Pavel Kindlmann *Editor*

Himalayan Biodiversity in the Changing World

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Preface

The Himalayan region has a unique assemblage of flora and fauna. Most of this mountainous region lies in Nepal – a country of great natural beauty and a rich cultural heritage. Nepal has always been a source of great attraction for its beautiful mountains, landscapes, lakes, waterfalls, hillsides and green villages serrated in the form of an endless series of terraces. Although this small country covers only 0.1% of the world's land area, it hosts 8.92% of bird species, 3.96% of mammal species, 3.72% of butterfly species, 1.87% of fish species and 2.2% of flowering plant species of the world. Many of these are endangered, critically endangered, or even close to extinction due to human impact, including habitat fragmentation and destruction, fuel wood consumption, poaching, livestock grazing etc.

Information about the real status of this vast amount of wildlife is, however, very poor, mainly because of the lack of empirical data. Most of the protected areas of Nepal are not easily accessible, and therefore researchers can visit only few of them. Many of the scarce existing data are hidden in local PhD and Master theses, in reports made for various governmental or nongovernmental conservation organizations, or in local journals not covered by the Web of Science (e.g., Trop. Ecol., J. of Bombay Nat. Hist. and others) and are therefore not easily available to the scientific world.

Here we aim to fill – at least partially – this gap. We present some results on selected taxa in the Himalayan region (mainly Nepal), pinpoint the threats to their survival and suggest ways how to avoid their extinction. Some chapters are based on graduate research projects – relatively long-term field studies – that were completed with the support of the Tribhuvan University in Kathmandu, Nepal and the Biodiversity Research Centre in České Budějovice, Czech Republic. Clearly, this entails some restriction on the width of the topics and taxa covered. As most of the papers are based on the research of a small group of researchers, the taxa covered reflect mainly their fields of expertise.

The book begins with two introductory chapters – general overviews of Nepalese biodiversity and problems of its conservation, followed by case studies, devoted to conservation of individual species, conservation of higher taxa, ecosystem processes and wildlife-human interactions. The habitats are spanning from the highest elevations, where life still exists (the Himalayan range) up to the subtropical lowlands – the

"Tarai" region. The species studied include mammals (tigers and other predators, Himalayan tahr and other ungulates), birds (storks and many others) and orchids. We investigate distribution, abundance, conservation threats, and interactions with people and domestic livestock of the species in question. The nomenclature used follows http://www.efloras.org for plants, http://www.iucnredlist.org for mammals and http://orientalbirdimages.org for birds.

The data presented are relatively recent, so the book can be a good source of updated information on the subject. Since the chapters are based on the prescribed course of studies for the graduate students of 2000 and beyond, the book can serve as a good source of reference or even as a textbook for both graduate and undergraduate students, particularly in the South Asian countries, including Bangladesh, India, Nepal, Pakistan, Sri Lanka, etc. We believe that it can very well serve as accompanying material for both undergraduate and graduate courses in conservation biology, mountain ecology, and wildlife ecology in these countries and elsewhere.

We hope that the data presented here will prove to be a very useful reference in future studies of Himalayan biodiversity. They also tend to pinpoint the existing gaps in our knowledge of this region. All the chapters are based on recent trends of biodiversity and conservation vision, so the book can be a potential alternative to the existing relatively older books with outdated vision and information. Our main goal, however, is to disseminate the information about biodiversity conservation problems in the Himalayan region among the people in the developed world. Should this book contribute to the increase of their awareness of these issues, to their understanding of the immense problems this region faces and/or will face in the future, and should it result in an increased support of biodiversity conservation in this region from the developed world, our time will have been well spent.

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Chapter 1
An Overview of the Biodiversity in Nepal

Prakash Kumar Paudel, Bishnu Prasad Bhattarai, and Pavel Kindlmann

1.1 Introduction

Nepal is a mountainous country in the central Himalayas, which occupies about one third of (800 km) of the entire length of the Himalayan mountain range. Nepal alone claims eight out of the top ten tallest mountains in the world, including Mount Everest (8,848 m). Apart from the mountains, deep gorges, river valleys and the flat lands it provides a unique assemblage of very different habitats and a great biodiversity within a small geographical area. The 147 181 km^2 that make up Nepal is slightly less than 0.1% of the global land mass, but contains a disproportionately large diversity of plants and animals. The country's 118 ecosystems harbour over 2% of the flowering plants, 3% of the pteridophytes and 6% of the bryophytes in the world's flora. Similarly, the country harbours 3.9% of the mammals, 8.9% of the birds and 3.7% of the world's fauna of butterflies (Table 1.1).

Nepal's rich biodiversity reflects its unique geographic position and variation in altitude and climate. Biogeographically, Nepal lies in the transitional zone between two biogeographical realms: the Palaearctic in the north and the Palaeotropic in the south (Udvardy 1975). Additionally, the country is situated at the confluence of the west Himalayan and east Himalayan floristic provinces and surrounded by six floristic

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Table 1.1 Faunal diversity: numbers of species in Nepal as a percentage of global numbers

Faunal group	Global numbers	Nepal[f] Number of species	Nepal/Global × 100 (%)	Endemic	Extinct
Mammals	4,675[a]	185	3.96	1	4
Birds	9,799[b]	874	8.92	2	11
Reptiles	7,870[a]	78	0.99	2	–
Amphibians	4,780[a]	118	2.47	9	–
Fish	10,000[c]	187	1.87	8	–
Butterflies	17,500[d]	651	3.72	29	–
Moths	160,000[d]	785	0.49	–	–
Spiders	39,490[e]	175	0.44	–	–

Source:
[a]Uetz et al. (2000)
[b]BirdLife International (2006)
[c]IUCN (2003)
[d]Smithsonian Institution (2007)
[e]Platnick (2006)
[f]BPP (1995a, b, c, d, e, f, g, h)

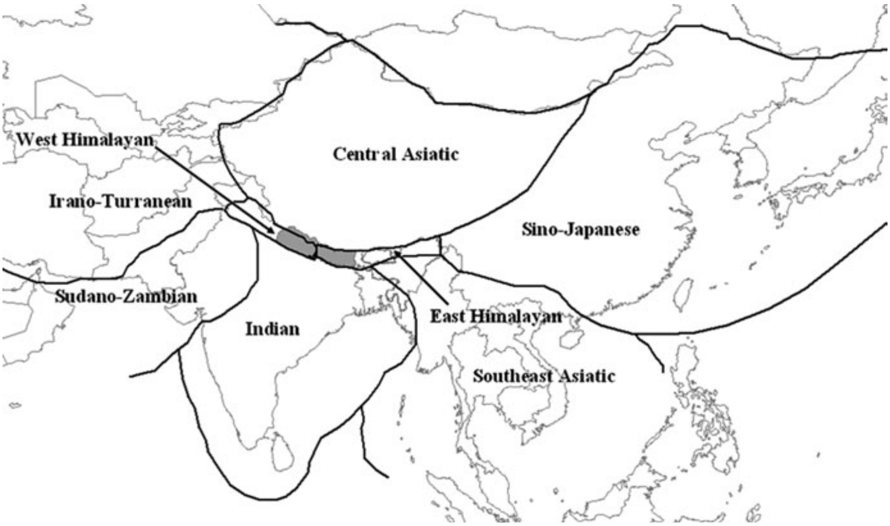


Fig. 1.1 Floristic provinces in Asia (Adapted from Dobremez 1976)

provinces of Asia: Central Asiatic, Sino-Japanese, South-East Asiatic, Indian, Sudano-Zambian and Irano-Turanian (Fig. 1.1). Apart from the influences of these floristic provinces, the mountain topography has resulted in a great diversity of habitats and vegetation. The three east-west running mountain ranges and intervening areas intersected by north-south flowing rivers constitute a complex pattern of landscapes, which – with the extreme variations in altitude (70–8,848 m) and precipitation (annual maximum 5,500 mm – Ichiyanagi et al. 2007) – provide a complex mosaic of habitats and ecological zones that range from tropical forests to alpine pastures.

1.2 Physiography

Physiographic division describes physical geography in terms of landform, climate, altitude and soils. Thus, it provides an important baseline for ecological studies. Physiographic division of Nepal is based on the three main mountain ranges, which have average altitudes increasing from south to north. In addition, different physiographic classifications (e.g., LRMP 1986; FSMP 1989; Ives and Messerli 1989; Hagen 1998) have been proposed and discussed. Among them, Hagen's classification (1998) offers a physiographic division. According to him, Nepal is divided into seven regions: (1) Tarai, (2) Siwaliks, (3) Mahabharat, (4) Midlands, (5) Himalayas, (6) Inner Himalayas and Tibetan marginal mountains (Fig. 1.2).

1.2.1 Tarai

This is a flat strip of land (25–32 km wide) in the southern part of the country running along the border between India and Nepal (Fig. 1.2), in the altitudes between 60 and 300 m, characterized by a tropical climate. It is a part of the Indo-Gangetic plain; hence the soil is alluvial and fine to medium textured. Previously, Tarai (also spelled as "Terai") consisted of an uninterrupted patch of dense tropical forest. With the eradication of malaria and the building of roads, Tarai became attractive to migrants from the hills because the area provided them with better livelihood options (Hrabovszky 1987). Consequently, most of the forest was destroyed and remaining areas subjected to intense human exploitation (Gurung 1983). Although Tarai covers about 17% of Nepal, it supports nearly half of the population (CBS 2001) and the main industrial areas (e.g., Biratnagar, Birganj and Nepalgunj).

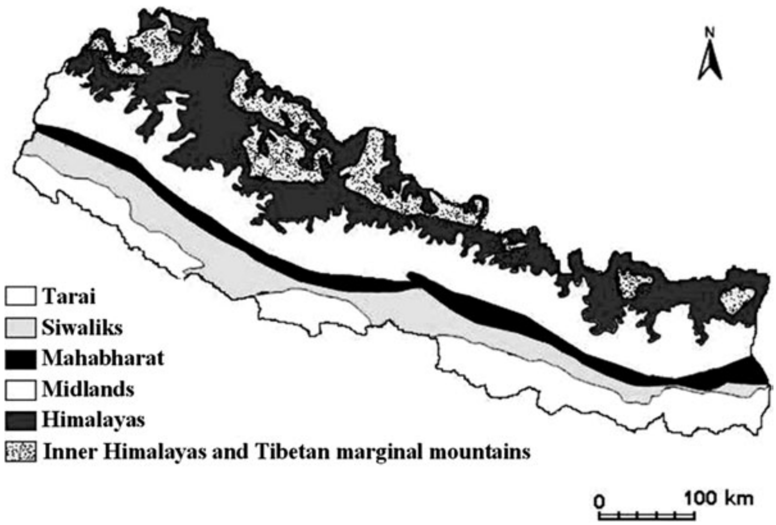


Fig. 1.2 Physiography of Nepal (Adapted from Hagen 1998)

1.2.2 Siwalik

To the north of the Tarai and Bhabar the land rises abruptly and reaches altitudes ranging from 700 to 1,500 m. This hilly range and its intervening area are commonly known as the Siwalik or Churia range. The Churia range is the youngest Himalayan range and is composed of sedimentary rock and big boulders (Valdiya 2001). This region is not suitable for agriculture and human settlements. However, there is productive land in Tarai like Dun valleys between the Siwaliks and Mahabharat, which are extensively exploited for agriculture and settlement (Bajracharya 1983). Dang in western Nepal, Chitwan in central Nepal and Trijuga in eastern Nepal are located in important dun valleys.

As in the Tarai, there are remnants of forest outside the protected areas. These forests could have conservation value given their high resilience. However, Siwalik forests are susceptible to rapid deterioration when exploited by man (Bhuju and Yonzon 2004). Thus, this area is subject to serious soil erosion, diminishing water catchment areas and flash flooding (HMGN 2002).

1.2.3 Mahabharat

This area is located between the Siwalik to the south and Midlands to the north (Fig. 1.2). The Mahabharat is an east-west running mountain range. It is composed of hard rocks of different ages, such as granite, quartzite and limestone (Valdiya 2001). The altitude ranges from 1,500 to 2,700 m and is characterized by a subtropical climate at low altitudes and a temperate climate at high altitudes. It is well developed in eastern and central Nepal and underdeveloped in western Nepal. Except for the river valleys, this region is moderately populated. The relatively gentle slope on the north face is cultivated and settled in places. On steep slopes, terrace cultivation is commonly practiced, which triggers soil erosion and nutrient loss. The forest on this range is severely exploited.

1.2.4 Midlands

This region lies to the north of Mahabharat Lekh and includes many high valleys, such as Kathmandu, Pokhara, Banepa and Trisuli. As its name suggests, it is situated in central Nepal and is an economically vibrant and well-populated region. Hagen (1998) called it the “heart of the country” because of its central role in the social development of the country. The altitude ranges from 600 to 3,500 m, with an average altitude of 2,000 m. Geologically, there are diverse formations, which are rich in schist and quartz rocks.

The low-lying riverbanks and gentle mountain slopes, including the terraced hill slopes are extensively utilized for agriculture. This region is the main catchment area for the rivers Kankai, Kamala, Trijuga, Bagmati, Babai and Rapti. Extension of agricultural land into what used to be forest follows the continuous process of deforestation (Bajracharya 1983). This region has the highest diversity of ecosystems, but they are not all equally well protected, even in the protected areas (BPP 1995a, b, c, d, e, f, g, h).

1.2.5 Himalayas

The word "Himalaya" is derived from the *sanskrit*, meaning "house of snow" (*him* – snow, and *alaya* – house). It is a mountain range running in the east–west direction above the altitude of 3,000 m cradled between high mountains, worn in the past by glaciers, north of the Midlands (Fig. 1.2). This Himalayan region is the home of the highest mountains in the world.

The region has a sub-alpine and alpine climate at the lower altitudes. At altitudes above 5,000 m, there is no vegetation and the area is considered to be an arctic desert or nival zone. Human settlement is mostly confined to low altitudes. Mountain pastures are important resources, which are used for both livestock grazing and collecting medicinal herbs during summer (Brower 1990).

1.2.6 Inner Himalayas and Tibetan Marginal Mountains

Inner Himalayas includes several inner Himalayan valleys with desert conditions, such as the upper Kali Gandaki and Bheri valleys, located at altitudes above 3,600 m. These valleys are dry, and the effect of the monsoon is virtually absent. Tibetan marginal mountains lie north of the Annapurna and Dhaulagiri mountains at altitudes of 6,000–7,000 m (Fig. 1.2). This region is characterized by a Tibetan type of vegetation and climate. It is the source of the Ganges river system. It includes some parts of the Dolpa, Mustang and Manang districts.

1.3 Climate

Nepal has a diverse climate ranging from tropical to arctic. All these can be found within a distance of approximately 180 km. The mountain ranges and their deep river valleys and gorges exhibit diverse climatic zones, which further increases the diversity of habitats due to the differences in precipitation, humidity, temperature and aspect.

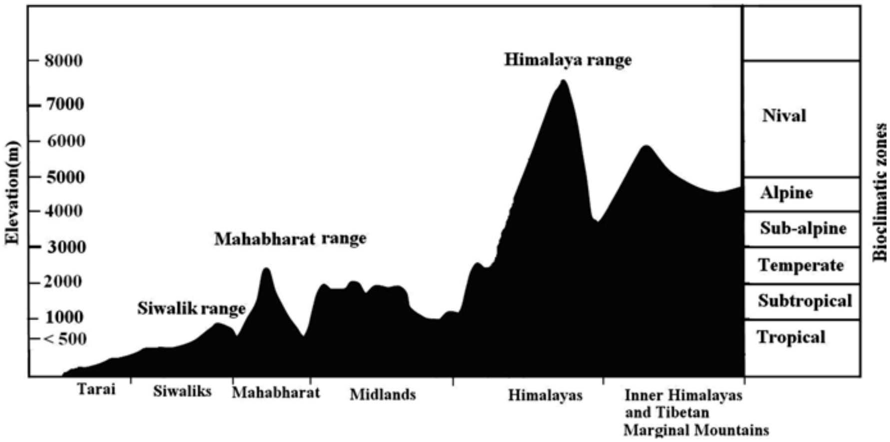


Fig. 1.3 Biographic and bioclimatic zones of Nepal

Precipitation in Nepal is brought by the summer monsoon and winter rains. The summer monsoon accounts for about 80% of the precipitation (June–September) and is accompanied by a northwesterly airflow from the Bay of Bengal (Shrestha 2000). Most of the east and the lower hills and lowlands of central and western Nepal receive more than 80% of the annual total precipitation during the monsoon season (Shrestha 2000). Spatial variation in the monsoon rains in this country is attributed to the influence of topography (Anders et al. 2006). Mountains affect the flow of air and influence precipitation by acting as physical barriers. The effect is that there is less precipitation in the westernmost hilly areas than in the eastern part, and less north of the Himalayas. In addition, these same mountains also act as a barrier to the cold fronts from central Asia and as a result the winters on the southern front of the Himalayas are warmer. Winter precipitation is pronounced in western Nepal (Kansakar et al. 2004; Ichiyanagi et al. 2007). It is associated with western disturbances and is caused by an eastward airflow from the Mediterranean and local surface heating effects, which enter western Nepal via northern India and Kashmir (Lang and Barros 2004).

Altitude affects the pattern of precipitation. In Nepal, precipitation increases with altitude up to 2,000 m and then decreases between 2,000 and 3,500 m (Ichiyanagi et al. 2007). Such a negative relationship between annual precipitation and altitude is common in western Nepal (Ichiyanagi et al. 2007).

Temperature is the most important aspect of the mountain climate. Generally, the climate of the Tarai (below 500 m) is tropical and that of the Dun valleys and part of the Siwaliks (up to 1,000 m) is subtropical. The climate of the Mahabharat (1,000–3,000 m) ranges from warm temperate to cool temperate. In the high mountains (3,000–5,000 m), it ranges from cool temperate to alpine (Fig. 1.3). The average temperature decreases by 0.5°C for every 100 m increase in altitude in subtropical regions (Bhattarai and Vetaas 2003). This relationship can vary depending on season, climatic zone, slope and solar radiation (Hooker 1854). In the eastern and western parts of Nepal the timberline and snowline are markedly different. The timberline varies between 3,700 and 4,200 m depending on local conditions. In general, 4,000 m is considered to be the upper limit of the timberline, but it is a few hundreds meters (3,700 m) lower in western Nepal (Manandhar 2002).

1.4 Biodiversity Patterns: Ecoregional Perspectives

The categorization and demarcation of vegetation is difficult because of the complexity of physiographic and climatic zones in the region. There is an array of bioclimatic zones along the vertical gradient of the mountain slope. Thus, the classification of vegetation in a country like Nepal is difficult to interpret (TISC 2002). Vegetation types provide the best overview of habitat associations in the different physiographic and climatic zones. However, vegetation types do not correspond to habitat types, and their interchangeable use can be misleading (Hall et al. 1997). Habitats are species-specific. A species' habitat can range from a certain type of vegetation to a complex mosaic of several different types of vegetation.

There are a number of works on the classification of the vegetation in Nepal. Schweinfurth (1957) and Stearn (1960) were the first to produce vegetation maps for the entire Himalayas. The climatological, florisitic, and ecological data used by Stearn (1960) to produce maps of the vegetation also provide a broad categorization of the vegetation in the three zones: Eastern, Western and Central Nepal, into humid east Himalayan flora and dry west Himalayan flora. However, he did not include any reference to altitudinal differences. This classification was used to illustrate the distribution of plant species in Nepal (e.g., Hara et al. 1978; 1979; 1982). There are comprehensive accounts of Nepal's vegetation in Stainton (1972) and Dobremez (1976). Stainton (1972) describes 35 types of forest based on altitude and climate. Dobremez (1976) further elaborated on the detail of this classification and identified 198 categories of vegetation. The Biodiversity Profile Project (BPP 1995a, b, c, d, e, f, g, h) simplified the classification and reduced it to 118 categories, which was revised by IUCN in 1998 and reduced to a list of 59 vegetation types. TISC (2002) further reduced it to 36 categories in ecological maps of Nepal. The classification of vegetation, however, is still a subject of debate as the gradients in latitude and altitude are complex and affected by local conditions (e.g., rainfall, aspect and soil). Stainton's (1972) classification of vegetation is widely used in Nepal. For convenience, this classification is used here to communicate the distribution of the different types of forest in Nepal.

Photograph of the Tarai-Duar savanna and grassland ecoregion in the Chitwan National Park: it is the prime habitat for ungulates and tigers and now only occurs in national parks (Photo by BP Bhattarai)

Habitat mosaic in lowland Tarai: grassland (*in front*), sal forest (*on the horizon*) and riverine forest (*between these two*). Tarai has a rich biodiversity but is badly degraded by human activities. Nearly half of Nepal's population resides in the Tarai region (Photo by BP Bhattarai)

Asiatic elephant (*Elephas maximus*). There are three populations of wild elephant in Nepal: western, central and eastern populations. Western and eastern populations, however, are part of a large population whose range extends into India. The central population is isolated and estimated to consist of 21 individuals (Smith and Mishra 1992) (Photo by BP Bhattarai)

Rhinoceros (*Rhinoceros unicornis*) in its natural habitat. Altogether 433 individuals in three populations were recorded in Nepal at the last count in 2008: Chitwan (408), Bardia (20) and Suklaphant (5) (DNPWC 2008) (Photo by BP Bhattarai)

A herd of spotted deer (*Axis axis*) in lowland Tarai: a major prey species of tiger (Photo by BP Bhattarai)

A flock of white-rumped vultures (*Gyps bengalensis*). Birdlife International predicts global extinction of Asian vultures within 10 years, due to the toxic effects of diclofenac residues in animal carcasses. Recently "vulture restaurants" – feeding sites provided with diclofenac-free carcasses, have been established in different parts of Nepal (Photo by BP Bhattarai)

Giant Hornbill (*Buceros bicornis*): a near threatened bird (Photo by BP Bhattarai)

Ruddy Shel-duck (*Tadorna ferruginea*) in Beeshazari Lake, a Ramsar Site. Nepal has nine Ramsar sites, totaling 34,455 ha (Photo by BP Bhattarai)

Common Kingfisher (*Alcedo atthis*) – a symbol of healthy wetlands (Photo by BP Bhattarai)

Flame of the forest (*Butea monosperma*) (Photo by BP Bhattarai)

Cassia alata in the lowlands of Nepal (Photo by BP Bhattarai)

Bauhinia variegata; the flower is used for pickle (Photo by PK Paudel)

Churia range: the youngest Himalayan mountains, made of sedimentary rocks and big boulders (Photo by PK Paudel)

Chir pine (*Pinus roxburghii*) forest has little or no understory vegetation. It is the dominant vegetation of Himalayan subtropical pine forests (Photo by PK Paudel)

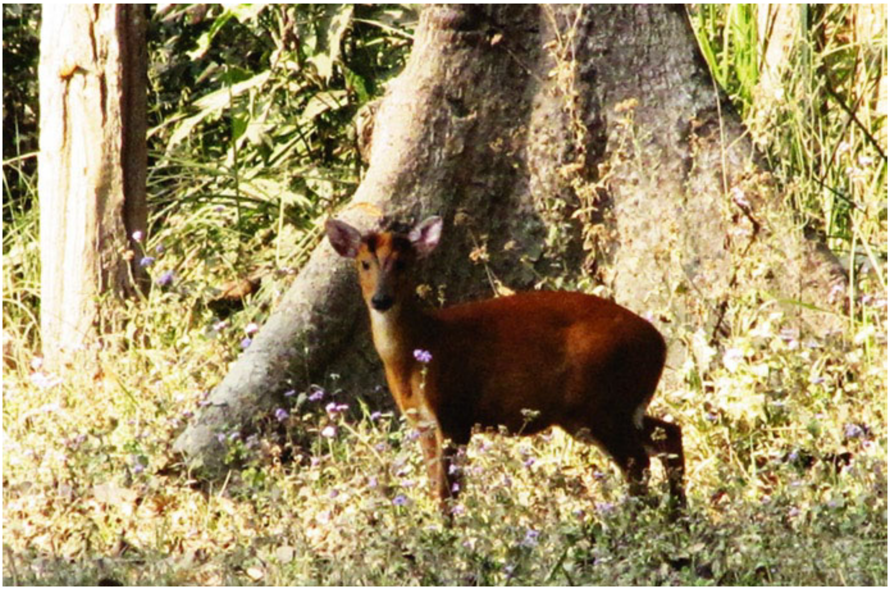
Sparse cover of chir pine: this species can grow even in areas with very poor soils (Photo by PK Paudel)

Sal forest in the midhills of Nepal; mostly degraded due to the harvesting of timber and proximity to villages. Most low lying areas along the river plains and at the bases of mountain in the midhills are used for human settlements (Photo by PK Paudel)

Churia hill gorge covered by sub-tropical deciduous sal forest (Photo by PK Paudel)

Rhododendron arboreum, a national flower of Nepal. Rhododendrons along with oak, hemlock, and firs form a number of forest types in different climatic conditions throughout the country (Photo by PK Paudel)

Himalayan goral (*Naemorhedus goral)*: a near threatened mountain ungulate. It is widely distributed throughout the mountains in Nepal (Photo by PK Paudel)



Barking deer (*Muntiacus muntjac*) is the smallest deer found in Nepal. It prefers energy-rich forests and it is resilient to human disturbance. Hunting is believed to be the main cause of its decline (Photo by BP Bhattarai)

Coelogyne corymbosa (Orchidaceae), Central Nepal. There are 90 genera and over 300 species of orchids in Nepal (Hara et al. 1978, 1982) (Photo by P Kindlmann)

Oak forest mixed with rhododendron in western Nepal. It is a part of Western Himalayan broadleaf forests ecoregion (Photo by PK Paudel)

A dense mixed forest (rhododendron, oak and conifers). It is a remnant forest in the altitude of 2,500–3,000 m in the midhills. Locally known as *Lekh*, the forests are important habitat for mountain ungulates and primates (Photo by PK Paudel)

Fir-rhododendron forest: a typical vegetation of Western Himalayan subalpine conifer forests ecoregion (Photo by PK Paudel)

Fir forest with *Rhododendron campanulatum* (Paiga Jajarkot, 3,480 m) (Photo by PK Paudel)

Oak forest in Kaigau, Dolpa. *Quercus semecarpifolia* is an important source of timber and fodder (Photo by PK Paudel)

Aconitum spicatum (Bikh-means poison), common in high altitude region, is widely used in the Ayurvedic medicine (Photo by PK Paudel)

Birch-rhododendron forest just below the timberline, Shey Phoksundo National Park, western Nepal (3,662 m). Characteristic forest of the sub-alpine zone (Photo by PK Paudel)

Alpine meadow (3,996 m), Shey Phoksundo National Park, Western Nepal. Such meadows play an important role in sustaining local economy and livelihood of the people and protecting biodiversity. They provide medicinal herbs, grazing for livestock and habitat for high altitude mammals (Photo by PK Paudel)

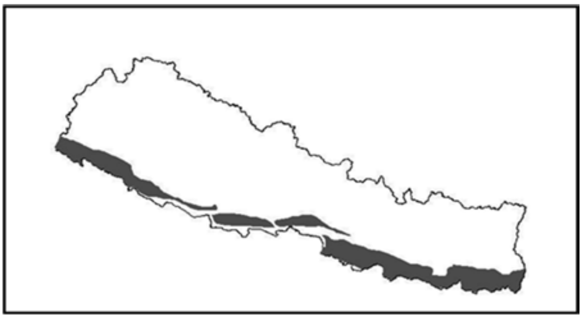
High mountains: good habitat for blue sheep (*Pseudois nayaur*) (Photo by PK Paudel)

Himalayan range: a perpetual source of water (Photo by P Kindlmann)

This section is organized within a "top down" framework, in which the ecoregion is presented first and then the type of forest and the fauna (large mammals and birds) it harbours. This presents a "big picture" of the pattern in biodiversity within an ecoregion hierarchy, and provides an overview of the distribution of vegetation and animals in each ecoregion. An ecoregion is a large area of land or water that contains a geographically distinct assemblage of natural communities that (1) share the majority of their species and have similar ecological dynamics; (2) share similar environmental conditions, and (3) interact ecologically in ways that are critical for their long-term persistence (Wikramanayake et al. 2002). From a conservation point of view, the ecoregion perspective takes conservation beyond endangered species into ecosystem integrity (Noss 2000) and provides a practical unit for conservation (Groves et al. 2002). Wikramanayake et al. (2002) provide a detailed account of the classification of the ecoregions in the Indian Pacific region. The classification presented here follows Wikramanayake et al. (2002) and the WWF Conservation Science Program (http://www.worldwildlife.org/science/). The map of the ecoregions (Olson et al. 2001; WWF US 2004) was used to the preparation of the distribution maps for Nepal.

1.4.1 Tarai-Duar Savanna and Grasslands

This ecoregion incorporates a narrow strip of land at the base of the Himalayas in southern Nepal, which includes Tarai, Bhabar (Siwaliks) and the Dun valleys (Fig. 1.2). It is characterized by wide range of savanna type grasslands, evergreen and deciduous forests, whose presence depends on the different climatic and moisture conditions prevailing here (Shrestha and Joshi 1997). This ecoregion includes five protected areas consisting of three wildlife reserves (Shukla Phanta, Parsa and Koshi Tappu) and two national parks (Bardia and Chitwan). However, these small and isolated protected areas are insufficient for protecting the extensive Tarai ecosystem and wildlife community, such as tigers. The Tarai Arc Landscape has been implemented to reduce the negative effects of habitat isolation by providing corridors for wildlife (Wikramanayake et al. 2004).



1.4.1.1 Vegetation

The major types of forest in this ecoregion are sal forest, tropical deciduous riverine forest, and tropical evergreen forest (Stainton 1972). Sal forest occurs throughout the flatlands of Tarai and is also present in the Siwaliks. Sal (*Shorea robusta*) is the dominant species. However, the species composition of sal forests in the Siwalik region varies. Sal forests are replaced by tropical deciduous riverine forest along the banks of rivers and on river terraces. The main species in this type of forest is *Bombax ceiba* along with *Trewia nudiflora, Garuga pinnata* and *Holoptelea integrifolia.* However, the *Acacia catechu* and *Dalbergia sissoo* association tends to be dominant in areas prone to flooding, where it forms a distinct riverine Khair-sissoo forest. This type of forest is found in this region between 70 and 500 m (Shrestha and Joshi 1997).

The tall grasses *Narenga porphyrocoma, Saccharum bengalense* and *Saccharum spontaneum* characteristically grow in association in riverine grasslands. In addition, the *Themeda arundinacea* association is common in *Trewia nudiflora-Bombax ceiba* riverine forest (Lehmkuhl 1994). The mixed tall grass and grass shrub association is a good habitat for Cervids and rhinoceros (Wegge et al. 2006). Tropical evergreen forests are confined to the humid north-facing slopes in the outer foothills in the tropical zone of East Nepal. *Michelia champaca* and *Eugenia jambolana* are dominant species in this type of forest (Negi 1994).

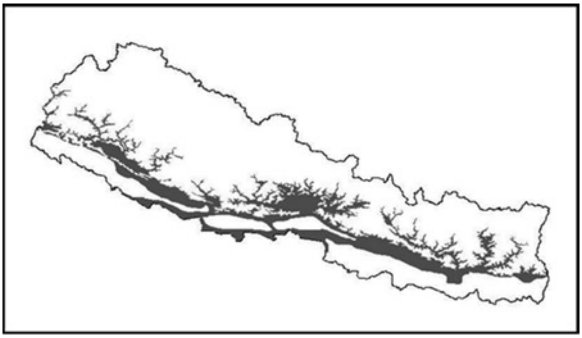
1.4.1.2 Fauna

This ecoregion is the habitat for globally threatened flagship species, such as the Bengal tiger (*Panthera tigris*), Asiatic elephant (*Elephas maximus*), one-horned rhinoceros (*Rhinoceros unicornis*), gaur (*Bos gaurus*) and blue bull (*Boselaphus tragocamelus*). This savanna-like grassland supports a high diversity of ungulates. Nowhere is there as diverse an assemblage of cervids as in this ecoregion: swamp deer (*Rucervus duvaucelii*), sambar (*Cervus unicolor*), chital (*Axis axis*), hog deer (*Axis porcinus*) and barking deer (*Muntiacus muntjac*) (Seidensticker 1976; Dinerstein 1980; Wegge et al. 2006). It supports the second largest population of the greater one-horned rhinoceros and is home for several other endangered mammalian herbivores including the Asiatic wild buffalo (*Bubalus arnee*) (WWF 2001). This ecoregion is also critically important for bird conservation. It is the habitat for 14 out of the 130 threatened birds of Nepal, such as Bengal florican *(Houbaropsis bengalensis)*, lesser florican *(Sypheotides indica)* and the large grass warbler (*Graminicola bengalensis*) – BirdLife International (2004).

1.4.2 Himalayan Subtropical Broadleaf Forests

On a large strip of land running in east–west direction in Nepal along the Siwalik and into gorges in the Mahabharat there is the Himalayan subtropical broadleaved forest.

River gorges and valleys with a subtropical climate in the midhills is a common phenomenon in Nepal. Hence, extension of this ecoregion from Siwaliks into the midlands is a functional outcome of the river systems. This ecoregion is poorly represented in the protected area system. Conservation programs such as the Tarai Arc Landscape (TAL) include only some of the Churia ridges and their southern slopes (GON 2004).



1.4.2.1 Vegetation

In this ecoregion we can find subtropical deciduous hill forest, *Terminalia* forest, subtropical semi-evergreen hill forest, *Schima-Castanopsis* forest, *Alnus* woods and *Dalbergia sissoo-Acacia catechu* forest (Stainton 1972).

Subtropical deciduous hill forest is characterized by sal (*Shorea robusta).* The associated genera are *Terminalia, Anogeissus, Lagerstroemia* etc. In central and western Nepal, *Terminalia* forms distinct patches of *Terminalia* forest. This type of forest is found in the areas with heavy or wet soils (TISC 2002). Subtropical semi-evergreen hill forest is common at altitudes of 700–1,800 m with a moderate rainfall. The main species in this forest are *Acer oblongum, Eugenia tetragona, Eurya acuminata etc.* This forest is replaced by *Schima-Castanopsis* forest in eastern Nepal. Chilaune (*Schima wallichii*) and Katush (*Castanopsis indica*) are the dominant species. It is found on both north and south-facing slopes between 1,000 and 2,000 m in east and central Nepal. In west Nepal, chir pine (*Pinus roxburghii*) replaces *Schima-Castanopsis* (Ohsawa et al. 1986*)*. On the banks of rivers and streams and in unstable areas, alder (*Alnus nepalensis*) forms large patches but they are not large enough to qualify as a distinct forest type (Chaudhary 1998).

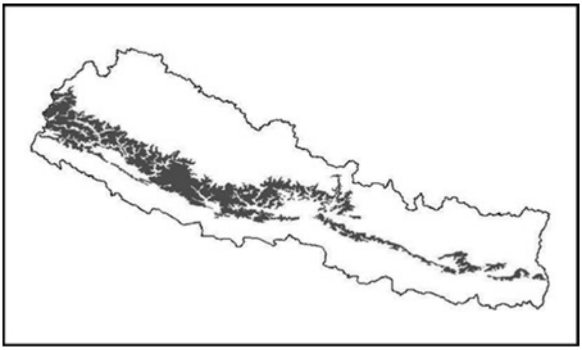
1.4.2.2 Fauna

The Siwalik range provides important habitats for tiger (*Panthera tigris*), Asian elephant (*Elephas maximus*), gaur (*Bos gaurus*) and sloth bear (*Melursus ursinus*). These endangered mammals, however, are not found in this ecoregion in the Mahabharat and midhills. Here, tigers are believed to be absent because of extensive human settlement and loss of prey species. The major mammalian fauna includes common leopard (*Panthera pardus),* clouded leopard (*Neofelis nebulosa*), Himalayan serow (*Capricornis thar*), barking deer (*Muntiacus muntjac*) and Asamese monkey (*Macaca assamensis*) (BPP 1995c, d, e).

The important large birds are the giant hornbill (*Buceros bicornis*), Oriental pied hornbill (*Anthracoceros albirostris*), Indian grey hornbill (*Ocyceros birostris*), peafowl *(Pavo cristatus),* hill myna *(Gracula religiosa*), crested serpent eagle *(Spilornis cheela)* and Asian paradise flycatcher *(Terpsiphone paradisi)* (Grimmett et al. 2000).

1.4.3 Himalayan Subtropical Pine Forests

This ecoregion is found throughout the Siwalik and Mahabharat ranges in Nepal and covers a large part of western Nepal. It is not rich in biodiversity but provides habitats for several birds and mammals. Most of it is either cleared of forest or degraded except in western Nepal, where a little of the natural vegetation still exists (Dobremez 1976). None of the protected areas in Nepal include this ecoregion, except for the narrow belt of pine forest on the tops of the Siwalik ridges.



1.4.3.1 Vegetation

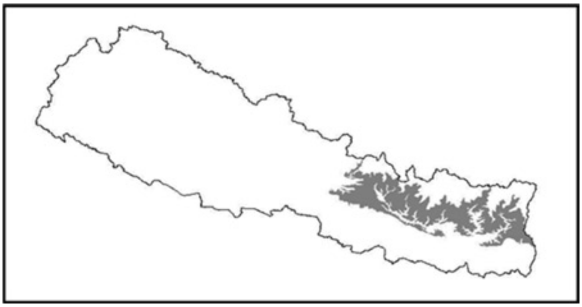
Chir pine forest is typical here. It is distributed from west to central Nepal at altitudes between 1,000 and 2,000 m on south-facing slopes in central and eastern Nepal, whereas it is common in the west (TISC 2002). Chir pine (*Pinus roxburghii)* is a large evergreen tree, which is extensively used for timber and firewood. It is adapted to dry climates and can flourish even in nutrient deficient degraded soils (Ohsawa et al. 1986; Singh and Singh 1987). There is little or no understory vegetation in pure chir pine forest. Because of their xeric nature, these forests frequently catch fire. In some regions, chir pine is associated with broadleaved species such as *Quercus incana, Q. lanata,* and *Rhododendron arboreum,* at its upper limit, and *Lyonia ovalifolia, Shorea robusta* and *Terminalia tomentosa* at its lower limit (TISC 2002).

1.4.3.2 Fauna

This ecoregion does not have a high faunal diversity. However, it provides large areas of habitat and ranges for a number of mammalian species, such as goral (*Naemorhedus goral*), barking deer (*Muntiacus muntjac*) and yellow-throated marten (*Martes flavigula*) (BPP 1995i). Similarly, it is home for cheer pheasant (*Catreus wallichii)*, spiny babbler (*Turdoides nipalensis*), rusty-bellied shortwing (*Brachypteryx hyperythra*), scaly-breasted wren babbler (*Pnoepyga albiventer*) and Nepal wren babbler (*Pnoepyga immaculata*) (Grimmett et al. 2000). In addition, this ecoregion is a biological corridor for a number of migratory birds.

1.4.4 Eastern Himalayan Broadleaf Forests

This ecoregion lies between 2,000 and 3,000 m and covers the Mahabharat and Midhills east of the Kali Gandaki River. It is globally outstanding especially in terms of its floral and faunal diversity. The high floral diversity is attributed to its position at the crossroads of several floristic provinces in Asia (Fig. 1.1). Only two national parks (Shivapuri and Makalu-Barun) overlap with this ecoregion. The rich rhododendron forests are being conserved by the Tinjure-Milke-Jaljale (TMJ) community-managed rhododendron conservation area project – Box 1.1.



1.4.4.1 Vegetation

The major forests are *Quercus lamellosa* forest, *Quercus dilatata* forest, *Castanopsis tribuloides – C. hystrix* forest, *Schima – Castanopsis, Lithocarpus pachyphylla* forest, lower temperate mixed broadleaved forest, upper temperate mixed broadleaved forest, rhododendron forest and *Betula utilis* forest (Stainton 1972).

Oak and rhododendron are the most common broadleaved species in this ecoregion. A number of oak species, especially *Quercus lamellosa* and *Quercus dilatata,* dominate the plant community. These species in association with rhododendrons, *Michelia*, *Magnolia* etc. form *Quercus lamellosa* and *Quercus dilatata* forest (Singh and Singh 1987).

Box 1.1 The Tinjure-Milke-Jaljale (TMJ) rhododendron conservation area

At the confluence of three districts – Tehrathum, Sankhuwasabha and Taplejung – in the eastern hilly region of Nepal, **the Tinjure-Milke-Jaljale (TMJ) area** is regarded as a potential Community Conserved Conservation Area (CCCA) because of its rich biodiversity, especially of rhododendrons. It has a total area of 585 km^2 and links the Kanchenjunga Conservation Area (KCA), Makalu Barun National Park (MBNP) and Sagarmatha (Mt. Everest) National Park (SNP).

There are more than 25 species of rhododendron in this area. About 25% of the total land area in TMJ is cultivated and the rest consists of forest, bush/shrub and grassland. The people in the TMJ are heavily dependent on its biological resources for their livelihood. (Adapted from IUCN Nepal 2010).

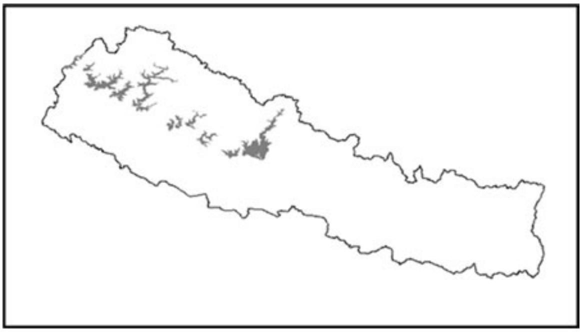
Eastern Himalayan broadleaf forests are rich in rhododendrons. Rhododendrons are widely distributed throughout Nepal at altitudes ranging from 1,500 to 4,300 m (Milleville 2002), but they do not form pure rhododendron forest in western Nepal (Shrestha 1984). However, Eastern Himalayan broadleaf forests do harbour pure rhododendron forests, especially in Milke Danda (Box 1.1), Pathibhara and Maipokhari. *Castanopsis tribuloides* and *C. hystrix* are common above 2,000 m, where they form *Castanopsis tribuloides* – *C. hystrix* forest (Ohsawa et al. 1973). This type of forest is very rare in western Nepal. In the extreme east and the Tamur valley, *Lithocarpus pachyphylla* occurs at 2,600–3,000 m as dense evergreen broadleaved forest in association with *Quercus lamellosa, Q. lineata* and *Michelia doltsopa*. *Lithocarpus pachyphylla* forest is uncommon in other parts of the country (TISC 2002). At between 2,600 and 3,000 m *Magnolia campbellii* and *Acer campbellii* with an understory of *Rhododendron barbatum* and *Symplocos pyrifolia* form a distinct assemblage (Ohsawa et al. 1973). At higher altitudes *Rhododendron arboreum* in association with a number of maple species (*Acer campbellii, A. sterculiaceum, A. pectinatum*) form another assemblage (Shrestha 1984), which Stainton (1972) classified as lower temperate mixed broadleaved forest and upper temperate mixed broadleaved forest.

1.4.4.2 Fauna

This ecoregion is the habitat of several threatened mammalian species, including the red panda (*Ailurus fulgens*), Himalayan serow (*Capricornis thar*), Assamese macaque (*Macaca assamensis*), Asiatic wild dog (*Cuon alpinus*), back-striped weasel (*Mustela strigidorsa*) and clouded leopard (*Neofelis nebulosa*). Here, red panda is limited to patches of mature fir (*Abies* species) forest with a bamboo understory (Yonzon and Hunter 1991). The birds in this ecoregion include several threatened species of pheasants (*Pucrasia macrolopha, Lophophorus impejanus, Lophura leucomelanos*), tragopans (*Tragopan satyra*) and hornbills (*Anthracoceros albirostris*) (Inskipp and Inskipp 1991).

1.4.5 Western Himalayan Broadleaf Forests

This ecoregion is distributed in the temperate zone between 1,500 and 2,600 m west of the Kali Gandaki river. There are both evergreen and deciduous species in the temperate broadleaf forests here. Western Himalayan broadleaf forests are, in particular its natural vegetation, severely degraded (HMGN 2002). No part of this ecoregion is in a protected area.



1.4.5.1 Vegetation

The major forests here consist mainly of *Quercus dialata, Quercus incana, Quercus semecarpifolia, Quercus ilex or Aesculus-juglans-acer,* plus *Alnus* woods (Stainton 1972). Thus, this ecoregion has distinct evergreen broad-leaved and deciduous broad-leaved forests. Some distinctive oak species (*Quercus dialata* and *Quercus incana)* are dominant on the moist rich southern slopes and form a variety of oak forests in association with Lauraceae (Ohsawa et al. 1973, Manandhar 2002). Similarly, *Q. ilex* dominates in dry regions on north-facing slopes. It is often associated with coniferous species in certain areas. *Quercus semecarpifolia* is widespread especially at high altitudes up to the timberline.

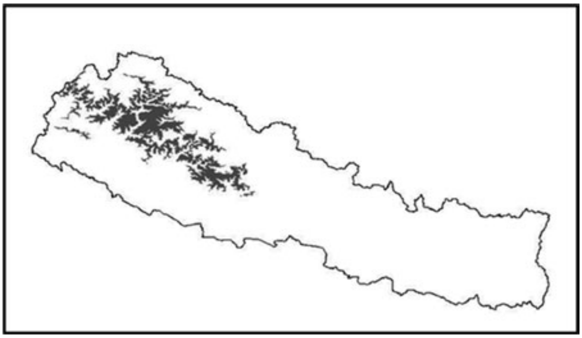
Forests along riverbanks are composed of *Aesculus indica, Juglans regia, Carpinus viminea, Alnus nepalensis* and several *Acer* spp. There are often *Aesculus-juglans-Acer* forests in this region (Negi 1994). *Alnus nepalensis* grows well in moisture rich areas, especially in river valleys, forming distinct alder woods (Chaudhary 1998).

1.4.5.2 Fauna

Western Himalayan broadleaf forests provide supplementary habitats for several threatened species, including Himalayan tahr (*Hemitragus jemlahicus*), Asiatic black bear (*Ursus thibetanus*), common leopard (*Panthera pardus*) and Himalayan serow (*Capricornis thar*). Pheasants are common, including the Satyr tragopan (*Tragopan satyra*), Koklass pheasant (*Pucrasia macrolopha*), impeyan pheasant (*Lophophorus impejanus*) and Cheer pheasant (*Catreus wallichi*) (BPP 1995i).

1.4.6 Western Himalayan Subalpine Conifer Forests

This ecoregion lies below 3,500 m in the Midhills and Himalayas to the west of the Kali Gandaki river. It is the border of the forested ecoregion in the western Himalayas. Although not endemic here, it supports a high mammalian diversity. Western Himalayan subalpine conifer forests are also rich in conifer forests dominated by western species – e.g., *Tsuga dumosa, Picea smithiana, Abies pindrow, Cedrus deodara, Cupressus torulosa* and *Juniperus wallichiana* (Chaudhary 1998). There are two national parks (Rara and Khaptad) one conservation area (Api Nampa) and one hunting reserve (Dhorpatan) here.



1.4.6.1 Vegetation

The major forests here consist of *Quercus incana – Quercus lanuginosa, Quercus dilatata, Quercus semecarpifolia, Betula utilis, Abies spectabilis, Tsuga dumosa, Pinus excelsa (wallichina), Picea smithiana, Populus ciliata* or *Juniperus wallichiana* (Stainton 1972).

Quercus incana (= Q. leucotrichophora) and *Q. lanuginosa* (= *Q. lanata*) forest is found at altitudes between 2,000 and 2,500 m, with *Rhododendron arboreum* and *Lyonia ovalifolia* as the most abundant associated species. In damp places, *Q. dilatata* dominates the vegetation. The *Q. dilatata* forest is not widespread and limited to lower altitudes in the temperate region. In the temperate zone, *Q. semecarpifolia* is abundant and forms mixed forest with fir, blue pine, hemlock and spruce. It forms pure *Q. semecarpifolia* forest in the lower part of the subalpine zone along the Karnali River (TISC 2002). Associations with species such as silver fir (*Abies spectabilis*), spruce (*Picea smithiana*), hemlock (*Tsuga dumosa*), blue pine (*Pinus excelsa*) and birch (*Betula utilis*) occur in the upper part of the temperate zone, where they form distinct types of forest depending on altitude and local climatic conditions (Ohsawa et al. 1986). *Tsuga dumosa* forest is found below 3,000 m in the mountains and is replaced by *Abies pindrow* forest at higher altitudes. *Abies pindrow* is common in northwest Nepal, whereas *Abies spectabilis* forest is distributed throughout eastwest Nepal (TISC 2002). Clusters of *Cedrus deodara* and *Cupressus torulosa* forests occur at 2,000–3,000 m. Pure *Picea smithiana* forest is found in valleys west of lake Rara and the Chankhali mountain ridge in Mugu district, and in some regions of Humla (Shrestha 1982). *Populus ciliata* woods occur in moist cool places in river gorges and on terraces in the temperate and lower part of the subalpine region (Shrestha 1982). Pure *Juniperus wallichiana* forest is found in the Dhorpatan, whereas in other parts it forms shrub-land (TISC 2002).

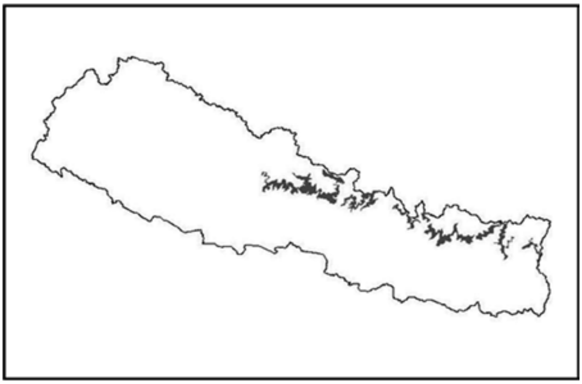
Pinus excelsa occurs at altitudes of 2,000–3,000 m and is found with *Pinus roxburghii* at the lower limit and with *Abies spectabilis* and *Betula utilis* at the upper limit along the timberline. It quickly colonizes deforested areas and grows in relatively dry regions (Stainton 1972). It forms a distinct forest (*Pinus excelsa* forest) in this ecoregion in western Nepal. Birch (*Betula utilis*) commonly known as "bhojpatra" is distributed throughout the country at altitudes of 3,000–4,000 m. It forms a dense forest with rhododendrons, *Abies spectabilis* and *Pinus excelsa* up to the timberline (Zobel and Singh 1997). Pure *Betula utilis* forest occurs in patches rather than as a continuous belt (TISC 2002).

1.4.6.2 Fauna

This ecoregion harbors several species of large mammals of conservation importance, such as brown bear (*Ursus arctos*), Himalayan serow (*Capricornis thar*) and goral (*Naemorhedus goral*) (Gurung 2004, ICIMOD 2007). In addition, this ecoregion provides occasional habitats for musk deer (*Moschus chrysogaster*), blue sheep (*Pseudois nayaur*) and Himalayan tahr (*Hemitragus jemlahicus*). There are many species of pheasants here. The Himalayan griffon (*Gyps himalayensis*) is the most important bird found in this ecoregion (Bird Conservation Nepal 2006).

1.4.7 Eastern Himalayan Subalpine Conifer Forests

This ecoregion lies in the upper part of the midhills and Himalayan physiographic region east of the Kali Gandaki river. It has a diverse flora and fauna. Rhododendrons form an extensive association with conifers (*Abies spectabilis, Pinus excelsa, Tsuga dumosa*) and provide habitats for important animals such as red panda and the Himalayan musk deer. There are two national parks (Makalu-Barun and Langtang) and one conservation area (Annapurna) here.



1.4.7.1 Vegetation

The major types of forest consist here mainly of either *Abies spectabilis, Pinus excelsa (wallichina), Betula utilis* or *Tsuga dumosa* and *Larix* (Stainton 1972). *Abies spectabilis* is the dominant forest in this ecoregion. Pure *Abies* forest occurs between 3,000 and 3,500 m (Schmidt-Vogt 1990). In *Abies* forests the understory consists mainly of a number of different species of rhododendrons. At 2,500–3,000 m, *Abies* forest is replaced by *Tsuga dumosa* forest (Manandhar 2002). *Larix* forest occurs above altitudes of about 3,200 m and extends up to the timberline. It either forms a pure forest or occurs in association with *Abies spectabilis, Betula utilis* and *Tsuga dumosa* (TISC 2002).

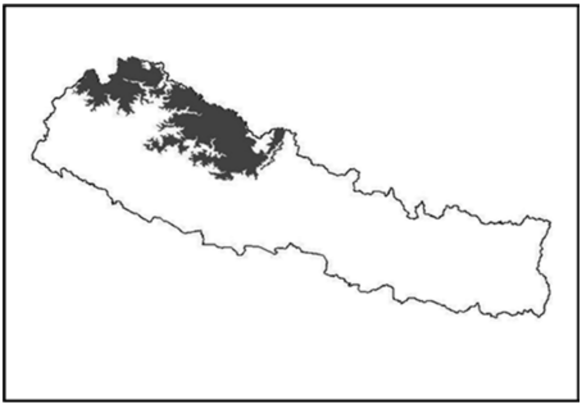
Pinus excelsa is widely distributed from 2,000 to 3,000 m and occurs with *Pinus roxburghii* at the lower limit and with *Abies spectabilis* and *Betula utilis* at the timberline (Stainton 1972). *Abies spectabilis, Pinus wallichiana, Rhododendron campanulatum, R. falconeri, R. hodgsonii* and *Betula utilis* are the dominant species at the treeline. There is no distinct *Pinus excelsa* forest in this ecoregion. Birch (*Betula utilis*) occurs throughout Nepal at altitudes of between 3,000 and 4,000 m (Zobel and Singh 1997). It forms a dense forest with rhododendrons, *Abies spectabilis, Pinus excelsa* up to the timberline. Pure *Betula utilis* forest occurs in patches rather than a continuous belt (TISC 2002). West Himalayan species (e.g., *Pinus roxburghii, Pinus wallichiana,* and *Quercus semecarpifolia)* occur locally in eastern Nepal in dry habitats (Ohsawa et al. 1986).

1.4.7.2 Fauna

The important animals here are red panda and the Himalayan musk deer, which are found in the fir and rhododendron forest (Yonzon et al. 1991). Other mammals include civets, martens, Himalayan tahr and barking deer (ICIMOD 2007). The important bird species are Lammergeiers (*Gypaetus barbatus*), Himalayan griffons (*Gyps himalayensis*), pheasants and tragopans (Inskipp and Inskipp 1991).

1.4.8 *Western Himalayan Alpine Shrub and Meadows*

This ecoregion corresponds to the region of the Himalayas between 3,000 and 5,000 m west of the Kali Gandaki river and is rich in plant species. This region is the last extensive habitat for high altitude Himalayan megafauna. Certain parts of this ecoregion are protected by the Dhorpatan Hunting Reserve, Shey-Phoksundo National Park, Api Nampa Conservation Area and Annapurna Conservation Area.



1.4.8.1 Vegetation

The major types of vegetation here are moist alpine and Hippophae shrubs (Stainton 1972). Moist alpine shrubs are dominated by a number of dwarf rhododendrons (Shrestha 1982). However, there are differences in species dominance between the eastern and western parts. In the eastern part, *Rhododendron anthopogon* and *R. setosum* are dominant and the most important associated species are *Juniperus wallichiana, Potentilla fructicosa* and *Lonicera obovata*. In the extreme west, *Rhododendron hypenanthum* replaces *R. anthopogon* (Shrestha 1982). In the damp and wet areas, *Hippophae* forms areas of shrub below 4,500 m. It is found as thickets along banks of streams and on unstable moist slopes (TISC 2002).

Alpine meadow and rangelands are distributed throughout the alpine regions of the Himalayas. They are common in central and western Nepal. The vegetation is composed of sedges (Cyperaceae), grasses (Gramineae) and many dicotyledonous herbaceous plants (Ohba and Akiyama 1992).

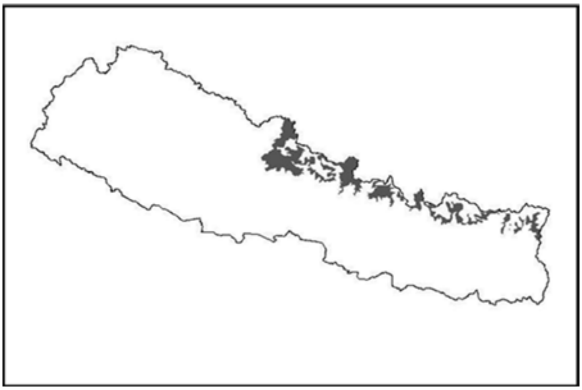
1.4.8.2 Fauna

This region provides the last extensive habitat for high altitude Himalayan megafauna, such as snow leopard (*Panthera uncia*), bharal or Himalayan blue sheep

(*Pseudois nayaur*), Himalayan tahr (*Hemitragus jemlahicus*), Himalayan musk deer (*Moschus chrysogaster*), and Great Tibetan sheep – argali (*Ovis ammon*) (Jackson and Ahlborn 1989). The important bird species are blood pheasant (*Ithaginis cruentus*), satyr tragopan (*Tragopan satyra*) and impeyan pheasant (*Lophophorus impejanus*). It is also home to large avian predators like lammergeyer (*Gypaetus barbatus*), golden eagle (*Aquila chrysaetos*) and Himalayan griffon (*Gyps himalayensis*) (Bird Conservation Nepal 2006).

1.4.9 Eastern Himalayan Alpine Shrub and Meadows

The eastern Himalayas alpine shrubs and meadows are situated at altitudes between 4,000 and 5,500 m east of Kali Gandaki. Thus, it is the life zone below the snowline. This ecoregion harbours many alpine plants and provides an important habitat for snow leopard (*Panthera uncia*), Himalayan tahr (*Hemitragus jemlahicus*) and blue sheep (*Pseudois nayaur*). A relatively large part of this ecoregion is in protected areas. Three national parks (Langtang, Makalu-Barun, and Sagarmatha) and two conservation areas (Annapurna and Gauri Shankar) overlap with this ecoregion.



1.4.9.1 Vegetation

The major types of vegetation here are dry alpine shrub and moist alpine shrub (Stainton 1972). The species of rhododendron that make up the shrub vegetation in this ecoregion are *Rhododendron campanulatum, R. wallichii, R. campylocarpum, R. thomsonii,* and *R. wightii* (Shrestha and Joshi 1997). At higher altitudes, dwarf rhododendrons (*R. anthopogon, R. nivale, R. setosum*) flourish and form an alpine mat (Shrestha 1982). Dry alpine shrub, consisting of *Juniperus indica, J. recurva* and *J. squamata,* replace dwarf rhododendrons in extremely dry places. *Ephedra gerardiana* and *Cassiope fastigiata* are the associated species (Shrestha and Joshi 1997).

1.4.9.2 Fauna

The major mammals here include snow leopard (*Panthera uncia*), blue sheep (*Pseudois nayaur*) and Himalayan tahr (*Hemitragus jemlahicus*) (Ale et al. 2007; Lovari 1992; Lovari et al. 2009). Similarly, this ecoregion provides habitats for some avian predators such as the lammergeyer (*Gypaetus barbatus*), Himalayan griffon (*Gyps himalayensis*), black eagle (*Ictinaetus malayensis*) and northern goshawk (*Accipiter gentilis*) (Bird Conservation Nepal 2006).

1.5 Conclusions

Nepal's great biodiversity is attributed to its very variable topography and climate. The flat lowland of the Tarai region is covered with a mosaic of sal and riverine forests with large patches of tall grassland. Sal extends into the mid-hills along river gorges and valleys throughout the country. However, the vegetation on the mountain slopes in the Mahabharat and mid-hills of eastern and western Nepal is very different. In eastern Nepal, there is comparatively dense forest dominated by several species of oaks and rhododendrons, depending on the altitude. In contrast, western Nepal is relatively dry and harbours large areas of pine forest. The Himalayan region has a similar type of vegetation except in western Nepal where conifers dominate. In the eastern part, moist climatic conditions favor oak and other broadleaved species over conifers. The composition of the vegetation in the alpine zone differs in eastern and western Nepal, especially in terms of rhododendron species.

The heterogeneity in the vegetation, from subtropical to alpine, provides a mosaic of habitats for a great variety of animals, which form the basis of the interconnected Himalayan ecosystem. Conservation in Nepal focuses mainly on the protection of flagship species, the protected areas for which are mostly located in the southern and northern part of the country. Like Tarai, the Himalayan region is rich in biodiversity that is protected by an extensive network of protected areas and a landscape conservation project. However, the Midhills and Mahabharat are under-represented in the protected area system. Historically, these regions were the first to be colonized by man, which resulted in the degradation of the forests. Thus it is now necessary to initiate conservation programs in the Mahabharat and Midhills in order to improve the interconnectedness of the ecoregions. Such conservation approach will improve the altitudinal connectivity for the seasonal migrations of mammals and birds. In view of the diversity of habitats and ecosystems, and anthropogenic threats, Nepal still needs an inter-ecoregion level research based conservation program. Such a program will ensure long-term conservation of the Himalayan hotspot, of which Nepal makes up one third.

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Chapter 2
Conservation of Biodiversity: An Outline of the Challenges

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2.1 Introduction

The conservation of biodiversity is an important issue in developing countries like Nepal. Subsistence agriculture, including livestock rearing, is the main occupation of the majority of the people in rural areas (Brydon and Chant 1993). This puts an ever-increasing demand on the forest as the human population increases. Consequently, many forests are either badly degraded or encroached by people seeking essential resources for their survival. Thus, conservation challenges in Nepal are of anthropogenic origin and the result of an unsustainable extraction of biological resources (Ives and Messerli 1989). The challenges get more complicated as the human population grows, thus the conservation strategies need to effectively harmonize human and conservation needs (Budhathoki 2004).

Before the 1950s, there were large forested areas throughout the country supporting viable wildlife and plant communities. The problem became apparent with the modernization of country. Tarai, for example, had uninterrupted virgin forested areas, which were inhospitable due to malaria. After the initiation of the malaria eradication program in 1954, fertile flatlands of the Tarai became an attractive

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destination for migrants from the hills (Spillet and Tamang 1966). As a result, Siwaliks and Tarai regions were more seriously deforested than the middle and high mountains (LRMP 1986). The increase in forest areas in the middle and high mountains (1.8%), and decrease in Tarai (24.4%) and Siwaliks (15.1%) over the period 1965–1980 (Metz 1991) was the result of a mass migration of hill people into the Tarai. Thus, many wild animals (e.g., swamp deer, water buffalo) that were previously widely distributed throughout the Tarai, disappeared from many areas and are now confined to few isolated forest patches (Gurung 1983). Further forest encroachment could result in the extinction of tiger, rhinoceros, elephant and ungulates (Dhungel and O'Gara 1991). In the midlands, population growth and government policy triggered deforestation. The Forest Nationalization Act in 1957 encouraged people to fell trees as the act defined any area with trees as a forest. Thus, people felt that their forest would be taken away from them and as a consequence they felled rather than protected the trees (World Bank 1978; Gilmour et al. 1989).

Modern conservation began with establishment of a rhinoceros sanctuary in the Chitwan valley in 1964 (currently Chitwan National Park). By the end of 1969, the country had seven hunting reserves, six in Tarai, and one in the mountains (Gurung 1983). Now, Nepal has an extensive network of 20 protected areas, totaling 23.1% of country's territory (Table 2.1 and Fig. 2.2). However, conservation needs to go beyond the frontiers of protected areas, as the country itself is a biodiversity hotspot (Conservation International 2004, Fig. 2.1).

2.2 Conservation in Nepal

2.2.1 Protected Species and Conservation

Wildlife extinction is a probabilistic phenomenon in which the likelihood of survival is dependent on the population size of the species and an uncertainty function (Shaffer 1981). Thus, species conservation is a matter of high priority for conservationists and biologists. It includes setting up protected areas for conserving viable wildlife populations, especially large mammals (Newmark 1996) and providing legal protection for certain species (Heinen and Mehta 1999).

The Nepal National Parks and Wildlife Conservation Act provides legal protection for fauna (Table 2.1) and flora based on the perceived conservation needs. It includes 12 species of plants, 26 mammals, 9 birds and 3 reptiles (BPP 1995). According to the act, protected species are legally protected even outside protected areas (Heinen and Mehta 1999). But the inability to enforce these conservation measures in such areas often result in overexploitation of protected species (Heinen and Yonzon 1994). Design of protected areas often involves an assessment of such species as indicators of an ecosystem (Heinen and Yonzon 1994). Koshi Tappu and Suklaphanta wildlife reserves, for example, were established for the conservation of water buffalo (*Bubalus arnee*) and swamp deer (*Rucervus duvaucelii*), respectively. Apart from this, regular monitoring of flagship species (e.g., tiger, rhino) is

Table 2.1 Species protected by the NPWC Act 1973 and the protection category of these species by the International Union for Conservation of Nature (IUCN):CR – critical, EN – endangered, VU – vulnerable, LC – least concern, and NT – near threatened and Convention on International Trade of Endangered Species (CITES) category, Appendices I, II and III (BPP 1995; Bhuju et al. 2007; IUCN 2009)

	Scientific name	English name	IUCN category	CITES appendix
Mammals				
1	*Macaca assamensis*	Assamese monkey	NT	II
2	*Manis pentadactyla*	Indian pangolin	EN	II
3	*Caprolagus hispidus*	Hispid hare	EN	I
4	*Canis lupus*	Wolf	LC	II
5	*Ursus arctos*	Himalayan bear	LC	I
6	*Ailurus fulgens*	Red panda	VU	I
7	*Prionodon pardicolor*	Spotted linsang	LC	I
8	*Prionailurus bengalensis*	Leopard cat	LC	I
9	*Lynx lynx*	Lynx	LC	II
10	*Neofelis nebulosa*	Clouded leopard	VU	I
11	*Panthera tigris*	Tiger	EN	I
12	*Panthera uncia*	Snow leopard	EN	I
13	*Elephas maximus*	Asiatic elephant	EN	I
14	*Rhinoceros unicornis*	Rhinoceros	EN	I
15	*Porcula salvania*	Pygmy hog	CR	I
16	*Moschus chrysogaster*	Himalayan musk deer	EN	I
17	*Rucervus duvaucelii*	Swamp deer	VU	I
18	*Bos gaurus*	Gaur	VU	I
19	*Bos mutus*	Wild yak	VU	I
20	*Bubalus arnee*	Wild water buffalo	EN	I
21	*Ovis ammon*	Great Tibetan sheep	NT	I
22	*Pantholops hodgsonii*	Tibetan antelope	EN	I
23	*Antilope cervicapra*	Black buck	NT	III
24	*Tetracerus quadricornis*	Four horned antelope	VU	III
25	*Hyaena hyaena*	Striped hyena	NT	III
26	*Platanista gangetica*	Gangetic dolphin	EN	I
Birds				
1	*Catreus wallichii*	Cheer pheasant	VU	I
2	*Lophophorus impejanus*	Impeyan pheasant	LC	I
3	*Tragopan satyra*	Crimson horned pheasant	NT	III
4	*Ciconia ciconia*	White stork	LC	–
5	*Eupodotis bengalensis*	Bengal florican	CR	I
6	*Sypheotides indica*	Lesser florican	EN	I
7	*Grus antigone*	Sarus crane	VU	II
8	*Buceros bicornis*	Giant hornbill	NT	I
9	*Ciconia nigra*	Black stork	LC	II
Reptiles				
1	*Gavialis gangeticus*	Gharial crocodile	CR	I
2	*Python* sp.	Python	NT	I
3	*Varanus flavescens*	Monitor lizard	LC	I

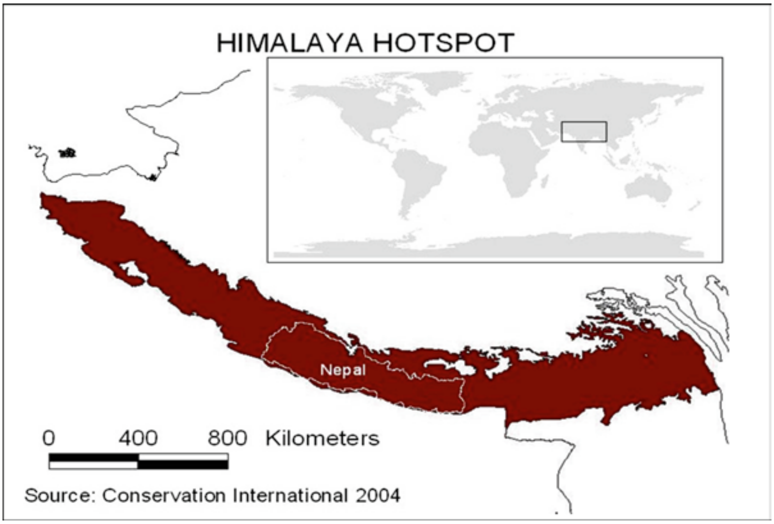

Fig. 2.1 Hotspot of biodiversity in the central Himalayas

undertaken so, that the conservation needs and planning for these species can be revised. Such monitoring provides useful information on species conservation. The captive breeding of *Elephas maximus* and *Gavialis gangeticus* in Chitwan are some of the initiatives aimed at conserving species. In the central zoo, there is a black buck (*Antilope cervicapra*) captive breeding program. Blackbuck Conservation Area was established in Khairapur of Bardia district for the conservation this species. Likewise, the one-horned rhinoceros has been reintroduced into the Bardia National Park (BNP) and Suklaphanta Wildlife Reserve (SWR), in order to provide new habitats for this rhinoceros (Dinerstein 1991) and maintain the carrying capacity of the Chitwan National Park (Laurie 1982). Besides this, the Nepal government has a long-term action plan for the sustainable conservation of tiger (*Panthera tigris*) and rhinoceros (*Rhinoceros unicornis*). For this it helps to recognize, restore, preserve and increase the size of areas suitable for such endangered and flagship species and to maintain viable populations of these species in Nepal (Foose and Strien 1997; DNPWC/WWF 1999).

2.2.2 Protected Areas

Protected areas (PAs) are vital for biodiversity conservation. They provide safe habitats for many endangered plants and animals. The first wildlife legislation was enacted in 1958. It provided the legal protection of rhinos and their habitats by establishing a rhino reserve in inner Tarai. After nearly one decade, six hunting reserves were established in 1969 with the enactment of the hunting rule (1967). However, the modern era of conservation began with the enactment of NPWC act 1973. This act provided a legal infrastructure for establishing protected areas in a country (Heinen and Mehta 1999). NPWC act 1973 and its subsequent five amendments provided a paradigm shift in conservation. The act also categorizes various protected areas (e.g., national park, strict nature reserve, wildlife reserve, hunting reserve, conservation area and buffer zone). Now, Nepal has an extensive network of protected areas. It includes ten national parks, three wildlife reserves, one hunting reserve and six conservation areas (Table 2.2). Protected areas and buffer zones account 23.1% of the country's total area.

The Department of National Parks and Wildlife Conservation (DNPWC) is the institution responsible for administration and management of protected areas. The DNPWC in collaboration with governmental and non-governmental organizations, donors, local people and academic institutions conducts conservation and research programs. The Nepalese army is responsible for preventing activities defined by law as illegal. Although the army is not directly involved in conservation, the local people have a close partnership with government officials and conservation organizations. Thus, protected area governance is categorized as either government managed protected areas, co-managed protected areas or community conserved conservation areas (Borrini-Feyerabend et al. 2004).

2.2.2.1 Strict Nature Reserve

A strict nature reserve is an area of unusual ecological significance, set aside for the purpose of scientific study. It is an IUCN category I protected area. No national park in Nepal is a strict nature reserve. However, an area in the lower Barun Valley, which is in the Makalu-Barun National Park in eastern Nepal, is designated as a strict nature reserve.

2.2.2.2 National Park

According to the NPWC act, a national park is an area set aside for the conservation and management of the natural environment, including the ecological, socio-cultural, biological and geomorphologic associations of aesthetic importance. Eco-tourism is the second most prioritized objective, but must be compatible with sustainable conservation. The ten national parks (31.9% of total protected area) of Nepal are IUCN category II protected areas. Among them, five are in the Himalayan region, two in the midlands and three in the Tarai and Siwalik regions. National parks are either specifically regulated, e.g., Chitwan National Park, or broadly regulated, e.g., Himalayan National Parks. These regulations allow for flexibility in park management, which reflect socio-cultural and local conservation needs.

Table 2.2 Protected areas in Nepal (DNPWC 2006; Bhuju et al. 2007; CBD Nepal 2009)

Protected areas (Year established)	Area (km^2) Core area	Buffer zone	Altitude (m)
National Parks (NP)			
Chitwan NP (1973)	932	750	150–815
Bardia NP (1976/1988)	968	328	152–1,494
Banke NP (2010)	550	343	Not available
Shivapuri NP (2002)	144	–	1,366–2,732
Khaptad NP (1984)	225	216	1,000–3,276
Makalu Barun NP (1992)	1,500	830	435–8,463
Langtang NP (1976)	1,710	420	792–7,245
Sagarmatha NP (1976)	1,148	275	2,800–8,850
Shey Phoksundo NP (1984)	3,555	1,349	2,000–6,885
Rara NP (1976)	106	198	1,800–4,048
Wildlife Reserves (WR)			
Koshi Tappu WR (1976)	175	173	90
Parsa WR (1984)	499	298	150–815
Suklaphanta WR (1976)	305	243	90–270
Hunting Reserves (HR)			
Dhorpatan Hunting Reserve (1987)	1,325		2,850–7,000
Conservation Areas (CA)			
Kanchenjunga CA (1997)	2,035		1,200–8,598
Manaslu CA (1998)	1,663		1,360–8,163
Annapurna CA (1986, 1992)	7,629		1,000–8,092
Gaurishankar CA (2010)	2,179		Not available
Api Nampa CA (2010)	1,903		518–7,132
Blackbuck CA (2009)	15.95		Not available
Subtotal	**28,566.95 (19.4%)**	**5,423 (3.7%)**	
Total area protected (%)	**33,989.95 (23.1%)**		

2.2.2.3 Wildlife Reserve

A Wildlife Reserve (IUCN category IV protected area) is an area established for the conservation of flora and fauna and their habitats. There are three wildlife reserves in Nepal: Koshi Tappu, Parsa and Shuklaphanta. All are located in the lowland region of eastern, central and western Nepal, respectively. They occupy 2.9% of total protected area. Wildlife reserve regulations provide guidelines for conservation and management.

2.2.2.4 Hunting Reserve

Hunting Reserve (IUCN category VIII protected area) is an area set aside for the conservation and management of wildlife and provides opportunities for legal

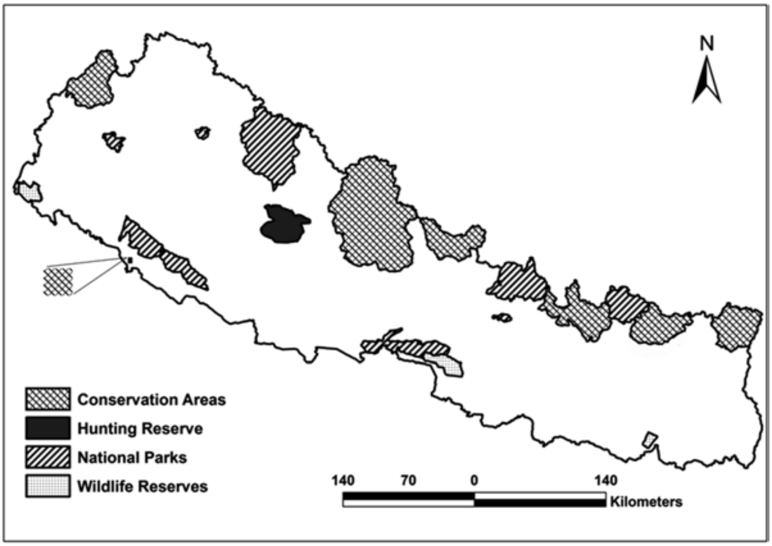

Fig. 2.2 Protected areas in Nepal

recreational hunting. Blue sheep (*Pseudois nayaur*) and Himalayan tahr (*Hemitragus jemlahicus*) can be hunted at Dhorpatan, the only hunting reserve in Nepal. It covers 3.9% of the total protected area.

2.2.2.5 Conservation Area

Conservation area (IUCN category VI protected area) is an area in which conservation and the sustainable use of the natural resources are integrated. There are three conservation areas in Nepal, namely, Annapurna Conservation Area, Kanchenjunga Conservation Area and Manaslu Conservation Area. They make up 45.4% of the total protected area. Annapurna Conservation Area (ACA) was the first in this category. It was officially gazetted in 1992 and responsibility for management was given to King Mahendra's Trust for Nature Conservation (now National Trust for Nature Conservation), a national NGO established by the Nepal government in 1982 with aim of conserving biodiversity. It was very successful in gaining the support of local people for conservation. Drawing upon the experience of the Annapurna Conservation Area Project (ACAP), two other conservation areas (Kanchenjunga and Manaslu) were established in 1997 and 1998, respectively. It is further extended into central and far western regions of country in 2010 with establishment of Gaurishankar Conservation Area and Api Nampa Conservation Area (Fig. 2.2). The conservation area serves as a model throughout Asia for getting the public to participate in biodiversity conservation.

2.2.2.6 Buffer Zone

Buffer zone is a designated area surrounding a national park or reserve within which the use of forest products by local people is regulated in order to ensure sustainability. It is a radical shift in protected area management in Nepal, which came into existence as a result of an amendment to the NPWC Act (released in 1973); the Buffer Zone Regulations 1996. These regulations promote community forestry programmes in buffer zones. Demarcation of buffer zones depends on the geographical location of the PA, the status of the villages and settlements located within the PA, and areas practicable and appropriate for management purposes (DNPWC/MFSC 1999; Nepal 2002). Land ownership is unaffected within a buffer zone.

A buffer zone is IUCN category VI protected area, in which the local indigenous people are involved in the management of the forest surrounding a protected area (Kanel 2004; Paudel et al. 2007) via a buffer zone community forest users group (BZCFUG). It aims to ameliorate park-people relations (Ghimire 1994) by involving the people in conservation and providing them with some of the benefits of conservation: 30–50% of park revenue goes to community development programs (Budhathoki 2004). Now, it is an integral component of the management of protected areas in Nepal, which includes 3.7% of the total area of Nepal and 15.9% of the protected areas (Table 2.1). The channeling back of park revenue into community development and the shared management of buffer zone areas are key features of community participation in protected area management. Community participation in the conservation of biodiversity has resulted in the improvement of ecological and social patterns, such as better conditions in the forests, social mobilization and income generation for rural development and institutional building (Acharya 2002). Ecotourism is the main benefit for local people residing in buffer zones, as protected areas are the most favoured tourist destinations in the country. According to DNPWC (2003), protected areas attract more than 45% of the tourists that visit Nepal. It also provides direct or indirect benefit to people by creating diverse economic opportunities, which consequently helps to improve park-people relations. Local people become involved in conservation in order to maintain the economic security that protected areas provide (Bookbinder et al. 1998).

2.2.3 Wetland Conservation

Wetlands are important biological resource (Gibbs 1995). Their value in terms of providing direct and indirect products/services and bequest values are now widely acknowledged (Brander et al. 2006). The Convention on Wetlands of International Importance, especially as habitats for waterfowl, commonly known as the Ramsar Convention on Wetlands, brought the need for conserving wetlands to international attention. All the countries that are signatories of the convention are obliged to designate at least one wetland in their respective territories as a Ramsar Site. Nepal acceded to the Ramsar Convention on 17th April 1988, and Koshi Tappu region was

Table 2.3 Ramsar sites in Nepal

	Site	Date of designation	Location	Area (ha)
1	Beeshazari and associated lakes	13/08/03	Chitwan	3,200
2	Lake Ghodaghodi	13/08/03	Kailali	2,563
3	Gokyo and associated lakes	23/09/07	Sagarmatha National Park	7,770
4	Gosaikunda and associated lakes	23/09/07	Langtang National Park	1,030
5	Jagadishpur reservoir	13/08/03	Kapilvastu	225
6	Koshi Tappu	17/12/87	Koshi Tappu Wildlife Reserve	17,500
7	Mai Pokhari	28/10/08	Ilam	90
8	Lake Phoksundo	23/09/07	Shey Phoksundo National Park	494
9	Lake Rara	23/09/07	Rara National Park	1,583

the first to be included on the Ramsar list of Wetlands of International Importance. Currently, Nepal has nine Ramsar sites, totaling 34,455 ha (Ramsar 2009; Table 2.3). Many other wetlands of high biodiversity value, distributed throughout the country, need conserving.

2.2.4 Landscape Conservation

Landscape conservation attempts to minimize the effect of habitat fragmentation and isolation by providing corridors between reserves (Bennett 2003). Protected areas are the last remaining habitats of many endangered species; however, isolated protected areas are not sufficient for achieving long-term conservation (Rodrigues et al. 2004). In southern Nepal, six protected areas are the last remaining habitats for tigers (Shuklaphanta, Bardia-Banke and Chitwa-Parsa) and rhinos (Chitwan National Park, except of few translocated rhinos in Bardia and Suklaphanta) (Smith et al. 1998; Wikramanayake et al. 2002). Landscape conservation programs in Nepal are designed to address the problems of habitat isolation and forest encroachment. Both protected and non-protected areas are included in these multi-faceted programs (WWF 2006b). Tarai Arc Landscape (TAL) and Sacred Himalayan Landscape (SHL) are the major conservation programs in Nepal. TAL covers more than 49 500 km^2, consists of a network of 11 protected areas in Nepal and India and focuses on trans-boundary conservation (WWF 2001). Sacred Himalayan Landscape (SHL) covers the eastern part of Nepal. It is a proposed trans-boundary conservation area covering 39,021 km^2 of which 73.5% is in Nepal, 24.4% in India and the remaining 2.1% in Bhutan. This landscape forms an important corridor in the eastern Himalayas from the lowlands up to 8,848 m on Mount Everest, which connects the Bhutan Biological Conservation Complex with the SHL.

2.3 Conservation Challenges

2.3.1 Overexploitation of Forests

Consequences of forest over-exploitation are habitat loss and fragmentation, which are major threats to the wildlife of Nepal. Most people depend on subsistence agriculture and resources from the forests, which with overpopulation results in environmental degradation and loss of biodiversity (Bajracharya 1983). The people exploit natural resources because most of them are poor (44% in rural and 23% in urban areas) and have no access to non-natural resources (World Bank 1999). Forest loss does not result from collecting firewood but from encroachment of cultivation into forest areas (HMGN-NPC 1999). The phenomenon of forest loss is countrywide. Overpopulation puts a great pressure on the forest as a source of materials needed for subsistence, such as firewood and fodder, as well as land for agriculture and settlement. This has resulted in an annual decrease in the area of forest of 1.7% (HMGN-DFRS 1999; CBS 2006). In 1979 only 43% of Nepal was forested, i.e., partially covered with trees and shrubs. According to the land resource-mapping project only 15% of the forest is closed canopy forest and 26% open canopy forest (LRMP 1986).

Comparing data from the 1978/79 land resource project with that from 1964/65 it is evident that during this period of 15 years about 42% of the total area of Nepal was considered to be forested, which includes bush and scrubland. The area covered by trees is only 5,518 thousand hectares, i.e., 37% of the total land area, of which 8% is in Tarai, 26% in Churia, 33% in mid-mountain, 30% in high mountain and 3% in the high Himalayan region. The loss of habitat results in inbreeding depression, slow reproductive rate and low populations of wildlife (Cracraft 1999). When the carrying capacity of a habitat for a species is exceeded it is likely to result in a dramatic decline in its population. Hence, most of the protected areas in the Tarai of Nepal have undergone some degree of faunal collapse (Heinen et al. 1988).

2.3.2 Loss and Alteration of Wetlands

Nepal's wetland biodiversity is under serious threat from encroachment, unsustainable harvesting, industrial pollution, agricultural runoff, silting, and the introduction of exotic and invasive species. Encroachment results in the reduction in the area of wetlands, deposition of silt, and eutrophication caused by agricultural runoff and/or industrial effluents (IUCN 1996). Silting is a serious threat to wetland. About 66% of the wetlands in the hills and mountains are seriously affected by silting. Similarly, empirical evidence from a survey of 163 wetland sites revealed that those in the Tarai are vulnerable, in particular, to the proliferation of exotic species. Most of the lakes in Nepal have been colonized by non-native species (IUCN 1996). Heavy use of fertilizers in agricultural areas has resulted in the eutrophication of wetlands. Water hyacinth (*Eichhornia crassipes*) threatens the survival of several wetland ecosystems in the Tarai, as it forms a dense mat that blocks out the sunlight, which ultimately results in changes in the chemistry of the water (Masifwa et al. 2001). The decline in wetland birds is due to eutrophication and colonization by non-native species (see Bhattarai in this book).

Indiscriminate discharge of industrial and domestic waste into rivers and lakes has resulted in a decline in the numbers of aquatic species. For example, the number of fish species in the Bagmati River has declined from 54 to 7 within a decade as a result of contamination by domestic effluents and industrial waste (IUCN 1996). The high concentration of organic matter and chemicals in effluents kills fish and destroys the plant life they depend on (Cordone and Kelley 1961).

2.3.3 Unsustainable Livestock Farming Practices

Rangelands (grasslands) are an important habitat for many wildlife species and their importance for biodiversity is acknowledged globally (Edroma 1981; McNaughton 1984; McNaughton and Banyikwa 1995). The consequences of livestock grazing range from soil erosion to degradation of this habitat for wildlife. Livestock grazing is common in Nepal. Keeping large herds of livestock, even without substantial economic benefits, is common. Rearing livestock for dung and benefits other than meat is traditional and has had a negative effect on biodiversity. The adverse effect of grazing by livestock is severe both in and outside protected areas, as in mountain pastures and the Tarai grasslands. Cattle grazing in Koshi Tappu Wildlife Reserve, for example, may result in a serious conservation problem (e.g., purity of the gene pool of wild water buffalo) as it triggers cross breeding between domestic and wild water buffaloes (Flamand et al. 2003).

2.3.4 Environmental Pollution

Pollution is a major problem for humans and biodiversity. Untreated industrial and domestic waste released directly into the aquatic and terrestrial habitats of wildlife is a serious threat to biodiversity. Some rivers passing through major cities in Nepal are badly polluted by untreated industrial and domestic waste. The decline in the numbers of river dolphin in the Narayani River is believed to be due to the effect of waste discharged by the paper industry (WWF 2006a).

The increased use of pesticides and introduction of high yielding varieties of crop plants is the main cause of agro-ecosystem pollution. Insecticides can have an adverse effect on mammals and other vertebrates and their persistent use has seriously affected livestock and wildlife. The use of pesticides over a large area may diminish the overall population of invertebrates, which are the source of food for many birds, especially migratory species. The effect of pesticides may be direct (increase in mortality) or indirect (reduction in reproduction). Populations of threatened wildlife species are more vulnerable when adult mortality is increased (Whitfield et al. 2004). In particular, aquatic communities are very vulnerable to the toxic effects of pesticides. Some insecticides like organochlorines (DDT), which are banned in developed countries, are still used indiscriminately in Nepal (WWF 2009). According to the report of the Department of National Park and Wildlife Conservation (DNPWC), poachers use these pesticides to kill fish, birds, and even tigers, rhino, bear and other large mammals. Poachers kill tigers and rhinoceros by spraying carcasses and grasslands with pesticides.

2.3.5 Climate Change

According to the Intergovernmental Panel on Climate Change (IPCC) estimates of climate change, the earth's average surface temperature rose by about 0.74°C in the last 100 years and the prediction is a further increase of 5°C by 2080 if the emissions of greenhouse gases are not greatly reduced (IPCC 2007). The Himalayan region is more vulnerable to climate change as it will have a pronounced effect on the recession of glaciers. An inventory carried out by International Center for Integrated Mountain Development (ICIMOD) and UNEP has shown that there are 26 glacial lakes in Nepal that are potentially threatened (ICIMOD 2008). Furthermore, alterations in the agriculture system, rainfall patterns including worse draughts, and water supply (water shortage and flash floods) are the likely results of climate change, and their effect on the Himalayan region is difficult to predict because of the fragile and marginal nature of the mountain environment.

2.3.6 Wildlife Poaching

Wildlife hunting is common in Nepal. The state sponsored large-scale wildlife hunting during the Rana regime resulted in excessive and indiscriminate hunting. During the course of seven hunting seasons, altogether 433 tigers, 53 rhinoceros, 93 leopards, 22 bears and 20 crocodiles were killed. Wildlife conservation in Nepal was initiated during 1960s by establishing protected areas. The National Parks and Wildlife Conservation Act, released in 1972, provided the legal and institutional framework for the protection of wildlife, and curbed poaching and trading in wildlife. But data (e.g., Fig. 2.3) indicate that the numbers of rhinoceros and tiger continued to decline in the Chitwan and Bardia National Parks (STF 2006; NTNC 2008), which are the only suitable habitats for these species in Nepal. The recent tiger count revealed a dramatic decline in the tiger population in the Bardia National Park and Shuklaphanta Wildlife Reserve (DNPWC 2009). This is mostly attributed to the low number of security posts and ineffective monitoring of protected areas. In rural areas, wildlife hunting is widespread and a part of subsistence living, and is likely to increase in the absence of alternative means of securing a livelihood.

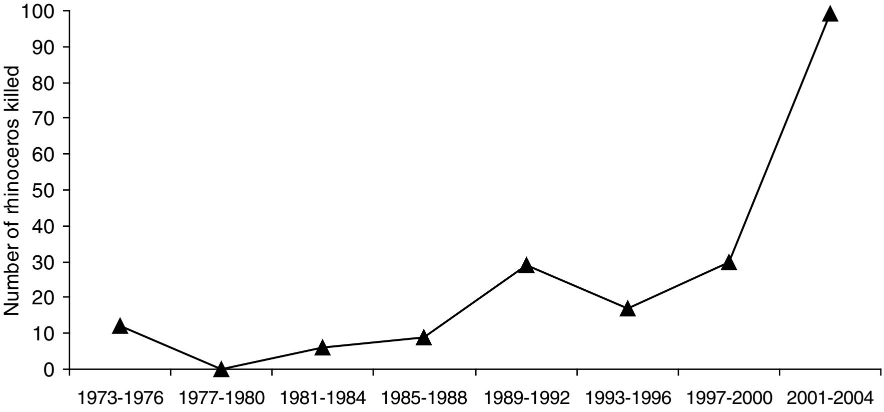

Fig. 2.3 Incidence of rhinoceros poaching from 1973 to 2004 (Source: DNPWC annual reports 1973–2004)

Habitat restoration – key to conservation (Photo by BP Bhattarai)

Agriculture – typical terraced fields (Photo by P Kindlmann)

Severely degraded forests in the midhills (Photo by PK Paudel)

Large population density is typical for midhills (Photo by PK Paudel)

Mountain ridge in the midhills with a dense cover of vegetation: remnants of forest survive here – most low-lying areas have already been converted to agricultural land (Photo by PK Paudel)

Local people collecting grass in the national park: competition or coexistence? (Photo by BP Bhattarai)

Non-Timber Forest Products (NTFP) are used for both subsistence and trade as an alternative source of income for local communities. Collection of bark of *Persea* sp. in Surkhet (Photo by PK Paudel)

Wildlife tourism: keeping balance between ecology and economy (Photo by BP Bhattarai)

Small hydroelectric power station in the buffer zone of the Shey Phoksundo National Park: involving local people in conservation (Photo by PK Paudel)

Roads in the mountains have severe ecological impacts (Photo by PK Paudel)

Cultivating potatoes in recently cleared forested areas. Shifting cultivation is present everywhere in the mid-hills. It causes loss of forest and biodiversity, soil erosion and landslides. *Bhairi Lekh, Jajarkot* (Photo by PK Paudel)

Bandarjhulla – deforestation in the Chitwan National Park (Photo by BP Bhattarai)

Road construction using heavy equipment in a fragile landscape (Surkhet) (Photo by PK Paudel)

Forest provides everything: constructing bamboo baskets (Photo by PK Paudel)

Nepali hand-made paper made from *Daphne papyracea* and *Daphne bholua* is famous for its durability and strength (Ramidanda VDC, Jajarkot) (Photo by PK Paudel)

Timber production in Dolpa (Photo by PK Paudel)

Firewood is the main source of energy for heating and cooking. People stock firewood for rainy and winter seasons (Kaigau, Dolpa). The impact of firewood collection on mountain environment is more pronounced in the Himalayan region, because the forests are less productive here (Photo by PK Paudel)

Forest fodder collection is vitally important for local people (Surkhet) (Photo by PK Paudel)

Sand and stone collection and its impact on biodiversity has often been ignored (Photo by BP Bhattarai)

A house of the Chepang people – ethnic people of the lowlands (Photo by BP Bhattarai)

Marshes: a good habitat for wetland-dependent birds (Photo by BP Bhattarai)

Village of Lower Dolpa – adapting in highlands (Photo by PK Paudel)

People of the Midlands (Photo by PK Paudel)

2.3.7 *Unsustainable Harvesting of Non-Timber Forest Products (NTFPs)*

NTFP covers all forest products except timber. They may be gathered from the wild, or produced in forest plantations, agro-forestry schemes and from trees outside forests (Hammett 1993). Among the forest products, NTFPs are the most important for rural people, ranging from life supporting herbal medicine to food (e.g., tubers, mushrooms) and important domestic accessories (e.g., ropes, baskets for grain) – Table 2.4 (Larsen et al. 2000). The effective conservation and commercialization of NTFPs can increase the socio-economic status of local people and increase the national income and employment opportunities. In Nepal, the NTFP are mainly used for subsistence and their commercialization is still limited to the international market (Edwards 1996). In recent years, NTFP trade has greatly increased due to increased access by road and establishment market centers. The major conservation issues for NTFPs include overharvesting, premature harvesting and habitat destruction. The trends indicate that there is likely to be an overexploitation of resources. This requires improvements in the existing system of harvesting and marketing (Edwards 1996). The exploitation of the opportunities for marketing NTFPs could alleviate poverty by improving the livelihood of rural people as well as mitigating its effect on biodiversity (Larsen et al. 2000).

Table 2.4 Examples of some overexploited NTFPs (AEC/FNCCI 2006)

Phyllanthus emblica (Amala)	*Nardostachys grandiflora* (Jatamansi)
Zanthoxylum armatum (Timur)	*Tagetes minuta* (Sayapatri)
Cinnamomum tamala (Tejpat)	*Bergenia ciliata* (Pakhanbed)
Matricaria chamomilla (Chamomile)	*Gaultheria fragrantissima* (Dhasingre)
Piper longum (Pipla)	*Rauvolfia serpentina* (Sarpagandha)
Mentha arvensis (Mentha)	*Dioscorea deltoidea* (Bhyakur)
Swertia chirayita (Chiraito)	*Rubia manjith* (Majitho)
Aegle marmelos (Bel)	*Tinospora sinensis* (Gurjo)
Sapindus mukorossi (Ritha)	*Aconitum spicatum* (Bisjara)
Cymbopogon flexuosus (Lemongrass)	*Morchella conica* (Gucchi chyau)
Cinnamomum galucescens (S.Kokila)	*Juglans regia* (Okhar)
Azadirachte indica (Neem)	*Aconitum heterophyllum* (Atees)
Asparagus racemosus (Kurilo)	*Neopicrorhiza scrophulariiflora* (Kutki)
Taxus baccata (Lauth Salla)	*Cordyceps sinensis* (Yarsagumba)
Valeriana jatamansi (Sugandhawal)	*Dactylorhiza hatagirea* (Panchaunle)
Rheum australe (Padamchal)	*Parmelia* species (Jhyau)
Acorus calamus (Bojho)	*Podophyllum hexandrum* (Laghupatra)

2.4 Conclusions

Nepal stands as a conservation leader among the developing countries. Initially, conservation was species driven but is now ecosystem orientated. All models, including those of protected area management, recognize the role of guardianship of local people in conservation. This is now reflected in the management of more than 40% of the area that is currently protected. Furthermore, transboundary conservation initiatives with neighboring countries (e.g., India, China, Bhutan) transcend traditional political jurisdiction and open up a new era of large-scale conservation. However, conservation challenges ranging from forest encroachment to illicit trade in wildlife are more serious than before. The widespread prevalence of poverty and economic insecurity makes conservation increasingly more difficult. Thus conservation needs to be integrated with community well being. Conservation, however, cannot provide all the needs of a community and therefore additional state investment is needed for creating alternative livelihood opportunities. In the absence of state investment conservation is likely to fail. Thus, international cooperation is urgently needed if we are to protect the precious natural heritages of this country.

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Chapter 3
Orchid Diversity in the Chitwan District

Iva Traxmandlová, Bishnu Prasad Bhattarai, and Pavel Kindlmann

Abstract Although the orchids in the Himalayan region are generally well known, there is little or no information on the orchids in the lowlands of Nepal. The aim of this paper is to shed light on the general status and distribution of orchids in one important lowland region, the Chitwan district. The study area included the Chitwan National Park (CNP), Barandabhar corridor forest (BCF) and the Mahabharat range (MR). The orchids in the trees, on rocks and on the ground were recorded along a total of 200 line transects: 40 in the BCF, 105 in the CNP and 55 in the MR. From the beginning of each transect, the first 50 trees within 10 m of the transect line were sampled. In addition, all terrestrial orchids and species of trees within 10 m of the transect line were also recorded. There was no association between the orchid and specific species of trees. There were nine orchid species in the MR that did not occur in the CNP and BCF, and seven in the CNP and BCF that did not occur in the MR. In the BCF, the orchids occurred on average on four different trees. In contrast, in the CNP the orchids occurred on average on eight different trees.

Keywords Orchids • Species-abundance • Nepal

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3.1 Introduction

Orchids in the Himalayan region have been studied for a long time (Duthie 1906; Amatya 1982; Paudyal 1982). In his three reports on the flora of the eastern Himalayas, Hara and Hohashi 1966, 1971 and 1974 mention 139 species belonging to 48 genera. According to recent records in the British Museum, there are 90 genera and over 300 species of orchids in Nepal (Hara and Williams 1979: Hara et al. 1978, 1982). Willis (1979) referred to in Sharma (1999) reported 735 genera and 17 000 species of orchids in the world. They are found in abundance in the tropics but are rare in arctic regions (Majupuria and Majupuria 1999). In the eastern part of Nepal, epiphytic species abound, while in the western part there are mainly terrestrial orchids (Majupuria and Majupuria 1999). The geographical distribution of orchids is mainly determined by the north-south orientation of a site, with species that prefer moisture living mainly on the northern slopes in hilly areas (Duthie 1906), and by altitude (Amatya 1982). Most orchid species are found at low altitudes (below 1500 m), with very few species above 2300 m (Duthie 1906; Amatya 1982; Paudyal 1982). However, there is no data, or any other information on orchids in the lowlands of Nepal, where most of the studies have focused on vertebrates and other plants. Thus the aim of this study was to shed light on the general status and distribution of orchids in one important region, the Chitwan district.

3.2 Methods

3.2.1 Study Area

The Chitwan district, also called “inner Tarai region”, is mainly tropical and subtropical lowland, surrounded by temperate regions, the Churia hills (150–800 m) in the south and Mahabharat hills (1200–1947 m) in the north. Politically, the Chitwan district consists of 36 village development committees (VDCs) and two municipalities. Of the 36 VDCs, nine are located in the hilly region Korak, Siddi, Saktikhor, Kaule, Kabilas, Dahakhani, Chandibhanjyang, Darechowk and Lothar, and the rest are in the lowlands. The population in this district was 472,048 in 2001 of which 90% lived in the lowlands (plain) and 10% in the hills (DDC Chitwan 2006).

The Chitwan district includes several ethnic communities, the Chepang (mainly in the hills), Bote, Mushahar and Tharu (PDDP 2002). As these people have very little agricultural land and are not allowed to fell trees for timber and collection of non-timber forest products, they find it difficult to earn enough money for their survival. Illegal dealers in wildlife products exploit the people in the poorer ethnic communities, such as Chepang, Bote and Tharu. Because of poverty and lack of

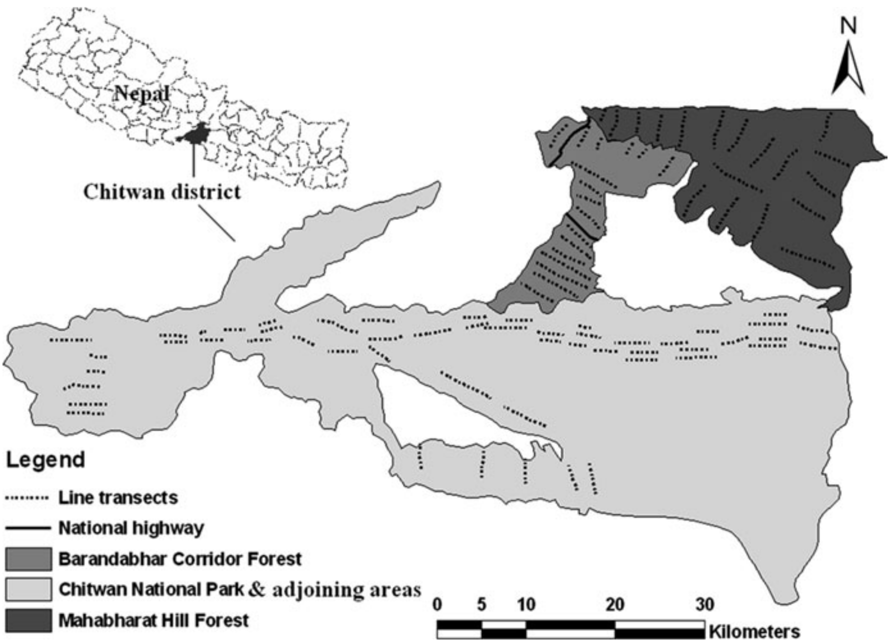

Fig. 3.1 Study area and locations of transects

education, these people become involved in illegal activities. The government is unable to provide basic amenities like healthcare, education, power and water. The increase in the local population has resulted in conflicts between the interests and socio-economic welfare of the people.

The study area (83°55′–84°48’ N; 27°21′–27°46′ E; 126–1947 m above sea level, total size 2238 km^2) consisted of the Chitwan National Park (CNP), Barandabhar corridor forest (BCF) and Mahabharat range (MR) (Fig. 3.1). Forest covers 58.7%, while agricultural land, cities and others cover 41.3% of the area this district. The national forest consists of productive forest (12.5%), community forest (21%), leasehold forest (2.1%) and protected forest (53.9%). The community and leasehold forest make up 4% and 5.9% of the area, respectively (DDC Chitwan 2006). All the areas in the national forest are governed by the district forest office, except the protected area and its buffer zone. The main habitats in the study area include sal forests (SF), mixed forests (MF), riverine forests (RF), wetlands and grasslands (Table 3.1).

The Chitwan National Park today is a successful testimony of nature conservation in south Asia. It is the first national park of Nepal, covers an area of 932 km^2 and preserves a unique ecosystem of great value for the entire world. The park consists mainly of lowland, but it also contains the Churia hills, which rise gradually towards the east. With the variation in the climate and altitude there is variation in

Table 3.1 Habitats and their abundance in the different parts of the Chitwan district

Habitat type	Dominant plant species	BCF	CNP	MR
Sal forest	*Shorea robusta, Terminalia alata, Dillenia pentagyna, Cleistocalyx operculatus, Adina cordifolia, Emblica officinalis, Lagerstroemia parviflora*	[a]	[a]	[b]
Mixed hardwood forest	*Terminalia bellarica, Cleistocalyx operculata, Dillenia pentagyna, Adina cordifolia, Syzygium cumini, Gmelina arborea, Garuga pillata, Derris elliptica, Lagerstroemia parviflora*	[b]	[b]	[c]
Riverine forest	*Trewia nudiflora, Bombax ceiba, Dalbergia sissoo, Gaultheria fragrantissima, Litsea monopelata*	[b]	[d]	[c]
Mixed rhododendron forest	*Rhododendron arboreum, Butea monosperma, Castanopsis tribuloides, Micenia champaca, Schima wallichii*	[c]	[c]	[d]
Mixed deciduous forest	*Schima wallichii, Aesandra butyracea, Micenia champaca, Terminalia alata, Castanopsis tribuloides, Shorea robusta*	[c]	[c]	[d]
Short grassland	*Imperata cylindrica, Ageratum conyzoides, Commelina benghalensis, Polygonum barbaratum, Hedyotis diffusa, Oplismenus compositus*	[a]	[b]	[c]
Tall grassland	*Themeda arundinacea, Saccharum spontaneum, Daphne papyracea, Phragmites karka*	[b]	[a]	[c]
Wetland	*Eichhornia crassipes, Cyperus rotundus, Ipomoea aquatica, Leersia hexandra*	[b]	[b]	[c]

[a]dominant
[b]present
[c]absent
[d]common

The Mahabharat range (Photo by BP Bhattarai)

Churia hills covered with sal forest in the Chitwan National Park (Photo by BP Bhattarai)

Sal forest and associated short grassland: a typical habitat in the Tarai region (Photo by BP Bhattarai)

Regeneration of the tropical riverine forest (Photo by BP Bhattarai)

wild fauna and flora (BPP 1995). The diverse geography of the Chitwan district has resulted in a rich biodiversity, both in plants and animals and ethnic and cultural diversity, which lures more than 70,000 tourists per year to the area (UNESCO/EoH 2003). However, most of the tourists visit the CNP and its adjacent buffer zone (BZ). As a consequence, it is reported that the spatial concentration of tourists is having a detrimental affect on the environment in the CNP. Several studies report that the effect of tourism ranges from habitat disturbance to vegetation damage and pollution (Curry et al. 2001).

The Chitwan National Park is an important rhino and tiger conservation area and was made a World Heritage Site by UNESCO in 1984 because of its unique ecosystems, which are of international importance (UNESCO/EoH 2003). To reduce the numbers of people living inside the core area of the CNP, the government of Nepal in 1996 declared an area of 750 km^2, made up of forests and private lands, including cultivated land surrounding the park, a buffer zone. The CNP has one of the highest densities of large mammals, including tigers and rhinos, in southern Asia.

Potential threats to the long-term conservation of wildlife in the CNP are habitat fragmentation, poaching and illegal collecting of forest products and livestock grazing. Local people collect various forest products for their subsistence. The local ethnic people are mostly poor, landless and socially dominated by other caste groups. Intentional and accidental forest fires, encroachments, cattle grazing, etc. are all long-term threats to the quality of the habitat and biodiversity of the area.

The second part of the study area, the Barandabhar corridor forest (BCF) is dominated by sal forest, which is rich in plants and animals. The conservation and management of the BCF is a priority for Nepal, as it links the Churia hills, Chitwan National Park and Mahabharat hill forest (KMTNC/BCC 2003). It is important for the long-term survival and mobility of the megafauna in the CNP and other migratory animals. Basic information on the BCF, its flora and fauna is lacking or scarce. BCF is part of a larger forest, which divides the Chitwan district into two parts: east and west Chitwan. The encroachment of people from both sides is the main threat to this area. Because of different conservation practices, more people collect forest products in the district forest area than in the buffer zone. The government declared an area up to 300 m from a village into the forest as the community's forest, where people from the village are allowed to fell the trees for their use, but nowhere else. Illegal logging of trees is a serious problem, as it results in the loss of many rare and endangered orchids, and other flora and fauna.

The east-west national highway divides the forest into the southern Barandabhar corridor forest of 57 km^2, which is a buffer zone for the CNP, and the northern Tikauli forest of 31 km^2, which is under district forest management. The incorporation of the BCF into the Chitwan National Park resulted in a major conflict between the communities around the BCF and the park authorities. The traditional practice of livestock grazing and collecting firewood and fodder was strictly limited inside the national park. In addition, conservation measures had a positive effect upon the numbers of wild animals, many of which moved into the BCF. However, people prevented from using natural resources inside the park were using those available in the BCF at an alarming rate. Therefore, in order to stop any further degradation of one of the few remaining Mahabharat forests, there is an urgent need to introduce an integrated conservation and development program for the BCF area (KMTNC/BCC 2003).

The conservation practices in the Mahabharat range (MR) differ from those in the CNP and BCF, as the MR is not a protected area. It is a government forest, managed by the district forest office of Chitwan. From the conservation and protection point of view, the people in this area manage the community forest areas, but there are many other large forests, mainly in hilly areas, where there are no people and the forest is in good condition. The higher humidity and better habitat in these areas support more orchid species. Because of the higher humidity on the north-facing slopes in hilly areas (Amatya 1982), the numbers of orchid species in these areas are also higher, even though they are not protected. The hilly regions of Chitwan are occupied by ethnic and low caste communities (e.g., Chepang, Magar) with a few settlements of high caste people (e.g., Brahmin, Chhetri). The people of low caste and ethnic communities are mainly traditional healers, i.e., they use plants (mainly orchids, ferns and some herbs) and animals (mainly small mammals and birds) to treat diseases. Because of the lack of good quality agricultural land in hilly areas the people there collect plants and animals of medicinal importance and make handicrafts for domestic use.

3.2.2 Sampling Methods

The field studies consisted of walking along transects walks in the study area and recording orchids growing in the trees, on rocks and on the ground. There were a total of 200 transects: 40 in the BCF, 105 in the CNP and 55 in the MR. Transects were chosen to include the main habitats in the region. The first 50 trees along and within 10 m of the transect line were sampled. Thus the length of the transect was not fixed: where the density of trees was low, the transect was long and vice versa. The species of each tree and all the orchids on each tree were noted. Along each transect, all the species of terrestrial orchids within a distance of 10 m from the transect line were also noted. The trees and associated orchids were identified using standard taxonomic keys (White and Sharma 2000; Rajbhandari and Bhattarai 2001). All the orchids were photographed for easier identification and later documentation.

3.2.3 Analyses

A canonical correspondence analysis (CCA) of orchid species preferences was done using CANOCO software (Version 4.5; ter Braak and Šmilauer 2002). The resulting ordination diagrams express both the variation in species composition and the principal relationships between species and environmental variables. Including tree species identity as dummy variables, differences in the epiphyte assemblages on trees were analyzed using Monte Carlo permutation tests (999 permutations). Infrequent tree species (less than 10 individuals in the whole data set) were excluded from the analyses.

3.3 Results

Results of the CCA analysis are shown in Figs. 3.1–3.9. Only those orchid species that showed a relationship with a particular tree species are displayed. Table 3.2 shows the presence/absence of the orchid species at specific sites and the abbreviations used in CANOCO.

Table 3.3 shows a list of the trees and their numbers as used in CANOCO.

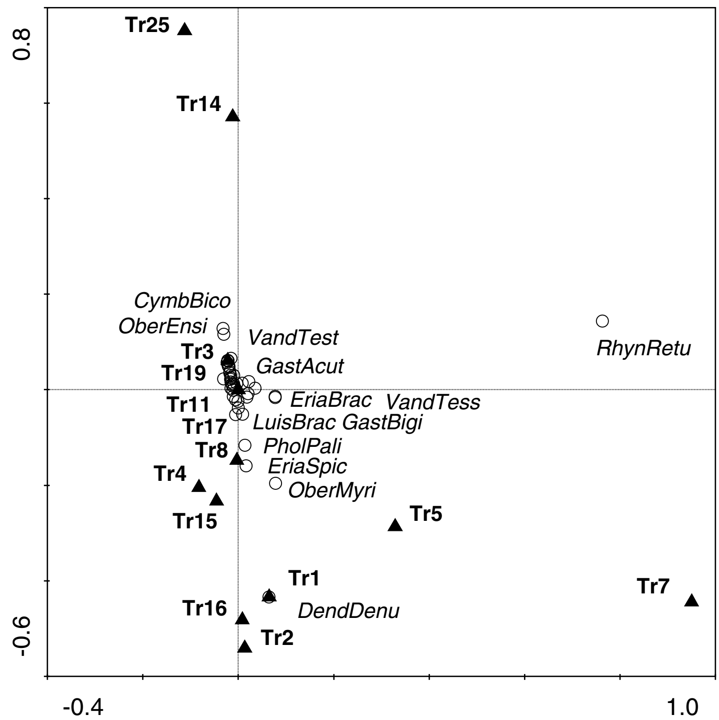

Fig. 3.2 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the sal forest in the Barandabhar corridor forest (*BCF-SF*). Monte- Carlo permutation test of significance of all canonical axes: F = 1.279, P = 0.122 (with 999 permutations). First two axes are displayed. The first axis explains 9.6% and second 6% of the variability

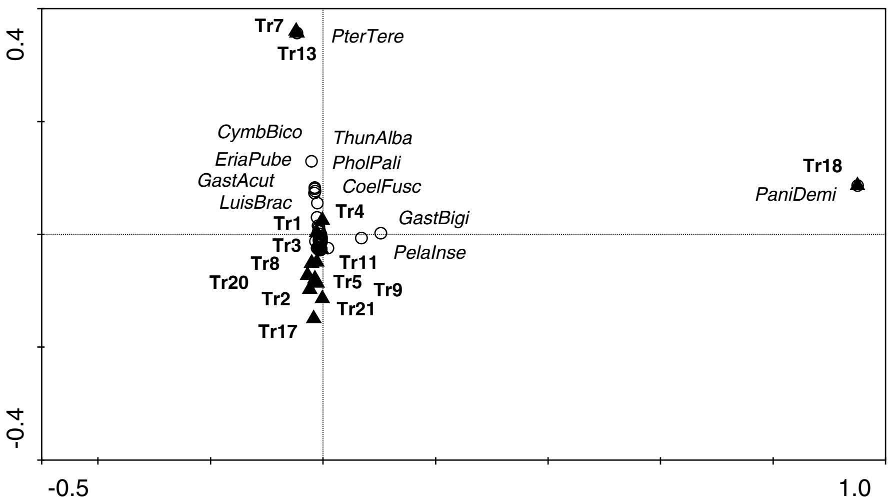

Fig. 3.3 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the mixed hardwood forest in the Barandabhar corridor forest (*BCF-MF*). First two axes are displayed. The first axis explains 25.9% and the second 13.8% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 1.197, P = 0.145 (with 999 permutations)

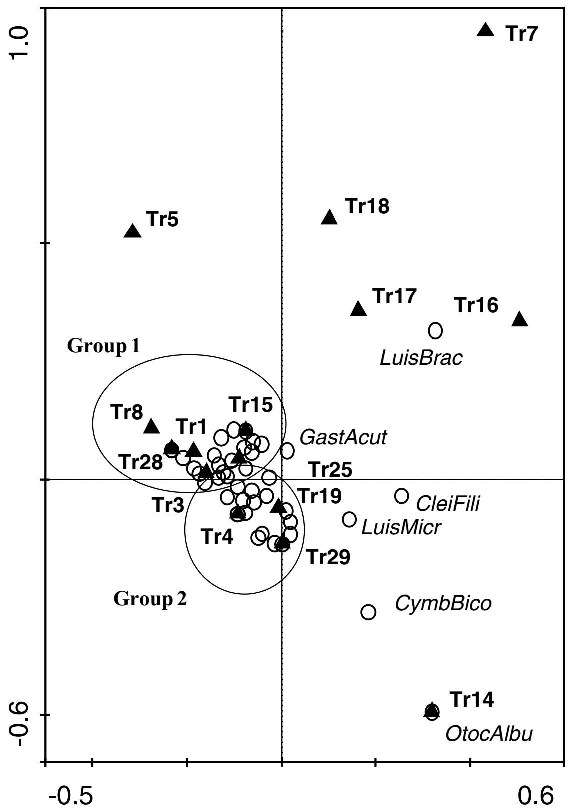

Fig. 3.4 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the riverine forest in the Barandabhar corridor forest (*BCF-RF*). First two axes are displayed. The first axis explains 31.7% and the second 20.2% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 1.534, P = 0.043 (with 999 permutations). In Group 1 there are: AcamPapi, AcamRigi, AeriOdor, AscoAmpu, BulbAffi, BulbLeop, CoelFlac, CoelFusc, CrypLute, CymbAloi, DendAphy, DendFimb, DendMosc, DendPunc, EchiSimo, EriaPube, GastCalc, LipaViri, OberEnsi, OberFalc, PaniDemi, PholImbr and VandTest, and in Group 2: AeriMult, BublCare, BulbGutt, BulbPoly, DendAnce, DendPrim, EriaBrac, EriaSpic, FlicFuxa, GastBigi, OberMyri, PelaInse, PholPali, ThunAlba, RhynRetu and VandTess

3.3.1 Barandabhar Corridor Forest

In the sal forest (Fig. 3.2) no association between orchid species and the different trees was recorded. Ten orchid species: *Agrostophyllum callosum, Bulbophyllum affine, Coelogyne cristata, Coelogyne flaccida, Coelogyne fuscescens, Cryptochilus lutea, Cymbidium elegans, Dendrobium anceps, Liparis viridiflora* and *Panisea demissa* were found only on *Shorea robusta. Dendrobium denudans* was observed

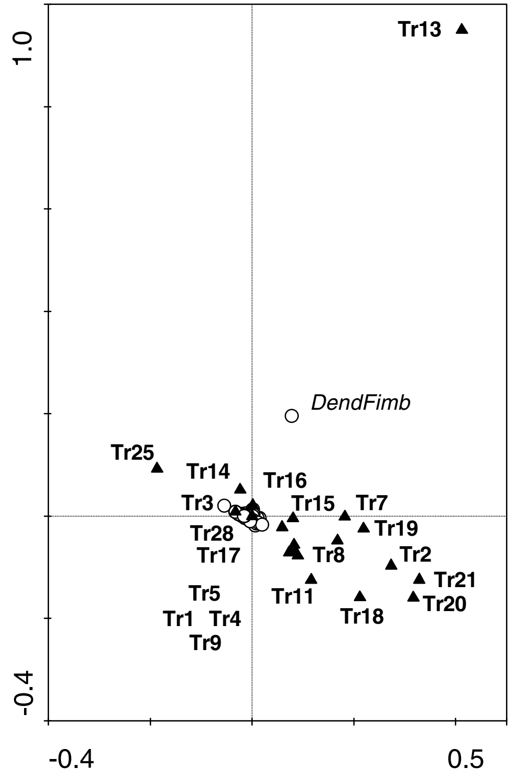

Fig. 3.5 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the sal forest in the Chitwan National Park (*CNP-SF*). First two axes are displayed. The first axis explains only 2% and the second 1.4% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 0.898, P = 0.694 (with 999 permutations)

only once, on *Cleistocalyx operculata.* The most common tree in this region is *Shorea robusta*, with which 48 orchid species are associated and *Cleistocalyx operculata*, with 34 orchid species. In the mixed hardwood forest (Fig. 3.3), a positive association was observed between *Panisea demissa* and *Bauhinia purpurea*, and between *Pteroceras teres* and *Dillenia pentagyna. Agrostophyllum callosum, Cymbidium elegans, Oberonia ensiformis* and *Oberonia falconeri* were found only on *Shorea robusta*. The most common tree in this forest was again *Shorea robusta* with 42 orchid species and *Lagerstroemia parviflora* with 36. In the riverine forest (Fig. 3.4) there were two groups of associations between trees and orchid species ($p < 0.05$): orchids in group one mostly grew on *Cleistocalyx operculata, Shorea robusta, Bombax ceiba* and *Careya arborea*, while those in group 2 mostly on *Lagerstroemia parviflora, Adina cordifolia* and *Gaultheria fragrantissima. Luisia brachystachys* was recorded mostly on *Trewia nudiflora* and *Otochilus albus* only on *Dalbergia sissoo.* The most common trees in the riverine forest were *Bombax ceiba* and *Gaultheria fragrantissima*, both with 28 orchid species, but more orchid species were recorded on *Cleistocalyx operculata*, 35.

Cymbidium aloifolium: one of the dominant epiphytic orchid species in the Tarai (Photo by BP Bhattarai)

Rhynchostylis retusa (Photo by BP Bhattarai)

Eria pubescens in the lowlands (Photo by BP Bhattarai)

Oberonia ensiformis in the Mahabharat range (Photo by BP Bhattarai)

Trudelia cristata in the Churia range (Photo by BP Bhattarai)

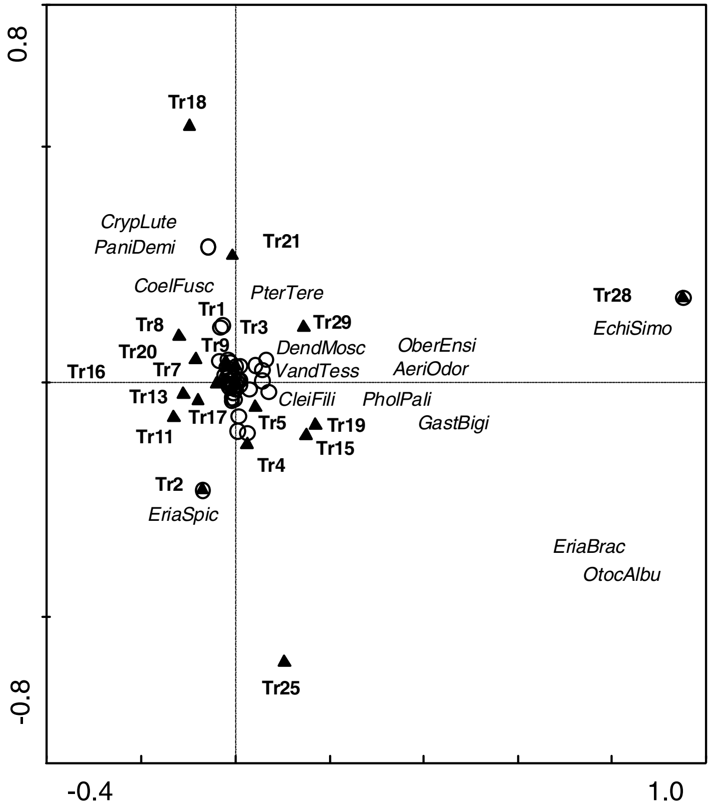

Fig. 3.6 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the mixed hardwood forest in the Chitwan National Park (*CNP-MF*). First two axes are displayed. The first axis explains 4.2% and the second 3.9% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 1.297, P = 0.052 (with 999 permutations)

3.3.2 Chitwan National Park

In the Chitwan National Park, there is also no association between orchid species and particular species of trees (Figs. 3.5 and 3.6, $p > 0.05$ in all cases). *Dendrobium fimbriatum* mostly occurred in the sal forest (Fig. 3.5) on *Shorea robusta*, but also on *Terminalia chebula. Cryptochilus lutea, Dendrobium bicameratum, Eria spicata* and *Otochilus albus* were recorded only on *Shorea robusta.* Other orchid species show no association with particular trees. The most frequently occurring tree in the sal forest was *Shorea robusta* with 45 orchid species and *Cleistocalyx operculata* with 36. In the mixed hardwood forest (Fig. 3.6) *Dendrobium nobile* occurred only on *Shorea* robusta, *Echioglossum simondii* only on *Careya arborea* and *Eria spicata* on *Syzygium cumini. Cryptochilus lutea* and *Panisea demissa* were recorded once on *Shorea robusta* and once on *Bauhinia purpurea.* The most common tree in this forest

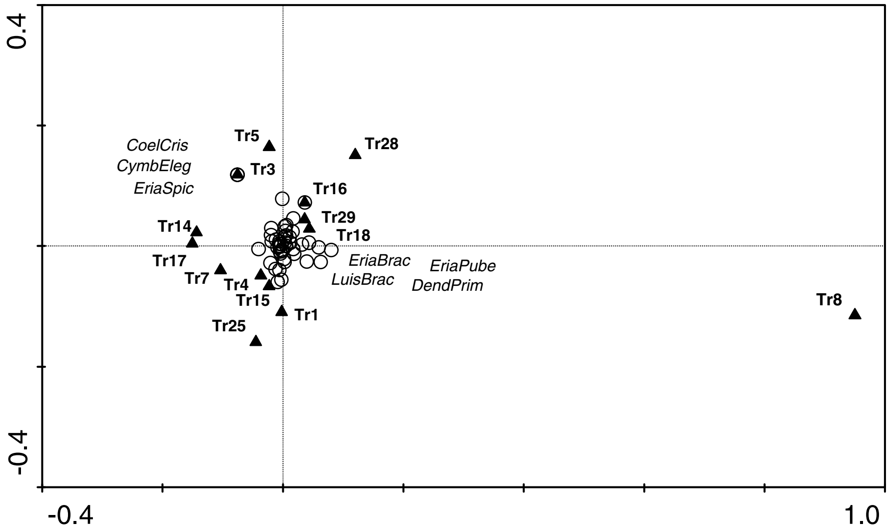

Fig. 3.7 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the riverine forest in the Chitwan National Park (*CNP-RF*). First two axes are displayed. The first axis explains 4.5% and the second 3.6% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 1.2, P = 0.114 (with 999 permutations)

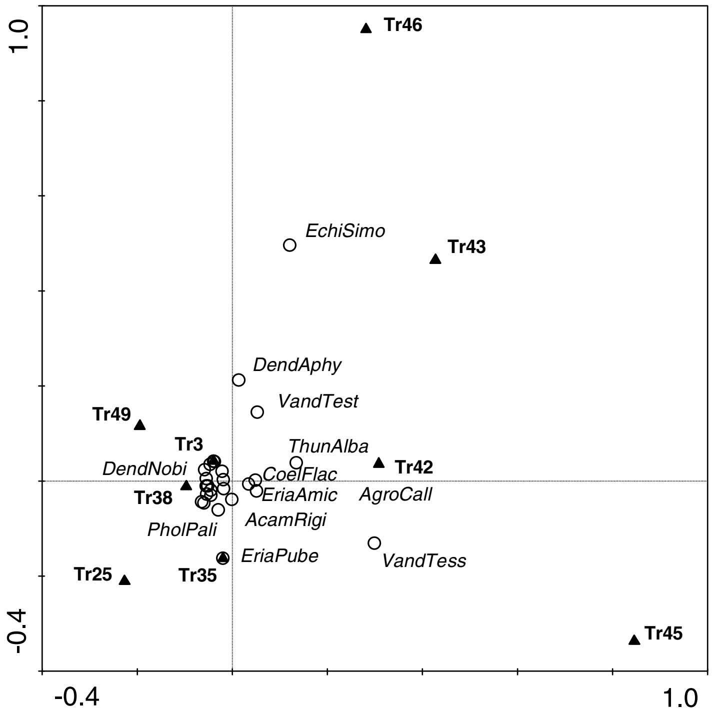

Fig. 3.8 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the hill sal forest in the Mahabharat range (*MR-HSF*). First two axes are displayed. The first axis explains 10.5% and the second 10.1% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 0.909, P = 0.458 (with 999 permutations)

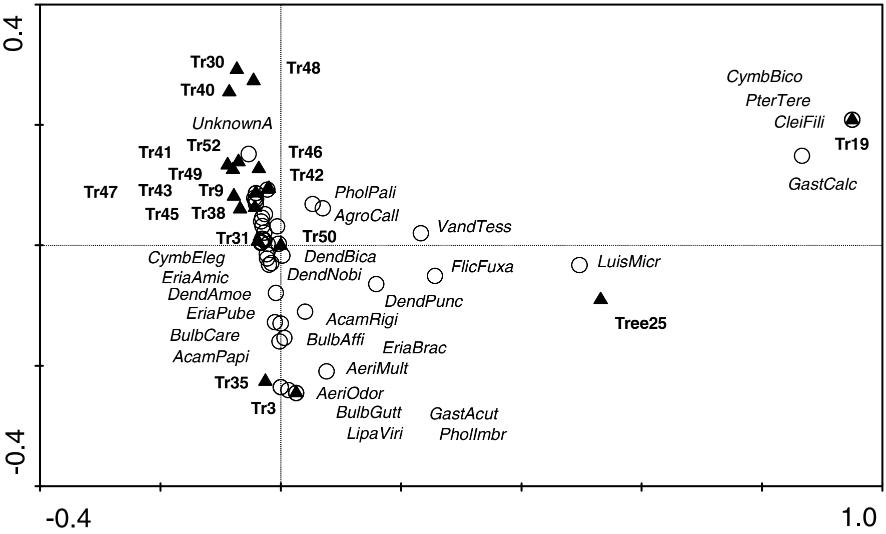

Fig. 3.9 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the mixed deciduous forest in the Mahabharat range (MR-MF). First two axes are displayed. The first axis explains 35.2% and the second 13.3% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 1.841, P = 0.006 (with 999 permutations)

was *Shorea robusta* with 43 orchid species and *Lagerstroemia parviflora* with 37. In the riverine forest (Fig. 3.7) *Coelogyne cristata*, *Cryptochilus lutea*, *Cymbidium elegans* and *Eria spicata* occurred mostly on *Shorea robusta* and *Dendrobium ochreatum* on *Trewia nudiflora.* However, most of the orchid species were found on *Bombax ceiba* (42 orchid species) and on *Trewia nudiflora* (41).

3.3.3 Mahabharat Range

In the Mahabharat range, several orchid species were clearly associated with particular trees. In the hill sal forest (Fig. 3.8) *Eria pubescens* was recorded only on *Aesandra butyracea* and *Gastrochilus acutifolium* on *Shorea robusta.* The most common trees in this type of forest were *Shorea robusta* with 26 orchid species and *Schima wallichii* with 20. In the mixed deciduous forest (Fig. 3.9) there was a statistically significant association ($p < 0.05$) between orchids and trees. For example, *Cymbidium bicolor, Pteroceras teres* and *Cleisostoma filiforme* were recorded only on *Adina cordifolia. Gastrochilus calceolaris* was recorded mostly on *Adina cordifolia* but also on *Terminalia alata. Aerides odorata* grew only on *Shorea robusta.* The most frequent tree in this forest was *Schima wallichii* with 34 orchid species, but more species were recorded on *Shorea robusta* (41 orchid species). In the rhododendron forest (Fig. 3.10) there was also a significant association between orchids

Table 3.2 List of orchid species with the abbreviation used in analysis and the presence/absence of these orchids in sal forests (*SF*), mixed forests (*MF*), and riverine forests (*RF*)

Scientific name	Abbreviation	BCF-SF	BCF-MF	BCF-RF	CNP-SF	CNP-MF	CNP-RF	MR-HSF	MR-MF	MR-RhF
Acampe papillosa	AcamPapi	+	+	+	+	+	+	–	+	–
Acampe rigida	AcamRigi	+	+	+	+	+	+	+	+	+
Aerides multiflora	AeriMult	+	+	+	+	+	+	+	+	+
Aerides odorata	AeriOdor	+	+	+	+	+	+	–	+	+
Agrostophyllum callosum	AgroCall	+	+	–	–	–	–	+	+	+
Ascocentrum ampullaceum	AscoAmpu	+	–	+	+	+	+	–	–	+
Bulbophyllum affine	BulbAffi	+	+	+	+	+	+	+	+	+
Bulbophyllum careyanum	BulbCare	+	+	+	+	+	+	–	+	+
Bulbophyllum guttulatum	BulbGutt	+	+	+	+	+	+	–	+	+
Bulbophyllum leopardinum	BulbLeop	+	+	+	+	+	+	–	+	+
Bulbophyllum polyrhizum	BulbPoly	+	+	+	+	+	+	–	–	+
Bulbophyllum secundum	BulbSecu	–	–	–	–	–	–	+	+	+
Cleisostoma filiforme	CleiFili	+	+	+	+	+	+	–	+	–
Coelogyne cristata	CoelCris	+	–	–	–	–	+	+	+	+
Coelogyne flaccida	CoelFlac	+	–	+	–	–	–	+	+	+
Coelogyne fuscescens	CoelFusc	+	+	+	+	+	+	–	+	+
Coelogyne nitida	CoelNiti	–	–	–	–	–	–	+	+	+
Cryptochilus lutea	CrypLute	+	–	+	+	+	+	–	–	+
Cymbidium aloifolium	CymbAloi	+	+	+	+	+	+	–	+	+
Cymbidium bicolor	CymbBico	+	+	+	+	+	+	–	+	–
Cymbidium elegans	CymbEleg	+	+	–	–	–	+	+	+	+
Cymbidium iridioides	CymbIrid	–	–	–	–	–	–	–	+	+
Dendrobium amoenum	DendAmoe	–	–	–	–	–	–	+	+	+
Dendrobium anceps	DendAnce	+	+	+	+	+	+	–	–	–
Dendrobium aphyllum	DendAphy	+	+	+	+	+	+	+	+	+
Dendrobium bicameratum	DendBica	–	+	–	+	–	–	+	+	+

Dendrobium denudans	DendDenu	+	+	–	–	–	–	+	+	+
Dendrobium fimbriatum	DendFimb	+	+	+	+	+	+	–	+	+
Dendrobium moschatum	DendMosc	+	+	+	+	+	+	–	–	+
Dendrobium nobile	DendNobi	–	–	–	–	+	–	+	+	+
Dendrobium ochreatum	DendOchr	–	–	–	–	–	+	+	+	+
Dendrobium primulinum	DendPrim	+	+	+	+	+	+	–	–	–
Dendrobium pulchellum	DendPulc	+	+	+	+	+	+	–	+	–
Echioglossum simondii	EchiSimo	+	–	+	+	+	+	+	+	+
Epigeneium amphum	EpigAmph	+	+	–	+	+	+	–	–	+
Eria amica	EriaAmic	–	–	–	–	–	–	+	+	+
Eria bractescens	EriaBrac	+	+	+	+	+	+	–	+	+
Eria pubescens	EriaPube	+	+	+	+	+	+	+	+	+
Eria spicata	EriaSpic	+	–	+	+	+	+	–	+	+
Flickingeria fugax	FlicFuxa	+	+	+	+	+	+	–	+	+
Gastrochilus acutifolium	GastAcut	+	+	+	+	+	+	+	+	–
Gastrochilus bigibbus	GastBigi	+	+	+	+	+	+	–	–	–
Gastrochilus calceolaris	GastCalc	+	+	+	+	+	+	–	+	–
Liparis viridiflora	LipaViri	+	–	+	+	+	+	–	+	–
Luisia brachystachys	LuisBrac	+	+	+	+	+	+	–	–	–
Luisia micrantha	LuisMicr	+	+	+	+	+	+	–	+	–
Oberonia ensiformis	OberEnsi	+	+	+	+	+	+	–	–	–
Oberonia falconeri	OberFalc	+	+	+	+	+	+	–	–	–
Oberonia myriantha	OberMyri	+	+	+	+	+	+	–	–	–
Otochilus albus	OtocAlbu	–	+	+	+	+	+	–	–	+
Otochilus porrecta	OtocPorr	–	–	–	–	–	–	–	+	+
Panisea demissa	PaniDemi	+	+	+	+	+	+	–	+	+
Pelatantheria insectifera	PelaInse	+	+	+	+	+	+	+	+	+
Pholidota imbricata	PholImbr	+	+	+	+	+	+	+	+	+
Pholidota pallida	PholPali	+	+	+	+	+	+	+	+	+

(continued)

Table 3.2 (continued)

Scientific name	Abbreviation	BCF-SF	BCF-MF	BCF-RF	CNP-SF	CNP-MF	CNP-RF	MR-HSF	MR-MF	MR-RhF
Pteroceras teres	PterTere	+	+	–	+	+	+	–	+	+
Rhynchostylis retusa	RhynRetu	+	+	+	–	–	–	+	+	+
Sunipia bicolor	SuniBico	–	–	–	–	–	–	+	+	+
Thunia alba	ThunAlba	–	+	+	–	–	–	+	+	+
Trudelia cristata	TrudCris	–	–	–	–	–	–	–	+	+
Unknown A	UnknownA	–	–	–	–	–	–	–	+	+
Vanda tessellata	VandTess	+	+	+	+	+	+	+	+	+
Vanda testacea	VandTest	+	+	+	+	+	+	+	+	+

Table 3.3 A list of the trees and their numbers as used in CANOCO

Number of tree	Scientific name	Number of tree	Scientific name
1	*Cleistocalyx operculatus*	25	*Terminalia alata*
2	*Syzygium cumini*	28	*Careya arborea*
3	*Shorea robusta*	29	*Gaultheria fragrantissima*
4	*Lagerstroemia parviflora*	30	*Saurauia napaulensis*
5	*Terminalia bellirica*	31	*Betula alnoides*
7	*Dillenia pentagyna*	35	*Aesandra butyracea*
8	*Litsea monopelata*	38	*Schima wallichii*
9	*Sapium insigne*	40	*Alnus nepalensis*
11	*Rhus javanica*	41	*Rhus succedanea*
13	*Terminalia chebula*	42	*Castanopsis tribuloides*
14	*Dalbergia sissoo*	43	*Michelia champaca*
15	*Bombax ceiba*	45	*Castanopsis indica*
16	*Trewia nudiflora*	46	*Butea monosperma*
17	*Garuga pinnata*	47	*Debregeasia salicifolia*
18	*Bauhinia purpurea*	48	*Cedrus deodara*
19	*Adina cordifolia*	49	*Rhododendron arboreum*
20	*Gmelina arborea*	50	*Quercus lanata*
21	*Comus oblonga*	52	*Rhus wallichii*

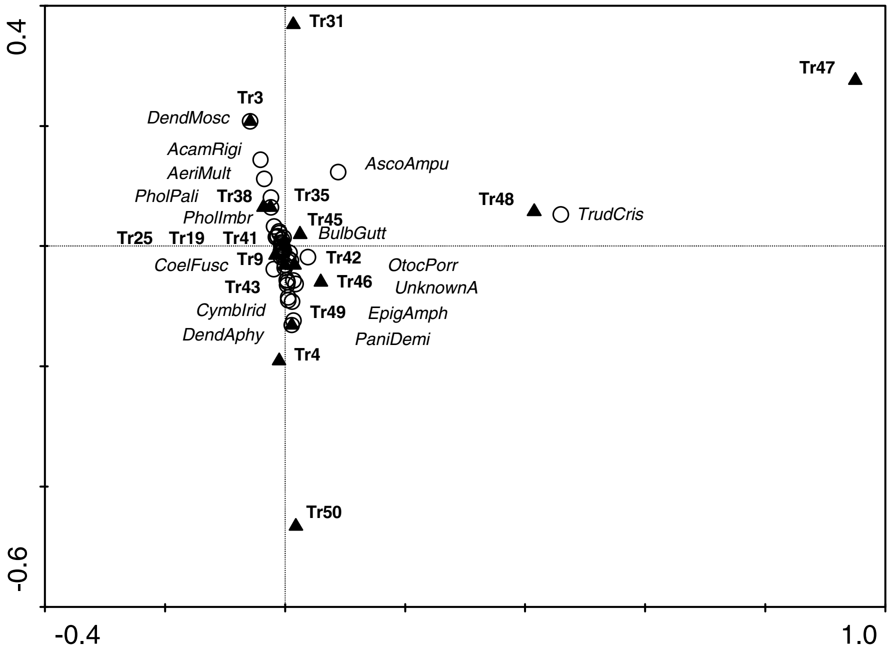

Fig. 3.10 CCA ordination diagram of the association between orchid species (*circles*) and certain trees (*triangles*) in the rhododendron forest in the Mahabharat range (MR-RhF). First two axes are displayed. The first axis explains 13.8% and the second 8.4% of the variability. Monte-Carlo permutation test of significance of all canonical axes: F = 1.95, P = 0.003 (with 999 permutations)

and the trees ($p < 0.05$). *Dendrobium aphyllum* was recorded only on *Rhododendron arboretum*, *Aerides odorata* and *Otochilus albus* only on *Castanopsis tribuloides* and *Dendrobium moschatum* only on *Shorea robusta.* Most orchid species were recorded on *Castanopsis tribuloides* (42 orchid species) and *Rhododendron arboretum* (35).

Figures 3.11–3.13 show orchid species-abundance relationships for the different regions. In the Barandabhar corridor forest, the orchids were most closely associated with particular trees and were recorded only on four different tree species. In contrast, in the Chitwan National Park, the orchids were recorded on average on eight different trees and in the Mahabharat range on five different tree species (Table 3.4). Between 45 and 50 orchid species were recorded in most regions, but only 27 orchid species in the hill sal forest in the Mahabharat range (Table 3.2).

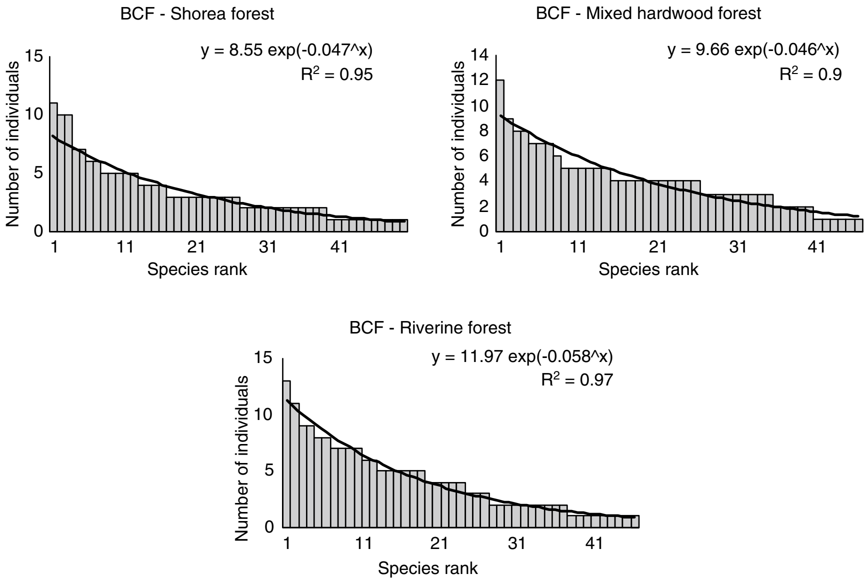

Fig. 3.11 Orchid species abundance relationships for the different types of forest in the Barandabhar corridor forest

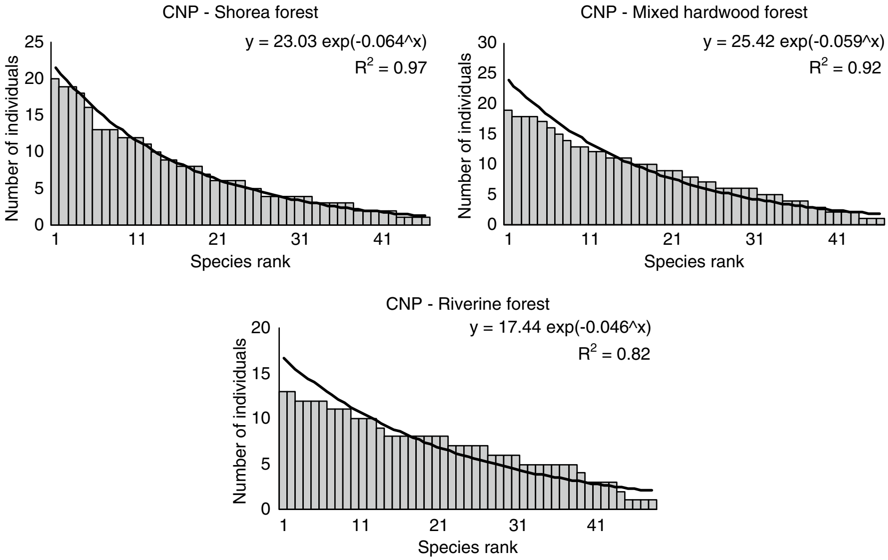

Fig. 3.12 Orchid species abundance relationships for the different types of forest in the Chitwan National Park

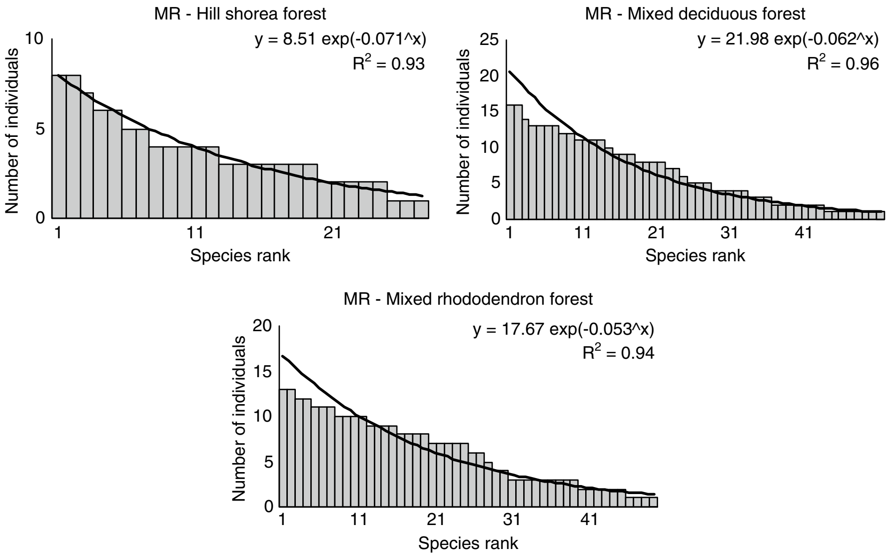

Fig. 3.13 Orchid species abundance relationships for the different types of forest in the Mahabharat range

Table 3.4 Descriptive statistics of the number of orchids per tree

	Number of orchid species	Minimum	Maximum	Median	Mean number of orchids per tree	SE
BCF-SF	49	1	11	3.0	3.33	0.35
BCF-MHF	45	1	12	4.0	4.02	0.35
BCF-RF	45	1	13	4.0	4.13	0.44
CNP-SF	45	1	20	6.0	7.20	0.81
CNP-MHF	45	1	19	8.0	8.42	0.78
CNP-RF	47	1	13	7.0	6.94	0.50
MR-HSF	27	1	8	3.0	3.67	0.38
MR-MDF	50	1	16	5.0	6.42	0.65
MR-RhF	48	1	13	6.5	6.13	0.54

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Chapter 4
Distribution and Diversity of Storks in the Adjoining Areas of Chitwan National Park, Nepal

Bishnu Prasad Bhattarai

Abstract The Barandabhar corridor forest (BCF) has a very high biodiversity and in terms of wildlife is globally significant. This study on the status of Ciconiidae (storks) in the BCF was conducted by means of direct observation along bird routes, line transects, roads, man-made tracks and riversides. A seasonal count was used to determine the actual status of the storks. Four species of the family Ciconiidae, the lesser adjutant stork (52 individuals); black stork (6); woolly-necked stork (148) and Asian open bill stork (363) were recorded during the course of this study. The population of storks was highest in the rainy season. Among the species studied, the Asian open bill stork, woolly-necked stork and lesser adjutant stork were resident in the area, whereas the black stork is migratory and only present in winter. Storks were recorded mainly around lakes and ponds (675 individuals) followed by marshy and swampy land (325), grassland (293), paddy fields (251), rivers and streams (187). The most abundant species is the Asian open bill stork, followed by the woolly-necked stork, lesser adjutant stork and black stork. All the diversity indices values showed that the Asian open bill stork was the dominant species in the study area, followed by the woolly-necked stork, lesser adjutant stork and black stork. Many wetlands inside the Chitwan National Park and the Barandabhar corridor forest dry out in summer, which directly affects the survival of these birds, as they are confined to protected areas in the dry season, when there is no water in the paddy fields. Degradation of aquatic ecosystems, overuse of pesticides in fields and overfishing of rivers and lakes using poisons and electricity, are the major threats to these species.

Keywords Storks • Corridor • Birding routes • Biodiversity • Pesticides • Threats

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4.1 Introduction

The storks, which fall under the family Ciconiidae, are the signs of the healthy wetlands. Distribution of storks in Asia and Europe ranges from India, south through Myanmar and Thailand to Laos, Cambodia, Vietnam and Peninsular Malaysia to the Greater Sundas, including Sumatra, Kalimantan, Java and Bali (Indonesia), Sabah and Sarawak (Malaysia) and Brunei. There are unconfirmed reports that some storks are under threat of extinction, like the lesser adjutant stork, black stork and white stork from Bhutan, which occurs as a vagrant east of Bali in the Lesser Sunda Islands (Nusa Tenggara), Indonesia (Birdlife International 2001). Storks have a wide distribution and are found on all continents, except Antarctica. They reach their greatest diversity in the tropical regions and show a strong preference for warmer climates, with the few species that breed in colder temperate areas migrating to warmer countries after nesting. North America has the least diversity, with the wood stork as the region's only and very marginal representative (http://www.answers.com/topic/stork?cat=technology).

Wetlands in Nepal are characterized by their diverse biological assemblages, high productivity and seasonal changes. They are shallow and largely depend on seasonal monsoon rains. Countless species of plants and animals depend on the highly productive wetlands for their survival (IUCN 2004). No wonder they are often called "the cradles of biodiversity". The wetlands also play a crucial role in flood control, storage and discharge of groundwater, microclimate regulation, retention of soil nutrients, conversion of toxins, biomass export and provision of important fish and wildlife habitats. Nepal has many different types of wetlands that range from areas of permanently flowing rivers to seasonal streams, lowland oxbow lakes, high altitude glacial lakes, swamps and marshes, paddy fields, reservoirs and ponds (Scott 1989). Birds are the most noticeable and diverse fauna in such wetlands. These areas are rich in biodiversity and regularly support more than 20,000 waterfowl during December-February (IUCN 2004). Out of the 872 species of birds in Nepal, 193 are dependent on wetlands, and of these, 180 are dependent on the wetlands of Tarai (IUCN 2004). Among them Ciconiidae are the most important bird taxon in the wetlands.

There are a number of wetland birds in Nepal, which are globally threatened. The lesser adjutant, greater adjutant, black and white storks occur in Nepal (Grimmett et al. 2000) and are listed as globally threatened species in the IUCN's Red Data Book (Birdlife International 2004; IUCN 2004). The black and white storks migrate to Nepal in winter. They are distributed throughout the southern part of Nepal, but due to habitat loss and alteration and human disturbance, these species now mainly migrate to some isolated habitats in lowland Nepal (Birdlife International 2001). They are mostly recorded in the Koshi Tappu Wildlife Reserve and its surroundings, the Chitwan National Park (CNP) and its surroundings, the Beeshazari Lake, Kapilvastu, Nawalparasi and Rupandehi districts, the Bardia National Park, the Ghodaghodi Lake and the Suklaphata Wildlife Reserve and surroundings. Currently, there is a concern about these species both internationally and in Nepal, as there is evidence that their numbers are declining. Some studies have been carried out in the Koshi Tappu Wildlife Reserve (Fleming et al. 1984; Pokharel 1998; Baral 2004), in the Chitwan National Park (Gyawali 2003; Hungden and Clarkson 2003; Tamang 2003), the Bardia National Park and the Suklaphata Wildlife Reserve (Schaaf 1978), but this baseline study was carried out in the southern part of Nepal in order to determine the population status and distribution of Ciconiidae. Studying the current population status and distribution of Ciconiidae is necessary for developing management plans to conserve these threatened species in their natural habitats.

The main objective of this study was therefore to investigate the present status, distribution and determine the conservation needs of Ciconiidae in the Barandabhar corridor forest. The specific objectives were: (1) to determine the population status and distribution of Ciconiidae in the Barandabhar corridor forest; (2) to identify the major habitats and trends in habitat utilization by Ciconiidae; (3) to determine the present threats to Ciconiidae and suggest a strategy for the sustainable conservation of Ciconiidae and other wetland birds.

4.2 Methods

4.2.1 Study Area

The intensive study area was in and around the Barandabhar corridor forest (BCF, 84°22′30″–84°33′0″ E, 27°34′7″–27°43′30″ N – Fig. 4.1) adjacent to the northern border of the Chitwan National Park (CNP) and the Mahabharat hill forest in the north of the Chitwan Valley, which is situated in the subtropical inner Tarai lowlands of the southern central part of Nepal (85°55′–84°47′ E, 26°22′–26°46′ N). The Beeshazari Lake, which is located in the Barandabhar forest at an altitude of 256 m, is the second largest natural wetland in Nepal and was recently included among the Ramsar sites by the Nepalese government (http://www.ramsar.org/wn/w.n.nepal_3new.htm). The east-west highway divides the Barandabhar Forest corridor into two executive jurisdictions. The buffer zone forest south of the east-west highway is managed by of the Chitwan National Park (CNP), while the District Forest Office (DFO) manages the forest north of the highway.

The BCF is a habitat linking two ecosystems at significantly different altitudes: the lowland CNP and the upland Mahabharat Range. The BCF has three major habitat types: (1) sal forest- disturbed sal forest, sal forest with mixed understory and sal forest with *Shorea-Terminalia* understory; (2) successional forest – riverine forest, short grassland, open *Bombax* forest and open-wooded bush and; (3) wetlands. The riverine forest of the BCF occupies a very small area and is located mostly in the northern belt, as well as along the Khagari stream on the eastern boundary of the BCF. The flora of the riverine forest includes *Trewia nudiflora*, *Bombax ceiba*, *Mallotus philippensis*, *Litsea monopetala*, *Sapium insigne* etc. The riverine forest harbors the nesting sites for the globally threatened bird species including the giant

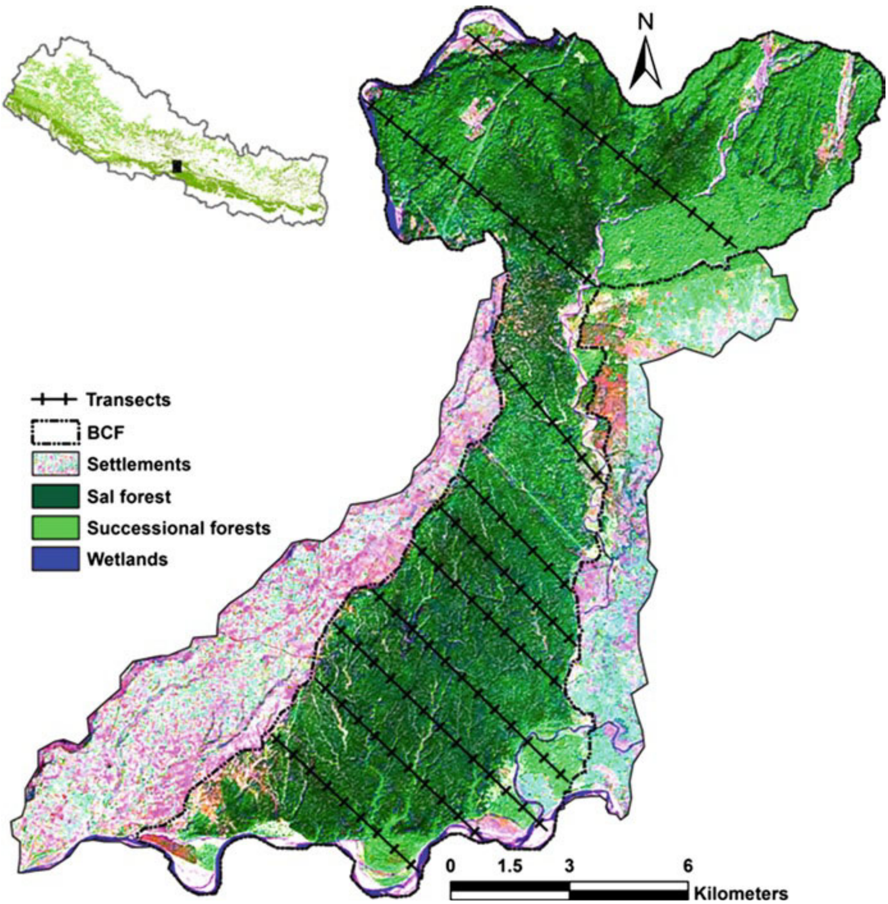


Fig. 4.1 Study area: the Barandabhar corridor forest and location of transects

hornbill (*Buceros bicornis*), and the lesser adjutant stork (*Leptoptilos javanicus*). There is large tracts sal (*Shorea robusta*) forest in the BCF, which extend up to the foothills of the Mahabharat range. Disturbed sal forest occurs along the entire length of the edge of the western side as well as the northern section of the BCF (Bhojad). *Shorea robusta* is the dominant species, also associated with species such as *Terminalia tomentosa*, and *Cleistocalyx operculatus*. The BCF, which is relatively rich in tree diversity, includes 24 species from 17 families. The southern area up to the east-west highway, under the jurisdiction of the Department of National Parks and Wildlife Conservation (DNPWC), is a relatively undisturbed habitat compared to the area north of the east-west highway, which is under DFO jurisdiction.

Sal forests dominating the BCF contain 22 species of mammals including tiger, common leopard, rhinoceros, Asian elephant, sloth bear, wild boar, sambar deer, spotted deer, hog deer, barking deer and 280 species of birds including giant hornbill, hill myna and storks. It is a critical habitat for many species of migratory birds (e.g., Siberian crane), aquatic birds, and mugger crocodile. More than 45 species of amphibians and reptiles, including frogs, toads, lizards, pythons and crocodiles are found in the Barandabhar corridor forest (KMTNC 2003). Wildlife often takes shelter in the BCF during flooding and fires in the National Park (IUCN 2004). During periods of food scarcity in the National Park, short grasses such as *Imperata cylindrica*, *Cyperus* species, *Digitaria ciliaris*, *Bulbostylis barbata*, and *Eragrostis tenella* in the BCF provide food for ungulates (KMTNC 2003).

Migratory birds use this area as a stop-off point (stepping stone) on the way to their ultimate destination (IUCN 2004). Previously, wetland habitat of BCF was a paradise for residential and migratory birds, but due to the invasion of exotic species, the number of birds has dramatically declined. Weeds, water hyacinths, and other invasive plant species have covered most of the surface of the Beeshazari lake. In addition, dams of the lake are often flooded, which reduces the biological value of the lake (Baral 1996). A total of four species of the family Ciconiidae (lesser adjutant stork, *Leptoptilos javanicus*; black stork, *Ciconia nigra*; woolly-necked stork, *Ciconia episcopus* and Asian open bill stork, *Anastomus oscitans*) are found in the BCF. Among them, the Asian open bill stork and the lesser adjutant stork are residential in the area, whereas the black stork and woolly-necked stork are winter migrants (Baral 1996).

4.2.2 Population Status, Distribution and Diversity of Storks

Total counts were used to determine the number of storks in different habitats. The birds were counted and studied in different wetland habitats of the BCF mostly during the morning and evening, periods of highest bird activity. For the total counts of storks, the bird routes, such as riversides, roads and man made tracks were used. Most of the wetlands and paddy fields around the study area were observed during the study period.

Transect counts were used to check the total counts. Altogether, there were ten transects of 3.2–7.8 km long and 0–300 m wide, depending upon the visibility in each of the different habitats of the storks. Photographs of storks and their habitats were used for identification and determining distribution in different parts of the BCF.

4.2.3 Identification of Key Habitats and Habitat Utilization Trends

The total counts and transects were also used to identify of habitats and habitat utilization by Ciconiidae. The habitats were classified and their preferred use by the storks recorded. The degree of habitat utilization by storks was determined by direct observation in the forest and at wetlands.

4.2.4 Identification of the Threats to Storks and Documentation of the Conservation Strategy

The threats to storks were determined by field studies, personal communication with local people and consultation with concerned authorities. The dissolved oxygen (DO- mg/l) in the water was also determined by the Winkler method in the rainy, winter and summer seasons (Winkler 1888). The number of local people, tourists and livestock encroachment of stork habitats were also investigated by direct counts. The identified threats and their management implications were used in compilation of a sustainable conservation strategy for storks in the study area.

4.2.5 Data Analysis

The data were analyzed using Microsoft Excel 2003. The diversity indices for storks were determined using *Past* (http://folk.uio.no/ohammer/past/download.html) software. The diversity indices were calculated following methods outlined by Harper (1999):

Dominance: $D = \sum \left(\frac{n_i}{n} \right)^2$, where n_i is the number of individuals of taxon *i*.

Shannon-Wiener index: $H = -\sum \frac{n_i}{n} \ln \left(\frac{n_i}{n} \right)$, where n_i is the number of individuals of taxon *i*.

Simpson index: $SI = 1/D$

Evenness: $E = \frac{e^H}{S}$, where *S* is the number of taxa and *H* as above.

Equitability: $J = \frac{H}{\ln S}$ where H is as above and S is the number of taxa.

The Shannon-Wiener index is one of several diversity indices used to measure diversity in categorical data. It is simply the information entropy of the distribution, treating species as symbols and their relative population sizes as the probability. The Shannon-Wiener index is maximized, when each species is present in equal numbers.

The Simpson's diversity index is another one of a number of diversity indices, used to measure of diversity. In ecology, it is often used to quantify the biodiversity of a habitat. The Simpson index represents the probability that two randomly selected individuals in the habitat belong to the same species.

Dominance, evenness and equitability are other indices of biodiversity, calculated based from the Shannon-Wiener index or from the Simpson index. Equitability and evenness are equal to the Shannon-Wiener index "normalized" by the number of species and dominance is the reciprocal value of the Simpson's index.

4.3 Results

4.3.1 Population Status, Distribution and Diversity of Storks

A total of four species of storks were recorded in the study area. Among them, the lesser adjutant stork and the black stork are globally threatened species. The woolly-necked stork and the Asian open billed stork were the commonest storks in the BCF (Fig. 4.2). In comparison with the global population, the population of the lesser adjutant stork is very low (Fig. 4.3). The population of storks was highest in the rainy season, followed by the autumn, winter and summer seasons. The winter migratory black stork (listed in the protected birds of Nepal, National Parks and Wildlife Conservation act 2029) is by far the rarest species (only 6 individuals altogether). The globally threatened lesser adjutant stork is also rare: 52 individuals were observed during the study, all the records were from wetland in the Barandabhar corridor forest.

The seasonal diversity indices (the Shannon and Simpson indices) of storks were high in winter, followed by those for the summer, autumn, and rainy seasons (Table 4.1). The dominance value for storks was high in the rainy season, followed by the autumn, summer and winter seasons. The species equitability and evenness values for storks were high in the summer season, followed by the rainy, winter and autumn seasons. The comparative diversity indices (the Shannon and Simpson

Simal (*Bombax ceiba*) offers nesting sites for storks and other birds (Photo by BP Bhattarai)

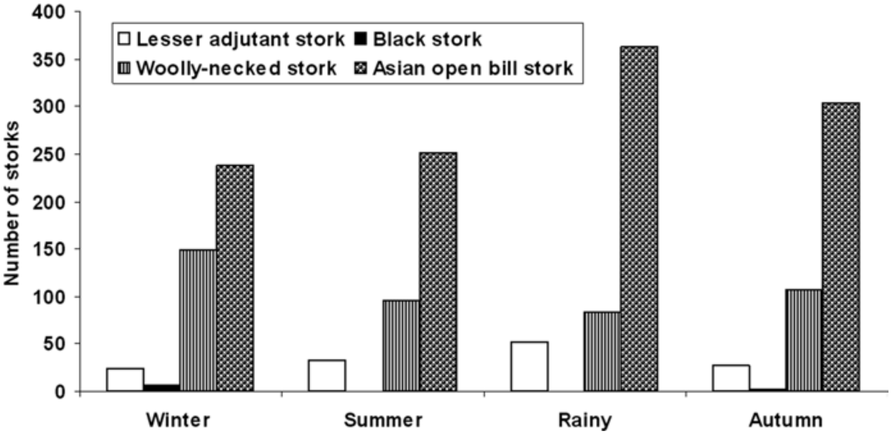
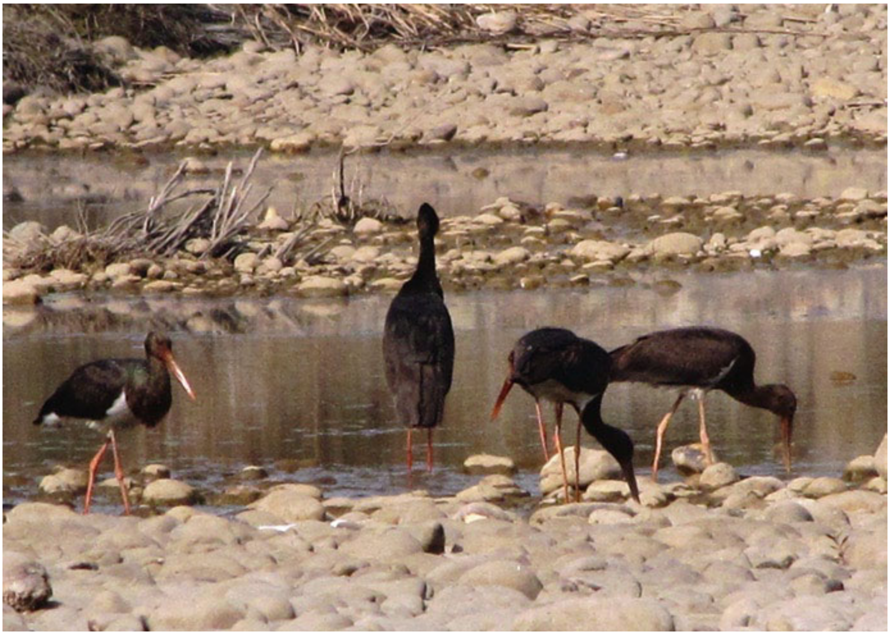


Fig. 4.2 Population status of the four species of storks in the BCF



Black stork (*Ciconia nigra*): a winter visitor bird in the lowlands of Nepal (Photo by BP Bhattarai)

Lesser adjutant stork (*Leptoptilos javanicus*) (Photo by BP Bhattarai)

Nesting sites of the Asian open bill stork (*Anastomus oscitans*) nearby the Beeshazari lake (Photo by BP Bhattarai)

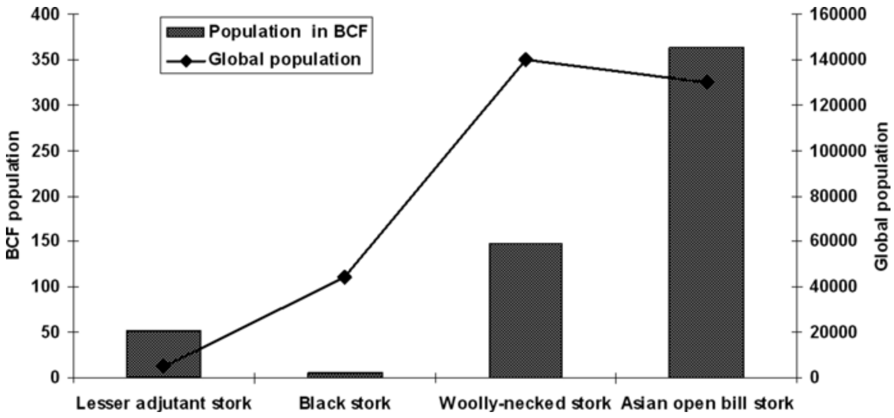


Fig. 4.3 Population status of storks in the BCF compared with their global population size (http://www.birdlife.org/datazone/)

Table 4.1 Seasonal numbers and diversity indices of storks in the BCF

	Seasons			
Name of storks	Winter	Summer	Rainy	Autumn
Lesser adjutant stork	24	32	52	27
Black stork	6	0	0	2
Woolly-necked stork	148	95	83	107
Asian open bill stork	238	251	363	303
Total	**416**	**378**	**498**	**439**
Dominance	0.46	0.51	0.57	0.54
Shannon index	0.91	0.83	0.76	0.80
Simpson index	0.54	0.49	0.43	0.46
Equitability	0.66	0.75	0.70	0.57
Evenness	0.62	0.76	0.72	0.55

indices) of each of the stork species reveal that the diversity of occurrence of the Asian open bill stork was the highest, followed by the woolly-necked stork, lesser adjutant stork and black stork (Table 4.2). Diversity of occurrence of the black stork was low, because it is a winter migrant in this area. This species was not recorded during the summer and rainy seasons. The species evenness and equitability values for the Asian open bill stork were higher than those for the other species; they were followed by the values for the woolly-necked stork, lesser adjutant stork and black stork. All the diversity indices indicate that the Asian open bill stork is the most abundant species in the study area.

The distribution of storks was mainly confined to wetlands, such as the Beeshazari lake system, marshy and swampy lands, short grasslands and rivers in the study area. The Beeshazari lake system was found to be the most restricted and isolated habitat for the storks (Fig. 4.4) and there are very few habitats for storks in this area.

Table 4.2 Comparison of diversity indices of storks in the BCF

	Diversity indices			
Name of storks	Shannon index	Simpson index	Evenness	Equitability
Lesser adjutant stork	1.34	0.72	0.95	0.96
Black stork	0.56	0.37	0.88	0.81
Woolly-necked stork	1.36	0.74	0.98	0.98
Asian open bill stork	1.37	0.74	0.99	0.99

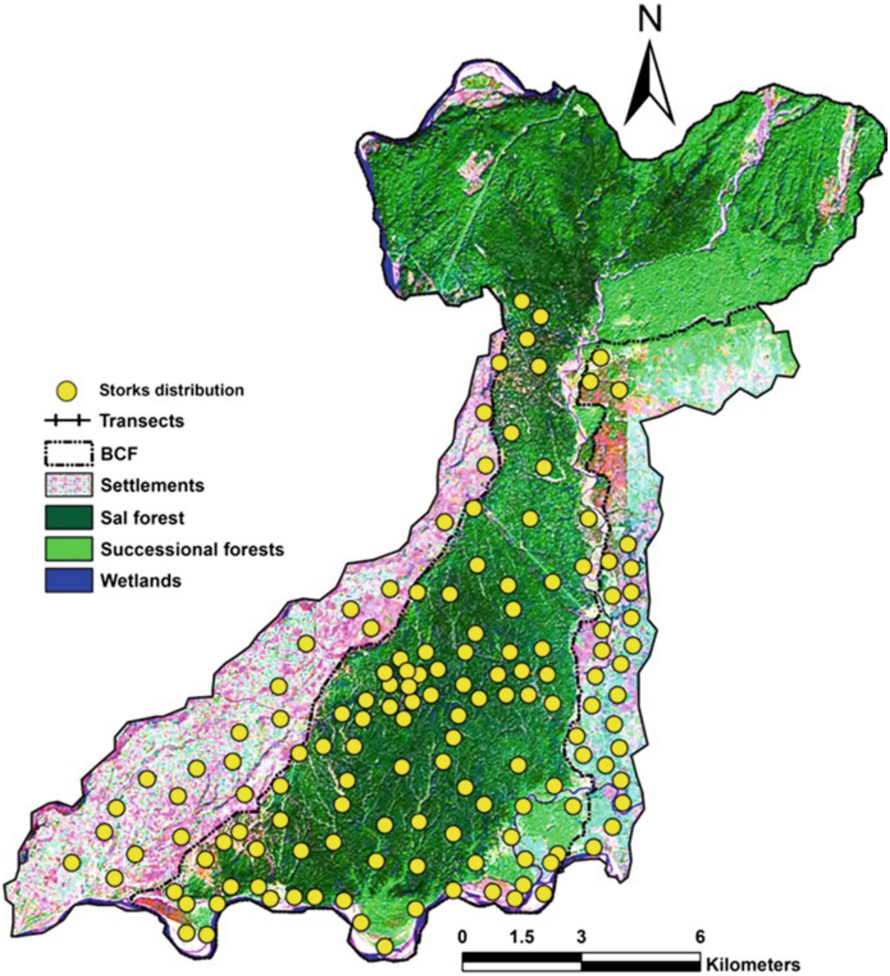


Fig. 4.4 Distribution of storks in the Barandabhar corridor forest and adjoining areas

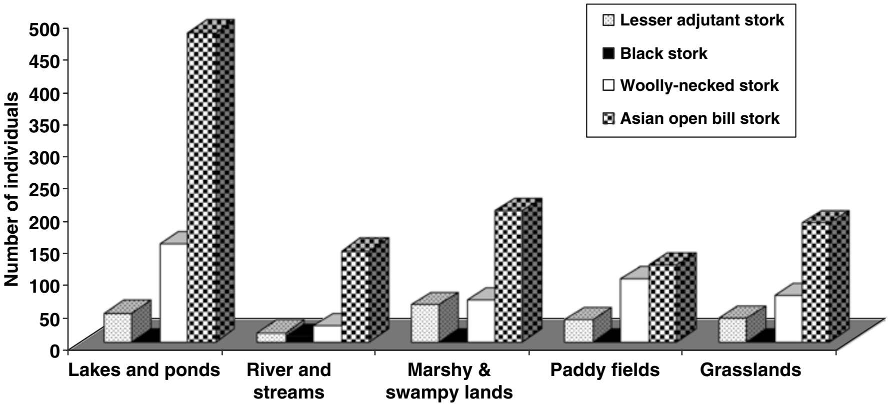


Fig. 4.5 Habitat utilization by storks in the BCF

4.3.2 Key Habitats and Habitat Utilization

Wetlands (the Beeshazari lake system; the Rapti, Budhi Rapti and Khageri rivers; marshy and swampy areas in the forest and short grasslands) were important habitats for storks in the study area. Storks were mainly found in and around lakes and ponds followed by marshy and swampy lands, grasslands, paddy fields, river and streams (Fig. 4.5). The black stork is a migrant in this area and was recorded along the Rapti river. The lesser adjutant stork preferred mostly marshy and swampy lands, followed by lakes and ponds, grasslands and paddy fields. The woolly-necked stork preferred lakes and ponds followed by paddy fields, grasslands, marshy and swampy lands, rivers and streams. Asian open bill storks were mainly confined to lakes and ponds followed by marshy and swampy lands, grasslands, rivers and streams and paddy fields.

4.3.3 Threats to Storks

4.3.3.1 Habitat Disturbance and Destruction

The numbers of storks were very low mainly because of habitat destruction and disturbance. The wetlands in the BCF are decreasing in size and quality for birds because of natural eutrophication. I recorded three darters (snake bird), trapped in the dense mat of water hyacinth and *Leersia hexandra*, which subsequently died of suffocation. Because of the dense growth of the water hyacinth, most of the wetlands (mainly lakes and ponds) look like grasslands. The water level was very low in the associated lakes of the Beeshazari Lake (e.g., Shorahazar and Satrahazar lakes) and wetlands in the forest. The level of dissolved oxygen in the water was also very low in Beeshazari lake (3.2 mg/l in the rainy season, 2.8 mg/l in the winter

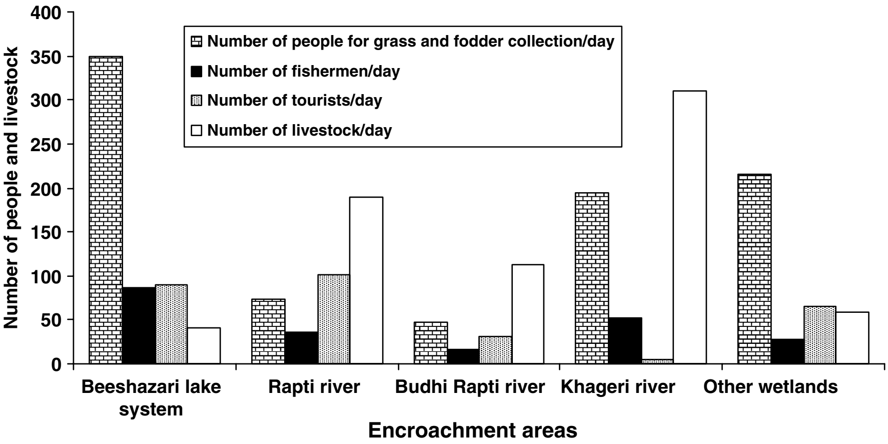


Fig. 4.6 Human and livestock encroachment in the study area

season and 3.8 mg/l in the summer season). Human and livestock encroachment on the forest, mainly of grasslands in the forest, was so high that it could change the population and behavior of the grassland dependent storks by decreasing the size of the feeding and breeding habitats. I have observed, on average, 880 people per day collecting grass, fodder and firewood; 219 fishing, collecting snails and other wetlands products; 292 foreign tourists and 712 domestic animals in and around the wetlands. Of the fishermen and other people collecting wetland products, 86 were doing so from the Beeshazari lake, 36 from the Rapti river, 17 from the Budhi Rapti river, 52 from the Khageri river and 28 from other wetlands in the forest (Fig. 4.6). Some of them, mostly the young collected eggs and young of birds in the study area, mainly in the Beeshazari lake area and along the side of the Khageri river.

4.3.3.2 Vulnerability to Pesticides and Inorganic Fertilizers

Local people in the adjoining area are applying liquid and powder pesticides along with fertilizers to their fields (pers. comm.). Their fields are located in the higher elevations of the study area and pesticides and fertilizers easily dissolve in water and are carried down to the wetlands (Khageri, Rapti and Budhi Rapti river). The Khageri canal is the major source of the chemical threats to Beeshazari lake system as it is the major source of water for the Beeshazari Lake. The farmers apply 5,000 l of liquid and 40 metric tons of powdered pesticides per year in the Chitwan district. Fertilizers (Urea, D.A.P., potash, etc.) are also heavily used in this district. There are a total of 62 authorized societies and suppliers in Chitwan, of which 20 are in Bharatpur and 10 in Ratnanagar municipalities (DADO 2002). Local people are applying more and more fertilizers and pesticides every year, in order to get higher yields. The percentage of organic fertilizers applied continuously declines (pers. comm.) with the increase in the use of inorganic fertilizers.

4.4 Discussion

Unlike previous studies, which focused on the species level (Gyawali 2003; Hungden and Clarkson 2003; Tamang 2003), the present study is mainly focused on the family level (Ciconiidae), in order to study their status, distribution, and develop a conservation database for the long-term survival of these threatened birds. The number of stork individuals recorded in the BCF during the study was very low, compared with previous studies in this area (Baral 1996; BirdLife International 2001; Tamang 2003) and also with the global average (lesser adjutant stork: 5,000 individuals, black stork: 44,000; woolly necked stork: 140,000, Asian open bill stork: 130,000 individuals – Bird Life International 2004 and http://www.birdlife.org/datazone/).

Previously, black storks were recorded as occurring in the Beeshazari lake system (Baral 1996), but I only observed them around the Rapti river, which indicates that the habitat of these migratory birds is now more restricted. This is probably because of the recent eutrophication of the Beeshazari lake system. Eutrophication greatly affects the population status and structure of wetland dependent birds like storks (Masifwa et al. 2001). The populations of storks are mainly confined to the Beeshazari Lake and its associated parts because of the scarcity of wetland habitats in other parts of the study area. During the rainy season, storks were recorded in all the wetlands and paddy fields, but in other seasons they were mostly observed along rivers and in the Beeshazari lake system due to lack of wetlands and paddy fields outside the forest.

The dramatic decline in wetland-dependent bird populations might be due to the scarcity of food (Inskipp and Inskipp 1991) and decrease in the number of wetlands (e.g., lakes associated with Beeshazari lake and other wetlands in the forest), because large numbers of local people are collecting fish, snails and other wetland products by hand, and by diverting the flow of water and by poisoning fish. The practice of killing fish by poisoning is common in the water system of Chitwan (Dahal 1999), but mainly confined to the Khageri canal and rivers in the study area. Such practices destroy the local habitats and directly affect species along with their food chains, including storks.

Storks are large and conspicuous; they are a favourite and easy target for bird hunters and their body parts, mainly the bills, are sold in shops in Kathmandu as medicine (Sapkota 2002). On the other hand, the disturbances of their habitat in the forest and/or in the protected areas (Baral 2005), these birds search paddy fields for food. The application of pesticides and fertilizers to the fields results in the storks being poisoned and, in the long term, a disastrous change in their gene pool and a lower reproductive success.

The wetlands of Nepal have suffered greatly from invasive alien plant species, primarily the water hyacinth *Eichhornia crassipes*, which is a native of Brazil, but has become widespread globally (Gopal 1987). This is also true for the wetlands in the study area, e.g., the Beeshazari lake and its associated lakes. The volume of water in the Shorahazar and Satrahazar lakes, which are the main lakes in the Beeshazari lake system, is very low due to the heavy organic matter produced by the dense mat of invasive plant species. In addition, the dense layer of water hyacinth prevents light penetrating into the water, and even traps diving birds (e.g., darter, kingfishers), causing a decline in their populations (Tamang 2003). Water hyacinth was first reported in Nepal in 1966 and is now widely distributed in most of the Tarai-protected areas, ranging from 75 m to 1,500 m (Tiwari et al. 2005). This species a major problem everywhere in South Asia (Gopal and Krishnamurthy 1993) and has caused more damage to Nepal's aquatic habitats than any other invasive, alien species (Inskipp and Inskipp 1991). The species has a high growth and reproductive rates and the free-floating mats have an adverse effect on wetland biodiversity. The enormous expanse of water hyacinth significantly reduced the open water area and caused a rapid decline in the number of wetland birds such as storks, darter and cormorants. The abundance of water hyacinth not only reduces the quantity of water, but also reduces the level of dissolved oxygen in the water (Gopal 1987), which might influence the dynamics of the benthic community that could negatively affect birds like storks. This invasive weed can also greatly reduce invertebrate communities as it reduces the level of dissolved oxygen in the water (Butchart 1998; Masifwa et al. 2001). Nevertheless, management of the water hyacinth is difficult, due to its extremely high growth rate and potential adverse effect on other ecosystem components (Gopal 1987).

Water hyacinth – consequence of natural eutrophication – Beeshazari Lake (Photo by BP Bhattarai)

The oxygen concentration in the water of the Beeshazari lake is very low, which affects the distribution of invertebrates, which in turn adversely affects the waterfowl and storks that feed on a wide range of invertebrates and small fish.

Agrochemicals present another threat (Pokharel 1998; Gyawali 2003) to many wetlands in Nepal. The feeding habitats of birds are being converted into agricultural land or used for the development of infrastructure. Changes in agricultural practices are taking place throughout the country. Farmers have shifted from traditionally grown crops to cash crops, such as paddy and wheat. Since storks depend on paddy fields, the change in agricultural practices might seriously affect them. Several threats, such as habitat loss, human and livestock disturbance and hunting (Shakya 1995; Pokharel 1998; BirdLife International 2001; Gyawali 2003) are the major threats for the sustainable conservation and management of storks and their habitat.

4.5 Conservation Strategy

Despite increased efforts to raise public awareness of the importance of birds and wildlife, the local people still do not understand and appreciate the value of conserving birds and wildlife. Large numbers of people are involved in the collection of bird food such as fish, snails etc., for their own use (Fig. 4.3). We need to provide them with an alternative ways of satisfying their needs. These might include establishment of fishponds outside the forest, providing biogas, agro-forestry, and some of their daily needs, such as forage for their livestock, firewood, thatch grass and traditional medicines.

The local people dependent on these wildlife habitats are low caste Chepang, Darai, Bote, Majhi, and Tharu communities. The majority of these people are illiterate and do not know anything about wildlife conservation and its importance (personal communication with people in the study area). These people are unknowingly using wildlife habitats as if part or a member of the forest ecosystem, so that their adverse effect on wildlife increases. Local people are using more and more fertilizers and pesticides to increase the production of their crops, which indirectly affects wetland-dependent birds, like storks. Others are heavily dependent on forest resources for survival, which could be addressed by income generation programs, which in turn will enhance the conservation of birds as well as the biodiversity of the region. Thus the low avifauna conservation awareness of the people living close to bird habitats is one of the most serious challenges for conservation agencies. Extensive conservation awareness programs targeted at these people are of primary importance.

4.6 Conclusions

The present study revealed that the migratory black stork is very rare, the lesser adjutant stork is rare, the woolly-necked stork is common and the Asian open bill stork is the most abundant species of the family Ciconiidae in the study area. All the diversity indices values for storks showed that the open bill stork is the most abundant species in the study area. The majority of the open bill storks were recorded around the Beeshazari lake. River banks, the Beeshazari lake and paddy fields are the most important habitats for storks in Chitwan. The major threats faced by Ciconiidae are disturbance of their habitats, food scarcity and excessive use of agrochemicals in the fields. The area and quality of the wetlands are decreasing due to eutrophication and human encroachment. Human encroachment (fishermen, hunters, large numbers of tourists), livestock pressure and collection of natural products like fish and snails from the habitat of storks needs to be reduced by means of conservation awareness programs and alternative ways of providing the daily needs of local people. Farmers should be encouraged to reduce their dependence on fertilizers and pesticides and use organic manure and biological control. Many wetlands and lakes in the Chitwan National Park and the Barandabhar corridor forest dry out during the summer. This drying out of wetlands directly affects the survival of birds, as they are then confined to protected areas since there is no water in the paddy fields. Therefore, it is necessary to pump in water into the paddy fields and other dried wetlands, in order to increase the survival rate of these wetland-dependent birds. Regular monitoring of storks is essential for their sustainable conservation.

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Chapter 5
Interactions Between the Himalayan Tahr, Livestock and Snow Leopards in the Sagarmatha National Park

Bikram Shrestha, Pavel Kindlmann, and Shant Raj Jnawali

Abstract Competition between wild ungulates and livestock for resources and interactions between these two and large predators are widely regarded as a major management issue in the Himalayas. Real data supporting these claims are scarce, but badly needed for developing good management strategies, which will effectively protect both wild ungulates and their predators in the Himalayas. Our study was done in August/September of 2006 in the Mongla and Phortse regions of the Sagarmatha National Park (SNP) with the aim of determining: (i) habitat overlap between tahr and domestic livestock, (ii) overlap in diets of tahr and domestic livestock, (iii) the effect of predators on tahr and (iv) explore the composition of vegetation in the region. Vantage points and regular monitoring from trails were used to observe the tahr and livestock. Direct observation and micro histological techniques were used to determine the overlap in diets of tahr and livestock. Diet of snow leopard was determined by scat analyses, which involved the microscopic identification of hair. There is overlap both in space and diet between tahr and livestock. Analysis of faecal samples revealed 24 species of plants in the faeces of tahr and 31 in those of livestock, of which 22 species were common to both. In total, 45 plant species were recorded at Mongla and 54 at Phortse. Two species of wild and four species of domestic mammals were identified in the scats of snow leopard, with that of Himalayan tahr being the most frequent. In terms of domestic animals, the hair of yak was most frequently

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found in the faeces of snow leopard. The results of a questionnaire revealed that the snow leopard is the main predator of domestic livestock. We conclude that there is currently no serious competition between livestock and tahr for food, the main threat now comes from the decline in plant productivity in the region due to overgrazing. This trend could seriously change the situation, as tahr and livestock would then compete for food. The most effective way of reversing this trend is to introduce measures that limit the amount of grass that is harvested for feeding livestock during winter, which is rapidly increasing.

Keywords Himalayan tahr • Snow leopard • Livestock • Prey-predator dynamics

5.1 Introduction

5.1.1 General Background

The Himalayan tahr *(Hemitragus jemlahicus*) belongs to the family Bovidae and is a migratory herbivore common at high altitudes. The Red Data Book of the Fauna of Nepal (BPP 1995) has categorized it as a species likely to become extinct, while IUCN has listed it in its category NT: near threatened. The Himalayan tahr, one of three species of tahr, is native to the Southern range of the Himalayan Mountains, including the Sagarmatha National Park (SNP) and is one of the most common species there. The other two species of tahr include the Nilgiri tahr *(Hemitragus hylocrius)* found in Southern India and Arabian tahr *(Hemitragus jayakari)* in Oman.

In our study area, the Khumbu region, which is a part of the Sagarmatha National Park (SNP), agro-pastoralism is the main occupation of the majority of people. Though tourism is emerging as an alternative source of income for people, those living in remote areas are still dependent upon traditional agriculture. Yak and its hybrids are the major livestock at high altitudes, while cows prevail at low altitudes. Domestic livestock in grazing the mountain pastures are thought to compete with wild herbivores by depleting resources and degrading the pastures (Schaller 1977; Shah 1998; Richari et al. 1992). The presence of livestock intensifies the competition between plant species and results either in the loss of species or in coexistence by partitioning of resources between species, spatially or temporally (Gause 1934; Begon et al. 1986). Buffa et al. (1998) and Shrestha (2006) note a spatial overlap in the occurrence of wildlife (tahr) and domestic animals, which is likely to lead to competition for food and habitat destruction due to overpopulation. Wildlife-livestock competition for resources is therefore widely regarded as a major management issue, particularly in the mountainous protected areas, such as the Shey Phoksundo National Park, Rara National Park, Khaptad National Park, Makalu Barun National Park, Dhorpatan Hunting Reserve, Kanchanjunga Conservation

Area and the Annapurna Conservation Area (Shrestha et al. 1990; KMTNC 1997; Richard et al. 1999; Basnet 2002).

The return of the snow leopard to the Mount Everest National Park (Ale and Boesi 2005) is likely to lead to conflicts between local people and snow leopard, if in the future this predator kills significant numbers of domestic animals. This predator may already have had a significant ecological effect on the prey-predator dynamics and community structure in the region. Shrestha (2004) and Ale and Boesi (2005) report that the kid to female ratio of the Himalayan tahr is now alarmingly low: 0.1, whereas it was about 0.6–0.8 in 1991–1992 (Lovari et al. 2006). This might be due to predation of juveniles by snow leopard, but this remains to be confirmed. As snow leopard and common leopard are potential predators of tahr, conservation of tahr results also in the conservation of pastures and large predators, which in turn play a critical role in maintaining the ecological integrity of the region. In order to preserve wildlife and improve the standard of living of local people, it is crucial that managers understand the interactions between humans and wildlife. Therefore, it is extremely important to develop a proper conservation strategy for the tahr in the SNP. However, neither this problem, nor the tahr-livestock prey-predator relationships in this area have been studied systematically and it is unknown, whether the grass cover in the area is sufficient to support both tahr and livestock.

5.1.2 Study Objectives

The overall aim of this study was to investigate: (1) interactions between Himalayan tahr and livestock, (2) effect of predators on both these ungulates and (3) the composition of the vegetation of alpine pastures in tahr habitats in the Sagarmatha National Park.

The specific objectives were to:

1. investigate the habitat overlap between tahr and livestock by comparing their use of this habitat in terms of altitude, aspect, slope, percentage vegetation and terrain type;
2. determine the differences in the diet of tahr and livestock and relative proportions of the different food plants in their diets;
3. determine the effect of predators on tahr and livestock – for this the percentage of scats containing hair of particular items of prey (Himalayan tahr and livestock) was determined and the loss of both tahr and livestock due to predators estimated;
4. explore diversity, productivity and vegetation cover of alpine pastures/meadows in tahr habitats;
5. determine conservation implications for tahr, pasturelands, main predators of tahr and the associated high-altitude ecosystems.

5.2 Study Area

Sagarmatha National Park (SNP, 27°45′-28°07′ N, 86°28′-87°07′ E) is in the Solo Khumbu district (Fig. 5.1) in the north-eastern region of Nepal. This National Park was founded in July 1976 and included on the World Heritage List in 1979. It has an area of 1,148 km^2. The park encompasses the upper catchments of the Dudh Kosi river system, which is fan-shaped and forms a distinct geographical unit surrounded by high mountain ranges. The northern boundary is defined by the main divide of the Great Himalayan Range, which follows the international border with the Tibetan Autonomous Region of China. In the south, the boundary extends almost as far as Monjo on the Dudh Koshi. The natural environment of the SNP is strictly protected. It hosts 28 species of mammals, 199 species of birds, 6 species of amphibians and 7 species of reptiles. The weather is usually sunny in autumn, October and November, but in winter the weather is cold with frequent falls of snow. The local people, the Sherpas, having originated from Salmo Gang in the eastern Tibetan province of Kham, some 2,000 km apart from their present homeland, are of great cultural interest. There were approximately 3,500 Sherpas in 63 settlements, mainly located in

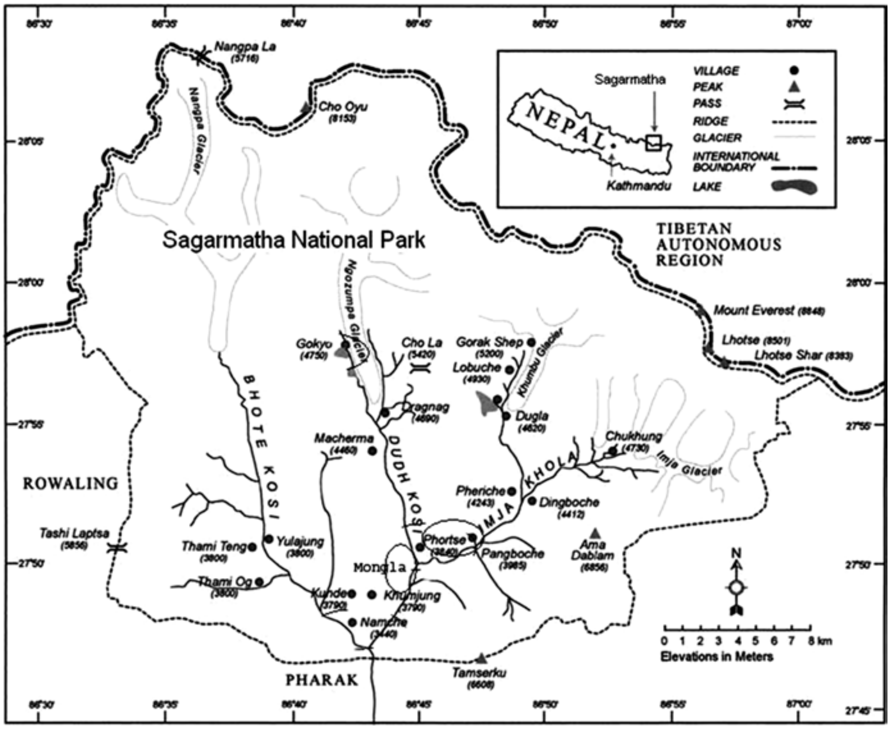

Fig. 5.1 The Sagarmatha National Park

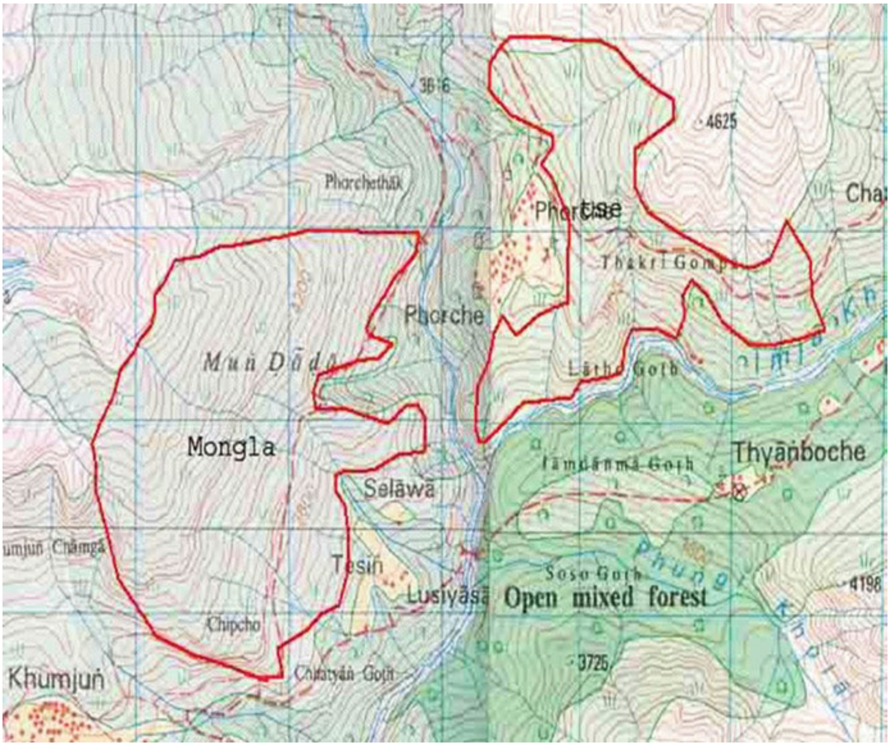

Fig. 5.2 The location of the two study areas at Mongla and Phortse

southern part of the park, in 1997. The study area is located in the Mongla and Phortse rangelands in the Sagarmatha National Park (Fig. 5.2).

5.3 Materials and Methods

5.3.1 General Field Methods

This study was done in August-September 2006. The areas selected were based on the distribution of tahr, which was identified in a previous study carried out in 2004 (Shrestha 2006).

Vantage points and regular monitoring from trails (Jackson and Hunter 1996) were the main methods used to record the numbers of tahr and livestock. Opportunistic observations of tahr and livestock made during the vegetation survey provided additional data to those recorded in the fixed-point counts.

Once animals (tahr or livestock) were located, the area was searched and animals identified using a 7×35 telescope. Each observation was treated as one group or sighting, irrespective of the number of individuals seen. For each sighting, the following information was noted for an area with a radius of approximately 30 m centered on the point of the highest aggregation of animals:

1. date and time of observation;
2. species of animal: tahr, yak hybrid (yak, nak, cow, dzom, zopkyo or ox);
3. group size and type (group types identified were: all males, females with young or mixed groups);
4. sex and classification of tahr: female (adult female and yearling), male (class I, class II and class III) and kid, following Schaller (1977);
5. slope;
6. aspect;
7. terrain type;
8. vegetation type;
9. distance to ridgeline;
10. distance to cliff;
11. GPS location of the point on the trail from where animals were sighted (wherever possible) and any other remarks.

5.3.2 Habitat Overlap Between Tahr and Livestock

Habitat overlap between tahr and livestock was investigated by comparing the habitats, in which these animals were observed, in terms of altitude, aspect, slope, percentage vegetation cover and terrain. The altitude, aspect and slope were measured using GPS and a Brunton Compass meter. The vegetation categories were grassland, rocks covered by vegetation and scrub. Similarly, the terrain was categorized on the basis of ground surface morphology as smooth, rugged or very rugged. A flat terrain with isolated undulating or small rocks was classified as smooth. Distinctly undulating or rugged surface, including ravines and gullies with some large rocks was classified as rugged. The presence of droppings was used to estimate the degree of spatial overlap.

5.3.3 Dietary Overlap of Tahr and Livestock

5.3.3.1 Direct Observation

This was done in tahr areas using binoculars during the active feeding periods between 7–12 a.m. and 3–5 p.m. Signs of plants having been recently eaten, such as exudation of sap, crushed tissue, fresh clippings etc. were recorded. A herbarium sheet for each plant species was prepared and taken to the Central Department of

Environmental Science, Tribhuvan University, Kathmandu and The National Herbarium, Godabari Centre, Kathmandu, for determination.

5.3.3.2 Micro Histological Analyses

A microscopic analysis of the indigestible plant fragments in dung, mainly epidermal parts, which are characteristic of different plant groups (Metcalfe 1960), was used to identify the plants eaten by the ungulates. This method is commonly used for studying diets of ungulates, as it is simple, effective and accurate (Baumgartner and Martin 1939; Anthony and Smith 1974; Dearden et al. 1975; Holechek et al. 1982). It has one limitation: the amount forage consumed cannot be quantified.

5.3.3.3 Faecal Analysis

Samples of faeces of tahr were collected from feeding sites in different habitats. They were kept in paper bags and each day's collection was labeled and air-dried separately for a minimum of 72 h. After drying, individual faecal samples collected on the same day were mixed thoroughly and packed in airtight polythene bags. Later on, the samples were transported to the laboratory of the Department of Environmental Sciences, Tribhuvan University, for further analyses.

Simultaneously, different plant species were collected and used to prepare reference slides for different tahr habitats. Slides were prepared following the method used by Vavra and Holechek (1980) and Jnawali (1995), and used by Fjellstad and Steinheim (1996) and Chetri (1999). The dried plant samples were separately ground to a small size in an electric blender. The resultant powder was sieved through two sieves (1 and 0.3 mm mesh size) placed one above the other. The material that did not pass through the 0.3 mm sieve was used to prepare slides. A teaspoonful of each of the final samples was treated with warm 10% NaOH solution in a test-tube and heated in a boiling water-bath for 4–6 min. The particles were allowed to settle in a cold water-bath before the supernatant dark fluid was removed. This procedure was repeated until a relatively clear supernatant solution was obtained. Then, the material was washed 3–5 times with warm distilled water and dehydrated using 25%, 50%, 75%, 90% and then 100% alcohol. The alcohol-treated samples were finally treated using a series of solutions of xylene and alcohol in which xylene gradually replaced the alcohol. A small amount of material was dried between tissue paper and mounted in DPX under a 24×50 mm cover slip. The slide was air dried for 5–6 days.

The slides of faecal samples were prepared in the same way as the reference slides, except that 10% NaOH solution was replaced by a 5% NaOH solution, before which the faecal samples were lightly washed with warm distilled water to remove soil. A total of five slides were made of each composite faecal sample, and labeled.

The reference slides were studied as recommended by Holechek and Gross (1982). A diagnostic key for each plant species was prepared using free hand sketches and any distinct character of the plant fragments in the faeces was noted and photographed and compared with the histological features of the plant material on the reference slides. The features include cell wall structure, shape and size of cells, hairs and trichomes, shape and size of stomata and inner-stomatal cells, fiber structure and arrangements of veins.

A compound microscope with 100× magnification lens and an ocular measuring scale was used to observe and measure the plant fragments on the slides of faecal material. On each slide, ten fragments were identified in at least one transect of the slide using the identification key and photographs of the epidermis of the reference material. Only fragments recognized as epidermal tissue and consisting of at least four plant cells or with visible stomata were recorded. In total, 200 fragments from faecal samples of both livestock and tahr were identified.

5.3.3.4 Statistical Analysis

To evaluate the niche breadth of plant species in the diet of each species, Levin's measure of niche breadth (B) was calculated using the following formula cited in Krebs (1999):

$$B = \frac{1}{\sum_{i=1}^{n} P_i^2},$$

in which P_i is the percentage of total samples belonging to species i ($i = 1, 2, \ldots, n$) and n is the total number of species in all samples. The value of B increases with increasing number of species in the diet. A low value indicates that a species is selective and eats only a few plant species.

In order to estimate dietary overlap between two species, the Simplified Morisita's index (C_H) was calculated using:

$$C_H = \frac{2\sum_{i=1}^{n} P_{ij} P_{ik}}{\sum_{i=1}^{n} P_{ij}{}^2 + \sum_{i=1}^{n} P_{ik}{}^2},$$

where P_{ij} and P_{ik} are the proportions of the resource used by the two species, j and k. The degree of overlap varies from zero to one; zero indicates no overlap and one complete overlap.

The Relative Importance Value (RIV) for each plant species in a faecal sample was calculated using the method described by Jnawali (1995):

$$RIV_i = D_i\sqrt{f_i},$$

where RIV_i is the relative importance value for species *i*, D_i is the mean percentage of species *i* in the sample an f_i is the frequency of species in the sample.

5.3.4 Floristic Composition

5.3.4.1 Sampling

A detailed vegetation analysis of the floristic composition of the study area was done based on a set of "modules", which are cross sections across the valley, centered on the valley floor and including the entire altitudinal range on either side. There were three "modules" for each rangeland (Mongla and Phortse), evenly spaced at intervals of 3 km throughout the expected range of the tahr in this region. At each of these "modules", six transects were established following the altitudinal contour, each of which was 100 m long. These transects were located at a range of altitudes, with 100–150 m separating them. Sites in the valley, which were covered by bushes and shrubs, were excluded, since tahr spend most of the time feeding in open areas (Schaler 1973). Along these transects, 1 × 1 m quadrats were placed 20 m apart. The plant cover in each quadrat and the use by livestock of the area in the vicinity of each quadrat were determined. The percentage cover of individual plant species, percentage of bare soil and rock in each quadrat were estimated visually following Smart et al. (1976). A sub-plot of 25 × 25 cm was randomly selected in each quadrat and all the vegetation in this sub-plot was removed and weighed. The fresh weight of the grass was then used to estimate wet biomass per unit area of pasture. Species area curves were plotted to calculate the minimum number of squares required for determining the floristic composition of the study area (Jnawali 1995), which was found to be 18.

5.3.4.2 Statistical Analysis

Simpson's Index of Diversity (Krebs 1994) was used to measure floral diversity:

$$D = 1 - \sum_{i=1}^{S} P_i^2$$

where *D* is Simpson's index of diversity, P_i the proportion of individuals of species *i* in the community and *S* the number of species in the community. Simpson's diversity index ranges from 0 (low diversity) to a maximum of (1 – 1/*S*).

Sørenson's index of similarity (ISs, Krebs 1994) was used to compare similarity of plant species in two habitats, A and B:

$$ISs = \frac{2C}{A+B} \times 100,$$

where C is the number of species common to both habitats, A the total number of species in habitat A and B the total number in habitat B.

Vegetation analysis – the following values were calculated:

Frequency of species A: $$f_A = \frac{\text{Number of quadrats in which species A occurred}}{\text{Total number of quadrats}} \times 100$$

Relative frequency of species A: $$RF_A = \frac{f_A}{\sum_{i=1}^{S} f_i} \times 100$$

Density of species A: $$D_A = \frac{\text{Number of individuals of species A in all quadrats}}{\text{Total number of quadrats} \times \text{Size of quadrat}}$$

Relative density of species A: $$RD_A = \frac{\text{Number of individuals of species A}}{\text{Total number of individuals of all species}}$$

Abundance of species A: $$A_A = \frac{\text{Total number of individuals of species A}}{\text{Number of quadrats, where species A occurred}}$$

Relative abundance of species A: $$RA_A = A_A \times 100$$

Importance Value Index: $$IVI_A = RF_A + RD_A + RA_A$$

Frequency classes: based on the prominence value, PV, species were assigned to one of five frequency classes (Sharma 2002) as follows:

PV	Frequency class
<1	very rare
1–5	rare
5–25	common
25–75	abundant
> 75	very abundant

5.3.5 Productivity and Forage Availability

The percentage cover of individual species in each quadrat was estimated visually following Smart et al. (1976). Prominence values, PV, were calculated and used to quantify the abundance of species at both of the rangelands following the method of Dinerstein (1979):

$$PV_A = M_A\sqrt{f_A},$$

where PV_A is the prominence value for species A, M_A is the mean percentage cover of species A and f_A is described above. Then the abundance of each species was categorized as very rare ($PV_A \leq 1$), rare ($1 < PV_A \leq 5$), common ($5 < PV_A \leq 40$) or abundant ($PV_A > 40$).

5.3.6 Effect of Predators on Himalayan Tahr and Livestock

In order to estimate the effect of predators on Himalayan tahr and livestock, the presence and identification of tahr or livestock hair in predator scat was determined by examining the scat under a microscope. Economic loss of livestock to predators was also estimated.

5.3.6.1 Microscopical Identification of Hair

The hairs in predator scats were used to determine the diet of the predators. The analysis of scat samples required a reference collection of hair samples, an identification key and slides of hair from scat.

Twenty scats of snow leopard were collected from the study area. The scats were identified on the basis of their size and associated signs, such as scrapes and pugmarks. The samples of scat were sun-dried, labelled and stored in polythene bags for laboratory analysis.

Each sample was first examined macroscopically and the colour and texture recorded. The sample was then put into 30% hydrogen peroxide overnight prior to microscopic examination. Each bleached sample was observed under a microscope at 400× magnification. The sample was then wet mounted in D.P.X. and the cortex and medulla of the hairs and the details recorded. The micrometer measurement of both the cortex and medulla were recorded at ten intervals along the shaft of each hair. These measurements were then converted to millimetres and the mean calculated. Similarly, the average diameter of the medulla was determined. In addition, medullar indices and their averages were calculated. The above calculations were made only for medullated hair. The medullary Index (MI) was calculated using the formula

$$MI = \frac{\text{Width of medulla}}{\text{Width of cortex}}.$$

A tuft of hairs was inserted into a straw and then molten wax was sucked into the straw. Once the wax solidified, the straw was cut open, the wax core and embedded hair removed and cross sections obtained by transversally cutting it with a razor blade. The sections were treated with xylene to remove the wax and viewed under a microscope.

The characteristics of the cuticular scales along the shaft of each hair from the root to the tip were noted. A thin layer of nitrocellulose lacquer (white nail polish) was applied to the surface of microscope slides and the hair samples placed horizontally on them. As the lacquer dried an impression of the surface of each hair formed, then the hair was peeled off and the impression viewed under a microscope.

Microphotographs of representative cross sections, medulla and scale patterns along the length of the hairs of each species were taken at a standard magnification. Compared to direct comparison and using the dichotomous key, reference to photographs proved more convenient and easier for the routine identification of hair. Therefore, a photographic reference key and microscopic examination of cuticular scales and the medullary type, thickness of cortex and medulla, medullary index etc., which are diagnostic tools for identifying species, were used in this study. Descriptions of the hair in the key includes only the maximum diameter of the primary guard hair and the most diagnostic features of the hair of each species. The key includes the eight wild and five domestic mammals found in the study area (not presented here).

Each scat was soaked overnight in liquid dettol mixed with water and then washed carefully over a sieve with a mesh width of 1 mm. Remains, like bones, teeth, hooves, hair and feathers were removed, air dried and stored. Microscope slide preparations of the hair in every scat were used to identify the species of prey by using the key and the microphotographs of the hair of potential prey as was done in preparing the key.

5.3.6.2 Statistical Analysis

The scat contents are presented here as "frequency of occurrence" (number of scats containing the hair of a particular species of prey) and "percentage frequency of occurrence" (% of scats containing the hair of a particular species of prey).

5.3.7 Depredation of Livestock

The questionnaires completed by the local herders at Phortse and the results of the group discussions gave an indication of the economic loss due to the depredation of livestock by snow and common leopards.

5.4 Results

5.4.1 Abundance of Himalayan Tahr

During the observations at the Mongla and Phortse pasturelands there were a total of 25 sightings of Himalayan tahr, which in total was 319 animals with an estimated total population of about 125, whereas there were a total of 113 individuals in the 15 sightings of livestock (Tables 5.1 and 5.2). The male to female ratio was 0.72, kid to female ratio 0.46 and yearling to kid ratio 0.65. Mean group size was 12.76 (range 1–38, standard deviation 10.65).

5.4.2 Composition and Numbers of Livestock

The 113 individuals of livestock included yak, jopkyo, cow, ox and calf. Yak made up 56% of the livestock in the study area, followed by jopkyo, cow, ox and calf (Table 5.2).

Table 5.1 Structure of the tahr population based on absolute numbers and all the animals seen at Mongla and Phortse in the summer of 2006 (n = 25)

	Mongla				Phortse			
	Known number		All animals tallied		Known number		All animals tallied	
Himalayan tahr	No.	%	No.	%	No.	%	No.	%
Female	14	42	70	45	36	39	73	44
Yearling	5	18	32	21	10	11	21	13
Kid	5	15	22	14	18	19	32	19
Total yearlings and kids	***11***	***33***	***55***	***35***	***29***	***30***	***53***	***32***
Male I	2	6	6	4	10	11	13	8
Male II	3	9	19	12	5	5	7	4
Male III	3	9	6	4	13	15	18	11
Total males	***8***	***24***	***31***	***20***	***28***	***30***	***38***	***23***
Total	**33**	**100**	**155**	**100**	**92**	**100**	**164**	**100**

Table 5.2 Numbers of the different kinds and percentage composition of the livestock observed at Mongla and Phortse in the summer of 2006

Livestock	No.	%
Yak	63	56
Jopkyo	33	30
Cow	8	7
Ox	5	4
Calf	4	3
Total	113	100

Table 5.3 Habitat preferences (frequency) of Himalayan tahr and livestock at Mongla and Phortse, in summer 2006

Habitat variable and category	Himalayan tahr, % (n = 25)	Livestock, % (n = 15)	Habitat variable and category	Himalayan tahr, % (n = 25)	Livestock % (n = 15)
Habitat type			Slope		
Barren	0	0	0°–30°	8	**33**
Grassland	**96**	**100**	31°–60°	**76**	**67**
Shrubland	4	0	61°–90°	**16**	0
Forest	0	0			
Terrain type			Aspect		
Cliff	0	0	East (69°–113°)	0	0
Very rugged	**36**	0	Southeast (204°–248°)	28	20
Rugged	**36**	**47**	South (159°–203°)	**52**	**73**
Rolling	28	**53**	Southwest (114°–158°)	20	7
Flat	0	0	West (249°–293°)	0	0
Altitude (m)			Distance to escape terrain (m)		
3,601–3,800	**24**	0	0	8	0
3,801–4,000	**44**	27	1–50	**32**	0
4,001–4,200	20	**66**	51–100	**48**	13
4,201–4,400	8	7	101–150	0	7
4,401–4,600	4	0	> 150	12	**80**
Position on slope			Nearest water source (m)		
Low	**40**	0	<200	**68**	7
Middle	**40**	**87**	201–400	4	0
Upper	20	13	> 400	28	**93**

Preferred habitats are in bold

5.4.3 Preferred Habitat of Himalayan Tahr and Livestock

Grassland was the preferred habitat of both tahr (96% of cases) and livestock (100% of cases). Tahr preferred very rugged (36%) and rugged (36%) slopes, whereas livestock preferred rolling (53%) and rugged slopes (47%). Tahr equally preferred the lower and middle slopes (40%), while livestock preferred the middle slopes (87%). Tahr preferred to graze at altitudes between 3,600 and 4,200 m and livestock between 4,000 and 4,200 m. Tahr preferred mostly southern aspects (52%) as did the livestock (73%). Both tahr and livestock preferred 31–60° slopes (76% and 67% respectively). Tahr was also found on slopes greater than 61°, which were avoided by livestock. Livestock was found on gentle slopes (0–30°) more frequently than tahr. Livestock was found in areas more than 150 m from escape terrain, whereas tahr occurred in areas less than 100 m from escape terrain (Table 5.3).

Droppings of both these ungulates were found in 45% of the squares at Phortse and 33% of those at Mongla, and there were no droppings of either ungulate in 5% of the squares in Phortse and 17% at Mongla. There were droppings in the remaining 50% (in both regions) of either tahr or livestock, but not of both.

5.4.4 Diet Composition

5.4.4.1 Diet of Himalayan Tahr

Of the 24 species of plant in the droppings of tahr, 53% were grasses and sedges belonging to 6 taxa: *Carex anomoea*, *Avena* sp., *Poa* sp., *Trisetum spicatum*, Cyperaceae sp. and *Imperata* sp. They were followed by *Gueldenstaedtia himalaica* and *Potentilla* sp., whereas *Pedicularis siphonantha*, *Persicaria capitata*, *Androsace sarmentosa*, *Trachyspermum ammi*, *Habenaria aitchisonii* and *Ephedra gerardiana* made up only a small fraction of the diet (Table 5.4). Niche breadth of tahr was $B=0.0137$.

In the diet of tahr, the highest RIV was for *Avena* sp. followed by *Carex anomoea*, *Poa* sp., *Gueldenstaedtia himalaica*, *Trisetum spicatum*, Cyperaceae sp. and *Potentilla* sp. Remaining species had very low RIVs (Table 5.4).

5.4.4.2 Diet of Livestock

Of the 31 plant species found in the droppings of livestock, 38.5% were grasses and sedges belonging to 6 taxa: *Avena* sp., *Carex anomoea*, *Trisetum spicatum*, Cyperaceae sp., *Poa* sp., and *Imperata* sp. They were followed by *Cotoneaster microphyllus*, *Potentilla* sp., *Bistorta affinis*, *Gueldenstaedtia himalaica*, *Polygonatum hookeri*, *Saxifraga brachypoda*, *Anaphalis contorta*, *Rhododendron lepidotum*, whereas *Anaphalis triplinervis*, *Fragaria daltoniana* and *Gentiana* sp. made up only a small fraction of the diet (Table 5.5). Niche breadth of livestock was $B=0.0175$.

In the diet of livestock, the highest RIV was for *Avena* sp. followed by *Carex anomoea* and *Cotoneaster microphyllus*. Among the species with low RIVs were *Gentiana sp.*, *Habenaria aitchisonii* and *Androsace sarmentosa* (Table 5.5).

5.4.5 Dietary Overlap Between Tahr and Livestock

Remnants of 22 species of common plants were found in tahr and livestock droppings (Tables 5.4 and 5.5). *Morina nepalensis* and *Ephedra gerardiana* were found only in tahr droppings, while *Gentiana* sp., *Gerbera gossypina, Notholirion macrophyllum, Parnassia nubicola, Polygonatum hookeri, Polygonum* sp., *Saxifraga parnassifolia,*

Table 5.4 Species of plants found in the droppings of tahr, their relative percentage and relative importance value (RIV)

Species name	%	RIV
Graminoids	**28.0**	**146.1**
Avena sp.	19.0	117.1
Imperata sp	2.5	5.6
Poa sp.	6.5	23.4
Sedges	**25.0**	**109.2**
Carex anomoea	13.5	70.1
Cyperaceae *sp.*	5.5	18.2
Trisetum spicatum	6.0	20.8
Herbaceous plants and shrubs	**47.0**	**120.6**
Anaphalis contorta	2.5	5.6
Anaphalis triplinervis	1.5	2.6
Androsace sarmentosa	1.5	2.7
Bistorta affinis	3.5	9.3
Cotoneaster microphyllus	4.5	13.5
Cyananthus hookeri	2.5	5.6
Cypripedium himalaicum	1.0	2.6
Ephedra gerardiana	1.0	1.4
Fragaria daltoniana	2.5	5.6
Gueldenstaedtia himalaica	6.0	20.8
Habenaria aitchisonii	1.0	1.4
Morina nepalensis	3.0	7.3
Pedicularis siphonantha	1.5	2.6
Persicaria capitata	1.5	2.6
Potentilla sp.	5.5	18.2
Rhododendron lepidotum	3.5	9.3
Satyrium nepalense	2.0	4.0
Saxifraga brachypoda	2.5	5.6

Salvia hians and *Sedum* sp. were found only the droppings of livestock. The Morisita index of niche overlap between livestock and tahr was high: $C_H=0.83$.

5.4.6 Floristic Composition and Vegetation Analysis

5.4.6.1 Rangeland at Mongla

At Mongla, 71.48% of the ground is covered by vegetation, the remaining 18.29% by bare soil and rock (10.23%). Vegetation consists of 45 species. The strongly dominant taxon (taxon with the largest *f*-value) at Mongla was the sedge (grass) *Avena* sp., followed by *Cotoneaster microphyllus*, *Rhododendron lepidotum* and *Carex anomoea* – Annex 5.1. The Simpson's diversity index for Mongla is $D=0.941$.

Table 5.5 Species of plants found in the droppings of livestock, their relative percentage and relative importance value (RIV)

Species name	%	RIV
Graminoids	**18.5**	**84.7**
Avena sp.	14.0	74.1
Imperata sp.	1.0	1.4
Poa sp.	3.5	9.3
Sedges	**20.0**	**74.3**
Carex anomoea	8.5	35.0
Cyperaceae sp.	5.0	15.8
Trisetum spicatum	6.5	23.4
Herbs and shrubs	**61.5**	**161.3**
Anaphalis contorta	3.0	7.3
Anaphalis triplinervis	2.5	5.6
Androsace sarmentosa	0.5	0.5
Bistorta affinis	4.0	11.3
Cotoneaster microphyllus	8.0	32.0
Cyananthus hookeri	1.5	2.6
Cypripedium himalaicum	2.0	4.0
Fragaria daltoniana	1.0	1.4
Gentiana sp.	0.5	0.5
Gerbera gossypina	1.0	1.4
Gueldenstaedtia himalaica	3.5	9.3
Habenaria aitchisonii	0.5	0.5
Notholirion macrophyllum	1.5	2.6
Parnassia nubicola	3.0	7.3
Pedicularis siphonantha	1.5	2.6
Persicaria capitata	1.0	1.4
Polygonatum hookeri	3.5	9.3
Polygonum sp.	2.5	5.6
Potentilla sp.	6.5	23.4
Rhododendron lepidotum	3.0	7.3
Salvia hians	1.0	1.4
Satyrium nepalense	2.0	4.0
Saxifraga brachypoda	3.5	9.3
Saxifraga parnassifolia	3.4	9.3
Sedum sp.	1.0	1.4

5.4.6.2 Rangeland at Phortse

At Phortse, 81.64% of the ground is covered by vegetation, 14.56% by bare soil and 3.8% by rock. Vegetation consists of 54 species. The dominant species (taxon with the largest *f*-value) at Phortse is *Carex anomoea*, followed by *Avena* sp., *Gerbera gossypina* and *Pedicularis siphonantha* – Annex 5.2. The Simpson's diversity index for Phortse is $D = 0.937$.

5.4.6.3 Sørenson's Index of Similarity (ISs)

The Sørenson's index of similarity (ISs) for Mongla and Phorte is *ISs* = 0.83 (83%), which indicates that the species at these two study sites are similar.

5.4.7 Productivity and Availability of Forage

The productivity of both rangelands was very similar: 2,643 kg/ha (wet weight) and 2,276 kg/ha (wet weight) at Mongla and Phortse, respectively.

Based on the prominence value, at Monga, 4 species were found in the droppings of tahr and livestock that are very abundant or abundant (*Avena* sp., *Carex anomoea*, *Cotoneaster microphyllus* and *Rhododendron lepidotum*), 12 species that are common (*Anaphalis contorta*, *Androsace sarmentosa*, *Cyananthus hookeri*, *Fragaria daltoniana*, *Gerbera gossypina*, *Habenaria aitchisonii*, *Notholirion macrophyllum*, *Persicaria capitata*, *Potentilla* sp., *Satyrium nepalense*, *Saxifraga brachypoda* and *Saxifraga parnassifolia*), 9 that are rare (*Bistorta affinis*, *Gueldenstaedtia himalaica*, *Imperata* sp., *Cyperaceae* sp., *Poa* sp., *Polygonatum hookeri*, *Salvia hians*, *Sedum* sp. and *Trachyspermum ammi*) and 6 that are very rare (*Anaphalis triplinervis*, *Parnassia nubicola, Pedicularis siphonantha* and *Trisetum spicatum*) – Table 5.6.

At Phortse, 4 species found in droppings of tahr and livestock are abundant (*Avena sp. Carex anomoea*, *Polygonatum hookeri* and *Rhododendron lepidotum*), 15 are common (*Bistorta affinis*, *Cotoneaster microphyllus*, *Cyananthus hookeri*, *Fragaria daltoniana*, *Gentiana* sp., *Gerbera gossypina*, *Gueldenstaedtia himalaica*, *Imperata* sp., *Notholirion macrophyllum*, *Parnassia nubicola*, *Pedicularis siphonantha*, *Persicaria capitata*, *Polygonum* sp. and *Potentilla* sp.), 7 are rare (*Anaphalis contorta*, *Habenaria aitchisonii*, Cyperaceae sp., *Poa* sp., *Saxifraga brachypoda*, *Saxifraga parnassifolia* and *Trachyspermum ammi*), and 3 are very rare (*Salvia hians*, *Satyrium nepalense* and *Sedum* sp.) – Table 5.6.

5.4.8 Effect of Predators on Tahr and Livestock

In total, 20 scats were analyzed. The prey consumed included two species of wild and four species of domestic mammals. The most frequent prey of snow leopard is Himalayan tahr, which was detected in 55% of the scats, followed by yak (25%), cow (20%), musk deer (20%), dog (10%) and horse (10%) (Table 5.7). Wild species were present in 75% and domestic species in 65% of scats.

The results of the questionnaire indicate that snow leopard is the main predator of domestic livestock. Between January 2005 and September 2006, snow leopard killed 16 animals belonging to 8 farming families (Table 5.8).

Table 5.6 Prominence Value (PV) of the species most frequently eaten by tahr and livestock at Mongla and Phortse

		Species prominence Value (PV)	
Sp. No.	Species name	Mongla	Phortse
1.	*Anaphalis contorta*	6.9	1.3
2.	*Anaphalis triplinervis*	0.7	–
3.	*Androsace sarmentosa*	5.8	–
4.	*Avena* sp.	84.9	58.2
5.	*Bistorta affinis*	3.2	7.1
6.	*Carex anomoea*	44.1	67.7
7.	*Cotoneaster microphyllus*	102.6	21.9
8.	*Cyananthus hookeri*	11.1	17.1
9.	*Fragaria daltoniana*	7.8	8.2
10.	*Gentiana* sp.	–	10.3
11.	*Gerbera gossypina*	10.1	11.9
12.	*Gueldenstaedtia himalaica*	4.3	6.3
13.	*Habenaria aitchisonii*	5.7	1.2
14.	*Imperata* sp.	1.9	6.0
15.	Cyperaceae sp.	1.2	5.0
16.	*Notholirion macrophyllum*	9.3	10.3
17.	*Parnassia nubicola*	0.8	18.7
18.	*Pedicularis siphonantha*	0.7	8.2
19.	*Persicaria capitata*	17.1	16.4
20.	*Poa* sp.	1.3	0.8
21.	*Polygonatum hookeri*	4.3	40.6
22.	*Polygonum* sp.	–	8.6
23.	*Potentilla* sp.	10.8	11.6
24.	*Rhododendron lepidotum*	55.7	63.6
25.	*Salvia hians*	2.1	0.3
26.	*Satyrium nepalense*	8.8	0.1
27.	*Saxifraga brachypoda*	9.7	2.0
28.	*Saxifraga parnassifolia*	5.6	2.5
29.	*Sedum* sp.	2.1	0.4
30.	*Trachyspermum ammi*	1.6	1.5
31.	*Trisetum spicatum*	0.2	–

Table 5.7 Absolute and relative frequencies of occurrence of prey items in the diet of snow leopard (n = 20)

Prey species	Frequency of occurrence	% Frequency of occurrence
Himalayan tahr	11	55
Yak	5	25
Musk deer	4	20
Cow	4	20
Dog	2	10
Horse	2	10

Table 5.8 Percentage composition of the six types of livestock killed by snow leopard at Phortse during 2005–2006

Livestock type	% killed by snow leopard (N = 16)
Yak	43.7
Nak	12.5
Jom	0.0
Jopkyo	0.0
Cow	31.2
Ox	12.5

5.5 Discussion

5.5.1 Status and Population of Himalayan Tahr and Livestock

Based on these results it is estimated that 125 tahr inhabit the rangelands at Mongla and Phortse. Lovari (1992) estimated that there were 300 tahr in 1989 present in the SNP at Namche, which includes the Mongla and Phortse valleys. He also estimated there were 27 individuals/km^2 in the area between Phortse and Pangboche. Shrestha (2006) surveyed tahr in 2004 and records 205 Himalayan tahr in the Namche (including Mongla), Phorche and Thame valleys of the SNP. In October-November 2004 there were 104 tahr in Gokyo, Phortse and Namche (including Mongla), and 3.2 and 5.1 individuals/km^2 in Phortse and Namche valleys, respectively, and in August-November 2005, 277 tahr in Gokyo, Phortse, Namche and Thame valleys and the number of individuals/km^2 of tahr ranged from cca. one in the Gokyo to as many as seven in the Namche valley (Ale 2006). Based on these data, it is likely that the population of tahr is smaller than was recorded in 1989 by Lovari (1992). The ratio of kid to female recorded in this study was 0.46, which is similar to that recorded by Ale (2006). For both pasturelands, the low kid-to-female ratio is consistent with what has been regularly reported for the area since 1992 (Lovari 1992, Sandro Lovari, personal communication). In contrast, Schaler (1973) reports a kid-to-female ratio of 0.56 in Kang Chu, eastern Nepal, where tahr is hunted, and 0.57 in the Annapurna region of western Nepal, an area where there are no large predators of tahr (Gurung 1995). The low kid-to-female ratio in Sagarmatha may be due to predation or disease. Snow leopard has recently re-colonized the Everest region. In order to determine, whether predation by snow leopards is responsible for the low kid to female ratio of Himalayan tahr in Sagarmatha, the diet of snow leopards there is currently being studied.

During this study only a small number of livestock (113 individuals) grazed the pastures at Mongla and Phortse, compared to the 3169 at Namche and Khumjung VDC (VDC is an administrative region in Nepal) in the Sagarmatha National Park in 2003 (DNPWC/TRPAP 2006). This may be because yaks and naks are moved to high pastures in spring and during the monsoon months, and returned to settlements at lower altitudes in summer and winter, and this study was done during the summer season.

5.5.2 Habitat Selection by Himalayan Tahr and Livestock

Himalayan tahr and livestock prefer to occupy similar habitats, with similar aspects and to some extent slopes (Table 5.3). Both tahr and livestock were found in rugged areas at middle altitudes with a southern aspect and slopes of 31°–60°. Tahr, however, can be found in more rugged and very steep areas at low altitudes and livestock in rolling, flat areas at high altitudes. Livestock is regularly observed feeding in areas more than 150 m from escape terrain, whereas tahr is almost consistently seen only in areas less than 100 m from escape terrain. A similar overlap in habitat is recorded for ibex and livestock in other trans-Himalayan protected areas, with ibex changing its grazing habitats during the season, which reduces competition.

5.5.3 Food of Himalayan Tahr and Livestock

In terms of species composition, the diets of livestock and tahr are similar, but not in the relative proportions of individual species. The proportion of woody plants (*Rhododendron* and *Cotoneaster*) was higher, and that of grasses and sedges lower in the diet of livestock than in that of tahr. This may be because livestock graze in the vicinity of villages, where other species of plants are scarce due to harvesting or overgrazing.

Parkes and Thompson (1995) found grass in the rumens of 48–65% of 253 tahr shot in the Southern Alps, particularly snow tussocks; they claim that tahr more often includes herbaceous than woody plants in its diet. In this study, the percentage of woody plants, like *Cotoneaster microphyllus* and *Rhododendron lepidotum,* was higher in the tahr's diet, but nevertheless they still eat more soft and herbaceous plants, compared to livestock, which often eat woody plants like *C. microphyllus* and *R. lepidotum*. According to Forsyth and Tustin (2001) males of tahr prefer herbaceous and woody plants to grasses and sedges in the period when the males and females are segregated. This study was also done during this period (July-August) and tahr grazed more on woody plants than is reported by Forsyth and Tustin (2001). The percentage of woody plants may, however, be overestimated, as they are difficult to digest and therefore more likely to be found in the faeces.

In this study, the tahr's diet consisted of 47% herbaceous plants and shrubs, 28% grasses and 25% sedges, which is similar to the yearly averages reported by Green (1979) for tahr in the Langtang valley (38% herbaceous plants and shrubs, 34% grasses, 21% sedges, 4% ferns and 4% mosses). According to Green (1979), however, there are seasonal differences in these percentages, e.g., in winter tahr supplements its diet with small amounts of mosses and ferns, presumably because other food is less readily available. The previous results differ from those of Parkes and Thompson (1995) who record that their diet is made up of 16.3% herbaceous plants, 55.7% grasses, 26.6% woody plants and 1.1% ferns.

5.5.4 Palatability

Herbivore diet depends not only on the abundance of vegetation, but also on the palatability of individual species. There are conflicting opinions about plant palatability in the literature. Species like *Rhododendron, Cotoneaster, Anaphalis contorta, Carex* sp. and *Bistorta affinis* are often considered to be unpalatable (Bauer 1990; Koirala and Shrestha 1997; Buffa et al. 1998). However, Schaler (1973) reports that tahr eats small quantities of *Rhododendron*, Sharma (2000) that blue sheep include *Anaphalis contorta* and *Cotoneaster microphyllus* in their diet, Awasthi et al. (2003) that ungulates in the Himalayas include *Carex* sp. in their diet and Wangchuk (1995) that both blue sheep and yak eat *Carex* sp., *Bistorta* sp., *Anaphalis* sp. and *Cotoneaster microphyllus*.

5.5.5 Niche Breadth and Food Overlap

Body size is the most important factor determining the metabolic rate and food requirements. Large-bodied mammals have higher food requirements, since they have higher cost of maintenance and production compared to small species (Geist 1974). Thus small-bodied ungulates tend to be limited by forage quality and large-bodied ungulates by forage quantity (Hanley 1982). Small animals tend to be more selective not only in terms of the number of plant species they eat, but also in terms of their diversity and have a smaller niche breadth.

In this study, livestock, which is larger than tahr, grazed more plant species than tahr and have a larger niche breadth. Thus, tahr is more selective feeder than livestock. There is also a large overlap in the diets of tahr and livestock expressed by the Morisita index (C_H=0.83). However, the fieldwork was carried out during the monsoon season, when net primary productivity is high and forage quality very good. During winter, the yak herders interviewed reported that yak eats any plant matter, including shrubs and tree bark. The same might hold for tahr. Consequently, dietary overlap might be 100% during winter.

Shrestha (2006) and Buffa et al. (1998) suggest that the spatial overlap in the habitats of tahr and livestock can lead to competition, which is not always the case (Squires 1982) as is well illustrated by the interactions between ungulates in the Serengeti National Park in East Africa (Krebs 1994). The present study also indicates there is a partial, but not a complete spatial overlap between tahr and livestock. However, there is a good availability of forage on both rangelands. In addition, tahr, which is more agile than livestock, is able to reach the vegetation growing in steep and rocky areas and therefore spatially separated from livestock. Therefore, strong competition for food is unlikely.

There were more individuals of tahr at Phortse than at Mongla, where forage diversity and availability are lower. Tahr is often observed grazing together with livestock (Gurung 1995) and sometimes even at low altitudes. This might be how it avoids predators like snow leopard. A similar phenomenon is reported by Basnet

(2002) for blue sheep, which graze together with livestock that protect the blue sheep from predators or attackers by chasing them away.

The worrying fact is, however, that the signs of overgrazing, such as bare and eroded pastures, are becoming increasingly noticeable in the SNP. This is a warning for the future, because if this trend continues, tahr will become an endangered species in this area.

5.5.6 Comparison of the Difficulties Associated with Direct Observation and Micro Histological Techniques

Direct observation is a simple, cheap and easy way to determine the food habits of both livestock and tahr, as neither is shy. Livestock is clearly used to the presence of man; males of tahr escape very quickly when encountered, while females with juveniles do not, as they seem to be used to the presence of man. Thus tahr was often observed from a distance of about 50 m. The problem with direct observation is in defining and quantifying the species of plant being grazed, and how much of a plant is consumed. It is difficult to differentiate between freshly and earlier eaten plants and even those that have only been trampled (Holechek et al. 1982).

Histological analysis is the most commonly used method for evaluating herbivore food habits (Holechek et al. 1982). The problem with faecal analyses is that the material has to be examined under a microscope in order to identify the plant fragments (Fitzgerald and Waddington 1979). The grass and sedge species are usually overestimated and herbaceous plants underestimated (Vavra and Holechek 1980; Gyawali 1986). In the present study, most of the fragments of grasses were very characteristic: *Avena* sp. has a very distinct trichome and inter-stomatal cell structure, which is clearly seen in faecal samples. The microstructure of other species, like *Carex* sp., Cyperaceae sp., *Trisetum spicatum* is, however, very similar and difficult to distinguish. *Ephedra, Saxifraga brachypoda* and *Potentilla* sp. have distinct characters and are easy to recognize.

5.5.7 Floristic Composition

Species diversity was higher at Phortse than at Mongla, which may be explained by their different altitudes. The range of most high altitude plants in the Northwest Himalayas is 3,600–5,500 m, sometimes only 3,900–4,200 m (Mani 1978). The rangeland at Mongla is at 3,400–3,800 m and at Phortse 3,600–4,200 m. Therefore, that at Phortse is in the transition zone between shrubland and grassland, in which vegetation diversity tends to be high. It is reported that the peak number of species occurs at 4,250 m (Gurung 1995). The floristic composition however, is also affected by slope and aspect.

The dominant shrub species on both rangelands are *Rhododendron lepidotum* and *Cotoneaster microphyllus*. Their dominance seems to be increasing (Bauer 1990) and they are rapidly colonizing new areas (Buffa et al. 1998). Bushes of *R. lepidotum* and *C. microphyllus* sometimes form very dense growths, especially on gentle slopes. Some grass and sedge species, like *Avena* sp. and *Carex anomoea* are almost uniformly distributed on both rangelands. The species diversity was highest, where the terrain is not rugged and the vegetation least disturbed on steep slopes.

5.5.8 Effect of Predation by Snow Leopard on Himalayan Tahr and Livestock

The snow leopard has re-colonized the Everest region. An analysis of its scat indicates that Himalayan tahr is its most important food, closely followed by livestock. Our sample size is too small to reach a definitive conclusion, but certain indirect factors indicate that snow leopards depend on tahr as food throughout the year. These include the low kid-to-female ratio in tahr, for which snow leopard might be responsible.

Ale (2006) reports that snow leopard started killing livestock in 2004. Our study also indicates that because snow leopard is quite rare, it does not kill many livestock. In addition, most villagers have a spiritual belief that animals should be respected. However, they may change their mind in the future, especially if the numbers of snow leopard increase and those of tahr decrease, which will result in snow leopard's supplementing their diet with livestock, beyond the level tolerable to local herders. This is typical of areas with depleted prey populations that are insufficient to sustain the local predators and can lead to a serious conflict interest.

5.6 Conservation Recommendations

Based on this study, it is recommended:

1. The tahr populations should be monitored regularly and any changes in population structure (mortality, fecundity), prevalence of diseases, reproduction, general health and other factors associated with the well being of populations recorded.
2. Trends in the productivity and carrying capacity of the tahr's habitat should be closely monitored and action taken if the decline in productivity continues.
3. An in-depth predator-prey population study based on monitoring the abundance of snow leopard, tahr, livestock and vegetation is needed.
4. As both snow leopard and tahr need protection and there is currently no serious competition between livestock and tahr for food, the main threat now comes from the decline in plant productivity in the region due to overgrazing. This trend

could seriously change the situation, as tahr and livestock would then compete for food.

5. The most effective way of reversing this trend is to introduce measures that limit the amount of grass that is harvested for feeding livestock during winter, which is rapidly increasing.
6. Delivery of hay from low altitude areas for feeding livestock during winter should be subsidized, so that it becomes economically attractive for the farmers not to use the overgrazed areas for hay production.

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Annexes

Annex 5.1 Floristic composition of the vegetation at Mongla (see text for notation)

Plant species	*D*	*f*	*RF*	*RD*	*A*	*RA*	*IVI*
Anaphalis contorta	4.6	52.4	4.5	3.5	8.8	2.1	10.1
Anaphalis triplinervis	0.6	9.5	0.8	0.5	6.5	1.5	2.8
Androsace sarmentosa	5.4	52.4	4.5	4.2	10.4	2.5	11.1
Avena sp.	19.4	90.5	7.7	14.9	21.4	5.1	27.7
Bistorta affinis	2.1	19.1	1.6	1.6	10.7	2.5	5.7
Briza media	1.0	4.8	0.4	0.7	20.0	4.7	5.9
Buplerium sp.	0.6	4.8	0.4	0.5	13.0	3.1	4.0
Carex anomoea	11.5	66.7	5.7	8.8	17.3	4.1	18.6
Cheilanthus sp.	0.3	4.8	0.4	0.3	7.0	1.7	2.3
Compositeae	0.1	4.8	0.4	0.0	1.0	0.2	0.7
Cotoneaster microphyllus	6.2	81.0	6.9	4.8	7.7	1.8	13.5
Cyperaceae sp. I	0.5	4.8	0.4	0.4	10.0	2.4	3.1
Cyperaceae sp. II	1.2	19.1	1.6	0.9	6.2	1.5	4.0
Cyananthus hookeri	8.4	38.1	3.3	6.4	22.0	5.2	14.9
Cyananthus microphyllus	9.2	57.1	4.9	7.1	16.2	3.8	15.8
Cypripedium himalaicum	0.8	14.3	1.2	0.6	5.7	1.3	3.2
Drosera peltata	3.1	47.6	4.1	2.4	6.6	1.6	8.1
Festuca sp.	0.3	9.5	0.8	0.2	3.0	0.7	1.7
Fragaria daltoniana	0.3	14.3	1.2	0.3	2.3	0.6	2.0
Gerbera gossypina	6.4	47.6	4.1	4.9	13.4	3.2	12.1
Gueldenstaedtia himalaica	4.1	33.3	2.9	3.1	12.3	2.9	8.9
Habenaria aitchisonii	0.1	9.5	0.8	0.1	1.5	0.4	1.3
Herminium josephii	3.6	38.1	3.3	2.7	9.4	2.2	8.2
Hieracium sp.	0.1	4.8	0.4	0.1	3.0	0.7	1.2
Iris sp.	0.3	4.8	0.4	0.3	7.0	1.6	2.3
Juniperus sp.	0.0	4.8	0.4	0.0	1.0	0.2	0.7

(continued)

Annex 5.1 (continued)

Plant species	*D*	*f*	*RF*	*RD*	*A*	*RA*	*IVI*
Leontopodium stracheyi	0.1	4.8	0.4	0.1	2.0	0.1	1.0
Microula pustulosa	0.4	4.8	0.4	0.3	8.0	1.9	2.6
Notholirion macrophyllum	1.6	19.0	1.6	1.2	8.5	2.0	4.9
Parnassia nubicola	0.1	4.8	0.4	0.1	2.0	0.5	1.0
Pedicularis siphonantha	0.0	4.8	0.4	0.0	1.0	0.2	0.7
Persicaria capitata	1.8	14.3	1.2	1.4	12.7	3.0	5.6
Poa sp.	1.1	23.8	2.0	0.9	4.8	1.1	4.1
Polygonatum hookeri	8.3	42.9	3.7	6.4	19.33	4.6	14.6
Potentilla sp.	7.0	19.0	1.6	5.3	36.5	8.7	15.6
Rhododendron lepidotum	5.4	71.4	6.1	4.1	7.5	1.8	12.0
Salvia hians	1.0	19.0	1.6	0.8	5.5	1.3	3.7
Satyrium nepalense	4.7	57.1	4.9	3.6	8.2	1.9	10.4
Saxifraga brachypoda	3.1	28.6	2.4	2.4	11.0	2.6	7.5
Saxifraga parnassifolia	2.7	57.1	4.9	2.1	4.7	1.1	8.1
Sedum sp.	1.9	9.6	0.8	1.5	20.0	4.7	7.0
Sedum sp.	0.0	4.8	0.4	0.0	1.0	0.2	0.7
Silene sp.	0.1	9.6	0.8	0.1	1.5	0.3	1.3
Trisetum spicatum	0.3	4.8	0.4	0.3	7.0	1.6	2.3
Unidentified gramineae (15)	0.2	4.8	0.4	0.2	5.0	1.2	1.8

Annex 5.2 Floristic composition of the vegetation at Phortse (see text for notation)

Plant species	*D*	*f*	*RF*	*RD*	*A*	*RA*	*IVI*
Allium wallichii	0.0	3.3	0.2	0.0	1.0	0.2	0.4
Anaphalis contorta	0.2	6.7	0.4	0.1	2.5	0.5	1.04
Avena sp.	9.0	96.7	6.4	5.8	9.3	1.8	14.1
Bistorta affinis	2.8	46.7	3.1	1.8	6.1	1.2	6.1
Campanula pallida	2.0	10.0	0.7	1.3	20.0	3.9	5.9
Carex anomoea	12.2	100.0	6.7	7.8	12.2	2.4	16.9
Cassiope fastigiata	1.7	10.0	0.7	1.1	17.3	3.4	5.2
Cheilanthus spp.	0.2	10.0	0.7	0.1	2.3	0.5	1.3
Compositeae	0.0	3.3	0.2	0.0	1.0	0.2	0.4
Cotoneaster microphyllus	1.9	43.3	2.9	1.2	4.5	0.9	5.0
Cyperaceae sp.	0.1	3.3	0.2	0.1	5.0	1.0	1.3
Cyananthus hookeri	8.4	63.3	4.2	5.4	13.3	2.6	12.2
Cyananthus microphyllus	5.2	50.0	3.3	3.3	10.3	2.0	8.7
Cyperus sp.	4.0	43.3	2.9	2.6	9.2	1.8	7.3
Cypripedium himalaicum	0.6	6.7	0.4	0.4	9	1.8	2.6
Dactylorhiza hatagirea	0.1	3.3	0.2	0.1	3.0	0.6	0.9
Drosera peltata	5.4	46.7	3.1	3.5	11.6	2.3	8.9
Dubyaea hispida	1.2	6.7	0.4	0.8	18.5	3.6	4.9
Ephedra gerardiana	0.2	6.7	0.4	0.1	2.5	0.5	1.0
Euphrasia himalayica	2.3	13.3	0.9	1.5	17.5	3.4	5.8
Fragaria daltoniana	2.9	56.7	3.8	1.8	5.1	1.0	6.6
Gentiana depressa	6.6	23.3	1.6	4.2	28.1	5.5	11.3

(continued)

Annex 5.2 (continued)

Plant species	*D*	*f*	*RF*	*RD*	*A*	*RA*	*IVI*
Gentiana sp.	1.0	23.3	1.6	0.7	4.4	0.9	3.1
Gerbera gossypina	7.2	73.3	4.9	4.7	9.9	1.9	11.5
Gueldenstaedtia himalaica	2.7	46.7	3.1	1.8	5.9	1.2	6.0
Halenia elliptica	1.5	20.0	1.3	1.0	7.5	1.5	3.8
Herminium josephii	0.3	6.7	0.4	0.2	5.0	1.0	1.6
Hieracium sp.	3.3	43.3	2.9	2.1	7.6	1.5	6.5
Leontopodium jacotianum	3.0	20.0	1.3	1.9	14.8	2.9	6.2
Morina nepalensis	3.5	36.7	2.4	2.3	9.6	1.9	6.6
Neottianthe calcicola	1.6	23.3	1.6	1.0	6.9	1.3	3.9
Notholirion macrophyllum	1.7	20.0	1.3	1.1	8.5	1.7	4.1
Parnassia nubicola	1.9	33.3	2.2	1.3	5.9	1.2	4.6
Pedicularis siphonantha	3.4	66.7	4.4	2.2	5.0	1.0	7.6
Persicaria capitata	5.6	36.7	2.4	3.6	15.2	3.0	9.0
Poa sp.	0.6	20.0	1.3	0.4	2.8	0.6	2.3
Polygonatum cirrhifolium	0.2	3.3	0.2	0.1	6.0	1.2	1.5
Polygonatum hookeri	29.7	56.7	3.8	19.0	52.4	10.3	33.2
Polygonum sp.	1.0	16.7	1.1	0.6	5.8	1.1	2.9
Polygonum sp.	0.4	3.3	0.2	0.3	12.0	2.4	2.8
Potentilla sp.	105.0	26.7	1.8	1.0	5.6	1.1	4.5
Primula sp.	2.2	6.7	0.4	1.4	33.5	6.6	8.5
Rhododendron lepidotum	3.1	60.0	4.0	2.0	5.2	1.0	7.0
Salvia hians	0.7	20.0	1.3	0.5	3.5	0.7	2.5
Satyrium nepalense	0.4	10.0	0.7	0.3	4.0	0.8	1.7
Saxifraga brachypoda	2.4	40.0	2.7	1.6	6.1	1.2	5.4
Saxifraga parnassifolia	1.4	36.7	2.4	0.9	3.7	0.7	4.1
Sedum sp.	0.2	13.3	0.9	0.1	1.7	0.3	1.4
Sedum sp.	0.6	6.7	0.4	0.4	9.0	1.8	2.6
Silene sp.	0.1	3.3	0.2	0.0	2.0	0.4	0.7
Thermopsis barbata	4.9	26.7	1.8	3.2	18.5	3.6	8.6
Thesium emodi	0.4	6.7	0.4	0.2	5.5	1.1	1.8
Trachyspermum ammi	0.7	13.3	0.9	0.5	5.2	1.0	2.4
Woodfordia sp.	0.1	6.7	0.4	0.1	1.5	0.3	0.8

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Chapter 6
Numbers, Distribution and Facts Limiting the Abundance of Tigers (*Panthera tigris*) in the Bardia National Park Extension Area

Ramji Bogati

Abstract The Bardia National Park (BNP) is inhabited by the second largest population of tigers in Nepal. To provide enough space, a good dispersal range and to offer migratory routes for them, the Bardia National Park Extension Area (BNP-EA) was created. The numbers, distribution and facts limiting the abundance of tigers in this area between October 1999, September 2000 and January 2005 were investigated using pugmarks and track survey. During this study, I recorded only two adult tigers with two cubs. The male tiger was identified by its pugmarks, whereas the female was identified by other signs (e.g., killings with pugmarks). Of fifteen pugmarks, only six were used for tracking and calculation. The male's pugmarks were found in an area stretching from Khairi Khola to Khairibhatti Khola, while those of the female tiger were found in an area from Katauti Khola to Jhanjhari Khola. Human population growth combined with the poverty of the people and their little concern for conservation were identified as the major threats to tigers. In addition, human-tiger conflicts constrained the increase in numbers of tigers. The BNP-EA is an excellent habitat for tigers, as it forms a link between the western and eastern Tarai ecosystems. However, there are very few tigers in the BNP-EA. Hence, for the long-term survival of tigers in the BNP-EA, conservation measures need to be implemented at the landscape level.

Keywords Tiger • Status • Distribution • Threats • Corridor • Landscape

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6.1 Introduction

The Tarai region in Nepal harbors a small population of an endangered animal, the Bengal tiger (*Panthera tigris)*. Before the 1940s, their status, population size and survival rate were unknown in this undisturbed habitat of virgin forests, swamps and grasslands (Gurung 1983). During the 1960s, particularly after the eradication of malaria, thousands of people migrated from the mountains and hills to the duns and Tarai. Human pressure resulted in encroachment on the forest and most of the dense forests being cleared for settlements and cultivation. By the end of the 1980s, only 17.4% of the total area of Nepal was still forest, including even low quality shrub forests (Dhungel and O'Gara 1991).

The dramatic increase in human population resulted in human-tiger conflicts, which caused a rapid destruction of tiger habitats throughout Nepal. The degraded and fragmented habitat put not only tigers, but also their prey at risk as the ungulates declined rapidly, both in abundance and distribution. Similar trends were recorded in many places in the tiger's range throughout the world (Dorji and Santipillai 1989; Rabinowitz 1993; Jackson 1995; Mingjang et al. 1995; Vinod 1997; Ali et al. 2000). Until the 1930s, hunting for sport was probably the main cause of decline in tiger populations. However, in the later decades, human-induced habitat fragmentation and the great demand for tiger body parts such as pelts, bones etc. by the Chinese, which accelerated the poaching of tigers, resulted in their recent decline (Martin 1992).

Protected areas are the most important for conservation of the mega-fauna, including tigers. However, tiger conservation outside protected areas is equally important, if sustainable conservation is desired. For this, proper management of potential corridors and extension areas is extremely important for their survival. However, there has not been enough research or data collected yet. Several studies on tigers were conducted in the past (e.g., Seidensticker 1976; McDougal 1977; Tamang 1982; Smith et al. 1989; Martin 1992; Smith 1993; Stoen 1994) within the Bardia National Park and other protected areas. Nevertheless, very few studies on the numbers and distribution of tigers have been conducted outside the protected areas (e.g., Smith et al. 2001), especially from the perspective of exploring the potential of conserving tigers at the landscape level. This study aims to add some data on tiger numbers and facts limiting their abundance in the BNP-EA and similar areas.

6.2 Objectives

The overall objective of this study was to collect basic ecological information on tigers, in order to explore the potentials for conserving tigers at the landscape level. The specific objectives were: (i) to explore the numbers and distribution of tigers in the Bardia National Park Extension Area and (ii) to determine the threats to tiger conservation.

6.3 Methods

6.3.1 Study Area and Time

The BNP-EA (27°58′13″-28°21′26″ N, 81°39′29″-82°12′19″ E) is located in the mid-western region of Nepal, occupying parts of Banke, Bardia, Dang and Salyan districts. The proposed BNP-EA is bordered by the Kohalpur-Surket Highway in the west, by the Shiva Khola and eastern border of the Banke district in the east, by the main Churia ridge and the Babai river in the north and by the Mahendra highway in the south (Fig. 6.1). The core area of the BNP-EA covers 549 km^2 and its buffer zone covers 344 km^2. It is 63 km long from east to west and its north to south width is 7–20 km (Basnet 2001a). The BNP-EA is divided into the Churia ridge, the rugged foothills, the Bhabar zone and the Tarai flat alluvial land. The Churia ridge dominates the northern part. It is made up of tertiary materials consisting of fine-grained sandstone with depositions of clay and shale. The Bhabar zone consists of boulders and gravels. The southern part consists of terrain flatlands consisting of fine alluvial soil with deposits of the quaternary materials. The elevation spans from 153 m near Dhakeri to 1,247 m at Kuine Phurkesalli (Basnet 2001a).

The main study area covers approximately 370 km^2 and is located in Bardia, Banke and Dang districts. It was divided into three sectors, western (Sector-A), central (Sector-B), and eastern (Sector-C) as by Basnet et al. (1998). Sector A

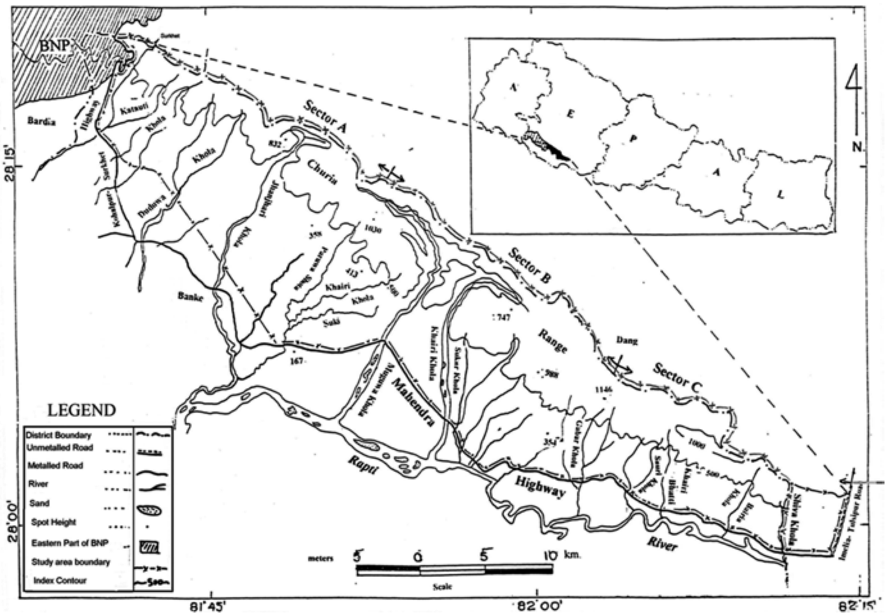

Fig. 6.1 Map of the study area. (Source: Bogati and Basnet 2001)

includes the area between the Kohalpur-Surkhet highway and Paruwa Sota. Small foothills demarcate the northern border, whereas villages and agricultural land from Chisapani to Obari demarcate the southern border. Sector B includes the area between Paruwa Sota and Gabar Khola. Various small foothills demarcate the northern border and the Mahendra highway southern border. Sector C includes the area between Gabar Khola and the Imelia-Dang road.

6.3.2 Data Collection Techniques

6.3.2.1 Numbers and Distribution

A preliminary field survey was conducted in October 1999, September 2000 and January 2005 in order to identify the best method of measuring tracks in the BNP. This was finalized after discussions with the park authorities, National Trust for Nature Conservation (NTNC) staff, the district and Ilaka forest staff, previous researchers, local people, herders and volunteers.

To assess the number of tigers in the study area, I surveyed dust roads, dry streambeds and sandy banks for tiger tracks. When tiger tracks were found, I followed them until good tracks suitable for tracing were found. The tracings were made on relatively hard ground with loose soil that recorded the fine relief of the tracks. When a fresh track was found, a tracing of left rear pugmark was made by placing a glass plate (25 cm × 20 cm × 3 mm) over the pugmark and tracing its outline on the plate. A piece of tracing paper was then placed on the glass plate and the pugmark was copied. If the pugmark was not distinct enough for tracing, the total pugmark length (PML) and breadth (PMB) were measured and recorded on the tiger status survey form along with the date, time, location and nature of the ground. Each tiger was identified by distinct differences in their tracks, such as the relative distance between fingers, pads, shape and size of pugmarks (WWF 1998).

The sex of each tiger was determined from its association with other tigers and from the shape of the track. If the sex of the tiger was not determined from its association with other tigers, sex was determined on the basis of the shape formed by their rear footprints. That of a male fits into a "prominently squares frame" and that of a female into a "relatively rectangular frame" (Panwar 1979). It is possible to distinguish the tracks of an adult male from those of an adult female by these measurements, as the hind foot of a male is more than 11 cm wide and that of a female less than 11 cm (McDougal 1999). Sagar and Singh (1990) found that the width of the hind foot of an adult male is more than 12 cm, that of a sub-adult 10–12 cm, and footprints less than 10 cm were attributed to leopards if the stride length was more than 90 cm or the track was not accompanied by an adult female tiger. In this study, sex was determined from the traced rear track and measurement of pugmarks based on the sizes cited by Panwar (1979), McDougal (1999) and Sagar and Singh (1990) and female tigers from social behavior as described by Stoen (1994).

To confirm the presence of tigers in different places in the study area, attention was given to records of livestock damaged by tigers and signs of their presence inside the area. Illegal settlements inside the BNP-EA were also recorded. Furthermore, officials, local people and herdsmen (*Gothalas*) were also asked simple questions in the buffer zone (from Chisapani to Shiva Khola area) during rapid rural appraisal (RRA).

6.3.2.2 Data Analysis

To determine the sex of a tiger, the PML and PMB of the rear tracks were used. I also calculated the ratio between PML and PMB and compared them using a t-test. The range of ratio is smaller in males than in females (Stoen 1994).

6.4 Results

6.4.1 Status and Distribution

During the study, I recorded one adult male tiger as resident and one female with two cubs as transient in the BNP-EA in 2000 (Table 6.1). In total, 15 tracks of male tiger were recorded in nine different places, of which only six were measured (Table 6.2). Tracks were recorded from Khairi Khola (Samsergunj) to Khairibhatti Khola (Kusum) – Table 6.3, Fig. 6.2. However, pugmarks were recorded only from Katuti Khola to Jhanjahari Khola. Unlike this, my field survey in 2005 indicated the presence of only one tiger.

The distinctive track characteristic of the male tiger was a large gap between the toes of the left paw. Six tracks were identified as belonging to this tiger. A female with two cubs (more than 6 months old) was observed by the local people ($N=6$) in the Katauti Khola near a buffalo kill on 18 September 1999 (personal communication, Rana Bahadur Rokka). One set of big tracks and two of small tracks were recorded on September 1999 in Jhanjhari Khola (personal communication, Goverdon Oli), indicating the presence of an adult female tiger with two cubs.

Table 6.1 Number of tigers in the BNP-EA

Year	Adult male	Adult female	Cubs	Total	Source
1995/96	1	3	–	4	McDougal (1997)
1999	1	–	–	1	Personal communication, Indra P. Jaisee, 1999
2000	1	1	2	2(2)	Track study
2005	1	–	–	1	Field survey

Table 6.2 Rear track measurements of tigers in BNP-EA

S.N	Date	Sex	PW(cm)	PML (cm)	PMB (cm)	Location, and nature of ground
1	15/1/2000	Male	9.7	13.3	12.2	Khairi, dusty place
2	15/1/2000	Male	9.7	13.3	12.3	Khairi, dusty
3	17/1/2000	Male	9.4	12.8	11.6	Kharibhatti, sandy wet
4	17/1/2000	Male	9.5	13.2	12.0	Khairibhatti, sandy wet
5	15/5/2000	Male	10.5	13.8	12.5	Khairi, dry sandy banks
6	18/9/2000	Male	9.3	12.8	11.5	Rajabash, hard ground with thin layer dust
	Mean		9.6	13.2	12.01	

PW palm width, *PML* pugmark length, *PMB* pugmark breadth

Table 6.3 Distribution of tigers in the BNP-EA

Sector	Sex	Area	Records	Evidence	
				Pugmarks	Kills
A	Female	Jhanjhari, Katauti Khola	Sept.–Oct. 1999	+	+
B	Male	Khairi, and Suki Khola	Dec. 1999, Jan., May, July and Aug. 2000	+	+
C	Male	Khairibhatti, Rajabash, Sauri and Gaber Khola	Jan., July, Aug. and Sept. 2000	+	+

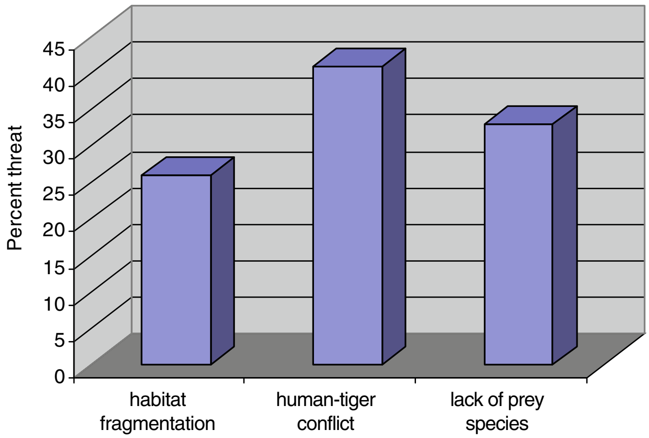

Fig. 6.2 Reasons regarding threats to tigers

The average mean PML was 13.2 cm and PMB 12.01 cm, which were positively correlated ($r = 0.96$) and significantly different (t-test, $t = 56.67$, $d.f. = 5$, $p < 0.05$) – Table 6.4. From these values, I considered that it was the pugmark of an adult male.

Table 6.4 Relationship between pugmark length (PML) and pugmark breadth (PMB)

	Sagar and Singh (1991)	Stoen (1994)		
Sex	Male	Male	Female	Male
No. of obs.	42	5	4	6
Mean PML(cm) ± S.D	12.4 ± 1.2	13.6 ± 0.60	13.1 ± 0.28	13.2 ± 0.40
Mean PMB (cm) ± S.D	11.6 ± 1.1	11.8 ± 0.49	10.3 ± 0.30	12.01 ± 0.50
Mean PML/PMB ± S.D	–	1.16 ± 0.02	1.27 ± 0.04	1.09 ± 0.05
Range PML/PMB	–	1.14 ± 1.18	1.23 ± 1.30	1.08 ± 1.11
t-test PML/PMB	–	>5.67	5.67	5.67
Significance of the t-test	–	>95%	95%	>95%
Correlation between PML and PMB (r)	0.891	–	–	0.96
Significance of r	>99.9%	–	–	above 99%

6.4.2 *Threats to Tigers*

The result of interviews with people in Chisapani to Kusum adjoining villages, with forest staff and local people revealed that there were only four tigers in the BNP-EA, including the cubs seen during the study period in 2000. However, this number reduced to only one in 2005. Sector B, particularly the Khairi Khola area, was a good habitat for tigers and hence they lived there permanently. In other sectors, tigers were found only occasionally due to high human disturbance, lack of suitable habitat and availability of prey, which was supported by the absence of pugmarks and of killed animals.

According to the interviews, 37% of the respondents confirmed the presence of 1–4 tigers, 40% did not confirm but thought tigers were present and 23% thought tigers were not present in the area. Hunters, herdsmen and local volunteers reported that there was one female in the Jhanjhari Khola area, one in the Hardwar area (forest of Dang), and one across Rapti. The respondents reported that the mobility of tigers now is not as high as it used to be in the past. Among the respondents, 26% reported that the low mobility of tigers in that area is due to habitat fragmentation, 41% attributed it to the dense human population and human-tiger conflict in the area, while 33% thought it was due to the lack of prey species (Fig. 6.2).

During the study, I recorded 49 (19 in Lutepani, 15 in Kalapani, 6 in Chunbhatti, 5 in Sukar, and 4 in Thuria) illegally built *Goths* and 3 *Machans* in different places in the foothills. I also discovered evidence for the killing of one sambar deer, one spotted deer and one leopard. In addition, one male tiger was killed by poachers in the Samsergunj forest in the 1980s and one female tiger was killed by poisoning of a cow killed by her in the Imelia forest in the 1990s. Thus it seems that illegal hunting/poaching and retaliatory attacks by local farmers are the major cause of the low number of tigers in the area.

6.5 Discussion

6.5.1 Numbers and Distribution

Establishing tiger numbers is extremely difficult because they are naturally secretive, forest dwelling animals, ranging over large areas. Most of their numbers are obtained from guestimates or from questionnaires (Jackson 1995). Radio telemetry (e.g., McDougal 1977; Sunquist 1981; Tamang 1982; Smith 1993) and the use of cameras (e.g., Karanth 1995; Karanth and Nicholas 1998) are the good methods of determining numbers of tigers, but both are costly and need technical support. Many scientists (e.g., Choudhury 1970; McDougal 1977; Panwar 1979; Sunquist 1981; Tamang 1982; Sagar and Singh 1990) used pugmarks because it is reliable, easier, cheaper and a more precise method. By tracking tigers and identification of individual track features, it is possible to explore a tiger population with little technical support (McDougal 1977).

In the whole BNP-EA, only one adult male tiger was recorded in 1999 (personal communication, Indra Prasad Jaisee), one adult male and three adult female tigers were recorded during the 1995/1996 survey (McDougal 1997) and 6–8 adult tigers were present in the BNP-EA in the 1980s according to a WWF report. The results of my study indicate that there are still very few tigers in the area (Table 6.1). A decline in tiger numbers has been reported from other parts of Nepal, particularly the Chitwan National Park (Tamang 1982; Martin 1992; Smith 1993) and other countries, like Bhutan (Dorji and Santiapillai 1989), China (Ming et al. 1998), India (Sivastava and Singh 1997; Vinod 1997), and Bangladesh (Ali et al. 2000). The decrease in the number of tigers may be attributed to illegal hunting/poaching, to retaliatory attacks by villagers and reduction in the amount of suitable habitat (Bogati 2001; Bogati and Basnet 2001). Which one of these factors is the most important in the decline in tiger numbers is unknown and should be determined by further studies.

I recorded tiger movement throughout the foothills and floodplain of the BNP-EA. The dispersal distance of male tiger was about 12–20 km in summer and 12–30 km in winter. However, the home range of female tiger was not estimated. Pugmarks and kills were more frequent in the Khairi Khola and Rajabash Khola areas. Due to human encroachment into the forests, particularly in the southern Himalayan forests, tigers are now found only in some isolated parks and reserves and adjoining forests (Smith et al. 1998). Due to habitat shrinkage, fragmentation (Jackson 1995; McDougal 1999), poor quality of habitat outside protected area and lack of prey species (Smith et al. 2001–2003), tiger distribution is also fragmented and the total size of the area they inhabit is much smaller than several decades ago.

I found an almost square-shaped (13.2 × 12.01 cm) left rear pugmark of tiger. One set of large pugmarks with two smaller sets was recorded near an animal kill in the Jhanjhari Khola,which was the pugmark of a female tiger. I found the similar set of pugmark in Katauti Khola area. Breeding tigers were also recorded in forests outside the protected area adjacent to Bardia National Park (Smith et al. 2001). Pugmarks and their measurement were an excellent source of information on the age, sex, routes and distribution of the predators (Bogati and Basnet 2001). Difference between PML and PMB was 1.2 cm and the ratio between these was 1.08–1.11; the PML and PMB were positively correlated (r = 0.96). Similar results were found by Sagar and Singh (1991) and Stoen (1994) – Table 6.4. Sagar and Singh (1991) found a difference between PML and PMB of less than 1.5 cm in male and more in female. Sagar and Singh (1991) also found that correlation is more significant in males than females. Stoen (1994) found ratios of PML and PMB to be 1.14–1.18 in males, which is less than in females (1.23–1.34). In my results, t-test value (59.67) was larger than that of Stoen (1994) (>5.67), which may not be correct, because he identified the female on the basis of two small sets of tracks associated with her tracks in Karnali floodplain area of BNP.

During this study, I identified four possible routes for tigers to move from east to west: Khairibahtti Galchi, Dhauleni Gaira, Gajbire and Kartikekhutti Dada inside the study area, two paths crossing the Rapti river near Shrista (Sikta to Gabar area) and Gabar Khola to Sauri Khola (Fig. 6.1). I found that tigers followed two paths inside the area Khairibhatti Galchi and Kartikekhutti Dada, and only one path when crossing the Rapti: Gabar to Sauri Khola area. Tigers mostly followed streambeds, footpaths and used roads. Animals killed by tigers (carcasses) and pugmarks of the male tiger were recorded in Khairi Khola on 31 December 1999. After the disturbance of its kills by local people, it followed the Khairibhatti Galchi route, where I recorded pugmarks on 2 January 2000. On 27 July 2000, a cow was killed in Khairi Khola and on 28 July 2000 an ox was killed in Kartikekhutti Dada. At that time, the tiger followed the Churia foothills route. From the kills and RRA, it seems that tigers mostly forage in foothills from May to September and floodplains from October to March. During October to March, local people build *Goths* in foothills to collect grasses such as khar (*Erianthus ravenna*), babio (*Eulaliopsis binata*) and many other species (*Imperata cylindrica, Phragmites karka, Saccharum spontaneum, Saccharum bengalense*) for various purposes including roof thatch, fodder for livestock, raw materials (e.g., for making paper). At that time, the tiger foraged in the floodplain area sometimes following the same routes (personal communication, Jeebach Yadav). During May to September, habitats in lower plain areas were highly disturbed by hunters, herdsmen and livestock. Intensive collection of firewood, sand and rocks from every streambed from early morning to late evening was recorded. Tigers used Gabar Khola to Sauri Khola areas to cross the Rapti river, as shown by its kills (cows) near Sauri Khola and pugmarks nearby Gabar close to the highway on 1 August, 2000. During field survey January 2005, I recorded presence of one tiger in sector B but I did not get any information in sector C of the study area.

During this study, two sambar deer, two groups of hog deer and one group (containing six individuals) of wild boar were observed in the Khairi Khola area. This indicates that the BNP-EA, particularly the Jhanjhari Khola and Khairi Khola areas could be a good habitat for tigers because of the presence of thick forests, abundant prey and water.

These major communities and ecosystems include forests, agricultural fields, rivers, Tarai, savanna and grassland. This ecoregion provides critical habitats for tigers that have been fragmented, isolated and scattered over time due to human disturbance (Basnet 2001a). If it is protected well through awareness rising among locals and habitat preservation thereby merging this area into Bardia National Park, or establishing a new national park the BNP-EA can become a better habitat for tigers and other migratory wildlife moving between the western and eastern parts of the savanna and grassland ecoregion.

6.5.2 Threats to Tigers

During the discussions with local inhabitants, many cases of tiger kills and human-tiger conflicts were reported in the study area. Poachers killed one female tiger, 2 m in length, on December 21, 2000 in the forest of Chaulahi VDC-9, Dang, which was just outside the BNP-EA. According to the WWF reports for the 1980s and 1990s, the tiger population declined from 50 to 28 in the BNP and from 6–8 to 4 in the BNP-EA, which corresponds to a 2.9% annual decrease rate. Unreported and scattered information showed that illegal hunting and poaching and retaliatory attacks by local farmers are the major threats to tigers in the BNP-EA.

After the 1960s, the greatest threat was loss of habitat due to human population expansion and activities such as logging. The demand for highly priced traditional medicines sourced from animals has increased the demand for parts of the tiger body, particularly bones (Jackson 1995). As an illicit trans-border market exists between Nepal and the Tibet Autonomous Region of China, poaching has become lucrative. Hunted for their pelt and bones, tiger populations in many areas are dwindling. Population growth combined with poverty and lack of conservation awareness resulted in an increased poaching of tigers.

Human-tiger conflict is another threat for tigers. This conflict results because local people are increasingly using prime habitats of tiger when collecting firewood and fodder or they convert it into agricultural land. This causes degradation of increasing areas of tiger habitat and reduces the abundance of its prey. As a result, tigers move into inhabited areas in search of food. Tigers are opportunistic predators, and therefore, when they occur in inhabited areas, they often kill livestock (mainly cows and buffaloes) rather than their natural wild prey because of the high encounter rates with the former. For example, an average of 1.22 US$ worth of livestock was lost per household per year due to tiger predation in the Suklaphanta Wildlife Reserve (Regmi 2000). This resulted in the poisoning of tigers by human beings. Presence of tigers close to human settlements also makes it easier for the poachers to hunt them. The human-tiger conflict is one of the main threats to tiger survival. Thus, poaching, habitat fragmentation, reduction in the abundance of natural prey species, tigers venturing into inhabited areas, which results in their poisoning by humans and poaching, are the major threats to the effective conservation of tigers.

6.6 Conclusions

The BNP-EA and its buffer zone area provide good habitats for tigers, their prey and other endangered wildlife species. There were at least two adult tigers (1 probably resident male and 1 probably transient female with two cubs) present during the study of 2000. The female tiger occurred in the area from the Katauti Khola to the Jhanjhari Khola and the male in the area from the Khairi Khola (Samsergaunj) to the Khairibhatti Khola. Jhanjhari Khola, Khairi Khola and Khairibhatti Khola areas were considered as the principal areas (hotspots) for tigers in the BNP-EA (Fig. 6.1). Published and unpublished results show that the number of tigers in the area has been declining because of habitat fragmentation and degradation, hunting of prey and poaching of tigers (McDougal 1977; Basnet et al. 1998). There were two main routes along which the tigers moved from east to west in the BNP-EA, one of which crossed the Rapti river. Local people, herdsmen, livestock, and the removal of rock and sand from streambeds disturbed the tigers.

Provided that the restoration of degraded forest is ensured, fragmentation of land is reduced, hunting of prey species is strictly prohibited and human-tiger conflict is reduced, The BNP-EA can be an excellent habitat for tigers and other species of wildlife as it links the western and eastern parts of the savanna and grassland ecoregion (Basnet 2001b).

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Chapter 7
Impact of Livestock Grazing on the Vegetation and Wild Ungulates in the Barandabhar Corridor Forest, Nepal

Bishnu Prasad Bhattarai and Pavel Kindlmann

Abstract We investigated how livestock grazing inside the Barandabhar corridor forest (lowland in the south-central part of Nepal) affects plant community structure and standing biomass of grassland in this area. There were 2,432 domestic animals regularly grazing inside the natural habitats. As much as 73% of the area is grazed by livestock, which resulted in competition between the livestock and wild ungulates for food. Grazed areas differed from ungrazed in species composition and community structure. In the ungrazed areas, the standing biomass was higher, the proportion of barren ground smaller and the number of plant species larger compared with grazed areas. Livestock grazing also affected the species composition of herbaceous plants and grasses. In order to restore these degraded grasslands, the grazing by livestock needs to be reduced by establishing public grazing areas for the local people.

Keywords Grazing • Livestock • Nepal • Ungulates • Grasslands

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7.1 Introduction

Livestock grazing in the natural habitats of wildlife, mainly grassland areas in protected forests, poses a problem for nature conservation in Nepal. Communities living close to these habitats are very poor and lack alternative resources. They are dependent on their livestock for survival and allow them to feed in the protected areas because they do not have enough pasture. Livestock grazing is therefore seriously affecting the natural grasslands in Nepal. These grasslands are, however, home to many protected species of mammals and consequently in need of protection.

Maintenance of grasslands in general is strongly dependent on the maintenance of biodiversity (Janzen 1969; Huffaker 1971; McNaughton 1976; Edroma 1981; Louda 1983; McNaughton 1983; Hartnett et al. 1996). Continuous grazing by many herbivores (mainly livestock) results in grasses tillering and the selection for more prostate ecotypes (Vesey-Fitzgerald 1974; McNaughton and Banyikwa 1995). The subsequent effects of grazing on grasslands in terms of loss of species, soil erosion, and degradation of wildlife habitats can be widespread and severe, as recorded in other parts of the world (Fleischner 1994). In east Africa, ungulates maintain short grasses ("grazing lawns") during periods of intense grazing (McNaughton 1984). Forage from these "grazing lawns" can have higher nutritive values and digestibility, and provide wild ungulates with high quality food (Olubajo et al. 1974; McNaughton et al. 1982; Rhodes and Sharrow 1990). However, because of the reduction in the standing biomass, competition with livestock may result in the wild herbivores needing a larger area per individual for survival.

Forested ecosystems that include some grassland areas can provide areas for livestock grazing, if the area of grasslands outside the forest is not sufficient. This is the case in many areas of Nepal. However, although the forested land is opportunistically used for grazing, it is rarely managed for both grazing and wood production. The problems associated with the grazing of open grassland, such as soil compaction, stream degradation, invasion of weeds, increased erosion and decreased soil productivity also occur in the grazed forests. As a result of this, the structure, composition and dynamics of grazed forests tend to change dramatically when subjected to livestock grazing. In many instances, forest ecosystems are more sensitive to grazing, because there is less ground cover to buffer the effect of livestock and the trees are profoundly influenced by alterations in the understory environment (McNaughton 1984). Documented concerns include increases in the incidence of the infestation of trees by insects and diseases, changes in natural seedling regeneration, reduction in tree growth, changes in the species composition of the trees and degradation of wildlife habitat (Edroma 1981). National forests in Nepal are therefore under a serious threat from the increase in livestock grazing and human encroachment into wildlife habitats (Jha et al. 1994).

Despite the above-mentioned general results, the true effect of livestock grazing on the grasslands in Nepal is unknown and has never been exactly quantified. The Barandabhar corridor forest is a good model area for studying these problems,

Livestock grazing in the natural habitats of wildlife poses a problem for nature conservation in Nepal (Photo by BP Bhattarai)

because of its large biological diversity, large and growing density of human population nearby, causing an increasing anthropogenic pressure on the natural habitats, and its relatively easy accessibility. The basic aims of this study were therefore: (1) to determine the number of livestock grazing in the grasslands inside the study area; (2) to quantify plant species composition, structure and standing biomass in grazed and ungrazed grasslands; (3) to suggest conservation measures in order to reduce the livestock grazing impact inside the natural habitats of wildlife.

7.2 Methods

7.2.1 Study Area

The study area is in and around the Barandabhar corridor forest (BCF, 84°22′30″-84°33′0″ E, 27°34′7″-27°43′30″ N), adjacent to the northern border of the Chitwan National Park (CNP), to the Mahabharat hill forest at the northern end of the Chitwan valley. The Barandabhar corridor forest is situated in the subtropical inner Tarai lowlands of the south-central part of Nepal. It covers an area of 87.9 km^2 and bisects the Chitwan district into the eastern and western Chitwan. This 29 km long forest is divided into two parts by the east-west national highway. More than one half, 56.9 km^2, forms a buffer zone of the CNP and 31 km^2 is maintained by the district forest office. The major rivers around the forest are the Rapti, Budhi Rapti and Khageri.

This forest is regarded as the only remaining wildlife corridor linking the lowland with the mid-hill ecosystems in the central region of the country (Yonzon 2000). The biological importance of the BCF was recognized a long time ago. In 1846, the Rana prime minister declared the Chitwan valley, including the BCF, as a hunting reserve. After the eradication of malaria from the area in 1960, a large number of people came here from the mid hills of Nepal and cleared a large area of forest for agriculture purposes (Sharma 1990). Most of the local people are low caste, subsistence farmers, dependent on forest products for their livelihood.

There are fields and human settlements along the entire eastern and western boundaries of the forest. The contact with human settlements is less intense on the eastern side due to the presence of the Khageri river. The BCF is surrounded by six villages (Bachhauli, Gitanagar, Patihani, Jutpani, Pithuwa, and New Padampur) and two municipalities (Ratnanagar and Bharatpur). About 70,000 people living around the periphery of the forest depend on it for livestock grazing, fuel wood, fodder, timber and grass, which put a continuous pressure on the forest.

The fauna and flora of the Barandabhar corridor forest are extremely rich due to the variable landscape, which includes disturbed sal forest, sal forest with mixed understory, sal forest with *Shorea-Terminalia* understory, riverine forest, short grassland, open-*Bombax* forest, open-wooded forest, sand, gravel and ponds. Short grasslands occur in small patches ranging from 0.02 to 0.3 km^2 throughout the BCF, covering 11% of the total area at low elevations and are associated with the natural drainage system of the BCF, which means there is some water present throughout the year. The predominant species in the short grasslands is *Imperata cylindrica* (KMTNC 2003). Sal forest, which dominates the BCF, supports 22 species of mammals, including tiger (*Panthera tigris*), rhinoceros (*Rhinoceros unicornis*), Asian elephant (*Elephas maximus)*, sloth bear (*Melursus ursinus*), wild boar (*Sus scrofa*), sambar deer (*Cervus unicolor*), spotted deer (*Axis axis*), hog deer (*Axis porcinus)*, barking deer (*Muntiacus muntjak*) and 280 species of birds, including giant hornbill (*Buceros bicornis*), hill myna (*Gracula religiosa*) and storks. It is a critical habitat of many species of migratory birds – e.g., Siberian crane and Ruddy Shel-duck (*Tadorna ferruginea*), aquatic birds, and mugger crocodile, and more than 45 species of amphibians and reptiles such as frogs, toads, lizards, python and crocodiles (Yonzon 2000).

7.2.2 Study Sites

Our study sites were the important grazing areas and adjacent ungrazed areas in the Barandabhar corridor forest. Originally, these areas did not differ in vegetation cover. Many years ago, the local people decided at random, which parts of these

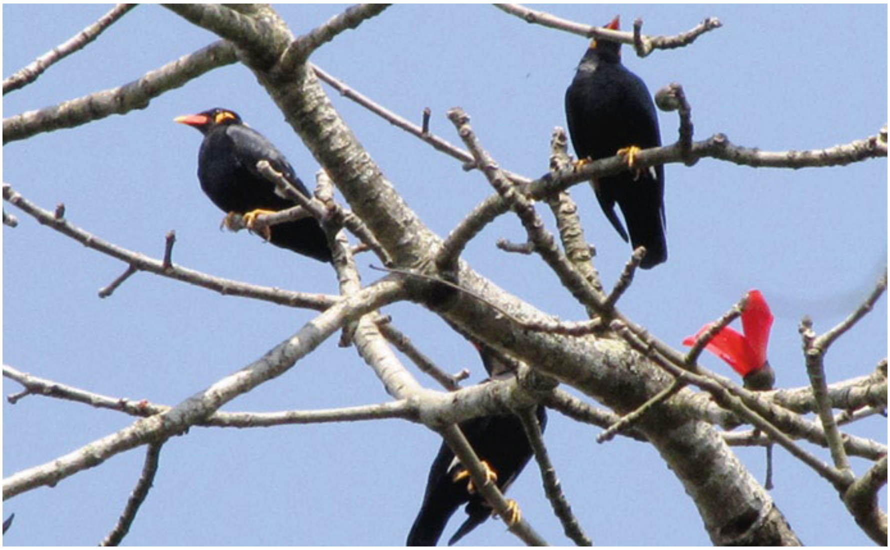
Tiger (*Panthera tigris*) (Photo by NTNC)

Rhinoceros (*Rhinoceros unicornis*) (Photo by BP Bhattarai)

Wild boar (*Sus scrofa*) (Photo by P Kindlmann)

Sambar deer (*Cervus unicolor*) (Photo by BP Bhattarai)

Mugger crocodile (*Crocodylus palustris*) (Photo by BP Bhattarai)



Hill myna (*Gracula religiosa*) (Photo by BP Bhattarai)

Jungle owlet (*Glaucidium radiatum*) (Photo by BP Bhattarai)

areas will be permanently grazed and which will remain permanently ungrazed. This study was carried out by observing livestock in the forest. The grazing effect was determined by studying plant species composition and structure of the short grassland vegetation. The area of intensive study covered 11% of the whole area of the BCF. The grazed and ungrazed grasslands were identified by a pilot survey of the wildlife habitat. The grazing areas were the grasslands, where the livestock grazed regularly and adjacent ungrazed grasslands. The ungrazed grasslands were the areas, where the livestock grazing was prohibited and were mostly in the community forests. The grazed grasslands were areas grazed both by livestock and wild ungulates and were scattered along the periphery of the BCF (Fig. 7.1).

7.2.3 Competition Between Wild and Domestic Ungulates

Competition between livestock and wild ungulates in the forest was determined by direct counting of livestock grazing in the forest. The number and distance between forest boundaries and grazing livestock in different areas were investigated during the field visits. This information was suitable for determining the interaction between wild and domestic ungulates, intensive grazing areas and their numbers.

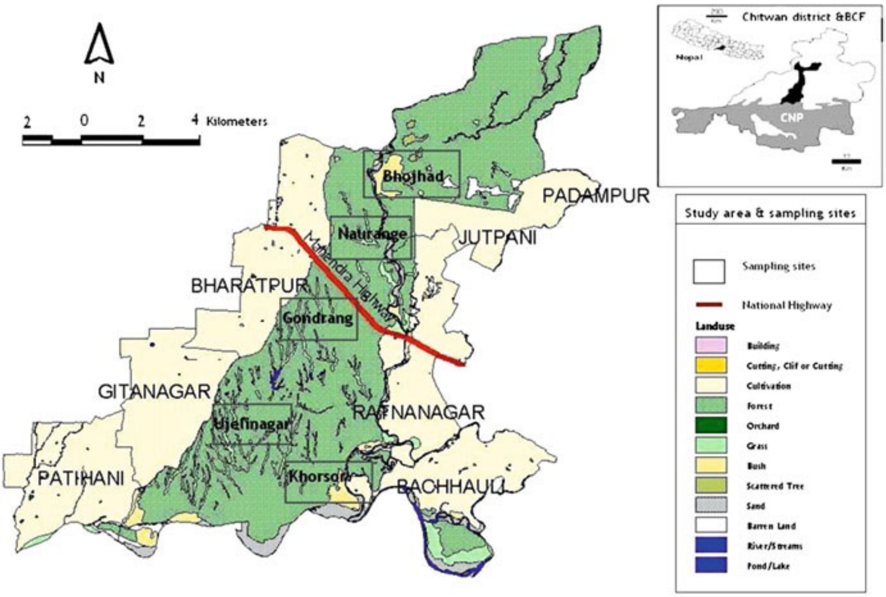


Fig. 7.1 The Barandabhar corridor forest – study area and sampling sites

A total of 1,000 households (400 households on the western side and 600 on the eastern side) were interviewed using questionnaires, to determine the number of grazing animals they possess and to obtain information about any measures they take to conserve wildlife.

7.2.4 Effect of Livestock Grazing on Natural Habitats

The impact of livestock grazing on habitats also grazed by wild ungulates was determined by sampling vegetation growing in grazed and ungrazed grasslands in the rainy, winter and spring seasons. The composition of the vegetation was determined by line transects at each sampling site. There were five sampling sites, each containing ten transects. The length of the transects varied from 200 to 800 m, depending on the shape and size of the grasslands. Along each transect, 1×1 m squares were established, 20 m apart. Altogether, 650 squares were studied. In each square, the plant species composition, number of species and relative cover of the different plant taxa (flowering plants, grasses, pterydophytes and bare ground) was estimated. The aboveground biomass of both grazed and ungrazed plots was then harvested and the dry weight (sun dried for 7 days or until a constant weight) of the plants determined and the difference noted.

7.2.5 Data Analysis

Plants collected from both habitats were identified with the help of the National Herbarium collection of Nepal and by using floras (Stainton 1972; Shakya et al. 1997).

The similarity of plant species in the grazed and ungrazed plots was compared using the Sorenson's index of similarity (Sorenson 1948):

$$IS = (2C \times 100)/(A + B),$$

where

A = total number of species in habitat A
B = total number of species in habitat B
C = species common to both habitats.

The canopy cover (%) of grasses, flowering plants, pterydophytes, unidentified plants and barren ground, and relative cover (%) of dominant plant species were determined by using the following mathematical indices (Moe and Wegge 1994):

$$\text{Canopy cover (\%)} = \frac{\text{Cover of individual groups}}{\text{Square size (1 m}^2\text{)}} \times 100,$$

$$\text{Relative cover (\%)} = \frac{\text{Cover of individual species of plants}}{\text{Total cover of all species}} \times 100$$

where individual groups or species indicated the cover of grasses, flowering plants or pterydophytes or unidentified plants or barren ground.

Two-sample Student t-test was used to test for differences between relative cover of different plant species and aboveground biomass of grazed and ungrazed sites.

7.3 Results

7.3.1 Competition Between Wild and Domestic Ungulates

Questionnaire survey of 1,000 households and field observation showed that most of the habitats were utilized by both wild and domestic ungulates. Of the people interviewed, 73% agreed that their livestock used the same habitat as the wild ungulates, whereas 27% were not sure. The most preferred plant taxa of the livestock were grasses (46%), followed by flowering plants (35%) and trees (19%). During the rainy and spring seasons, rhinoceros and buffaloes shared the same habitats.

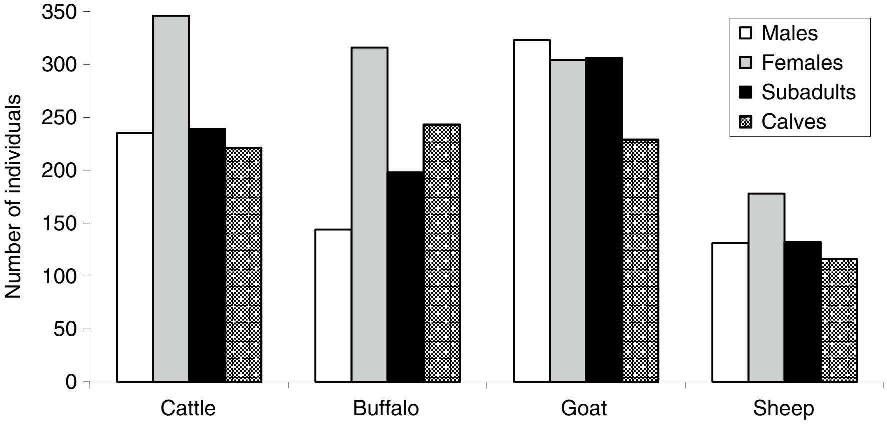


Fig. 7.2 Type and amount of livestock of the communities living around the forest

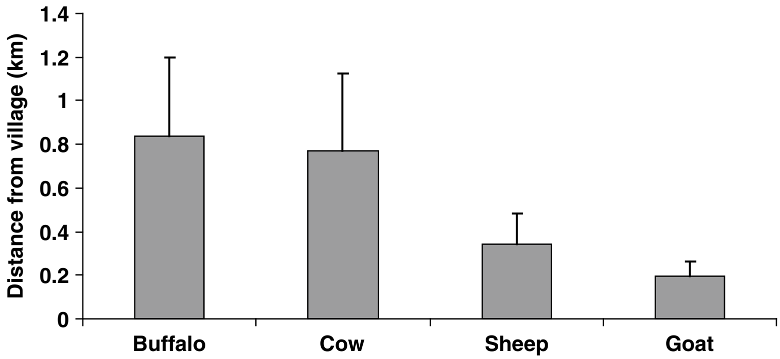


Fig. 7.3 Livestock grazing and average distance from the nearest village (mean ± SE)

There were altogether 3,661 domestic animals in the area (Fig. 7.2): 1,041 cattle, 901 buffaloes, 1,162 goats and 557 sheep belonging to 1,000 households (Fig. 7.3), which is on average 3–4 animals per household. Most of the domestic animals were female, with a few males and juveniles. The female cattle and buffaloes were kept mainly for milk and the males were used for plowing the farmland. The cows were mostly local varieties and buffaloes were pedigree stock. The local people mainly grazed their cattle in the forest, because they were reluctant to risk having their expensive buffaloes killed by tigers. The manure produced by the cows was used for fertilizing the farmland. The poor, lower caste individuals had a large number of unproductive livestock, compared to the higher caste individuals, such as the Brahmins.

We recorded 2,432 individuals of livestock regularly grazing inside the forest within the area of 87.9 km^2, which is approximately 27.7 animals/km^2. The animals were grazing mainly along the village forest borders (Table 7.1). Of them, 1,583 were recorded in the non-buffer zone of the forest, which means that grazing by

Table 7.1 Livestock observed at different sites of wildlife habitat in the BCF

Grazing sites	Dominant forest around grazing areas	Cow	Buffalo	Goat	Sheep	Total
Gundre-mandre	Riverine forest	187	132	–	–	319
Bhojhad	Sal forest	152	102	66	46	366
Naurange	Sal forest	102	65	42	28	237
Khageri bank	Mixed hardwood forest	263	244	96	58	661
Gondrang	Sal forest	75	62	52	–	189
Khorsor	*Shorea* - mixed understory	178	110	38	18	344
Mainahari	Tall grassland	64	46	–	–	110
Ujelinagar	Sal forest	10	36	132	28	206
Total		**1,031**	**797**	**426**	**178**	**2,432**

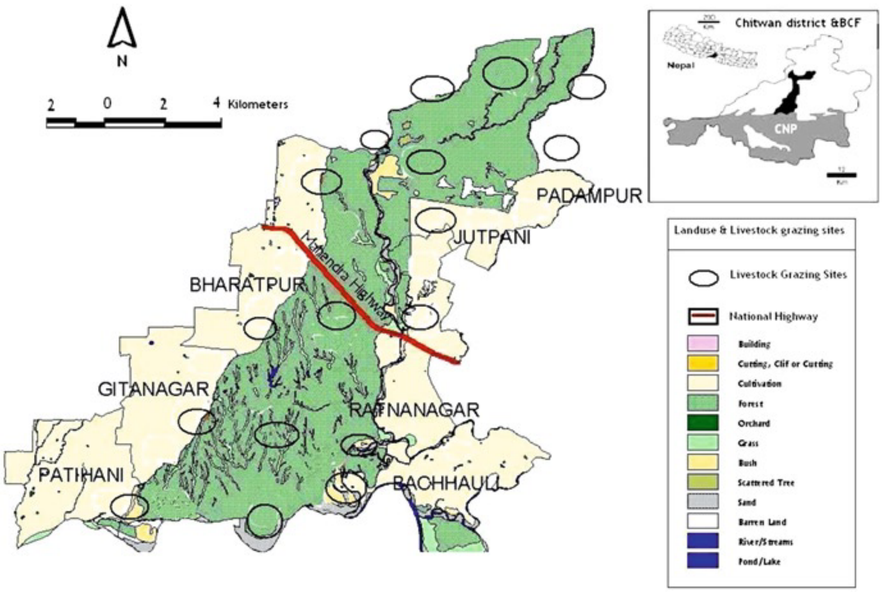


Fig. 7.4 Distribution of livestock grazing sites inside the Barandabhar corridor forest

domestic animals was more common there than in the buffer zone of the BCF (Fig. 7.4). In most places, the domestic animals grazed unattended in the forest.

Cows and buffaloes were recorded in the middle of the forest, whereas goats and sheep were recorded mainly near villages and at the forest edges (Fig. 7.3). This means that most parts of the forest were affected by at least one kind of domestic animal (Fig. 7.4). The farmers did not let their goats and sheep graze far away from the village, because deep inside they were easy prey for forest predators.

Table 7.2 Number of plant species and Sorenson's similarity index of grazed and ungrazed plots in the Barandabhar corridor forest

	Number of species			
Season	Grazed (A)	Ungrazed (B)	Common species (C)	Species similarity (%)
Rainy	54	42	29	60.4
Winter	36	25	13	42.6
Spring	43	31	20	54.1

7.3.2 *Effect of Grazing by Livestock on Natural Habitats*

7.3.2.1 Plant Species Abundance

Sampling of the vegetation in both grazed and ungrazed plots at different sites in the Barandabhar corridor forest has shown there are several palatable plant species in the study area. In total, 102 species of plants (55 flowering plants, 33 grasses, 3 pterydophytes and 11 unidentified) were recorded. The grasslands close to the forest boundary were dominated by *Cyperus* species, *Cynodon dactylon* and *Festuca leptopogon*. Moist and grazed areas were dominated by exotic herbs like *Ageratum conyzoides*. Wet parts of the grasslands were dominated by wetland plant species, such as *Persicaria barbata, Polygonum* species, *Alternanthera sessilis, Eclipta prostrata, Leersia hexandra* and *Floscopa scandens*.

7.3.2.2 Species Number and Similarity

Sorenson's index of similarity was highest in the rainy season and lowest in the winter season (Table 7.2). Grazed grasslands contained consistently and significantly more plant species than ungrazed grasslands (Table 7.2). It would be interesting to determine whether grazing positively affects plant species number, or whether domestic animals graze preferably in species-diverse habitats? This question remains unanswered. In the rainy season, the number of common plant species in the grazed and ungrazed areas was higher than in the spring and winter season (Table 7.2). In the dry season (winter), most of the grasslands were dry, and therefore the number of species was lower than in other seasons.

7.3.2.3 Species Composition

The relative cover of graminoides was significantly lower in the grazed plots, compared with the ungrazed ones (two-sample t-test, $t=114.5$ d.f. = 2, $p<0.05$), while in the herbs, the reverse was true (two-sample t-test, $t=37.52$, d.f. = 2, $p<0.05$) – Table 7.3. Barren ground was significantly more common in the grazed plots, compared with the

Table 7.3 Mean percentage cover of different plant species in the plots

	Percentage cover									
	Grass		Flowering plants		Pterydophyte		Unidentified		Barren	
Season	G	NG	G	NG	G	NG	G	NG	G	NG
Rainy	49.7	77.4	33.1	18.1	1	0.6	2.4	1.7	13.8	2.1
Winter	60.1	87.4	20.0	6.2	–	1.2	1.7	1.6	18.1	3.6
Spring	55.2	82.1	26.4	12.6	0.4	1.1	1.6	1.4	16.2	2.8

G grazed, *NG* ungrazed grassland

Fig. 7.5 Relative cover (%) of Graminoideae, herbs and barren area in the sampling sites

ungrazed ones (two-sample t-test, t = 15.89 d.f. = 2, p < 0.05) – Table 7.3. The dominant grass species was *Imperata cylindrica* (relative cover = 24%), especially in the ungrazed plots. Other common grass species included *Cyperus* species (relative cover = 14%), *Digitaria ciliaris* (relative cover = 10%), *Eragrostis tenella* (relative cover = 9%) and *Bulbostylis barbata* (relative cover = 7%). The flowering plant communities were dominated by *Ageratum coryzoides* (relative cover = 31%). The relative cover of Graminoideae was higher in ungrazed sites as compared to the higher cover of herbs and barren area in grazed sites (Fig. 7.5).

7.3.2.4 Standing Biomass

The aboveground dry biomass was much smaller in the grazed, compared with the ungrazed plots, but there were no differences in its amount between the seasons and between the sites. (two-sample t-test, t = 8.58 in rainy, 9.26 in winter and 9.20 in spring season; P = 0.05, df = 4). The larger standing biomass in the ungrazed areas (Table 7.4) was mainly due to the higher relative cover there of *Imperata cylindrica* and *Cyperus* species.

Table 7.4 Standing biomass (g/m^2) at different locations in the Barandabhar corridor forest

Sampling sites	Associated forest	Rainy season		Winter season		Spring season	
		Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed
Bhojhad	Sal forest	85.8	268.8	62.1	229.2	75.2	243.2
Naurange	Sal forest	88.2	213.6	74.2	195.2	81.3	206.3
Gondrang	Sal forest	106.4	324.1	87.0	285.1	96.6	305.5
Ujelinagar	*Shorea-Terminalia* understory	79.8	312.4	58.2	281.1	64.2	292.4
Khorsor	*Shorea* - mixed understory	125.2	265.2	89.8	231.2	102.4	249.1

7.4 Discussion

7.4.1 Competition Between Wild and Domestic Ungulates

The effect of grazing by domestic animals in the Barandabhar corridor forest is aggravated by the villagers only grazing their unproductive livestock in the forest. They have both highly productive and unproductive livestock, but mainly only graze their many unproductive animals in the forest because they are afraid to let their expensive and more productive buffalo graze deep in the forest due to the risk of predation by large predators like tiger and leopard. Grazing is higher in the non-buffer zone than in the buffer zone due to restrictions imposed on livestock grazing in the buffer zone.

Livestock grazing in the buffer zone area was mainly confined to the Khoresor-Mainahari flood plain area and the vicinity of the highway in Gondrang, whereas in the non-buffer zone, most grazing was close to the bank of the Khageri River and Bhojhad. The local people in these villages are mostly of lower caste and have very little food. They are mostly dependent on the forest for grazing, fodder collection, firewood, timber and non-timber forest products like tubers, medicinal plants etc. They keep large numbers of unproductive domestic animals for milk, plowing and producing compost for their fields. Their domestic animals were recorded in the meadows, riverbanks or forests, which are part of the wildlife habitat, because of the lack of ample grazing areas outside the forest. Domestic and wild ungulates therefore often use the same meadows for grazing, which reduces the food available for the wild ungulates, and contact between domestic and wild animals may result in the transmission of diseases (Moe 1993).

Grazing by livestock was mainly confined to the village forest border. Local people grazed their cattle and buffaloes from the border up to 3.5 km inside the forest, but goat and sheep grazing were confined to the forest border. This results in an increased environmental degradation of the forest border and affects the distribution and abundance of wildlife (Jackson and Ahlborn 1987). Dinerstein (1979) also reports there is a high grazing pressure exerted exclusively by goats and sheep along the forest boundary. Grazing may have a marked impact on the terrestrial invertebrate fauna, although this is usually attributed to a decrease in species richness or diversity (Bromham et al. 1999; Seymour and Dean 1999). It is likely that the negative effect of livestock grazing on insectivorous bird assemblages, particularly ground-foraging species, is due in part to a reduction in invertebrate food resources, which may in turn reduce reproductive success of the birds (Luck 2003). Grazing generally has a negative effect on bird and mammal herbivore richness or abundance, particularly of small insectivores, in other countries (Dobkin et al. 1998; Bock and Bock 1999; James 2003).

7.4.2 Effect of Livestock Grazing on Natural Habitats

In total, 102 species of plants were recorded in the grasslands of the BCF. Plant species richness was higher in grazed plots, which may be attributed to a lowered competition between the species in grazed areas (Whittaker 1977). The relative cover of flowering plants and that of grasses were lower in grazed plots, which was also recorded in other studies (Edroma 1981; Day and Detling 1990). The wild ungulates prefer grasses to flowering plants; therefore the increase in the relative cover of flowering plants directly affects the food quality of the grazed areas for wild ungulates (Bhattarai 2003). The difference in the relative cover in grazed and ungrazed areas was also partially affected by the nature of vegetation, landscape and degree of human and livestock influence (Belsky 1986).

The high percentage of barren ground and dramatically lower aboveground biomass in grazed plots is evidently a result of the regular grazing by livestock. The high percentage of the barren ground might result in an increase in soil erosion and subsequently cause a loss of soil nutrients, reduce soil porosity, and affect the water table. Overgrazing and trampling can severely affect soil erosion by compacting the topsoil, which leads to a decrease in rates of infiltration, increased surface runoff and subsequently to erosion (Broersma et al. 2000). We found a hard land surface in most of the grazed sites, but did not measure it quantitatively.

The aboveground biomass was greater in the ungrazed than in the grazed grasslands, but very little of this biomass is likely to be a palatable food for selectively feeding wild ungulates, while the reverse is true for the grazed areas (Sinclair 1974). The foraging efficiency (i.e., the biomass intake and nutrient intake per bite), as well as the number of bites per unit time is likely to be higher in the grazed areas, as compared to ungrazed (Bailey et al. 1996; Bradbury et al. 1996). However, due to the low aboveground biomass in the grazed grasslands, the large wild herbivores need a much larger area to satisfy their food requirements.

Livestock grazing is one of the major factors in the decline of natural structure and composition of remnant vegetation (Garnett and Crowley 2000). The indirect effects of livestock grazing are alterations in the structure and composition of the native vegetation (Saunders et al. 1991). It is known that livestock grazing reduces the competition among plant species and in this way promotes species richness and diversity within a community (Detling 1998). We found that the species richness was higher and standing biomass lower in the grazed compared to the ungrazed areas. In some places, the grazed areas appear to be maintained by excessive grazing and enrichment by the deposition of excrement. The severe effects on the vegetation of the grazed areas might, however, change the population structure of the ungulate and other herbivore communities grazing there, which may ultimately result in the decline of numerous wildlife species.

7.5 Conservation Implications

Livestock grazing is one of the foremost threats to the conservation of wildlife in Chitwan. Their grazing not only reduces the quality and quantity of the grazing for wildlife, may result in the transmission of various livestock diseases to wildlife, when livestock and wildlife share the same habitat. To reduce the adverse effects on wildlife, the following changes in management are proposed: (1) the non-buffer zone area of the Barandabhar corridor forest should be added to the buffer zone of the Chitwan National Park; (2) livestock grazing zones should be clearly demarcated and the local people encouraged to avoid grazing pedigree stock there and, most importantly, (3) community-based programs, such as community forestry, agro-forestry and biogas, need to be implemented in the Barandabhar corridor forest, so that even the poorest people in the region have alternative ways, of achieving their basic needs.

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Chapter 8
Challenges to Wildlife Conservation Posed by Hunting in Non-protected Areas North of the Bardia National Park

Prakash Kumar Paudel

Abstract The hunting of wildlife for subsistence and trade is a serious threat to conservation. It is widespread in the non-protected areas. However, there is no understanding of the nature and trends in hunting and their consequences for protected areas. The nature and scale of hunting north of the Bardia National Park were assessed to determine the spatial variations in hunting intensity. Focal group discussions with forest user groups and transect surveys were used to determine the abundance of wildlife. Detailed interviews with hunters were used to explore their hunting patterns. Apart from the information obtained from the interviews, encounters with hunting teams, hunting signs and information from herders were used to identify hunting sites. Hunting is widespread throughout the region, but the intensity of hunting is greater close to the northern edge of the national park, which is associated with the relative abundance there of wildlife. Hunting along the immediate periphery of the national park is increasing. The hunting of common and protected species suggests that it is both for subsistence and trade, which could severely deplete the wild animals in the forests and consequently affect the protected area. Hence, it is necessary to legalize community-based monitoring by forest users groups and establish effective government supervision.

Keywords Wildlife-hunting • Landscape • Bardia National Park • Non-protected area

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8.1 Introduction

Human exploitation of biotic resources is causing degradation of the habitats of many species, resulting in their rapid decline and extinction (Primack 2002). Approximately 10–20% of all vertebrate and plant species are at risk of extinction over the next few decades (IUCN 2005). Wildlife hunting for subsistence and commercial purposes constitutes a major threat to species survival (WCS and TRAFFIC 2004). In Southeast Asia, illegal trade in wildlife exceeds billons of US dollars each year (Deeks 2006).

Nepal has a greater biodiversity (Chaudhary 1999) than expected from its geographical size and is regarded as one of the world's biodiversity hotspots (Braatz 1992). Altogether, 39.6% of the total land area in Nepal is covered by forests and shrubs (Härkönen 2002). The protected area network covers 18% of the country's surface (DNPWC 2003). The country has adopted different measures for conserving biodiversity. In Nepal, hunting wildlife without permission is punishable by law. The National Parks and Wildlife Conservation Act provides varying degrees of protection based on the species concerned. Hunting is not permitted in the national parks, but might be allowed under license in other categories of reserve. The act basically focuses on protected areas and there is little legal infrastructure for enforcing conservation outside protected areas (Heinen and Kattel 1992).

The area north of the Bardia National Park (BNP), the Siwalik Hills, is covered by dense forests. It connects the park with forests in the mid hill region. It is an underrepresented region in the protected area network in Nepal (Chaudhary 2000; Balasinorwala et al. 2008). Subsistence agriculture, raising livestock, collection of non-timber forest products (e.g., medicinal herbs) are important occupations of the mid hill people (Upadhyaya 2000). Subsistence hunting, a common off-farm activity of people in many regions of this mountainous landscape, is threatening the biodiversity of the area (BPP 1995; HMGN/MFSC 2002). Disappearance of the Himalayan tahr from the lower mid hills (Green 1979) and decrease in the goral population (Wegge and Oli 1997) are believed to be the combined result of hunting and habitat loss. This threat increases with human population growth; hence there is an urgent need to assess hunting patterns and their trends over the entire landscape. Such data are needed for devising an effective conservation strategy for this landscape, including the national park.

The Bardia National Park is the largest national park in the lowland Terai region of Nepal. The park covers an area of 968 km^2. It is home to the second largest tiger, rhino and elephant populations in Nepal. The park is dominated by subtropical broadleaved sal forest, with riverine forests and grasslands also abundant (Jnawali and Wegge 1993). The alluvial grasslands are remnants of the once-extensive ecosystem of the Gangetic floodplain (Dinerstein 2002). The park covers a part of the Terai-Duar savanna and grasslands and Himalayan subtropical broadleaf forest ecoregions (Wikramanayake et al. 2002). The park harbours 55 species of mammals, 54 species of reptiles, 125 species of fish and 470 species of birds (BPP 1995). It is one of the WWF's focal tiger landscapes (WWF 2002) and is a designated site for rhino conservation (DNPWC 2006). Department of National Parks and Wildlife Conservation is solely responsible for park management and the Nepalese army for maintaining security. An area of 327 km^2 surrounding the national park, except on the northern edge, is designated a buffer zone.

8.2 Objectives

The research presented here was carried out in the area north of the BNP with the aim of determining the general pattern, nature and scale of hunting. The study aims to answer the following questions:

1. What is the spatial and temporal pattern of hunting?
2. What factors determine the hunting practices?
3. What would be the consequences of hunting in the national park and adjacent areas?

8.3 Methods

8.3.1 Study Area

The study area is a human-dominated forest landscape north of the BNP. The study was carried out in areas supervised by 27 Village Development Committees (VDCs) in the Surkhet, Dailekh and Jajarkot districts. The area lies north of the national park and extends northwards, perpendicular to the park boundary. Rujun and Sot Khola (streams) form the western boundary of the southern part. The western boundary runs parallel with the district boundary of Surkhet, which encompasses Goganpani, Piladi, Awal Parajul, Katti, Lalikanda, Jagannath and Moheltolee VDCs of Dailekh district. In the north, it is confluent with the Jajarkot, Dailekh, Kalikot and Jumla district boundary and covers the Garkhakot and Daha VDCs of Jajarkot. The eastern boundary passes through the eastern boundary of Garkhakot and Suganauli VDCs and covers western areas of Salma and Dasera VDCs in the Jajarkot district. The eastern boundaries of Ratu, Jarbuta and Latikoili VDCs in the Surkhet district form the eastern boundary in the south. Dhulepaire Khola and Bheri rivers and the Nepalgunj-Surkhet highway form the south eastern boundary (Table 8.1, Fig. 8.1). The study area was classified based on its proximity to the national park (Table 8.1).

The study area extends south to north (71 km) at altitudes ranging from 520 to 4,200 m. Forest covers almost two thirds of the total area (CBS 1994; DDC/Surkhet 2002; PDDP 2003). The total human population in the area is estimated to be 120,000 inhabitants, out of which 44% are illiterate (CBS 2001). The Chhetris, the second highest caste in the Hindu caste system, is the dominant group, which is followed by the so called "untouchables." Ethnic groups, such as the Magar and Gurung etc., are found in clusters throughout the area. Subsistence agriculture and animal husbandry, their main occupations, hardly sustain the daily and incidental needs of the people. Based on the Human Development Index (HDI) of 75 districts in Nepal, which includes parameters

Table 8.1 Administrative units (Village Development Committees and Municipality) in the southern, middle and northern parts of the study area

Part of the study area	VDCs/Municipality	Districts
Southern	Latikoili, Uttarganga, Taranga, Hariharpur, Birendranager municipality	Surkhet
Middle	Lekhgau, Kunathari, Pokharikanda, Salkot, Gadi, Jarbuta, Ratu	Surkhet
	Goganpani, Piladi, Lalikanda, Awal Parajul,	Dailekh
Northern	Salma, Dasera, Suganauli, Majkot, Daha, Kortang, Garkhakot,	Jajarkot
	Katti, Jagannath and Moheltolee	Dailekh

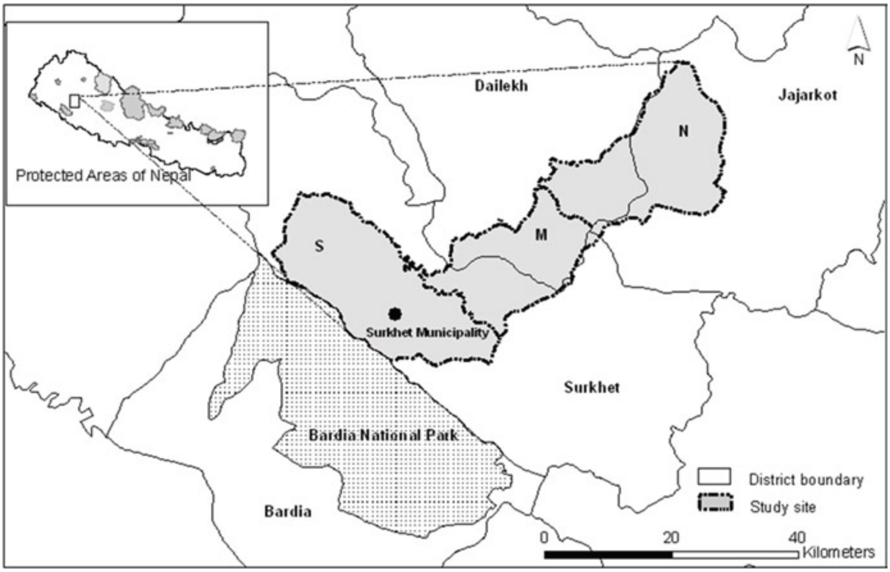


Fig. 8.1 Map showing the location of the southern, middle and northern parts of the study area (*S* – southern, *M* – middle, and *N* – northern)

such as life expectancy, literacy and standard of living, the districts Surkhet, Dailekh and Jajarkot rank 44th, 67th and 71st, respectively (UNDP 2004).

8.3.2 Data Collection

8.3.2.1 Focused Group Discussions

The area supports a lot of protected wildlife of global conservation significance, but their distribution in the landscape is unknown. A qualitative approach was used to assess the presence/absence of each species. Sampling areas were selected to include the major forest patches. However, locations for the Focus Group Discussions (FGD) were selected at random. The FGD is a useful technique for obtaining qualitative information, which can be used to evaluate habitats in cases where their

Table 8.2 The species of wildlife that were subjects of the discussion and their status

		Status		
Scientific name	Common name	CITES	IUCN	Nepal[a]
Capricornis thar	Himalayan serow	I	NT	
Macaca mulatta	Rhesus monkey		LC	
Moschus chrysogaster	Himalayan musk deer	I	E	√
Muntiacus muntjak	Barking deer		LC	
Naemorhedus goral	Himalayan goral	I	NT	
Neofelis nebulosa	Clouded leopard	I	V	√
Panthera pardus	Common leopard	I	NT	
Semnopithecus entellus	Common langur	I	V	
Sus scrofa	Wild boar		LC	
Tetracerus quadricornis	Four-horned antelope	III (Nepal)	V	√
Ursus thibetanus	Himalayan black bear	I	V	

E Endangered, *V* Vulnerable, *NT* Near Threatened, *LC* Least Concerned
[a]Species protected by National Parks and Wildlife Conservation Act 1973

condition is uncertain (Yamada et al. 2004). Forest user groups were used as the basic unit for discussion. It is a community-based organization, constituted for conservation and sustainable harvesting of forest products (timber, firewood) from a designated area. 104 FGDs were organized throughout the entire area. The participants were executive members, forest guards and users. Due attention was given to ensure participation of women and guards, who frequently visit the forests. Semi-structured questions were used in order to structure the discussion.

Presence/absence data for the targeted species of wildlife were collected (Table 8.2). The participants in the discussions were asked to state the level of wildlife presence, using the scale: A – come once/twice a year, B – frequent visitor (more than every 4 months), C – resident based on sighting every month. In such studies, absent species are seldom recorded except by identification or transcription errors (Gu and Swihart 2004). In some cases, uncertainty of the species identification results when a single term is used for more than one species. Photographs were used to identify some of the species. Initially, the ability of the people to identify species was determined by asking them to identify species in photographs.

This wildlife presence data provided information on (1) spatial distribution of species, and (2) habitat suitability. Presence of the species in the forest area throughout, or once or twice a year, carries different meanings and assigning geometric values to each presence level gives the best index of their presence. Therefore, the geometric values (A = 1, B = 10, C = 100) were assigned to the species presence scale and the total presence scale (PS) for each species was calculated for the whole area:

$$PS_i = \sum_{K=1}^{n} PV_{ik}$$

where

PS_i = presence scale of species *i* in the landscape
PV_{ik} = geometric value of species *i* in forest unit *k* (A = 1, B = 10, C = 100)

8.3.2.2 Transect Surveys

A wildlife survey provides quantitative information about the distribution of wildlife communities. Line transects are commonly used in different situations as described in Buckland et al. (2001). The forest area of each forest user group was surveyed using a transect. Direct observation of animals and their signs (dung, footprints and calling) were recorded. In some places, where the terrain was steep, observations were made from fixed-points. Each survey was conducted between 6:00 and 18:00. A total of 135.6 km of transect were surveyed and observations from 30 fixed recorded. This data was used to confirm the distribution of wildlife obtained from the FGDs. Confirmation of the qualitative data by this means increases one's confidence in the data and helps in devising methods and processes of carrying out questionnaire surveys in ecology (White et al. 2005).

8.3.2.3 Questionnaire-Based Surveys and Interviews with Hunters

Identification of hunters and obtaining information from them are difficult tasks, as they are reluctant to disclose such information to outsiders. The close rapport and relationship established with local people was used to reach and communicate with the hunters. In some cases, the local staff, who accompanied us during the transect surveys, were hunters. A close rapport was developed with the hunters by acknowledging the necessity of hunting as a means of supplementing their nutritional needs and for recreation. This proved to be an effective way to develop trust and confidence. Altogether, 63 surveys were conducted to assess the extent of hunting by 25 teams of hunters. I did not record hunting activities that resulted either from retaliatory actions, or opportunistic hunting, because they are ad hoc and make up only a small proportion of the total. This type of hunting is infrequent and occurs when wild animals visit a settlement or cropland. In the northern part of the study area, a sudden arrival of wildlife in a village is seen as an ominous sign and killing them the only way of eliminating such foreboding. Retaliatory hunting is more common in the areas that suffer high crop depredation. Hunting of wild boar and monkey falls into this category, but it is significantly rarer than organized hunting by a team.

A hunting team is defined as a group of hunters that organize and plan hunting expeditions several times a year, and in which the key hunters and their close aides remain the same for most of the time. A typical team consists of from 10 to 25 members. Each member carries a gun, a spear or long stick. The team is sometimes accompanied by dogs and stays overnight in the forest. Data on the place and means of hunting were recorded from several members of each team to reduce bias and used to produce a report on the hunting activity of the team over the last 3 years.

Data collection and cross-validation for each team took 3–5 days, depending on the availability of hunters for questioning and their cooperation. In the southern part of the study area, people were reluctant to disclose anything about hunting. In the northern part, however, people openly discussed their hunting of wildlife, such as barking deer, wild boar, goral and common langur, as most of them regarded this transgression of rules as common practice and rooted in tradition. Cross validation of data from teams was used to assess the numbers of leopards, bears and musk deer killed, as all of them are protected in Nepal. In some cases, people were reluctant to disclose that they hunted protected animals but often indicated that other people did. Apart from the interviews, information obtained from accidental encounters with hunters and people trading in wildlife was recorded. This information was recorded as supplementary data and used to refine the main data set.

8.4 Results

8.4.1 Wildlife Distribution

Wild boar (*Sus scrofa*), rhesus monkey (*Macaca mulatta)* and barking deer (*Muntiacus muntjak*) were the most common mammals in the area. They were reported from 90% of the sites sampled (Fig. 8.2). Among them, barking deer had the highest presence scale. Common langur (*Semnopithecus entellus*), goral (*Naemorhedus goral*), bear *(Ursus thibetanus)* and common leopard *(Panthera pardus)* were in the second group, when ranked in terms of abundance. They were reported from 55% to 70% of the areas sampled. However, they had a variable presence scale index (common langur – 14.92, goral – 17.75, bear – 3.66, common leopard – 2.75). Common leopards were reported to be resident in the dense forests near the BNP and in forests along the river Bheri. These sites are located in the southern and middle parts of the study area. The incidence of attacks on livestock at these sites is high (Fig. 8.3). In the northern part, bears were reported only from the Kechali and Nepane forest areas of Daha VDC of Jajarkot. In other areas, these mammals were reported only occasionally.

Of the wildlife surveyed, barking deer (0.324 km^{-1} in the south, 0.263 km^{-1} in the central part and 0.337 km^{-1} in the north) were the most frequently sighted, followed by goral (0.12 km^{-1}) and wild boar (0.22 km^{-1}). The indices obtained from the focal

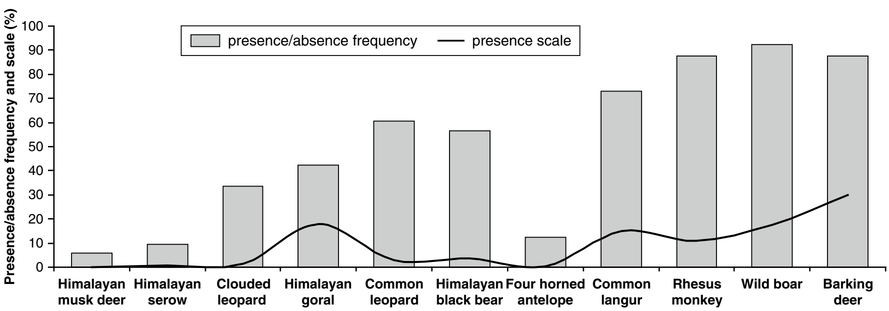


Fig. 8.2 Wildlife present in the study area [Presence/absence at sampled sites and their presence scale]

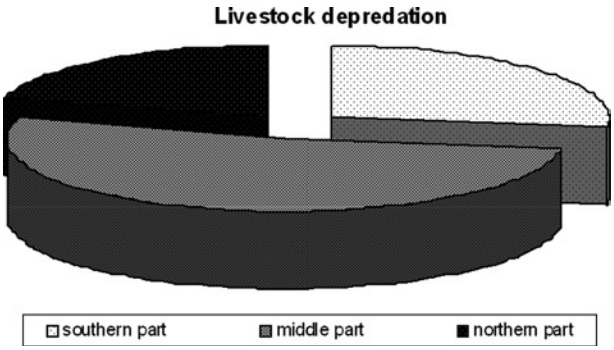
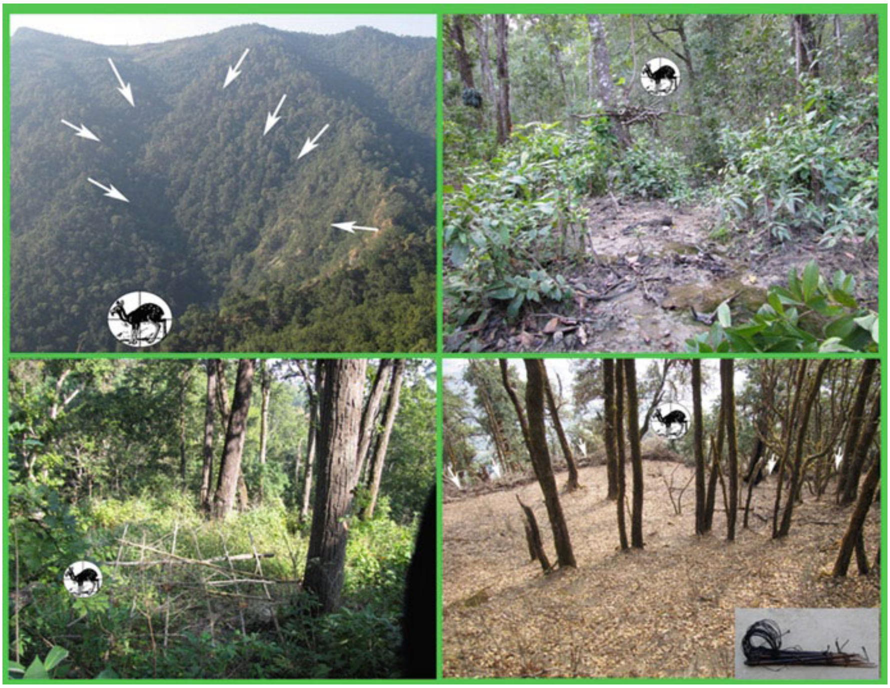


Fig. 8.3 Depredation of livestock during the period 2005–2007

Wildlife hunting has been a major conservation challenge in Nepal. Hunting serves for both subsistence and trade. Remnants of *Capricornis thar* (Himalayan serow) killed by hunters near the Bardia National Park (Photo by PK Paudel)

Common langur (*Semnopithecus entellus*) – hunted for meat, used in traditional medicine (Photo by BP Bhattarai)



Commonly used hunting techniques: chase and hunt (*top left*), wait and hunt (*top right*), hunting with net (*bottom left*) and hunting with snares (*bottom right*). Hunting icon indicates position of hunter with gun (*top left* and *right*) and places of snares and net (*bottom left* and *right*). In *inset*: a typical snare used to hunt the red Jungle fowl (*Gallus gallus*) – see Table 8.4 for details (Photos by PK Paudel)

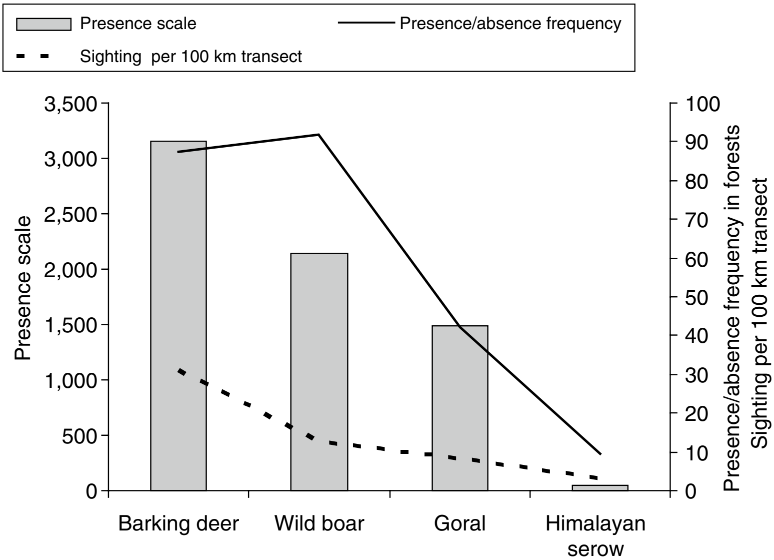


Fig. 8.4 Abundances of wildlife in the study area [only verified presence indices are included]

group discussions were significantly positively correlated with the results for the major prey species recorded by transect surveys (r = 0.93). However, the presence of clouded leopard and bear was not verified. Clouded leopards are very secretive, partially nocturnal (Austin and Tewes 1999) and well adapted to the moist subtropical semi-deciduous forest in western Nepal (Dinerstein and Mehta 1989). There were no signs of musk deer being present in the northern part of the study area, where they were said to be present. However, body parts of musk deer were found in residences of the local people, thus it is likely these deer are present (Fig. 8.4).

Goral (*Naemorhedus goral*) is relatively frequently recorded, even though only from less than half of the areas surveyed. They prefer very steep slopes covered by grass, which makes it easier for them to hide and escape from predators. Clouded leopard (*Neofelis nebulosa*) is the least common species. Himalayan serow (*Capricornis thar*) and musk deer (*Moschus chrysogaster*) are reported from the middle and northern parts of the study area. Of the wildlife, four horned antelopes had the lowest presence scale (PS = 0.35). They were reported only from the southern part, in forests along the river Bheri.

8.4.2 Hunting Groups and Their Preference for Particular Species

The data indicated widespread hunting in the region. Of the 25 hunting groups identified, 6 were in the southern, 10 in the middle and 9 in the northern part. There were considerable differences in the group's hunting scores. A hunting group killed an average of 29 ± 19.5 animals in 2005, 37.0 ± 21.9 in 2006 and 64.6 ± 49.1 in 2007.

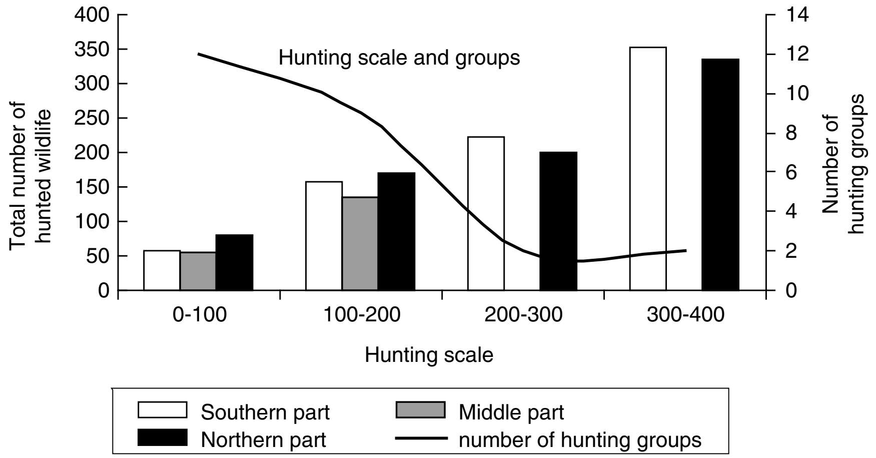


Fig. 8.5 The numbers of hunting groups and numbers of animals they killed in the different parts of the study area

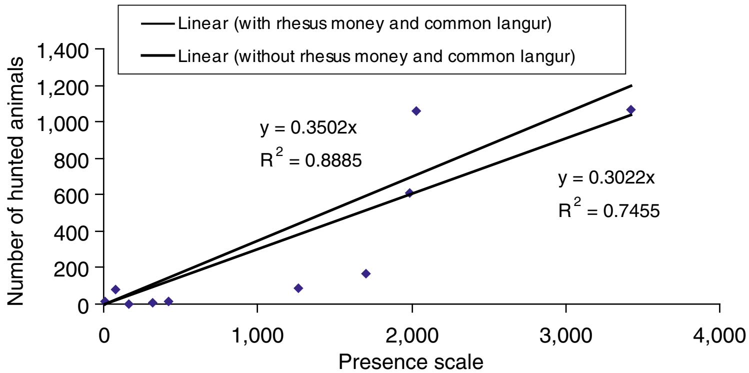


Fig. 8.6 A regression analysis of the relationship between the number of animals hunted and their presence scale

The total number of animals hunted per group ranged from 33 to 412 in the 3 years. This indicates that there was more hunting of animals in the southern and northern than in the middle parts of the study area during the last 3 years (Fig. 8.5). It was not possible to determine the average size of the hunting groups, because it is flexible due to off-farm employment in India and on farm activities. About half of the groups (48%, 12 groups) killed less than 100 animals, followed by 9 (36%) that killed 100–200, 8% that killed 200–300 and 8% that killed 300–400 (Fig. 8.5).

Hunting was significantly positively correlated with the relative occurrence of a species (Fig. 8.6). Thus, the more abundant species were more likely to be hunted. The residuals were not influenced by the species, except in the case of the rhesus monkey, which were hunted less than their PS suggested (Fig. 8.6). Rhesus monkeys

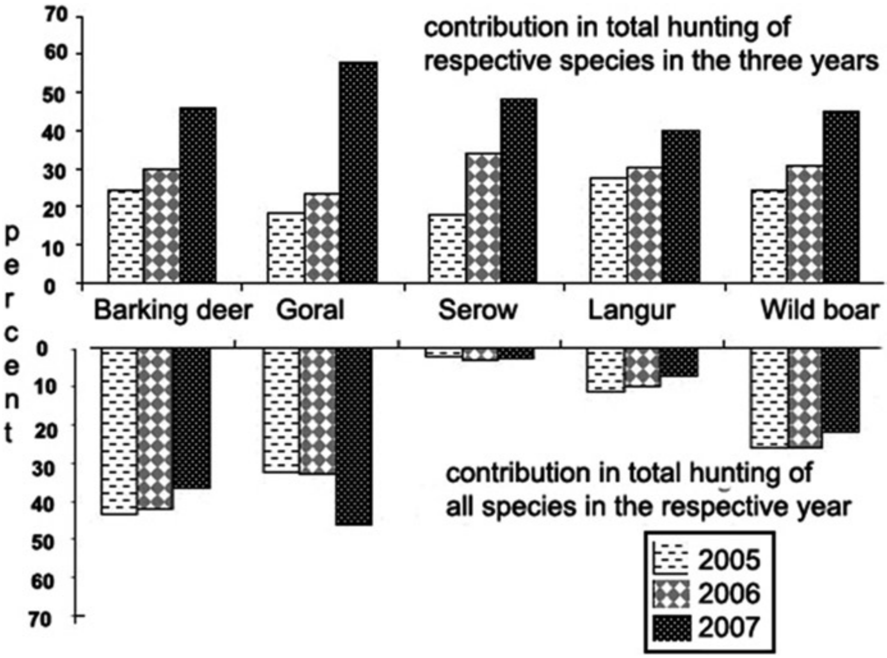


Fig. 8.7 Trends in the hunting of wildlife

are less frequently hunted than common langur. Common langurs are hunted for their meat, which is thought to have medicinal properties. Rhesus monkeys, however, are not hunted for their meat but because they damage the crops.

Barking deer was the most commonly hunted animal, followed by goral, wild boar and monkey. Barking deer made up 37.1%, 36.1% and 31.8% of the total number of animals hunted in 2005, 2006 and 2007, respectively (Fig. 8.7). However, the numbers killed each year increased. Of the total number of barking deer hunted, 29.9% were hunted in 2006 and 45.9% in 2007. Gorals were the second most preferred mammal. They made up 27.9%, 27.8% and 39.6% of the total number of animals hunted in 2005, 2006 and 2007, respectively. There is an increasing trend in the hunting of goral over this period of 3 years with 58.2% hunted in 2007 compare with the 18.4% and 23.4% hunted in 2005 and 2006, respectively. Wild boars make up 22.2%, 22.2% and 18.6% of the animals killed in 2005, 2006 and 2007, respectively. Of them, 24.1%, 30.7% and 45.1% were hunted in 2005, 2006 and 2007.

Langur/monkey and serow were the fifth and sixth most hunted species. They made up 8.5% and 2.3% of the total number of animals hunted over the 3 year period. Kills of bears, musk deer and leopards (common and clouded) were reported mainly in 2006 and 2007. There was an increasing trend in the numbers of wildlife of all species hunted (Fig. 8.8). Results of Duncan post hoc tests, at a 5% significance level, of the increases in the hunting of the different species are given in Table 8.3. Different letters indicate statistically significant differences between

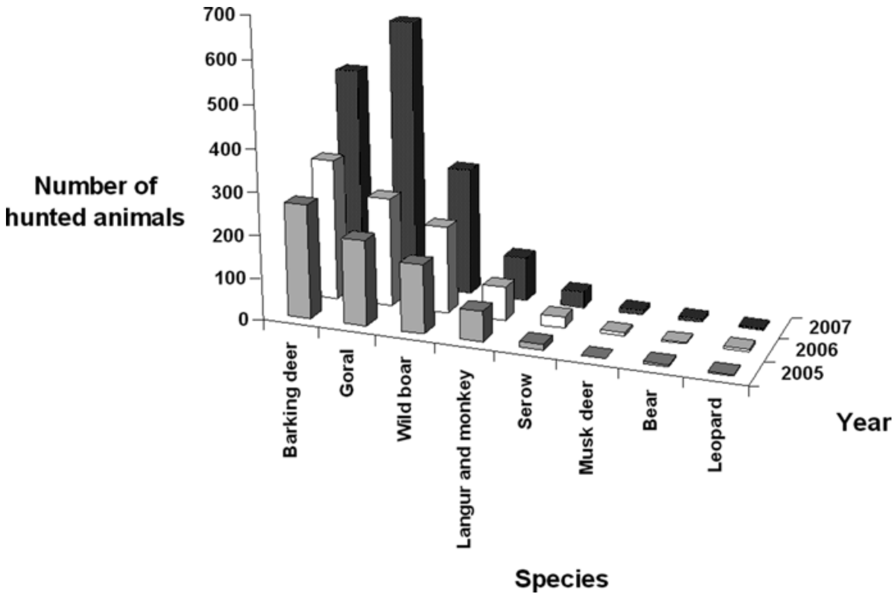


Fig. 8.8 Trends in the hunting of different species of wildlife over the 3 year period 2005–2007

Table 8.3 Results of Duncan post hoc test of the differences in the incidences of hunting of the different species of wildlife

Barking deer	Goral	Wild boar	Langur and monkey	Serow	Musk deer	Bear	Leopard
A	A	AB	BC	C	C	C	C

values. There are no significant differences in the trends for (a) barking deer, goral and wild boar. (b) wild boar, and langur and monkey and (c) langur and monkey, serow, musk deer, bear and leopards.

8.4.3 Hunting Techniques and Methods

Hunting techniques depended on the target species, its availability and weapons available (Table 8.4). The most common weapon was a home made gun, the *Bharuwa Banduk*. In addition to guns, nets, snares and spears (*Bhala*) were commonly used. A gun is a pre-requisite for organized hunting and their use grew rapidly over the period 2005–2007. Only three groups (12%) had a gun in 2005, one group in the southern part and two in the northern part of the study area. These three groups were among the top 4 hunting groups in terms of animals killed. However, very few guns were reported at this time. By the beginning of 2006 a gun was the most important weapon of 20 groups. In 2007, almost all groups used guns for hunting.

Table 8.4 Common methods of hunting

Common place	Method	Target species
1. Chase-and-trap		
Low wildlife density area and in the hill gorge	A group of between 10 and 25 people, sometimes accompanied by dogs, chased wildlife from the hills on both sides of a gorge towards hunters with guns.	Barking deer, goral and serow
2. Wait-and-hunt		
Water sources and fruit trees	Hunters hide themselves near water sources or in fruit trees and wait the animals	Barking deer, goral and langur
3. Chasing hunting with dogs		
–	Small groups of hunters use dogs to chase and catch wildlife, which are then shot by the hunters or stabbed with a spear, lance or pike.	Barking deer and wild boar
4. Trapping using nets and snares		
Wildlife tracks through the forest	Snares (mostly) and nets are placed across the tracks (Also used to kill wild boar at the fringes of the forest near settlements and on agriculture land)	Serow and musk deer

Chase-and-trap and wait-and-hunt were the mostly frequently used methods of hunting (Table 8.4). Other methods were very dependent on the nature and type of species and place of hunting. Traps were commonly used in forests near settlements and on agricultural land, because they are easy to install and convenient to monitor. Use of efficient weapons, such as guns, is considerably high than that of other traditional techniques. This has contributed to the growing scale of hunting in terms of the area subjected to hunting.

Most hunters (91.3%) reported a decline in the abundance of large mammals. More than 2/3 of the hunters thought hunting a common practice, accepted by the society as means of recreation and meeting nutritional requirements. Despite being regarded as a part of the social organization, 24% of hunters said they felt insecure when hunting. Likewise, 68% of them admitted that they hunted wildlife in order to generate income.

8.5 Discussion

High levels of hunting were recorded in the southern (adjoining national park) and northern parts of the study area, where wildlife is abundant. There are very few settlements in the large patch of forest that runs parallel to the park boundary in the southern part of the study area north of national park boundary. This together with lack of a conservation program for this area made it a safer place for hunters. The most favored spot for hunting is the region south of the river Beri. The relationships between hunting and species abundance (Rao et al. 2005), markets/settlements (Clayton et al. 1997) or institutional and legal mechanisms (Carrillo et al. 2000) indicate that hunting is a combined result of socioeconomic and institutional factors that influence the behavior and activity of the people.

There was an increase in hunting and change in the species hunted after the declaration of peace in the country. Nepal underwent a decade of armed conflict, starting in 1996. It ended in 2006 after a comprehensive peace accord was signed between the Nepalese Government and the Nepalese Communist Party (Maoist). During the conflict lack of security meant that people did not move very much and the Maoists confiscated most of the guns from the hunters. Thus, hunting was limited to the vicinity of villages and relied on traditional methods. With the resumption of peace, hunters gained both weapons and places to hunt. The hunting of goral increased as a result of both factors. Goral prefer steep rocky slopes and feed on grassy ridges (Wegge and Oli 1997). Such areas, which were previously inaccessible to people due to lack of security, became available for hunting. The use of more efficient techniques contributed to a great increase in hunting in 2007, which accounts for half of the total of wildlife killed (barking deer – 45.9%, goral – 58.2% and serow – 48.0%).

The association of hunting with wildlife abundance recorded in this study is also documented for Myanmar and Tanzania (e.g., Rao et al. 2005; Ndibalema and Songorwa 2007). The common factor in all these areas is that the trade-off between hunting of available wildlife and searching for preferred prey depends on the resources required. Generally, hunting is dependent on the relative abundance of wildlife. But hunting for trade is influenced by market demand, which can result in the local extinction of those species that can be marketed at a high price. Subsistence hunting can serve hunting for trade in areas, where subsistence options are very limited. In such situations, hunting is mainly for trade (Carpaneto and Fusari 2000). This has resulted in the marketing of surplus meat in the southern and middle parts of the study area, and hunting leopards, bear and musk deer in the northern part. This is supported by the attitude of the local people who thought we might be merchants coming to buy *Kusturi Bina* (musk). Such hunting has a detrimental effect on the wildlife. Madhusudan and Karantha (2002) and Dutta et al. (2008) report a dramatic decline in wildlife (especially mammals) in large and intact forests as a result of hunting. The loss of species through hunting in a fragmented landscape has profound secondary effect on biological diversity and community structure (Robinson 1996).

Although hunting inside the national park by groups operating from outside the park was not detected, hunting in the area around the periphery of the national park (0–4 km, Fig. 8.9) where there is an abundance of wildlife has increased. This area is inaccessible by road and there is little possibility of hunters being caught. Hunting in areas around the national park is likely to have an effect on the abundance of wildlife in the protected area. Non-protected areas adjacent to

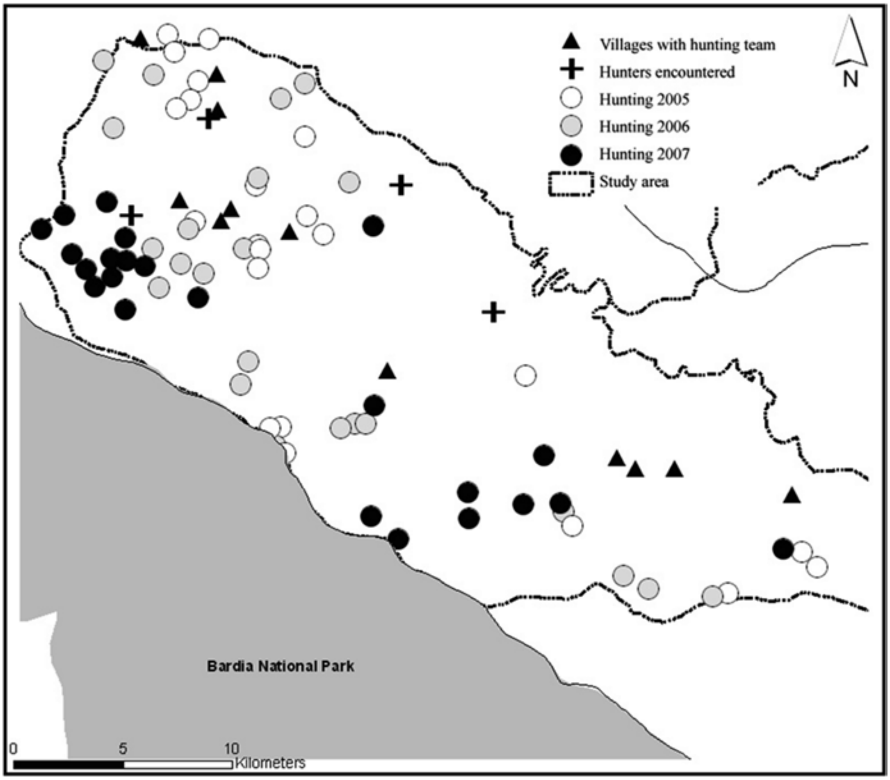


Fig. 8.9 Incidence of hunting in the area adjacent to Bardia National Park

the national park provide habitats, corridors and buffer zones for species protected in the national park (Bennett 1990, 1998; Saunders et al. 1991; Bennett and Mulongoy 2006). Hence, it is necessary to implement conservation practices in these areas. Institutionalizing and strengthening community forests is an ideal way of reducing hunting. The change in the behavior of the people due the restrictions associated with the establishment of community forests is documented for Nepal (e.g., Mehta and Kellert 1998). Effective restriction has a positive effect on conservation (Heltberg 2000). It has resulted in a reduction in hunting and an increase in the abundance of wildlife. Carrillo et al. 2000 has shown that wildlife abundance is dependent on restricting hunting and that any reduction in vigilance in strictly protected areas can have the same result as a reduction in hunting restrictions. However, a complete restriction on hunting, as in protected areas, may not be possible under the current technical, administrative and financial conditions. Thus there is a need to extend the buffer zone on the northern boundary of the national park and integrate the community based conservation and forestry programs in the area.

8.6 Conclusions

The hunting of wildlife occurs throughout the study area. There is a direct relationship between wildlife abundance and hunting, and the intensity of hunting is greatest in the southwestern part of the study area adjacent to the boundary of the national park. The increasing trend in hunting, mainly of goral, indicates a great increase in hunting in an area, which was previously inaccessible because it was insecure. In addition, the increased hunting of highly valued and protected species could lead to their extinction in particular areas. A buffer zone needs to be established north of the national park in order to gain the support of the local people and so reduce hunting.

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Chapter 9
Delineating a Wildlife Corridor in an Agricultural Mosaic: Effects of Landscape and Conservation Pattern

Prakash Kumar Paudel

Abstract In conservation the establishment of links between major habitats is commonly used to reduce the effect of habitat fragmentation and loss. There is no common model of a corridor, as it largely depends on the particular spatial configuration of land types and the way it is used. Geospatial information on land management practices provide the information required for corridor building programs. This paper aims to delineate a wildlife corridor between the Bardia National Park in Nepal and Katerniyaghat Wildlife Sanctuary in India. Data obtained from maps, a questionnaire and vegetation survey were integrated and used to quantify land cover and land use patterns. It proved difficult to delineate the boundary of corridors in a landscape consisting of diverse land types, when each is managed differently. Instead of delineating forest areas as a corridor, the integrated conservation of all land parcels, including private and settlement areas, provided the best approach. This makes the corridor a basic unit of management, and makes it convenient to deal with all issues in an integrated and holistic way.

Keywords Corridor • Landscape • Land use • Land management • Mapping

9.1 Introduction

Habitat alteration in the form of land-use development is a major cause of the loss of biodiversity (Crist et al. 2000; Sala et al. 2000). It contributes to habitat fragmentation either by decreasing the total area of habitat or by apportioning the remaining area into ever more isolated pieces (Wilcove et al. 1986). The concept of providing

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a corridor of habitat to connect natural environments and populations that would otherwise be isolated as result of human activity is one of the earliest practical recommendations arising from the worldwide concern over the ever-worsening loss and fragmentation of natural habitats (Bennett 1997). Corridors, in ecological terms, are connections between separate areas of similar habitat (Bolen and Willam 1995) and geographical extensions, continental or maritime, whose function is to connect areas and facilitate the movement of plants and animals and provide natural conditions that guarantee their conservation (Rivera et al. 2002). In order to identify potential corridors, both landscape properties and land use dynamics need to be quantified (Tischendorf 2001). It helps to understand the ecological function of large areas and hypothesizes that the spatial arrangement of ecosystems, habitats, or communities has ecological implications (Turner 1990). Thus, a joint assessment of natural landscape heterogeneity and management domains would provide information that could be used for corridor identification and management.

The southern region of Nepal, locally known as the Tarai (lowland), is one of the most bio-diverse areas in Asia. It harbours some of the remaining natural habitats of tigers (*Panthera tigris*), Asian elephants (*Elephas maximus*) and greater one-horned rhinoceros (*Rhinoceros unicornis)* (Smith and Mishra 1992; Smith et al. 1998). The region has few natural habitats, including five protected areas. At present, approximately 43% of the Tarai landscape (15,692 km^2) is still covered with forest of different quality, ranging from heavily degraded to intact forest (MOPE 2001). Protected areas constitute 19.7% of the Tarai forest. The pressure on forests, including protected areas is intense and their conservation a formidable challenge (Maskey 2001; MOPE 2001).

The Bardia National Park (BNP) is situated in the western part of Nepal. The park is connected with the Katerniyaghat Wildlife Sanctuary (KWS) in India by a small patch of forest in Nepal (Fig. 9.3). The forest areas that connect the BNP with the KWS pass through an agriculture mosaic.

Box 9.1 Tarai Arc Landscape

The Tarai Arc is one of the WWF's 25 focal ecoregions. It is also a priority area of the Save the Tiger Fund. It is a joint program of Nepal's Department of National Parks and Wildlife Conservation, the Department of Forests, WWF's Nepal Program, local communities and NGOs. The TAL covers approximately 49,500 km^2, stretching from Nepal's Bagmati River in the east to India's Yamuna River in the West. It links 11 trans-boundary protected areas, from the Parsa Wildlife Reserve in Nepal to Rajaji National Park in India. The landscape is the home to some of Asia's largest mammals – Bengal tiger (*Panthera tigris*), Asian elephant (*Elephas maximus*), greater one-horned rhinoceros (*Rhinoceros unicornis*), gaur (*Bos gaurus*) and swamp deer (*Cervus duvaucelii*).

(continued)

Box 9.1 (continued)

Tarai Arc Landscape (TAL) was initiated in Nepal with the dual objectives of biodiversity conservation and livelihood improvement. The project aligns with the following guiding documents: Nepal Biodiversity Strategies (NBS), Millennium Development Goals (MDGs) and Sustainable Development Agenda of Nepal (SDAN). The program adopts a landscape level conservation approach, which involves linking a network of protected areas with corridors to facilitate the long term survival of endangered wildlife and maintain the ecological integrity of the lowlands of Nepal (HMGN 2004, Fig. 9.2).

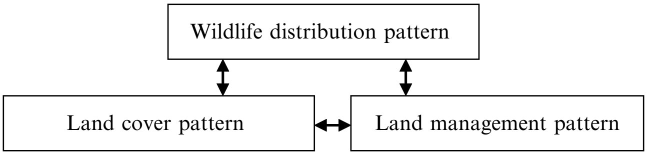

Fig. 9.1 Theoretical approach to conservation assessment

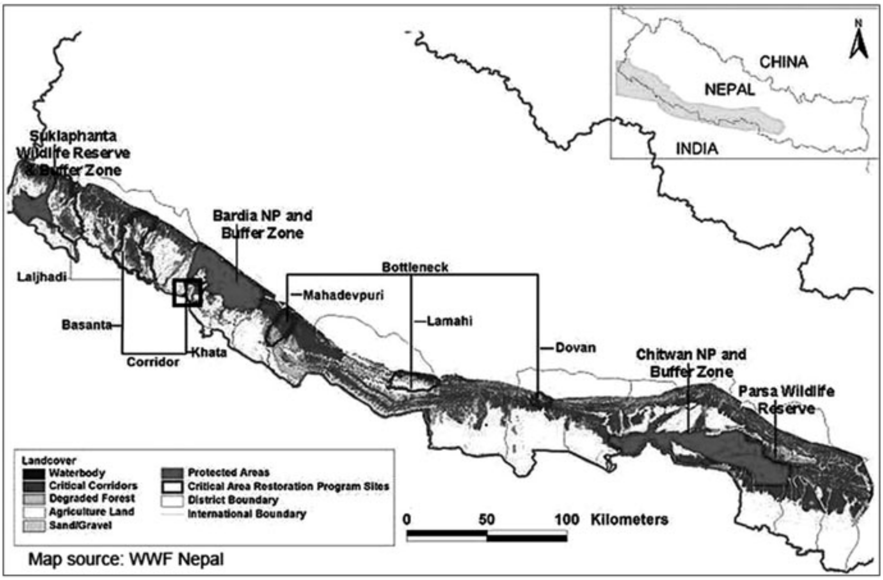

Fig. 9.2 Map of the Tarai Arc Landscape Area Project on which the *box* indicates the location of the study area (Source:WWF 2001)

An assessment of the landscape cover and land management pattern is the first step in developing a corridor management plan. Delineation of corridors in agriculture mosaics based on the spatial pattern of forest areas is generally inadequate because interactions among wildlife and people are multidimensional. Studies on wildlife are either on wildlife-human or wildlife- habitat interactions. An integrated assessment is lacking because detailed, reliable ground-survey data are often unavailable. Hence, assessment based on a theoretical approach is necessary to devise an effective conservation strategy. Such an integrated assessment, however, is less frequently applied (Bennett 1997), but offers a valuable tool for nature-conservation studies.

This study therefore uses a theoretical approach (Fig. 9.1) to explore and map a potential corridor between BNP and KWS within the Tarai Arc Landscape (Fig. 9.2). The basic objectives of this study were to: (1) assess proportion of the area under different types of land cover; (2) identify and delineate land management patterns; (3) assess the implications of land use and management patterns for the proposed corridor, and (4) delineate the boundary of the corridor necessary for conservation.

9.2 Methods

9.2.1 Study Area

The study area is in the southern part of Nepal and encompasses Shano Shree, Dhodhari, Bagnaha, Suryapatuwa, Khairichandanpur and Neulapur Village Development Committees (VDCs) of Bardia district. It is bordered in the south by the KWS, the buffer zone (BZ) of the BNP, Dalla, Chaugurdi forest and Orai river in the north, Neulapur – 4, 8 and 9, Bagnaha – 3, 5, 6 and 9 and Thakurdwara VDC in the east, and Khairchandpur VDC in the west (Fig. 9.3).

The BNP is situated in the mid western Tarai region of Nepal (81°20′ E, 28°35′ N) in the flood plain of the Karnali and Babai Rivers. The major vegetation of the park includes *Shorea robusta* forest, open grassland, savannah and riverine forest (Dinerstein 1979). The park harbours about 53 species of mammal, 25 species of reptile, three species of amphibia, 125 species of fish and 400 species of birds. A total of 50–65 elephants reside in the BNP and its buffer zone (pers. comm. Chief Warden BNP). On the southern border of the BNP lies the Katarniyaght Wildlife Sanctuary, which is close to the Indo-Nepal border. It is spread over an area of 400 km^2. Like the BNP, this sanctuary includes most of the flora of the Tarai region. The climax sal (*Shorea robusta*) forest is the dominant vegetation. The dominant tree species are *Shorea robusta, Aegele marmelos, Dalbergia sissoo* and *Terminalia tomentosa* (BJPS 2002a, b).

The climate is characterized by extreme seasonal and annual variability, with general characteristics of a tropical climate. It can be categorized as having three distinct seasons on the basis of temperature and rainfall: the monsoon season from mid June to late September, a hot and dry season from February to mid June, and a cool and dry season from late September to February. Rainfall is high in the rainy season as a result of west-east winds coming from the Bay of Bengal. The geographical formation of the study area is an alluvial plain with characteristics similar to the genetic plain of India to the south. The alluvial deposit of the Ganges plain is

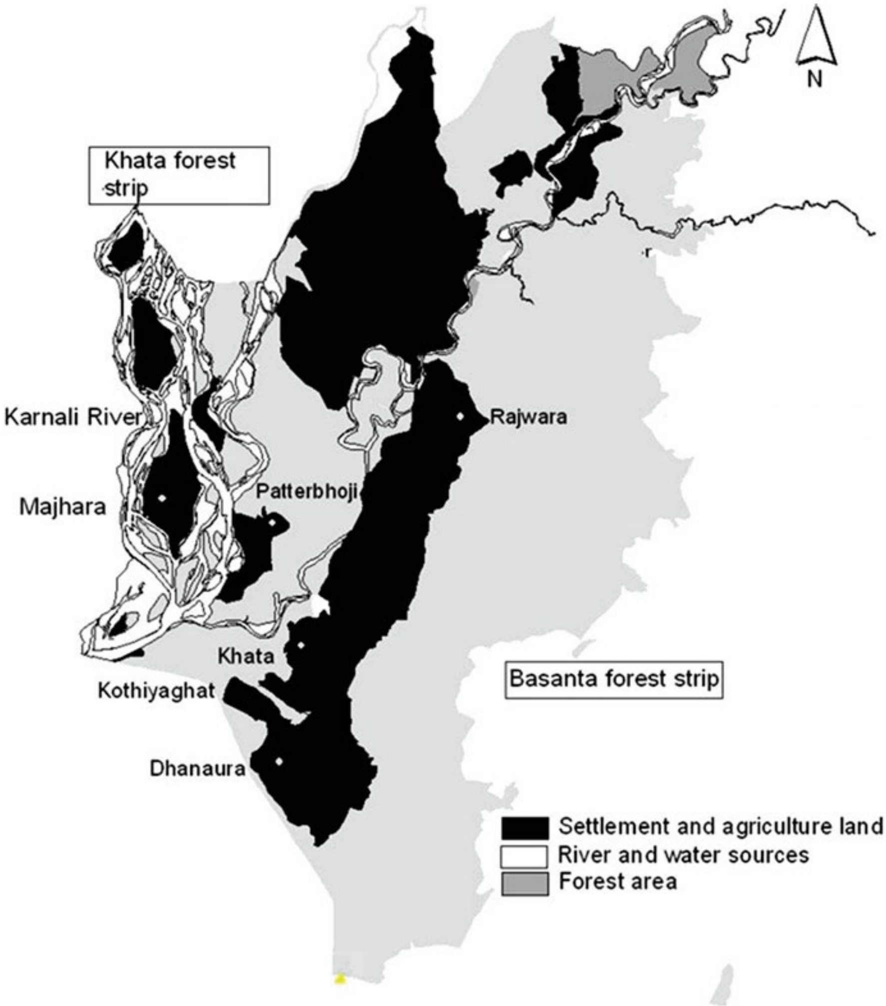

Fig. 9.3 A map of the study area

mainly composed of unconsolidated beds of sand and gravel in varying proportions (Bruijnzeel and Bremmer 1989).

9.2.2 Corridor Indices

The study area is the last remnant of forests that connect both protected areas. The corridor assessment is based on three parameters (Table 9.1): pattern of (1) land cover, (2) wildlife distribution and (3) land management. To delineate the corridor boundary, the likelihood of a strip of forest serving as a corridor was assessed using

Table 9.1 Parameters used in corridor delineation and assessment

Corridor assessment variables	Description	Assessment criteria
Land cover	Spatial distribution of the different types of land cover mapped on 1:25000 topographic maps of Nepal	Heterogeneity of land use Size of forested areas
Wildlife distribution	Spatial distribution of wildlife based on their occurrence	Relative presence of wildlife
Land management	Forest management practices and their potential implications for the forests	Proportion of community managed forest and government managed forests Differences in the forest structure

four criteria: land cover and its heterogeneity, occurrence of key wildlife species, land management and its existing and potential effect on the status of the forest. Whether or not forest strips connecting protected areas can serve as a corridor or result in an increase in human-wildlife conflict was assessed from a management perspective.

Topographic maps (Department of Survey, Government of Nepal) were used to gather spatial data. Sheet no 288 109 ‘B’, 288 109 ‘D’, 288 110 ‘A’ and 288 110 ‘C’ were used to map the pattern of land cover. Since diverse habitats are important for a wide range of species (prey and predators), habitat heterogeneity, obtained by superimposing a grid map of 500 m by 500 m on a land cover map of study area, was used to measure the variability in the type of land cover.

A list of the major species in both protected areas was prepared and their occurrence and distribution assessed based on presence/absence criteria. The frequency of wildlife occurrence was determined at four scales (1 – residential: wildlife reported throughout the year, 2 – frequent visitor: wildlife reported more than three times a year, 3 – rare visitor: wildlife reported once or twice a year) by interviewing cow-herders, forest guards and local people.

Data on land management practices were recorded for three broad categories: community forest areas, government forest areas and private land. According to the Forest Act (1993), community forest is a national forest handed over to local people for its development, conservation and utilization for the collective interest. The act defines all lands other than that owned by people as national forest. Government managed forest is national forest managed by the government of Nepal. The boundary community forests were delineated in the topographical maps (scale 1:25,000) with the assistance of forest staff. The maps were scanned, georeferenced and digitized. The extent to which each category of forest (community and government forests) was used to provide firewood, fodder and timber was assessed by questioning the residents of villages within 500 m of the periphery of the forest. Altogether 300 households were selected at random. The respondents, preferably household heads, were briefed about the general purpose of the study prior to this survey. Two local assistances were hired to make the research environment more comfortable and trustful because of the widespread security problems prevailing in the study area.

The regeneration status and vegetation structure were surveyed in both community managed and government managed forest areas. Six sites in the community forest and three in the government forest areas were chosen randomly from the map. A plot of 10 m by 10 m was used for trees. In the same plot, a 5 m by 5 m plot was placed in the centre of the large plot and used to assess the number of saplings. A 1 m by 1 m plot was established at each corner of each 10 m by 10 m plot for counting the number of seedlings. Trees with a diameter at breast height (dbh) greater than 25 cm were classed as trees, those with a dbh of 12.5–25.0 cm and less than 12.5 cm as poles and saplings, respectively. The following formulae were used to derive relative density and relative frequency of each plant species:

$$\text{Relative frequency }(\%) = \frac{\text{Frequency of individual species}}{\text{Sum of the frequencies for all species}} \times 100$$

$$\text{Relative density }(\%) = \frac{\text{Density of individual species}}{\text{Total density of all species}} \times 100$$

9.3 Results

9.3.1 Pattern of Land Cover

The analysis of the pattern of land cover revealed that forest covered 70.92% of the study area and was made up of mixed sal forests (53.43%), mixed forest (2.23%), sandy areas (5.82%), water bodies (5.46%), grassland areas (3.43%), bushy areas (1.42%) and barren areas (1.35%) – see Fig. 9.4. The mosaic in land-use patterns revealed a diversity of habitats (70.92% or 78.41 km^2) for terrestrial flora and fauna.

Two forest strips structurally connect the two protected areas: the forest along the Geruwa-Karnali river (Khata forest strip – see Fig. 9.3) and those of the Basanta and Madhuban area (Basanta forest strip – see Fig. 9.3) (Figs. 9.3 and 9.4). The Khata strip is 8.2 km long with an average width of 1.5 km, whereas the Basanta forest strip is 17.48 km long with an average width of 3.3 km (Table 9.2). There are several settlements and agriculture areas in these strips, making up 12 clusters of settlement and agriculture areas (Fig. 9.4).

There was a diverse pattern of land cover in the western part of the study area (Khata forest strip – see Fig. 9.3). It included grasslands (38 patches), bushy areas

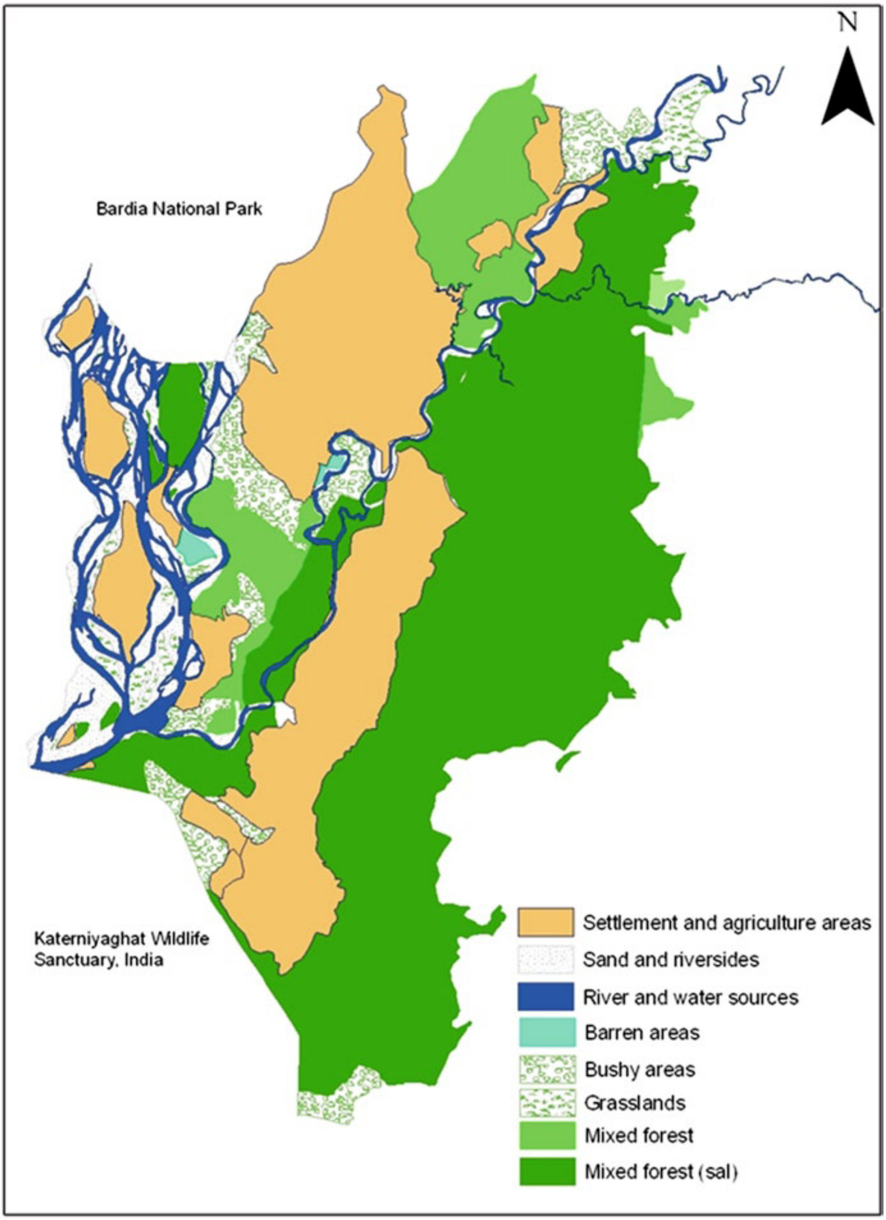

Fig. 9.4 Classification of the land cover in the study area. Data source: Department of survey, 1996

(21 patches) and floodplain areas (234 patches) along the Karnali River. In the eastern part (Basanta forest strip – see Fig. 9.3) the vegetation was more homogenous mainly consisting of mixed sal forest including grassland (four clusters) and bushy areas (six clusters). The land cover heterogeneity per 500 m by 500 m grid in forest strips along

Table 9.2 Major features of land cover in the study area

Type area	Length (km)	Width (km)	
		Maximum	Minimum
Basanta forest strip	17.48	4.18	1.58
Khata forest strip	7.56	3.20	1.08
Khata settlement area	8.29	1.89	0.94
Patterbhoji settlement area	1.85	0.97	0.32
Majhora settlement area	2.67	0.98	0.12
Karnali-Geruwa River area	8.34	–	–

the Khata forest strip was higher (2.723 ± 0.838) than in the Basanta forest strip (1.377 ± 1.046) (see Fig. 9.4). Thus, there was a significant difference in land cover heterogeneity in these two forest strips (Mann–Whitney *U* test, $P < 0.0001$).

9.3.2 Land Management Practices

The pattern of land management showed that more than half of the area was made up of government forest and of the three types of the land management: private land (settlement and agriculture area), community land (community managed forest areas) and government land (government managed forest areas), private land made up 29.08% and government land and community land, 62.43% and 8.47% of total area, respectively (Fig. 9.5).

There were no private forests in the study area except for a few trees at the boundary of private land. A major threat to corridor connectivity is private land, because its use for agricultural and residential purposes makes it inhospitable for wildlife. Private land is distributed throughout the area in the form of 12 lots. In the eastern part, they form a large block of land running parallel to the areas of forest (average patch size 2.97 km^2, number of patches 5), whereas in the western part along the Karnali-Geruwa, private lands are more patchily distributed (average patch size 0.47 km^2, number of patches 7). There were altogether 21 community forests in the study area. Most of them are situated in the fringe areas in the vicinity of villages in government managed forests (Fig. 9.5).

9.3.3 Community vis-à-vis Government Forests: Differences in the Structure of the Tree Vegetation and Pattern of Use of Forest

9.3.3.1 Vegetation Structure

Table 9.2 summarizes the average number of plant species recorded in government managed and community managed forest areas. Altogether nine tree species were recorded both from community and government management forest areas. There

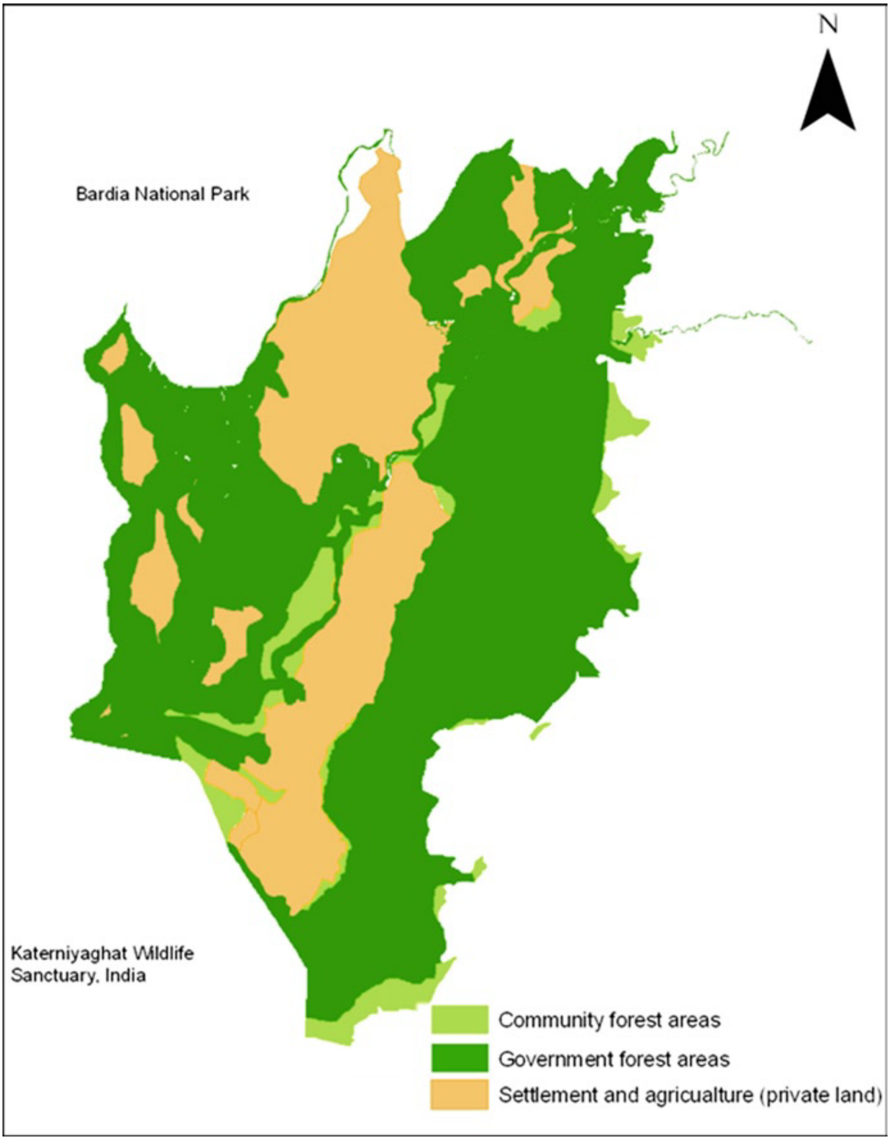

Fig. 9.5 Pattern of land management. National forest areas covered by buffer zone were treated as government forest areas. Data source: Department of survey, 1996

was a near significant difference in the average number of species of trees between government managed and community managed forest (one way ANOVA, df = 7, F = 2.859, P = 0.69). Government managed forest areas had a higher tree species richness and density of *Mallotus philippensis* and *Shorea robusta* (Table 9.3). In contrast, the average numbers of seedlings and saplings in government managed

Table 9.3 Average number of species of trees recorded in government and community managed forest areas. Figures for community forests are averages for six plots and government managed forests for three plots. Only species with a relative frequency > 5% were included

	Government managed forest areas				Community managed forest areas			
Species	X	SD	RF (%)	RD (%)	X	SD	RF (%)	RD (%)
Acacia catechu	0.00	0.00	0.00	0.00	0.17	0.37	6.67	4.35
Madhuca longifolia	0.33	0.47	9.09	3.85	0.00	0.00	0.00	0.00
Mallotus philippensis	2.00	1.63	18.18	23.08	0.83	0.90	20.00	21.74
Murraya kenigii	0.33	0.47	9.09	3.85	0.00	0.00	0.00	0.00
Schleichera oleosa	0.67	0.94	9.09	7.69	0.00	0.00	0.00	0.00
Shorea robusta	3.00	0.82	27.27	34.62	1.17	1.07	26.67	30.43
Syzygium cumini	0.33	0.47	9.09	3.85	0.83	0.90	20.00	21.74
Terminalia alata	1.67	1.25	18.18	19.23	0.83	0.69	26.67	21.74

X mean, *SD* standard deviation, *RF* relative frequency, *RD* relative density

Table 9.4 Average numbers of saplings and seedlings of tree species recorded in the community managed and government managed forest areas

	Community managed forest		Government managed forest	
Species	sapling	seedling	sapling	seedling
Adina cordifolia	0.33	0.83	0.00	0.00
Acacia catechu	4.00	2.83	0.67	0.00
Aegle marmelos	3.00	3.00	0.67	0.00
Madhuca longifolia	0.83	1.17	0.00	1.33
Mallotus philippensis	1.67	4.67	1.33	3.00
Melia azedarach	1.00	1.33	0.00	0.00
Murraya kenigii	0.50	49.33	0.00	0.00
Schleichera oleosa	1.50	0.67	1.67	4.67
Semecarpus anacardium	0.00	0.33	0.00	0.67
Shorea robusta	2.00	7.50	2.67	3.67
Syzygium cumini	0.33	1.33	0.00	0.00
Terminalia alata	1.83	1.50	0.67	3.67
Teminalia chebula	0.17	0.33	0.00	0.33
Unidentified species A	0.17	1.00	0.00	0.00
Unidentified species B	0.00	0.17	0.00	0.00
Unidentified species C	0.17	0.00	0.00	0.00
Unidentified species D	0.33	0.00	0.00	0.67

forest areas were lower than in community managed forest areas (Table 9.4) except for *Schleichera oleosa, Semecarpus anacardium* and an unidentified species D.

There were more species of trees in community managed forest (16) than in government managed forest (11). *Shorea robusta* was the most common species. After *S. robusta,* the next most frequent species were *Mallotus philippensis, Schleichera oleosa* and *Terminalia alata* in both types of forests. Most of the species of trees were regenerating more markedly in community managed than government managed forest areas (Table 9.4).

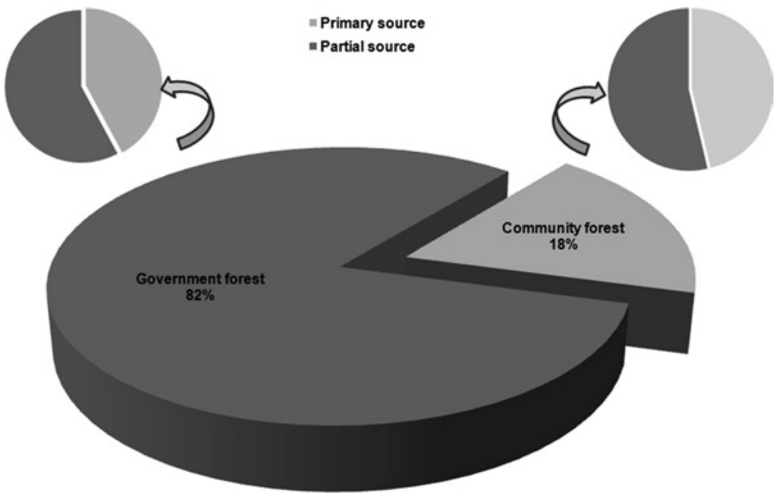

Fig. 9.6 Government and community forest as sources of firewood and fodder

9.3.3.2 Pattern of Forest Use

In the rural areas, forest is the primary source of firewood for heating and fodder for livestock. Grazing in forested areas is the main way of raising cattle (70.1%), for which government forests are the most important (80%). Similarly, they are the primary source of firewood and fodder for 34% of the people and a partial source for 46.67%. In summary, the dependence of the people for firewood and fodder is highly skewed towards the government managed forests. Considering both partial and primary users of both forest types, 80.67% of the people benefit from the government forests (Fig. 9.6). This indicates a heavy dependence on government-managed forests, which potentially may have a negative effect on the forest in the corridor.

9.3.4 Wildlife Occurrence and Distribution

Higher numbers of wildlife species were reported in the Khata forest strip. This strip – intertwined with the Karnali-Geruwa/Orai river system – was reported to have all wildlife species considered. Although, large flagship species, especially rhinoceroses, elephants and tigers were infrequent in the study area and reported only in the Khata forest strip (Table 9.5). In this strip, the presence of wildlife was most marked in the forest area near Dalla, Pattarbhojhi and Dandagau. Wild boar, spotted deer and leopards occur in the Basant forest strip, mainly in the areas north of the Orai river adjoining Bardia National Park.

Table 9.5 Distribution of the fauna in the study area

Common name	Species name	Occurrence	Location	Government protected	CITES code	IUCN status
Spotted deer	*Axis axis*	Frequent visitor	Khata forest area			
		Rare visitor	Basanta forest area			
Royal Bengal tiger	*Panthera tigris*	Rare visitor	Khata forest area	√	I	E
			Basanta forest area			
Common leopard	*Panthera pardus*	Frequent visitor	Khata forest area	√	I	
		Rare visitor	Basanta forest area			
One horned rhinoceros	*Rhinoceros unicornis*	Rare visitor	Khata forest area	√	I	E
Asian elephant	*Elephas maximus*	Rare visitor	Khata forest area	√	I	E
Wild boar	*Sus scrofa*	Residential	Khata forest area			
			Basanta forest area			
Ganges River dolphin	*Platinista gangetica*	Residential	Karnali River	√	I	V

9.4 Discussion

Two forest strips connecting BNP with KWS were identified as potential corridors. However, it is difficult to delineate the boundary of a corridor, because it is uncertain how animals behave in this landscape. Research indicates that the lack of a clear and consistent terminology creates confusion over the role of corridors (Saunders and Hobbs 1991; Simberloff et al. 1992). Restoration of corridors that do not have a well-defined function may yield contradictory and even disappointing results (Hess and Fischer 2001). Use of multiple focal species (tigers, rhinoceros and elephants in this study) makes it possible to assess the corridor conservation unit. The Khata forest strip is rich in wildlife, which is attributed to the diversity of types of land cover there. In conservation planning, landscape structure and patterns are recognized as an important biodiversity surrogate because the size of a specific habitat is not necessarily equal to the area of suitable habitat (Lindenmayer et al. 2008). The Khata forest strip is shorter than the Basanta forest strip. Although infrequent there, these forests provided a range of habitats for tigers, elephants and rhinoceros, but are not large enough to provide an uninterrupted habitat. For large predators, corridor width needs to be more than the size of their home-ranges and must include enough suitable habitat, and prey for them to remain within it (Harrison 1992). The width of the forest strips (maximum 4.18 km, minimum 1.08) is below the average size of the home range of tigers, and is not big enough to provide habitats for rhinoceros and elephants. In such areas, large herbivores cause massive damage to agriculture, resulting in increased incidence of human-wildlife conflict (Thirgood et al. 2005) because angry local people may resort to retribution (Wang and Macdonald 2006).

From the wildlife perspective, landscape is as an area of land containing a mosaic of habitat patches, often within which a particular “focal” or “target” habitat is embedded (Dunning et al. 1992). The patch/corridor/matrix model (Forman and Godron 1986) describes the landscape in terms of human-dominated areas with the corridors situated in inhospitable surroundings. Conservation practices used in such areas influences the effectiveness of the corridor. Most of forest areas (62%) are under government management whereas a small proportion of the forests are managed (8%) as community forests. The community forests are mostly located at the fringes of human settlements, which is a result of the government policy that prevents large blocks of forest being given to communities (Joshi 2001). Consequently, community forests are poorer habitats than national forests (Nagendra 2002).

Forestry, as an integral part of subsistence agriculture, is the main basis of the livelihood of the people. In such regions, there are complex and inseparable relations between forests, agriculture and human subsistence (Gilmour and Fisher 1991). The results presented show that government managed forests are the primary source of fodder, firewood and timber for local people. These forests had lower seedling and sapling species richness compared to community forests, which may be the result of conservation of community forest at the expense of government forest. Chakraborty (2001) found that government managed forests serve as a reserve for satisfying the subsistence needs of the community, which has partially contributed to the success of community forests in Nepal's Tarai. In a landscape consisting of a mosaic of patches of forest, the quality of forest is a consequence of the conservation practice employed. It is therefore important that land planning supports conservation. Such planning affords a great opportunity for protecting natural systems because such plans provide stewardship before restoration or mitigation is necessary (Karr 1990). In Nepal landowners can use discretion about how to use and make profit from lands. Here, local government institutions (District Development Committee, Village Development Committee and municipalities) have very little authority to constrain landowner option for development. Studies have shown that incentives provided to local people are instrumental in obtaining more support for conservation (Wells 1998). Parker and Osborn (2006) note that the cultivation of an unpalatable cash crop (*Capsicum annuum*) on private land was effective in reducing people-wildlife conflict in Zimbabwe. Conservation education is needed to ameliorate the people's perception of conservation (Spiteri and Nepal 2006). However, a stable institution capable of delivering resources and support for conservation is of prime importance. It is, therefore, important to include all patches of land within the boundary of the corridor, as it then makes it more convenient to manage an area in an integrated and holistic way.

In landscape, agriculture lands are not necessarily an unsuitable habitat for wildlife but form a part of variegated landscape (Lindenmayer and Franklin 2002), whereas settlement areas are destroyed habitats. Thus, the managing of human populations is increasingly becoming important in wildlife conservation (Decker and Chase 1997). Thus, in order to institutionalize an Integrated Conservation and Development Program (ICDP) in the area the creation of a "Corridor Conservation Unit" is recommended. The conservation approaches must be tailored to characteristics of the community and wildlife (Woodroffe et al. 2005). Land cover and management patterns are important components in corridor restoration in an agriculture mosaic. They give spatial and temporal data required for understanding landscape matrices. A number of different attributes are used in landscape classification such as configuration of vegetation (e.g., Forman 1995); habitat for a particular species (e.g., Fischer et al. 2004) and functional attributes or landscape processes (e.g., Ludwig et al. 1997). Since corridors are recommended for critically endangered flagship species that use large areas, conservation activities need to be implemented in the entire area including private land. Hence it is urgent to integrate all parcels of land irrespective their size and shape into the corridor planning process. The implementation of such a plan requires a legal framework, administrative procedure and economic sanctions.

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Chapter 10
Where to Go Next?

Pavel Kindlmann

For the readers who have survived reading all chapters of this book, it is now pertinent to ask: what should be done next? The answer has two aspects: research and conservation. These two aspects go together side by side: no good conservation plans can be developed without a good research of the conservation problem and research that is not directly focused on certain conservation problems, even if academically interesting, will not help in solving the real conservation issues.

The past research in the Himalayan region (including ours) has concentrated mainly on the charismatic megafauna and flora – flagship species, which are well known to the public and attract funding from international agencies, like tiger, rhino, snow leopard etc. The recent Kathmandu Tiger Workshop (October 2009), and Tiger Summit (2010), whose leaders endorsed the Global Tiger Recovery Program are good examples. Neglecting of other taxa by the researchers is nicely illustrated by our search in Web of Science for the expression "(Himalaya or Nepal) and (insect* or fish* or reptile* or amphibian*)" in title, abstract or keywords. It revealed that only few anecdotal results were published between 1948 and 2010 on these taxa in the Himalayan region in journals covered by Web of Science. Some people argue that by conserving the habitats of the flagship species we simultaneously conserve also thousands, maybe millions of other less conspicuous species, which share this habitat. This is true, but absence of research of the latter may result in that some of these species will go extinct for some reason (e.g., incompatibility with the conditions that the flagship species may still tolerate) even before we will discover their existence. Most of the biodiversity of fish, reptiles, amphibians, insects, ferns, mosses, and other groups in the Himalayan region (or at least in some of its remote parts) seem to be a *terra incognita* for science.

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The past research in the area has mainly concentrated on individual species. As no species exists without interactions with other species, the future research should be extended to community and ecosystem level. Only by proper understanding of predator-prey or competitive interactions between the species and also of their associations and interactions with humans we can completely understand the dynamics of whole communities and propose well-founded management plans.

Highland and lowland areas have been relatively well studied in the past. The Sagarmatha National Park, the Annapurna Conservation Area in the highlands and the Chitwan and Bardia National Parks in the lowlands may serve as examples. The mid-mountains, however, have been mostly neglected and the future research should be much more concentrated on these. For example, the area between the Shey Phoksundo and Bardia National Parks might serve as a promising extension of both national parks and possibly even as a corridor, connecting them and enabling migration of animals northwards in case of temperature increase caused by global warming. However, this area is quite pristine for researchers.

Most of the existing research is qualitative and explorative. This means that data are mainly available about the presence or absence of the species, but not on their abundances. Such data cannot serve as a good base for predictions of future population dynamics of the species and the threat of their extinction. The emphasis should be much more on collection of quantitative data and using methodologies enabling comparison of data gained from different sources.

Poverty and rapid human population growth rate are big conservation problems in the Himalayas, including Nepal. In many chapters of this book, it was stressed that local inhabitants living close to protected areas or other areas of high natural value are very poor and often have to resort to (sometimes illegal) utilization of natural sources in protected areas. This includes collecting firewood, domestic livestock being increasingly grazed in protected areas, conflicts between domestic livestock and wild animals (tahr, deer and other ungulates, etc.). Consequently, overgrazing by synergetic effect of wild animals and livestock grazing leads to decline of available vegetation for herbivores, subsequent decline of wild herbivore population sizes and ultimately to food shortage for wild predators, like tigers and snow and common leopards. These predators then often resort to killing domestic animals, which in turn leads to negative attitude of local inhabitants towards wild predators. So, we have a vortex of adverse effects here, which ultimately leads to decline of biodiversity in the region, initiated by human poverty and rapid human population growth rate.

The international community can help Nepal to conserve its biodiversity, if it will target its financial support to meaningful conservation programs, based on true knowledge of the needs of the Himalayan ecosystems. Many of the threats to the biodiversity of the Himalayas are synergistic, which means that the negative effects of several separate factors – such as logging, overhunting, fire, climate change, and poverty – combine additively or even multiplicatively to destroy biodiversity. The task for conservation biologists – for the editor of this book, for its contributors, but mainly for its readers – is to clearly define these targets and find appropriate solutions. Himalayan nature surely does deserve them.

Information About the Editor

Pavel Kindlmann is professor of ecology at the Charles University in Prague, Czech Republic and performs research on various aspects of biodiversity as the Head of the Biodiversity Research Centre, in the CzechGlobe – Global Change Research Centre, Academy of Sciences, in České Budějovice, Czech Republic. His main interests include population and metapopulation dynamics and life history strategies with a special emphasis on insect herbivores, their predators, and on the orchid family. He authored or edited several books on population systems, orchids and conservation biology and published about 100 scientific papers in prominent journals.

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Species Index

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Subject Index

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