agriculture**	
	Total area of patches >=0.01 km^2	183.94	74.73	84.61	
	% of total landscape area	8.88	3.61	4.09	
	Largest patch index (%)	0.62	0.20	0.04	
	No. of patches	2786.00	1245.00	3087.00	
	Patch density (no./ km^2)	15.15	16.66	36.49	
	Mean patch size (km^2)	0.07	0.06	0.03	
	Patch size Standard Deviation -	0.39	0.16	0.04	

	PSSD (km^2)				
	Patch size Coefficient of Variation - PSCV (%)	587.45	262.83	140.79	
	Total edge (km)	6311.67	2082.98	4093.83	
	Edge density (km/ km^2)	34.31	27.87	48.39	
	Largest edge (km)	303.62	42.35	25.76	
	Mean edge length (km)	2.27	1.67	1.33	
	Edge length Standard Deviation (km)	9.91	2.26	1.28	
	Edge length Coefficient of Variation (%)	437.26	134.95	96.49	
E3	**Forest cover**				
	Spatial indices	**TMEF**	**TSEF**	**TMDF**	
	Total area of patches >=0.01 km^2	201.48	465.62	574.68	
	% of total landscape area	0.10	0.22	0.28	
	Largest patch index (%)	2.50	4.83	1.94	
	No. of patches	780.00	2488.00	4338.00	
	Patch density (no./ km^2)	3.87	5.34	7.55	
	Mean patch size (km^2)	0.26	0.19	0.13	
	Patch size Standard Deviation - PSSD (km^2)	3.19	2.24	0.94	
	Patch size Coefficient of Variation - PSCV (%)	1235.71	1196.30	706.36	
	Total edge (km)	2689.90	10687.43	18310.19	
	Edge density (km/ km^2)	13.35	22.95	31.86	
	Largest edge (km)	492.48	1545.48	941.41	
	Mean edge length (km)	3.45	4.30	4.22	
	Edge length Standard Deviation (km)	28.17	35.58	23.11	
	Edge length Coefficient of Variation (%)	816.83	828.23	547.56	

Appendix 6

Select indices representing the patch characteristics of individual elements of protected area network (*i.e.*, protected areas and reserved forests). All area in km^2.

Balpakram National Park, NNP = Nokrek National Park, SWS= Siju Wildlife Sanctuary, ARF = Angratoli RF, BRF = Baghmara RF, ERF = Emangiri RF, RRF = Rewak RF.

Land cover class	**Spatial indices**	**BNP**	**NNP**	**SWS**	**BRF**	**RRF**	**IRF**	**ARF**	**Community land**
Tropical Moist Evergreen Forests	Number	160	63		3				780
	Area	112.26	25.67		0.06				201.48
	Mean area	0.70	0.41		0.02				0.26
	Largest patch area	68.85	14.02		0.03				52.47
	Std. deviation	6.02	1.94		0.01				3.19
Tropical Semi-evergreen Forests	Number	368	115	1	41	9	8	51	2488
	Area	67.88	12.64	3.50	14.96	2.24	7.13	9.60	465.62
	Mean area	0.18	0.11	3.50	0.36	0.25	0.89	0.19	0.19
	Largest patch area	15.50	1.78	3.50	4.35	1.68	5.29	7.05	101.27
	Std. deviation	1.06	0.28		0.92	0.55	1.83	0.98	2.24
Tropical Moist Deciduous Forests	Number	255	67	8	61	9	23	73	4338
	Area	17.17	2.52	1.30	17.86	2.03	2.61	12.18	574.68
	Mean area	0.07	0.04	0.16	0.29	0.23	0.11	0.17	0.13
	Largest patch area	2.77	0.64	0.56	5.74	1.10	0.95	3.60	40.66
	Std. deviation	0.21	0.08	0.20	0.96	0.39	0.23	0.53	0.94
Habitation/Abandoned *Jhum*	Number	46	8		44		2	26	2786
	Area	1.32	0.31		1.48		0.03	0.79	183.94
	Mean area	0.03	0.04		0.03		0.02	0.03	0.07
	Largest patch area	0.12	0.11		0.20		0.02	0.16	12.95
	Std. deviation	0.03	0.04		0.04		0.01	0.03	0.39

Land cover class	Spatial indices	BNP	NNP	SWS	BRF	RRF	IRF	ARF	Community land
Permanent Agriculture	Number	16	1	1	26	1		3	1245
	Area	0.32	0.01	0.06	1.18	0.02		0.12	74.73
	Mean area	0.02	0.01	0.06	0.05	0.02		0.04	0.06
	Largest patch area	0.04	0.01	0.06	0.21	0.02		0.06	4.08
	Std. deviation	0.01			0.05			0.03	0.16
Shifting cultivation/grasslands	Number	69	30		49	5	2	14	3087
	Area	1.62	0.86		1.03	0.09	0.03	0.27	84.61
	Mean area	0.02	0.03		0.02	0.02	0.02	0.02	0.03
	Largest patch area	0.12	0.12		0.06	0.04	0.02	0.05	0.89
	Std. deviation	0.02	0.02		0.01	0.01	0.00	0.01	0.04
Bamboo/Secondary forest (6-10 years)	Number	38	14		24	3		50	2692
	Area	0.80	0.32		0.48	0.10		0.98	98.63
	Mean area	0.02	0.02		0.02	0.03		0.02	0.04
	Largest patch area	0.06	0.06		0.06	0.06		0.09	1.42
	Std. deviation	0.01	0.02		0.01	0.03		0.02	0.07
Plateau Grasslands/*Shola* type forests	Number	17							
	Area	2.64							
	Mean area	0.16							
	Largest patch area	1.77							
	Std. deviation	0.42							
Shadow	Number	91	13	2	20			6	1497
	Area	2.96	0.74	0.05	0.79			0.12	53.33
	Mean area	0.03	0.06	0.02	0.04			0.02	0.04
	Largest patch area	0.21	0.19	0.03	0.22			0.03	1.76

Land cover class	Spatial indices	BNP	NNP	SWS	BRF	RRF	IRF	ARF	Community land
	Std. deviation	0.03	0.05	0.00	0.05			0.01	0.07
Water-bodies	Number			1	5	2			57
	Area			0.02	0.53	0.05			1.83
	Mean area			0.02	0.11	0.02			0.03
	Largest patch area			0.02	0.23	0.03			0.22
	Std. deviation				0.09	0.01			0.04
Total number of patches		**1060**	**311**	**13**	**273**	**29**	**35**	**223**	**18970**
Area of all patches		**206.98**	**43.07**	**4.93**	**38.35**	**4.53**	**9.81**	**24.06**	**1738.86**
Mean area of all patches		**0.20**	**0.14**	**0.38**	**0.14**	**0.16**	**0.28**	**0.11**	**0.09**
Largest patch area		**68.85**	**14.02**	**3.50**	**5.74**	**1.68**	**5.29**	**7.05**	**101.27**
Std. deviation (all patches)		**2.43**	**0.90**	**0.95**	**0.59**	**0.37**	**0.91**	**0.56**	**1.14**

Appendix 7

Examples of key cultural functions of plants and animals in *Garo* Hills

Examples of key cultural functions of plants and animals used by *Garo* people in the *Garo* Hills of western Meghalaya for religious rites and rituals (source: Sangma 1993). Species common or scientific names are included as mentioned by Sangma (1993). We identified the scientific name of some species by cross-referencing *Garo* names given by Sangma (1993) to descriptions of common or scientific names given in Nengminza (1996). Species not identifiable to scientific specific epithet are listed here only with their *Garo* names *[G.]* and descriptions.

Plants

Used in religious rites and rituals:

- Dum Attiakola *[G.]*, a large variety of banana plant – used to counteract evil-minded folk medicine practitioner; a flower bud is carefully extracted while it is still about two and a half cubits inside the bole, and the evil-minded adept is severely beaten with it
- *Macropanax undulatum*, a small tree -- used as above
- *Cynadondactylong*, doob grass -- a circle of which is dried out by use of a potent herb while reciting the name of the evil-minded adept and his place of residence; as the doob grass wilts and dries, the victim's body suffers and dies
- *Aquilaria agaklocha*, aloe wood – used on which to scribe specific chants and spells
- *Adenantherepavoniva*, red sandal-wood – used as a pen for writing down chants and spells, the ink of which is devised from several ingredients including the juice of the plants *Aegamarmelos* and *Ocymum sanctum* (black basil)
- *Macaranga indica*, boltotu shrub – used in a ritual to heal one's wandering soul
- *Entadascandens*, sue or gila plant – fruit or seed used to emotionally startle an adept or shaman
- *Colocasisindica*, kochu – chewed by an adept or shaman during a ritual of reciting chants and spells
- *Spatholobus roxburghii*, maari (a common climber) – used to startle certain kinds of evil adepts; also the juice of which is smeared on a stool, bench, or chair to prevent an evil adept from sitting.
- Also used to frighten evil adepts are seeds of *Erythnasuberosa* (mandal tree), *Clerodendron infortunatum*, and *Acacia concina*; the fruit of gila*Entadascandens*; and the odors of onion, garlic, and panat*Ocymum canum*. To kill an adept or shaman, he is secretly given a concoction of the bark of maari, the roots of Gnengsi *[G.]* a small perennial grass with razor-sharp blades, the leaves of panat, and garlic. A nocturnal adept can be caught and killed at night by their long hair tangling in thorny branches of the kangkani tree *Marjorca indica* or in the thorny shoots of *Mezoneurum cucullatum*. Sangma (1993) lists many other plant species used against evil adepts or shamans.

Used for medicines:

Sangma (1993:184-190) lists many plant species used in *Garo* folk medicine for healing or for killing. *Garo* folk medicine is intricately tied with religious rituals and rites. A few examples follow.

- *Ocymum sanctum*, black tulsi – a leafy branch is used to sprinkle water over an ailing person while reciting a specific chant
- Plants used in transformation rituals – Under specific spells, the plucked leaves of tarai bamboos or water bamboos *Malocanna bamboosoides* are said to be transformed into fresh lasso fishes. A folded rind of the banana plant is said to be turned into a Calbasu or kaila fish. A tuber of lokra*Xanthium strumarius* or a globous root of a large kind of banana plant is said to be turned into a living pig.
- Bon Harangjhora *[G.]*, a parasitic plant – used as a salve to mend broken bones.
- *Cratoevaeoxburghii*, jongsia tree – leafy branch held in the right hand of an adept or shaman who utters a secret chant to cure leprosy. However, to cause virulence in offending persons living in distant places, the adept keeps a piece of duringkap*Cryptolepis buchananii* wedged in the bark of the wakru tree *Engel hardiaspicata* while reciting secret chants.

Animals

Used in religious rites and rituals:

- Lizard – A *chuar* is an otherworldly being that appears as a luminous flying lizard. The initiate can transform into a *chuar* and then be able to attract ripe foodgrains from other people's cultivations.
- Flying squirrel – A *bakwan* or *matwan* is an otherworldly being that appears as a grey winsome flying squirrel, which can attract worldly riches and material goods.
- Bat – A *rakasi* is an otherworldly being that appears as a bat. Usually invisible, it can appear luminous in flight and as an extraordinarily keen and clear-headed person who is able to garner great riches and material goods.
- Pigs, mice, owls – Used to thwart and kill evil spirits and malicious otherworldly beings.

Used for medicines:

Arboreal animals:

- tree squirrel *Myhaepus congaing Bengalensis*
- rarek or lajjbatibander*[G.]* "an ape-like arboreal animal which covers its face with both hands on seeing human beings"
- Marsi *[G.]*, "a reddish-yellow flying chameleon-like creature, which lives in deep woods," possibly draco of flying lizard *Draco dussumieri*
- flying squirrel *Petaurista* sp.

Terrestrial mammals:

- great Indian onehorned rhinoceros *Rhinoceros unicornis* (horn and bile of which are considered to be of medicinal value)
- Chinese pangolin *Manis pentadactyla* (scales and liver used for medicines)
- jackal *Canis aureus* ("the bone and horn, if any, which looks like a small red hook, is of medicinal value;" sic., as jackals lack "horns" per se)

Birds:

- Dosildura *[G.]*, "a rare myna-like bird with red glistening head," possibly scarlet finch *Haematospiza sipahi* (leg-bone is of medicinal value)
- Baya weaver*Ploceus philippinus* (liver and bones of medicinal value)
- Chamchora*[G.]*, "a small agile bird, which used to make nests inside rof or dwelling-houses" (flesh and bones used to cure impotency)
- fire-tailed sunbird*Aethopyga ignicauda* (fat and bones of medicinal value)
- hornbill, species not specified (fat is of medicinal value)
- black-rumped flameback (=lesser goldenbacked woodpecker) *Dinopium benghalense* (bones are of medicinal value)

Reptiles:

- ChipuChinnong or Chipu Gra *[G.]*, "a small reddish-yellow snake," possibly monocellate cobra *Naja kaouthis* (Chipu gram means cobra) ("breaks itself to pieces when one lifts up a stick to beat it but loosened pieces of which rejoin themselves again and crawl away, when left alone; the first piece, which moves first of itself to rejoin the broken pieces, is considered to be of great medicinal value;" bile is considered of medicinal value)
- lizard, unidentified species (Matpu *[G.]*, "iguana;" there is no iguana in India) (fat is used to restore atrophied male genitals)
- Wakkime *[G.]*, listed by Sangma as reptile but possibly an invertebrate, "a rare scorpion-like creature, which usually dwells under massive rocks, the flesh of which posseses magical virtues"

Fish:

- electric eel *Electrophorus electricus* (flesh and bones used in preparing a healing medicine)
- puffer *Tetraodon cutcutia* (flesh used as medicine)
- gar, unidentified species of family Lepisosteidae (head used to cure chronic vertigo)
- zebra fish *Brachydanio rerio* (flesh used in preparation of nutritive pills)
- *Cyrenus robita*, no common name (fat is of great nutritive value)

Insects:

- cicada, unidentified species of family Tibicinidae (of all flying insects has greatest medicinal and magical value; eggs are considered to be antidotal against possibility of drowning)

Appendix 8

Tree species and their parts used as food by selected mammal species based on the results of focus group interviews

Tree species	**Macaques**	**Slow loris**	**Sambar and Barking deer**	**Serow**	**Squirrels**	**Hoolock gibbon**	**Capped Langur**	**Asian Elephant**	**Indian Bison**	**Wild pig**	**Himalayan yellow throated Martin**	**Himalayan black bear**	**Bats**	**Civets**	**Porcupine**	**Total**
Grewia microcos	B	F	F,L	F,L	F	YL	L	F, L	F	F	F	F	F	F	F	15
Artocarpus chaplasha		F	F	F	F	F,L	F,L	F, L	F	F	F	F	F		F	13
Syzygium cumini		F		F,L	F	F		F	F	F	F	F	F	F	F	12
Lepisanthes rubiginosa		F	F	F,L	F	L	F,L	L		F		F	F		F	11
Artocarpus gomezianus	B,L		F		F	F	L	L	F		F	F	F			10
Ficus semicordata	B,L		F		F	L	L	L	F		F		F	F		10
Lannea grandis		F	F,L	F,L	F	L		F,L	F			F	F	F		10
Bursera serrata	B,L	F	F		F	F,L	L	F		F	F	F				9
Dillenia pentagyna		F	F	L	F	F,L	F,L	F,L			F	F				9
Ficus subulata	B,L			F,L		F,L	L	F,L	F		F	F		F		9
Garcinia lancifolia		F	F	F	F	F		F				F	F		F	9
Ilex umbellulata		F	F	F,L	F			F	F	F			F			8
Syzygium balsameum	B,L, F		F			F,L	F,L	L	F		F		F			8
Alangium chinense		F	F	F	F					F		F	F			7
Bauhinia stipularis		Y.L, Fl	F	F,L	Fl	L,Fl	F,L	F,L								7

Tree species	Macaques	Slow loris	Sambar and Barking deer	Serow	Squirrels	Hoolock gibbon	Capped Langur	Asian Elephant	Indian Bison	Wild pig	Himalayan yellow throated Martin	Himalayan black bear	Bats	Civets	Porcupine	Total
Garcinia kydia		F	F		F	F	F,L			F			F			7
Macaranga indica		F	F	F,L		L				F			F			6
Mangifera indica	F		F			F			F		F		F			6
Mangifera sylvatica	F		F			F			F		F		F			6
Trema orientalis	B,L		F	L		L	L	L								6
Callicarpa arborea		F	F	F,L			L			F						5
Flacourtia jangomas		F	F	F	F							F				5
Abrus precatorius			F			F,L	F,L	F,L								4
Ficus foveolata						L	F,L	L					F			4
Garcinia tinctoria	B,L	F	F		F											4
Gmelina arborea				L		F, YL	F,L	F,L								4
Morinda augustifolia		F	F	F	F											4
Pterigota alata	B,L			F	F			F,L								4
Aporusa dioica				F	F								F			3
Emblica officinalis						F,YL		F					F			3
Eurya accuminata		F		F				F								3
Maesa sarmentosa		F	F					L								3
Syzygium operculatum			F,Y L		F						F					3
Wendlandia excelsa						L	L	L								3

Tree species	**Macaques**	**Slow loris**	**Sambar and Barking deer**	**Serow**	**Squirrels**	**Hoolock gibbon**	**Capped Langur**	**Asian Elephant**	**Indian Bison**	**Wild pig**	**Himalayan yellow throated Martin**	**Himalayan black bear**	**Bats**	**Civets**	**Porcupine**	**Total**
Bridelia retusa			F					F,L								2
Croton joufera				F,L									F			2
Hodgsonia macrocarpa	F						F,L									2
Holarrhena antidysenterica				L		L										2
Pterospermum acerifolium	B		F													2
Vitex peduncularis						B,L				F						2
Aesculus assamica				L												1
Albizia chinensis				L												1
Albizia odoratissima				L												1
Anthocephalus chinensis														F		1
Aristolochia tagala				F												1
Bridelia monoica		F														1
Careya arborea								L								1
Dalbergia paniculata				L												1
Elaeocarpus rugosus	B,L															1
Erythrina stricta	B															1
Glochidion spharogynum													F			1

Tree species	**Macaques**	**Slow loris**	**Sambar and Barking deer**	**Serow**	**Squirrels**	**Hoolock gibbon**	**Capped Langur**	**Asian Elephant**	**Indian Bison**	**Wild pig**	**Himalayan yellow throated Martin**	**Himalayan black bear**	**Bats**	**Civets**	**Porcupine**	**Total**
Mallotus roxbughianus	B,L															1
Ostodes paniculata													F			1
Polyalthia simiarum			F													1
Pterospermum lancifolium	B,L															1
Tetrameles nudiflora	B															1
Total species used	**28**	**27**	**25**	**25**	**21**	**20**	**20**	**18**	**18**	**12**	**12**	**11**	**11**	**6**	**5**	

Appendix 9

Use of important tree species based on the results of focus group interviews

S. No.	Species	Botanical name	Edible	Medicine	Timber	Fuel wood	Boat
1	Agatchi	*Dillenia pentagyna*	1	1	1	1	1
2	Artak	*Terminalia citrina*	1	1	1	1	1
3	Chrum	*Artocarpus chaplasha*	1		1	1	1
4	Kimbol/makanchi	*Callicarpa arborea*	1		1	1	1
5	Gambil/dambil	*Careya arborea*		1	1	1	1
6	Bolbret	*Cedrala toona*	1		1	1	1
7	Chambu sirsang	*Euginia aquea*	1		1	1	1
8	Aruwak	*Garcinia tinctoria*	1	1	1	1	
9	Tebe	*Hodgsonia macrocarpa*	1		1	1	1
10	Bolbet	*Litsea monopelata*	1		1	1	1
11	Thegatchu	*Mangifera indica*	1		1	1	1
12	Thegatchu	*Mangifera sylvatica*	1		1	1	1
13	Aburispil	*Micromelon pubescens*	1	1	1	1	
14	Tebrong	*Syzygium balsameum*	1		1	1	1
15	Dodikimsong	*Actinodaphne obovata*			1	1	1
16	Bolribu	*Aesculus assamica*			1	1	1
17	Chandana	*Ailanthus grandis*			1	1	1

S. No.	Species	Botanical name	Edible	Medicine	Timber	Fuel wood	Boat
18	Shishu	*Albizia lebbek*			1	1	1
19	Khilbe	*Albizia odoratissima*			1	1	1
20	Bolapal	*Aphanamixis polystachya*			1	1	1
21	Armu/arimu	*Artocarpus gomezianus*	1	1		1	
22	Gakkal	*Betula alnoides*			1	1	1
23	Dongram	*Canarium strictum*			1	1	1
24	Chako chiring	*Castonopsis hystrix*			1	1	1
25	Chako	*Castonopsis purpurella*			1	1	1
26	Teja bifa	*Cinnamomum bejolghota*			1	1	1
27	Rongrip	*Cynometra polyandra*			1	1	1
28	Bolasin	*Disoxylum hamiltonii*		1	1		1
29	Bolchhim	*Duabunga grandiflora*			1	1	1
30	Ambre	*Emblica officinalis*	1	1		1	
31	Bokta	*Ferminiana colorata*			1	1	1
32	Bolchiring	*Glochidion velutinum*		1		1	1
33	Gambari	*Gmelina arborea*			1	1	1
34	Mugasalgro	*Heteropanax fragrans*			1	1	1
35	Bolong	*Kaeya floribunda*			1	1	1
36	Bolanchi	*Knema limifolia*		1	1	1	

S. No.	Species	Botanical name	Edible	Medicine	Timber	Fuel wood	Boat
37	Khimde	*Mesua ferrea*			1	1	1
38	Champa	*Michelia champaca*			1	1	1
39	Solwa	*Polaquim polyanthum*			1	1	1
40	Adingok	*Pterospermum acerifolium*			1	1	1
41	Adambit/Laisa	*Pterospermum lancefolium*			1	1	1
42	Boldak	*Schima wallichii*			1	1	1
43	Bolsal	*Shorea robusta*			1	1	1
44	Churi	*Terminalia bellirica*	1	1		1	
45	Bolbok	*Tetrameles nudiflora*			1	1	1
46	Khrenti/Kranchi	*Walsura arborea*			1	1	1
47	Kitma/Sabong	*Abrus precatoius*	1			1	
48	Bolpha	*Albizia chinensis*				1	1
49	Kadam	*Anthocephalus kadamba*			1	1	
50	Megong	*Baunia purpurea*	1			1	
51	Ambilatong	*Bursera serrata*		1		1	
52	Matmi	*Croton joufera*	1			1	
53	Bolmendu	*Dalbergia paniculata*			1		1
54	Gap	*Diospyros embryopteris*	1			1	
55	Ankisipak	*Elaeocarpus rugosus*			1	1	

S. No.	Species	Botanical name	Edible	Medicine	Timber	Fuel wood	Boat
56	Chamisi	*Eurya accuminata*			1	1	
57	Goerangsang	*Ficus foveolata*	1			1	
58	Aminsep	*Ficus semicordata*	1			1	
59	Dengaduti	*Garcinia kydea*	1			1	
60	Boljagro	*Glochidion spharogynum*			1	1	
61	Bolsubret/Damsuri	*Grewia macrocos*	1			1	
62	Bolibu	*Gynocardia odorata*			1	1	
63	Mao	*Hibiscus macrophyllus*			1	1	
64	Ajakari/Bolasari	*lagerstroemia speciosa*			1	1	
65	Gawigran	*Lapisanthus rubiginosa*	1			1	
66	Boldukaki	*Litsea sebifera*		1		1	
67	Rimikgital	*Macaranga indica*		1		1	
68	Kiring	*Oroxylum indicum*	1	1			
69	Nameaga	*Persia villosa*		1		1	
70	Bolgisim	*Polyalthia simiarum*			1	1	
71	Dokimi	*Premna latifolia*	1			1	
72	Changsim/Cherasu	*Sapium baccatum*				1	1
73	Kimkol	*Saraca indica*	1			1	
74	Chambu	*Syzygium cumini*	1			1	

S. No.	Species	Botanical name	Edible	Medicine	Timber	Fuel wood	Boat
75	Pakram	*Trema orientalis*	1			1	
76	Bolkha	*Trewia nudiflora*		1	1		
77	Rangri	*Vitex peduncularis*			1	1	
78	Garadek	*Wendlendia excelsa*	1			1	
79	Boljalik	*Actinodaphne augustifolia*				1	
80	Rengokmi	*Alangium chinense*				1	
81	Bolapu	*Albizia stipulata*				1	
82	Sokchon	*Alstonia scholaris*		1			
83	Chamolja	*Aporusa dioica*				1	
84	Terimu	*Aristolochia tagala*				1	
85	Bolchhu	*Bombax ceiba*			1		
86	Kasi	*Bredelia retusa*				1	
87	Kasi dupret	*Bredelia stipularis*				1	
88	Sinaru	*Cassia fistula*		1			
89	Tejpatta	*Cinnamomum tamala*	1				
90	Tewak	*Ficus hispida*	1				
91	Chigambil	*Garuga pinnata*				1	
92	Bolgolmatra/Matalwe	*Holarrhena antidysentrica*				1	
93	Bolchhenda	*Ilex embedioides*				1	

S. No.	Species	Botanical name	Edible	Medicine	Timber	Fuel wood	Boat
94	Boltajong	*Ilex umbellulata*				1	
95	Boldubok	*Kydia calycina*				1	
96	Sidai	*Lagerstroemia parviflora*				1	
97	Bolgreng	*Ligustrum robusm*				1	
98	Chhagro/Bolajak	*Macaranga denticulata*				1	
99	Mangritchok	*Maesa sarmentosa*				1	
100	Boltatu	*Mallotus roxbughianus*				1	
101	Matchmikong	*Mallotus tetracoccus*				1	
102	Kilkira	*Oriocnoides integrefolia*				1	
103	Charapak	*Pterigota alata*				1	
104	Bolmising/Bolmicheng	*Rhus accuminata*		1			
105	Chengsu	*Sterculia colorata*				1	
106	Olmak	*Sterculia villosa*				1	
107	Bandikuri	*Vitex glabrata*				1	
108	Bolkingrak	*Walsura tubularis*				1	
Total			**33**	**20**	**54**	**98**	**43**

Appendix 10

Management of specific substrates within *Jhum* activities

In *Garo* Hills, *Jhum* has substantially reduced the original extent of old, primary forests and their associated vegetation elements. As possible, old-forest associated wildlife would likely benefit if such old-forest elements were restored and conserved during *Jhum* activities and during any forest management activities. The kinds of substrates and vegetation elements (of old forests or otherwise) that could be provided, either through use of permanent buffers between *Jhum* plots or with extended *Jhum* rotation cycles, can be described according to the habitat requirements of wildlife species of interest. Following are some examples of such habitat elements found in *Garo* Hills, with a few examples of associated wildlife species that use the elements for breeding, feeding, or other functions:

- Snags – greater racket-tailed drongo, verditer flycatcher, dollarbird, peregrine falcon, stork-billed kingfisher
- Snag recruits (dying trees, live trees with dead portions) – white-rumped vulture, grey-headed fish-eagle, vernal hanging parrot
- Hollow trees, chimney trees (living or dead) – pigtail macaque, barking deer, brown hawk owl, India pied hornbill
- Tree cavities (natural or created) – slow loris, leopard, tiger, streak-throated woodpecker
- Large old trees (living) – white-throated fantail, red-headed vulture, small Indian civet, India pied hornbill
- Trees with fluting boles and buttresses – little spiderhunter, greater racket-tailed drongo, red junglefowl
- Down wood – painted francolin, red junglefowl, Indian porcupine, barking deer, Manipur bush quail
- Litter and duff (decaying matter) – spotted deer, gaur, sambar, Tickell's blue flycatcher
- Litter in streams – lesser whistling duck, pintail snipe
- Lianas – little spiderhunter, spotted deer, gaur, green imperial pigeon
- Fruit-bearing shrubs – spotted deer, gaur, sambar, wild pig, peafowl
- Fruit-bearing trees – barking deer, pigtail macaque, stumptail macaque
- Epiphyte patches – vernal hanging parrot, hoolock gibbon

Appendix 11

Potential demonstration projects

Potential demonstration projects for the *Garo* Hills in western Meghalaya. These are potential projects that could be implemented as small demonstrations to illustrate specific measures and approaches for conserving old forest or important wildlife habitats in GCA.

BACKGROUND

The *Garo* Hills Conservation Area (GCA) assessment may result in identifying forest biodiversity conservation needs for the area. These needs can be expanded into tests in demonstration areas within the GCA. This document presents ideas on three possible demonstration areas for the GCA following the current project.

DEMONSTRATION AREA THEMES

Three potential themes for demonstration area for the GCA are: (1) Additions to protected areas, (2) Protection of primary forests and mature forests in wildlife corridor habitat areas, and (3) Provision of elements of older secondary forests as wildlife habitat and for biodiversity conservation in heavily *jhummed* areas.

For each of these three themes, a small portion of the GCA can be selected to demonstrate how results from the overall GCA Assessment can be used at finer scales. Each theme focuses on a very different environmental condition and management focus within the GCA, with the overall aim of contributing to long-term conservation of wildlife habitat and biodiversity within the area as a whole.

GCA DEMONSTRATION I THEME: ADDITIONS TO PROTECTED AREAS AS BUFFERS

Objective: The objective is to demonstrate how to select specific sites for adding onto existing protected areas, including national parks, reserved forests, and wildlife sanctuaries. Additions can be peripheral to the existing boundaries and can be part of a buffer boundary system..

Problem: The existing protected areas of GCA do not seem to be established according to biosphere reserve designs with sanctum sanctorum core areas and surrounding partial-use buffer areas. Older forests adjacent to existing protected areas are being incurred for *jhum* cultivation and resource extraction with no specific guidelines to ensure the integrity of the protected areas.

Demonstration tasks:Identify, through the vegetation mapping of GCA, areas of older forest adjacent or very near to existing protected area boundaries. Identify such areas that are also undergoing undue incursion for *jhum* agriculture, and where habitat values for wildlife conservation are high. Then, allocate selected, specific forest sites as the start of an additional buffer area around the protected area. Identify the set of activities that can continue or be permitted within the site that would also provide for the older-forest habitat conditions, such as selected nontimber forest product use.

Products: The following products may result from this activity: [1] a map of older-forest zones adjacent to existing protected area boundaries that may serve as buffer areas; [2] a set of management guidelines for activities permissible within such buffer areas that would protect habitat values; [3] a list of habitat and wildlife values that would be conserved over time by institution of this approach. A further product might include a list of other priority areas for possible consideration.

GCA DEMONSTRATION II THEME: CONSERVATION OF PRIMARY AND MATURE FORESTS AND KEY HABITAT ELEMENTS FOR WILDLIFE CORRIDORS

Objective: This objective pertains to maintaining forest habitat conditions in specific areas as migration and movement corridors for wildlife. As well, specific forest use activities by local peoples may be identified as compatible with provision of corridor habitats.

Problem: More and more, the intensity of forest use is increasing in areas traditionally used as corridors by wildlife, especially elephant and other large species associated with older forest conditions such as dense tall tree canopies. If continued at the present pattern and pace, this will doubtless lead to further conflicts, including elephant-man altercations. Loss of wildlife corridor habitat also will lead to isolation of wildlife populations into smaller, disconnected centres. Such smaller wildlife population “islands” then have far higher risk of local extinction from many types of events. Also, linkages of specific habitat elements across the landscape can help maintain viability of many types of wildlife.

Demonstration tasks: A demonstration project focused on conserving primary and mature forests and key habitat elements for wildlife corridors would first identify areas that currently serve as wildlife movement corridors, and, second, provide specific guidelines for the kinds of resource use activities by local peoples that would be compatible with maintaining the habitat values of such corridor areas for wildlife. Wildlife included in this task are principally elephant, and also other species associated with older forest conditions, such as hoolock, slow loris, other arboreal species of primates and squirrels, and other species of older forest conditions.

Products: [1] A general map of known or suspected wildlife corridors in the *Garo* Hills; [2] a specific map of particular sites that contribute to one of the corridors for the demonstration activity; [3] a list of the habitat conditions to provide within the corridor, such as forest canopy contiguity and density, occurrence of snags or down wood, occurrence of specific forage and food types and sources, and corridor width and area; and [4] a list of forest resource-use activities that are compatible with maintaining these habitat conditions. Compatible forest resource-activities may specify the type, intensity, and frequency of extraction of nontimber forest products, the desirability or undesirability of man-set fires, the level of grazing, and other actions and uses.

As with the Demonstration I objectives, above, the aim is to help provide for rationale and compatible human use of forest resources, not to blindly exclude all uses and incursions which would be unnecessary and impossible to accomplish.

GCA DEMONSTRATION III THEME: PROVISION OF OLDER SECONDARY FOREST HABITAT ELEMENTS IN HEAVILY *JHUMMED* AREAS

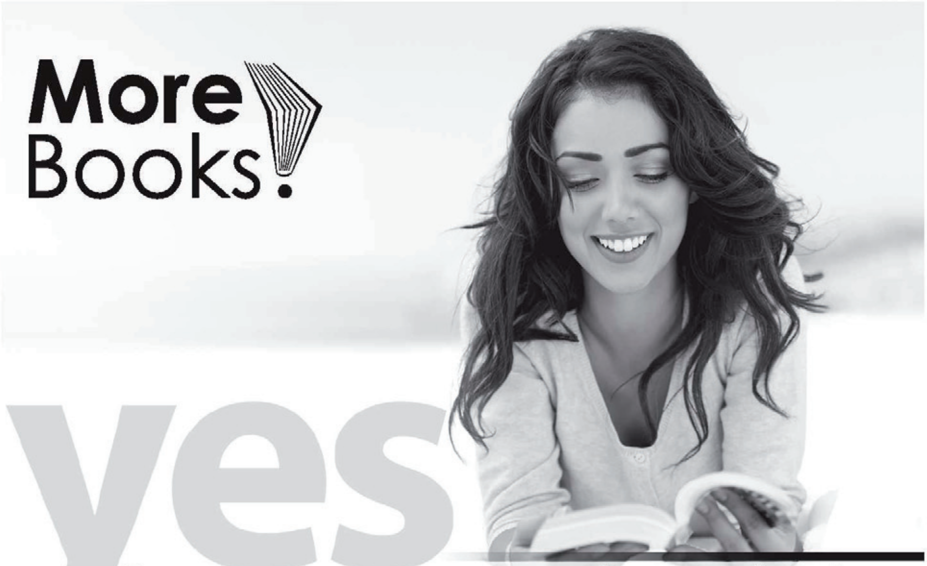
Objective: The objective of this theme is to provide for selected elements of forest habitat conditions within heavily *jhummed* landscapes to help conserve forest-associated wildlife with a minimal impact on agriculture.

Problem: Accelerated use of forest land in the *Garo* Hills for *jhum* agriculture has led to a severe shortage of old forest habitats and specific elements of old forests. Such forest habitat elements include large mature trees, local canopy clumps of older trees, standing dead trees, down trees, and key fruit- and seed-bearing shrubs and trees as wildlife food sources, all of which are used by many species of wildlife species. The loss of such habitat elements has meant that a large portion of the forest wildlife fauna has been severely reduced or eliminated from large areas of the *Garo* Hills. In turn, this makes conservation of such wildlife populations only within the few protected areas of the region difficult to impossible.

Demonstration tasks: A demonstration project can entail identifying a few specific forest plots within heavily *jhummed* landscapes; listing the set of forest habitat elements for conservation focus; developing operating guidelines for *jhum* activities that would help protect or create such habitat elements; carrying out such activities in a few selected sites; and monitoring results.

Illustrating the potential for permanent plot agroforestry is an important part of this theme. Accomplishing this will entail selecting specific demonstration sites which can be developed for intensive and ongoing agricultural and timber tree interplanting. The demonstration site may entail terracing to help stave off soil erosion, ease access for site and crop management, and ease interim treatment activities. The purpose is to demonstrate alternatives to the short-cycle *jhum* activities that will permit some *jhum* sites to lay fallow for longer than 8-10 years by which some mature forest conditions as habitat for wildlife can regenerate.

Products: Products for this demonstration theme can include: [1] a list of the habitat elements and associated wildlife species; [2] *jhum* operating guidelines or activities to protect or create the habitat elements, such as extending the *jhum* fallow period; [3] an evaluation of the efficacy of the operations and how well they provide for the habitat elements in the field. Monitoring may include evaluating economic and ecological results, including agricultural crop production, tree and timber crop growth, and reduction in soil erosion and retention of productive soils.



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