



Grassland Ecology and Management in Protected Areas of Nepal

*Volume 2: Technical and Status Papers
on Grasslands of Terai Protected Areas*

Editors

Camille Richard

Khadga Basnet

Jay Prakash Sah

Yogendra Raut

Jointly Organized by
Department of National Parks and Wildlife Conservation, HMG/Nepal
International Centre for Integrated Mountain Development
WWF Nepal Programme

Grassland Ecology and Management in Protected Areas of Nepal

Proceedings of a Workshop

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Credits:

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Back cover - Top - Elephant in the Mist with Thatch (*D. Miller*)
Bottom - Grassland Scene (*C. Richard*)

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In Praise of Grass

Grass is the forgiveness of nature – her constant benediction. Fields trampled with battle, saturated with blood, torn with the ruts of cannon, grow green again with grass and carnage is forgotten. Streets abandoned by traffic become grass-grown like rural lanes, and are obliterated. Forests decay, harvests perish, flowers vanish, but grass is immortal. Beleaguered by the sullen gusts of winter, it withdraws into the impregnable fortress of the subterranean vitality and emerges upon the first solicitation of spring. Sown by the winds, by wandering birds, propagated by the subtle horticulture of elements, which are its servants and masters, it softens the rude outline of the world. It invades the solitude of the forests, climbs the inaccessible slopes and forbidding pinnacles of the mountains, modifies climates and determines history, character and destiny of nations.

J. Ingals

Foreword

Globally, grasslands and rangelands occur in polar, temperate, sub-tropical, and tropical latitudes, from low to high elevations. In total, they cover 45 million square kilometres or one quarter of the earth's surface. In the Hindu Kush-Himalayan Tibet-Qinghai Plateau, rangelands and pastures cover some 60 per cent of the total area. They vary from sub-tropical savannas to alpine meadows in the eastern, central, and western Himalayas and steppe formations on the Plateau. As such, they contain a wide diversity of grasses and other plant species on which a number of endangered wildlife species depend. This diversity is matched by the cultural diversity of the people who have adapted their lifestyles to the harsh environment.

It is ICIMOD's, World Wide Fund for Nature's (WWF), and the Department of National Parks and Wildlife Conservation's (DNPWC) concern about the relationship between the people and their rangelands, between environment and development, and between nature and culture, that has brought together the scientists and managers represented here in these volumes. These proceedings provide valuable information on grassland ecology and management, not only for protected area managers here in Nepal, but also for scientists and managers working in other countries with similar ecological conditions.

It was only in 1995, when the first four-year Regional Collaborative Programme for the Sustainable Development of the Hindu Kush-Himalayas started, that ICIMOD could appoint its first rangeland management specialist and allocate some modest resources to a programme addressing rangeland issues. In ICIMOD's Second Regional Collaborative Programme (RCP-II), which covers the period from 1999-2002, rangelands have become an important focus of work on the mountain commons. We are very fortunate that the Government of Austria is funding the three-year Regional Rangeland Programme that allows us to carry out a comprehensive programme of research, capacity building, and extension, continuing until the end of 2001. The primary focus of the programme is to develop approaches that involve the local custodians of the rangeland resource – the communities themselves – in conservation and development of the rangelands upon which they so heavily depend. It is vital that collaborative management be the focus of future conservation efforts, both in Nepal and abroad, to ensure sustainable and equitable management of biological resources during this period of rapid change. This has been the approach of both WWF Nepal Programme and the DNPWC, who have pioneered work in collaborative management in the region.

Important issues that affect the grasslands and rangelands in protected areas of the Hindu Kush-Himalayas are the following:

- how to maintain biological diversity and multiple use of rangelands to promote co-existence of domestic and wild grazing ungulates and predators within and outside protected areas;

- how to find technical and institutional mechanisms to accommodate the needs of local communities to continue to access protected area resources while simultaneously promoting conservation;
- how to save and use the indigenous knowledge regarding use and management of rangeland resources; and,
- how do changing patterns of rangeland use and conservation affect the local communities, considering differential effects among diverse ethnic groups, on gender relations, and eventually on policy.

This compilation of working group outputs and research is a vital step in beginning to answer these important questions and provides working guidelines for protected area managers to help them prioritise future activities. The grasslands of the Himalayas are not only vital to the livelihood of many poor mountain families but to the sustainability of the varied and beautiful ecosystems that our in our trust. This work, and the innovative and committed people who have contributed to it as authors and editors, will help to conserve our mountain future.

J. Gabriel Campbell PhD.
Director General, ICIMOD

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First we would like to offer our thanks to the Department of National Parks and Wildlife Conservation (DNPWC), the International Centre for Integrated Mountain Development (ICIMOD), and WWF NEPAL Programme for the support provided for organizing and conducting this workshop on "Grassland Ecology and Management in Protected Areas of Nepal." Staff from the organizations working in the Royal Bardia National Park (RBNP), the Bardia Integrated Conservation Project (BICP), WWF Nepal Programme, Care Nepal, and The King Mahendra Trust for Nature Conservation (KMTNC) were instrumental in making this workshop successful on the ground. In particular we would like to thank Mr. Shiva Raj Bhatta (Chief Warden and BICP manager) for taking on all the responsibility for local management and facilities; Dr. Shanta Raj Jnawali (Director, KMTNC, Bardia) for supporting local management; Ms. Sushila Nepali (Assistant Manager, BICP) for her active role in public relations and logistics; Mrs. Sarita Jnawali for her management of food and beverages; Mr. C. P. Bhandari (Finance and Administration Assistant, BICP) for financial matters and logistics; Mr. Ramesh Thapa (Ranger, RBNP) for taking care of the workshop complex; Mr. Bhusal (Health Assistant) for providing first aid services; Mr. Ramji Shivakoti (RBNP/CARE Nepal), Mr. Naresh Subedi (Park and People Project), Ashok Bhandari, and the senior game Scouts for their logistical support, and the drivers of RBNP for their invaluable assistance transporting participants.

We are also grateful to the following people for their direct and indirect support in helping to make the workshop run effectively: Mr. Sushil Bhattarai, Joint Secretary, Ministry of Forest and Soil Conservation (MoFSC) for inaugurating the workshop; Mr. D. D. Bhatta (Director, Regional Forest Directorate), Mr. Shyam Bajimaya (Conservation Officer, DNPWC), Mr. Sawarkar (Scientist, Wildlife Institute of India), and Mr. Krishna Man Shrestha (former Chief warden of RBNP) for chairing various sessions of the workshop; and Basant Subba for serving as rapporteur. Special thanks are due to the editorial committee for their hard work in bringing this document to its present shape.

Finally, we would like to thank Dr. T.M. Maskey (Director General, DNPWC), Dr. U.R.Sharma (Joint Secretary, MoFSC), Mr. Egbert Pelinck (ex-Director General, ICIMOD), and Mr. Mingma N. Sherpa (Country Representative, WWF Nepal Programme) for their continuing support to conservation efforts in Nepal.

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Abbreviations and Acronyms

ACA	Annapurna Conservation Area
ACAP	Annapurna Conservation Area Project
AGB	above ground biomass
APPA	appreciative participatory planning and action
BZ	buffer zone
CAMC	Conservation Area Management Committee
DHR	Dhorpatan Hunting Reserve
DNP	Dudwa National Park
DNPWC	Department of National Parks and Wildlife Conservation
ERBC	ecoregion-based conservation
GIS	geographical information system
HKH	Hindu Kush-Himalayas/Himalayan
HMG/N	His Majesty's Government of Nepal
ICIMOD	International Centre for Integrated Mountain Development
KCA	Kanchenjunga Conservation Area
KMTNC	King Mahendra Trust for Nature Conservation
KNP	Khaptad National Park
KWR	Koshi Tappu Wildlife Reserve
LNP	Langtang National Park
masl	metres above sea level
MBNP	Makalu Barun National Park
MCA	Manaslu Conservation Area
NGO	non-government organization
PA	protected area
PAN	Protected Area Network
PAR	participatory action research
PPP	Plants and People Project (WWF)
PRA	participatory rural appraisal
PWR	Parsa Wildlife Reserve
RBNP	Royal Bardia National Park
RCNP	Royal Chitwan National Park
RNP	Rara National Park
RRA	rapid rural appraisal
RS	remote sensing
RSWR	Royal Shukla Phanta Wildlife Reserve

SNP Sagarmatha National Park
 SPNP Shey Phoksundo National Park
 SRV species richness value

UNDP United Nations Development Programme

WWF Worldwide Fund for Nature

Glossary

Physiographic Regions of Nepal (Carson 1992¹)

- **Terai** — Alluvial piedmont plain occurring at the base of the Himalayan range, from 60-300 masl. This is an extension of the broad Gangetic plains including the Bhabar region and the alluvial fans of the Siwaliks. The region is heavily traversed by the major river systems of Nepal. It exhibits a tropical type of climate. *Dalbergia sissoo*, *Shorea robusta*, and *Eucalyptus* are the major vegetation types of forest, interspersed with riverine savanna grassland. Much of the forests and savannas of the Terai have been converted to agriculture.
- **Churia Hills (Siwaliks)** — The outermost Himalayan foothills are classified as the Siwaliks, ranging from 300-1,000m, and they represent the most recent zone of uplift. The soils are shallow, erodible, and drought prone, originating primarily from highly erodible sedimentary rock composed of previous piedmont plain alluvial sediments. The climate and vegetation of this region are mainly sub-tropical depending on the elevation, but forests are dominated by sal (*Shorea robusta*). Due to the fragility of the landscape, land-use pressures are not severe.
- **Middle Hills** — Landscape between 1,000 and 2,000m occurs throughout the Mahabharat range. Slopes are more gentle than in the Siwaliks and a significant portion of the sloping hills is cultivated under relatively sophisticated terrace systems in the form of low (irrigated) and upland (dry). The forests of the middle hills are heavily exploited for fodder, firewood, litter, and timber collection.
- **High Mountains** — The landscape ranges between 2,000 and 3,000m, however, a range of sub-tropical to cool temperate conditions can occur within the same valley. Bedrock is predominantly highly metamorphosed sedimentary rocks, thus landscapes are steeper than in the middle hills because rocks are relatively more resistant to weathering. Deep 'V'-shaped valleys are common throughout the region. Forests in the high mountains tend to be in better condition than in the middle hills due to lower population densities.
- **High Himalayas** — Landscapes are usually >3,000m in altitude. Most of the area below 4,300m is natural forest with alpine zone above the treeline. Bedrock is predominantly more competent and forms very steep and rugged terrain. Dry forest types and grassland steppes occur in the rainshadow behind the main mountain ranges. The area has a very low population density because of lack of cultivable land and cold winter conditions.

¹ Carson, B. (1992) *The Land, The Farmer, and The Future: A Soil Fertility Management Strategy for Nepal*, ICIMOD Occasional Paper No. 21. Kathmandu: ICIMOD.

Seral — Early to mid-stage in ecological succession.

Climax — Final stage of a succession where a given assemblage of species is in equilibrium with the prevailing natural environment.

Phanta(s) — Grasslands dominated by short perennial grasses, such as *Imperata cylindrica*, which have originated following human intervention (forest clearing, burning, domestic stock grazing, and cultivation); they occur on more or less stabilised soils.

Tall (Riverine) Grassland — Riverine grassland dominated by tall grass species' assemblages maintained by inundation during the monsoon and/or by fire and grazing. These grass species range from *Typha elephantina*, *Phragmites karka*, and *Saccharum spontaneum* assemblages that colonise new alluvial deposits in flood plains to assemblages on drier and better developed soils dominated by *Narenga porphyrocoma*, *Saccharum bengalense*, and *Themeda arundinacea*. These herbaceous species eventually give way to dominance by non-flooded climax deciduous forest which is predominantly composed of sal (*Shorea robusta*).

Himalayan Alpine Shrub/Meadow — Mesic herbaceous and scrubby meadows that occur above the treeline on the south facing Himalayan range, dominated by herbaceous grassy genera such as *Kobresia*, *Poa*, *Deyeuxia*, *Agrostis*, and *Festuca* and shrubby species such as *Rhododendron* and *Juniperus*. These regions contain a rich floral and faunal diversity.

Trans-Himalayan Rangelands — Vegetation communities dominated by desert steppe vegetation such as *Caragana*, *Lonicera*, and xeriphitic grass genera such as *Stipa*. Although relatively low in floral species' diversity, these rangelands support large herds of ungulates and wild predators.

Buffer Zone — Areas adjacent to or within a PA in which land use is partially restricted and which are managed to provide an added layer of protection to the PA itself while providing valued benefits to the neighbouring rural communities (MacKinnon *et al.* 1986²).

Eco-development — A site-specific package of measures, developed through peoples' participation, with the objective of promoting sustainable use of land and other resources, as well as farm and off-farm income generating activities, not deleterious to protected area values (Panwar 1992³).

Eco-development area — (used in India, similar to a Buffer Zone in Nepal) a conservation designation in the Indian Wildlife Act for areas adjacent to core Protected Areas. The area is managed so as to reduce or eliminate human pressure on core protected areas using eco-development measures.

² MacKinnon, J.; MacKinnon, K.; Child, G.; and Thorsell, J. (1986) *Managing Protected Areas in the Tropics*. Gland, Switzerland: IUCN.

³ Panwar, H.S. (1992) *Ecodevelopment: An Integrated Approach to Sustainable Development for People and Protected Areas in India*. Paper presented at the IV World Congress on National Parks and Protected Areas, 10-21 February 1992, Caracas, Venezuela.

Workshop Summary

Natural grasslands cover approximately 14% of Nepal and are important areas in terms of biodiversity and sources of forage for wild ungulates and domestic livestock. In the plains of Nepal (the *Terai*), natural grasslands occur along flood plains and terraces. As a result of increasing population pressures in this region, these grasslands only exist in their natural state within protected areas (PAs) as neighbouring grassland and sub-tropical forest habitats have been rapidly converted into agricultural land and grazing commons. At higher altitudes, trans-Himalayan and alpine rangelands are home to a diverse array of wildlife and are grazed by livestock, which are an integral part of the livelihood of several different ethnic groups. While there is a general assumption that these high elevation areas are being overgrazed, little is known about the ecology and sustainability of prevailing land-use practices.

To address these issues, a workshop on Grassland Ecology and Management in Protected Areas of Nepal was organized jointly by HMG/Ns Department of National Parks and Wildlife Conservation (DNPWC), the International Centre for Integrated Mountain Development (ICIMOD), and WWF Nepal Programme, from March 15-19, 1999, at Royal Bardia National Park, Nepal. The idea for the workshop arose from discussions on protected area (PA) management during the Wardens' Seminar in 1998, in the Annapurna Conservation Area. The DNPWC endorsed the recommendation of the Wardens' seminar, and ICIMOD and WWF pledged financial and technical support. The goal of the workshop was to summarise the major grassland ecological research work conducted to date and devise effective research and management strategies for grasslands in PAs in the mountain and Terai areas of Nepal. Participants included representatives from the Ministry of Forest and Soil Conservation, protected area managers from Nepal, independent researchers from Nepal and abroad, and guest scientists from India who have worked in similar environments in their own country. Some invited papers from research workers who were unable to attend the workshop were included in the background papers (and will be published in the proceedings) to ensure completeness in the coverage of technical information.

A series of technical and status papers were presented summarising research for both Terai and Himalayan grassland ecosystems. Working groups were formed to prioritise issues, to identify research and management gaps, and to devise research and management guidelines for both grassland ecosystems. The Terai working group sessions revealed that while much research on grasslands has been conducted to date, the results have not been incorporated into grassland management practice. The participants of the Terai working group outlined a number of management strategies to address these gaps, primarily focussing on maintenance of grassland habitats for key wildlife species. The mountain group sessions indicated a significant absence of research related to high elevation rangelands. Thus these participants focussed on developing research strategies to address the high priority issues of wildlife-livestock competition, crop and livestock depredation, medicinal plant extraction, stakeholder involvement, and transboundary protection. Research and management committees have been

recommended to follow up and refine these guidelines. The proceedings from the "Workshop on Grassland Ecology and Management in Protected Areas of Nepal" are divided into three volumes. Volume I is the Workshop Action Summary and contains a brief summary of the papers presented in Vols. II and III, as well as a summary and synthesis of the workshop findings and recommendations; Volume II presents status and research papers from the Terai protected areas of Nepal and India; and Volume III presents status and research papers from mountain protected areas.

Volume I. Action Summary

Volume II. Technical and Status Papers on Grasslands of *Terai* Protected Areas

A. Technical Papers on *Terai* Protected Areas

A Landscape Approach to Managing the Indian *Terai* Ecosystem with Reference to Uttar Pradesh, India

Vishwas B. Sawarkar

Status of Research and Monitoring in Protected Areas of the Indian *Terai*: An Overview

Pradeep Kumar Mathur

Managing the *Terai* Grasslands in Nepal: Recent Research and Future Priorities

Nic Peet, Diana J. Bell and Andrew R. Watkinson

The Organization and Human Use of *Terai* Riverine Grasslands in Royal Chitwan National Park, Nepal

John F. Lehmkuhl

Grasslands and Large Mammal Conservation in the Lowland *Terai*: A Preliminary Synthesis Based on Field Research Conducted in Royal Bardia National Park, Nepal

Per Wegge, Shant Raj Jnawali, Torstein Storaas and Morten Odden

Koshi Tappu's Treasure: Grasslands or Wetlands?

Jay Prakash Sah

Effects of Management Practices on the Grassland Vegetation and Their Use by Ungulates in Dudwa National Park, Uttar Pradesh, India

Harish Kumar

Importance of Tall Grasslands in Megaherbivore Conservation

Shanta Raj Jnawali and Per Wegge

Grassland Management Impacts on Small Mammals

Tika Ram Adhikary

Impact of Grassland Management on Avian Fauna

Hem Sagar Baral

B. Status of Grasslands in *Terai* Protected Areas: Management Issues and Gaps

Parsa Wildlife Reserve (PWR)

Surya Bahadur Pandey

Royal Bardia National Park (RBNP)

Shiv Raj Bhatta

Royal Shukla Phanta Wildlife Reserve (RSWR)
Ram Prit Yadav, Sher Singh Thagunna and Jay Prakash Sah

Volume III. Technical and Status Papers on Grasslands of Mountain Protected Areas

A. Technical Papers on Mountain Protected Areas

Indigenous Livestock Management Systems on the Upper Slopes of Central Nepal
Santosh Rayamajhi, Don Messerschmidt and Bill Jackson

Alpine Vegetation of North Western India: An Ecological Review
Gopal S. Rawat

Rangeland, Animal Husbandry and Wildlife in Annapurna, Nepal: A Case Study
Som Ale

Grasslands in the Damodar Kunda Region of Upper Mustang, Nepal
Rita Arjel Koirala, Rinjin Shrestha and Per Wegge

Ecological Separation between Ibex and Resident Livestock in a Trans-Himalayan Protected Area
Yashveer Bhatnagar, Gopal S. Rawat, A.J. Thomas Johnsingh and Michael Stüwe

A Participatory Approach to Rangeland Research and Management: Developing an Action Plan for Rangeland Conservation in Mountain Protected Areas
Camille Richard and Colleen McVeigh

Managing People-Wildlife Conflict on Alpine Pastures in the Himalayas
Rodney Jackson

B. Status of Grasslands in Mountain Protected Areas: Management Issues and Gaps

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Jhamak Karki and Colleen McVeigh

Kanchenjunga Conservation Area (KCA)
Fanindra R. Kharel

Dhorpatan Hunting Reserve (DHR)
Ramchandra Kandel

Khaptad National Park (KNP)
Nilamber Mishra

Rara National Park (RNP)
Gopal Ghimire

Shey Phoksundo National Park (SPNP)
Tulsi Ram Sharma

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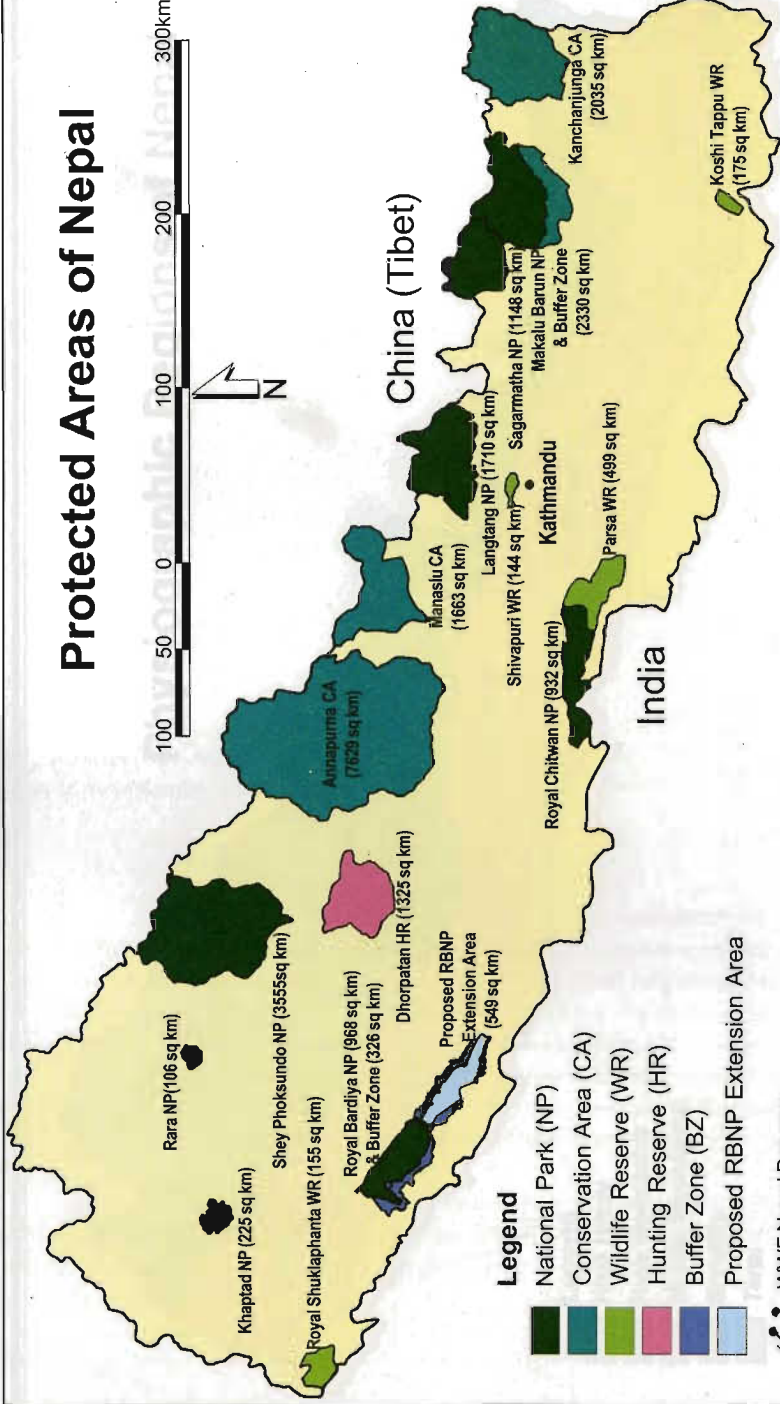
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Protected Areas of Nepal



Legend

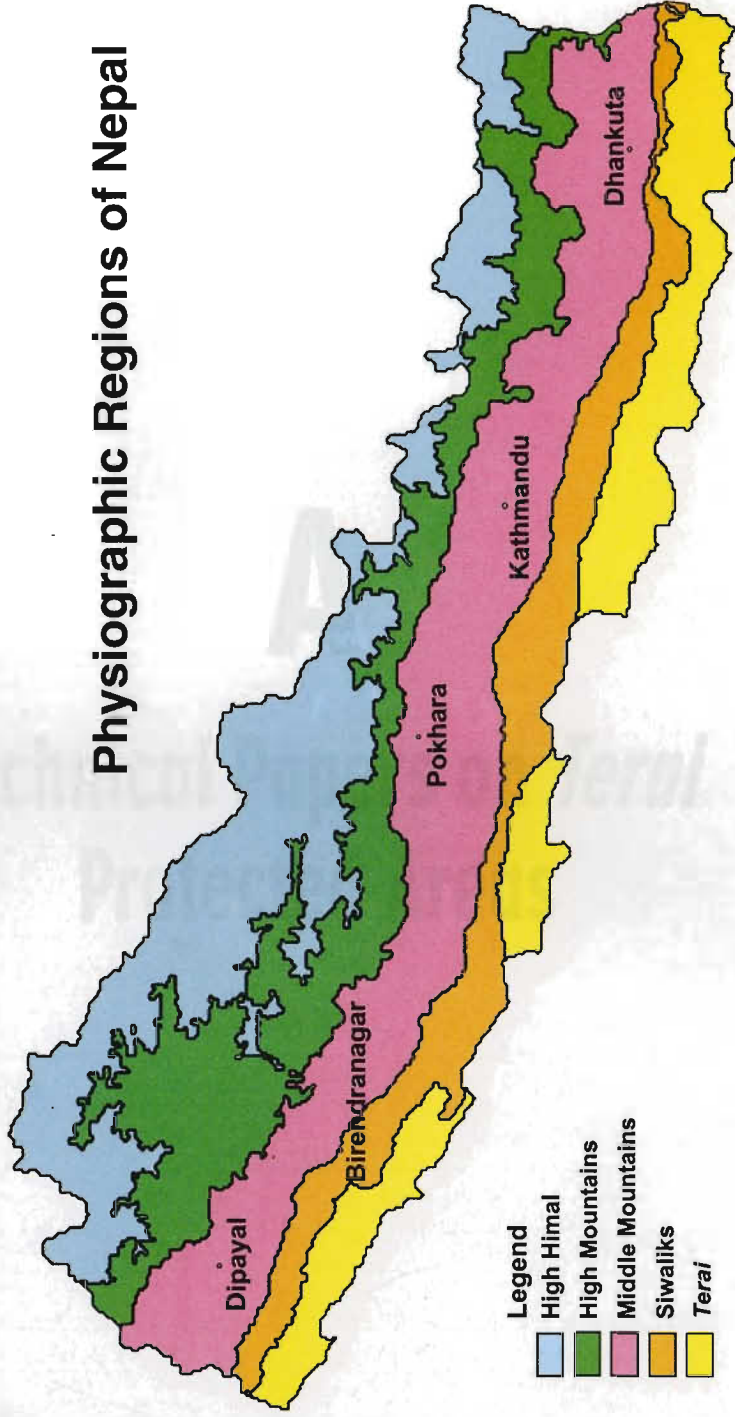
- National Park (NP)
- Conservation Area (CA)
- Wildlife Reserve (WR)
- Hunting Reserve (HR)
- Buffer Zone (BZ)
- Proposed RBNP Extension Area



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(Source: DNPWC, KMTNC and WWF Nepal Program)

Physiographic Regions of Nepal



A Landscape Approach to Managing Terai Ecosystems
with Reference to Ghazal National Park (NP), India

A

**Technical Papers on *Terai*
Protected Areas**

A Landscape Approach to Managing *Terai* Ecosystems with Reference to Uttar Pradesh (UP), India

Vishwas B. Sawarkar¹

Abstract

One of the reasons for the rapid loss of grassland habitats and their allocation to disparate landuses during the past several decades has been the popular belief that grasslands, unlike woodlands, are economically unproductive. The *Terai* grasslands were not an exception. Following the emergence of an ecological perspective, however, the managerial approach is changing significantly in favour of maintaining the existing wild grassland habitats. The *Terai* in Uttar Pradesh, India, is located within the biogeographic province 07 A, the upper Gangetic Plains, and is estimated to extend over approximately 11,200 sq.km, 19% of which is included in Protected Areas (PAs). Grasslands account for 16% of the extent of the PAs, the rest is highly fragmented and degraded.

The Dudwa National Park (490 sq.km), the Kishanpur Wildlife Sanctuary (204 sq.km) and the Katerniaghat Wildlife Sanctuary (400 sq.km) constitute one of the significant PA clusters. They represent 12 major vegetation communities and contain at least 24 plant species of conservation importance. The endangered species of animals include at least 12 mammal, 29 bird, and 5 reptile species. The Dudwa National Park has a reintroduced population of *Rhinoceros unicornis* and Katerniaghat is contiguous with the Royal Bardia National Park, Nepal. The PAs are situated within a landscape of *Shorea robusta* dominated forests, sugar cane and paddy fields, scattered hamlets, and small townships and thus have a large interface with a variety of human activities, several of which are significantly dependent on the resources of the *Terai* ecosystem. This inevitably leads to conflicts arising from the seeming contradictions between the ecological and the socioeconomic concerns. While the wildlife management practices within the PAs are a mix of traditional approach and innovative experiments in the abutting managed forest, there is little focus on wildlife habitats and ecosystem functions.

Wildlife management plans typically address the PAs alone, likewise forest working plans address only the managed forest, and there is some mismatch of objectives between these two categories. The influences and issues affecting the PA management in the larger context of the landscape go unanswered by default. To secure the ecological interests in the *Terai* grassland ecosystem, it is necessary to adopt a landscape approach to management planning that incorporates hierarchical spatial scales capable of addressing ecological and biological concerns ranging from those at micro habitat levels to those at the levels at which concerns for habitat corridor connections, metapopulations, ecological processes, functions, and socioeconomic aspects can be addressed and demonstrated. This is discussed from the management standpoint.

Introduction

In India, there are broadly five kinds of grassland ecosystem: the alpine pastures in the Himalayas above the timber line; the montane grasslands in the shola-grassland system of the Western Ghats; the *Terai* grasslands south of the

¹ Wildlife Institute of India

Himalayan foothills, together with the Indo-Gangetic and Brahmaputra flood plains; the grasslands in the arid zone of Western India; and the grasslands of anthropogenic origin in peninsular India (Dabadghao and Shankararayan 1973; Puri *et al.* 1983). Each of these grasslands is represented in the lands controlled by the forest department, which is the custodian of wildlife and natural ecosystems in India. In the popular perception, the importance of grasslands is seen only in their utility for grazing livestock. The foresters till very recently considered them unproductive, and administrative and political decisions in favour of regional development have diverted large tracts of grasslands to other uses. Grasslands are overgrazed, subjected to uncontrolled fires, taken over by an abundance of weeds, and subjected to degradation. They are thus among the most threatened ecosystems. Of the estimated 11,200 sq.km of *Terai* in UP, 19% lies within Protected Areas (PAs). Grasslands constitute 16% of the total area of the PAs; the remainder is highly degraded and fragmented (Qureshi *et al.* 1992). This paper addresses some of the broad issues relating to the management of *Terai* ecosystems using a tract of *Terai* in the Lakhimpur-Kheri district in Uttar Pradesh as an example, and makes suggestions in favour of adopting a landscape approach in management planning.

Grasslands in Managed Forests

The first organised scientific approach to managing forests in India dates back to the year 1861 in Central India, which is now a portion of Madhya Pradesh. The Forest Department was established in 1865 and the years till the turn of the 19th century saw surveys, demarcation, and consolidation of lands being undertaken to bring these under the control and management of the Forest Department (Forest Research Institute 1961).

The first forest policy of 1894 (Government of India 1894) recognised the economic dependence of pastoral communities, and of others who reared cattle, sheep, and goats on grasslands. In view of their scattered nature, and the limited resources of the Forest Department, most such lands were either excluded from government control or were more or less ignored since they were not 'productive' in the sense of producing timber or other economically valuable products. The policy did not have any reference to wildlife or, understandably, to the ecological productivity of grasslands.

The next National Forest Policy of 1952 (Government of India 1952) included most grasslands under the category of village forests in recognition of their utility as grazing areas for cattle and production of fodder, most of the remainder were included in unclassified or vested forests. The biological values and ecological functions continued to be ignored, and *ipso facto* grasslands were considered unproductive in the foresters' lexicon.

The *Terai* in the Lakhimpur-Kheri district of UP, like the *Terai* elsewhere, was malarious and also inhospitable for other reasons, such as its swampy nature, the extensive tracts of tall wet grasslands, and the abundance of wild animals, several of which were formidable and potentially dangerous to human life. Post independence policy encouraged the refugees from western Pakistan to settle in these areas. These homeless and hardworking people drained swamps, reclaimed grasslands, and set up the origins of an agricultural system of paddy

and sugar cane that now occupies large tracts of *Terai*, causing extensive fragmentation of the *Terai* grasslands.

The *Terai* Grasslands of Lakhimpur-kheri

Although the *Terai* grasslands are unique in their structure, composition, biological and physical attributes, and ecological functions, they cannot be seen in isolation from the matrix of forests (woodlands) and other categories of land uses within which they are located.

During the turn of the 19th century, the interest of the Forest Department in the *Terai* of Kheri district was focused on the great forests of sal (*Shorea robusta*) in the upland areas. In the mid 1800s these forests were regarded as wastelands and covered under the Wasteland Rules of 1860 (Rizvi 1979). Subsequently, the forests produced a major proportion of the railway sleepers derived from sal timber in this region (Sawarkar 1988a). The area was renowned for tigers (*Panthera tigris*) and swamp deer (*Cervus duvauceli duvauceli*). Notwithstanding the richness and diversity of wildlife, no management efforts for wildlife were invested in this area prior to 1958.

The first attempt to establish a protected area (PA) was during 1958 when Sonaripur Wildlife Sanctuary (WLS) was created for conservation of the swamp deer (16 sq.km). A series of enlargements resulted in the establishment of the Dudwa National Park (490 sq.km) in 1977 along the Indo-Nepal border (Singh 1983). The park now has an additional buffer zone of 190 sq.km. Thirty kilometres south of Dudwa and across the Sharda river, the Kishanpur Wildlife Sanctuary had been established in 1972 (201 sq.km). The Dudwa and Kishanpur PAs together with Dudwa's buffer zone were declared the 'Dudwa Tiger Reserve' under PROJECT TIGER during 1987. The Katarniaghat WLS, in Bahiraich district, was declared in 1976 (400 sq.km). The last named is contiguous with the Royal Bardia National Park in Nepal with the river Geruwa being shared. It contains two endangered species, the gharial (*Gavialis gangeticus*) and the Gangetic dolphin *Platanista gangetica*. The Dudwa National Park, Kishanpur WLS, and Katarniaghat WLS, all fall within the Biogeographic Province 07A, the Upper Gangetic Plain, within the Biogeographic Zone 07, the Gangetic plain, as per the biogeographic classification of India. The two PAs in Lakhimpur-Kheri district have abutting managed forests (768 sq.km) in the North and South Kheri forest divisions (WII 1998).

Biological Attributes and Ecological Functions

According to the classification of forests by Champion and Seth (1968), the woodland forests are represented by five sub-groups: Northern Tropical Semi Evergreen, North Indian Moist Deciduous, Tropical Seasonal Swamps, Northern Tropical Dry Deciduous, and Northern Tropical Thorn. These are further divided into 21 forest types (Rizvi 1979; Gaur 1983; Singh 1983), which provide some idea of the diversity of woodland communities. These are mainly upland woodlands.

Grasslands occupy the lowlands amidst interspersed seasonal and perennial swamps. The forests and grasslands (the natural *Terai* ecosystem) are part of a landscape that has rich agriculture, human habitations, cattle, and other

indicators of progress of human society. Therefore there are a wide range of interacting influences, including the powerful socioeconomic interests of humans, that affect the physical and biological attributes and the ecological functions of the *Terai* ecosystems.

The current inventory of the *Terai* PAs records 75 tree species, 37 shrubs, 20 species of climbers, 179 species of aquatic plants, and 77 species of grasses. The animals include 56 species of mammals (12 endangered), 455 species of birds (29 endangered), 16 reptiles (5 endangered), 19 amphibians, and 79 species of fish (Government of India 1972b; Gaur 1983; IUCN 1982; Tikader 1983; Qureshi *et. al* 1992; Sinha and Sawarkar 1992; ZSI 1994; WII 1998).

Among the megaherbivores, the elephant (*Elephas maximus*) appears seasonally in Dudwa National Park and Kishanpur WLS. The numbers fluctuate. The maximum tally in Dudwa so far has been over 70 (Sawarkar 1988a). A few straggler males are seen in both these areas the year round. Rhino (*Rhinoceros unicornis*) was reintroduced in Dudwa National Park during 1984 (5 animals) and 1985 (4 animals), translocated from Assam and Nepal respectively (Sale and Singh 1987; Singh and Rao 1984; Singh 1985; Sinha and Sawarkar 1991, 1992). Currently, the population stands at 14. Other species of conservation importance among the mammals are the tiger (*Panthera tigris*), leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), fishing cat (*Felis viverrina*), leopard cat (*Felis bengalensis*), smooth Indian otter (*Lutra perspicillata*), swamp deer (*Cervus duvauceli duvauceli*), hog deer (*Axis porcinus*), Gangetic dolphin (*Platanista gangetica*) (in Katarniaghat WLS), and hispid hare (*Caprolagus hispidus*). Among the birds the Bengal florican (*Houbaropsis bengalensis*) and the swamp partridge (*Francolinus gularis*) are of special interest as they, like the rhinoceros, hog deer, swamp deer, and hispid hare are obligates of the *Terai* grasslands. Dudwa is probably the last area in UP where the summer immigrant Bengal florican (population approximately 40 birds) is regularly seen (Shankaran and Rahmani 1988). The status of such species is dependent upon the status of the *Terai* grasslands.

The Dudwa National Park is the largest intact area in UP that represents all the characteristics of the *Terai*. Even areas of nearly 500 sq.km, such as the Dudwa, must be regarded as a fragmented habitat within a landscape when the range of the large bodied and wide ranging species and the communities and the populations of wild animals it is required to support are considered. Fragmented habitats have serious implications for population viability of most wild animals, especially for large mammals; wide ranging species; and rare, endangered and habitat obligate species, all of which are represented in the *Terai* (Harris 1984; Oliver 1985; Soule 1986; 1987; Decker *et. al* 1991; Qureshi and Sawarkar 1991; Morrison *et al.* 1998).

Management Strategies in Practice

It is necessary to review the past and current management practices as they bear direct relevance to the habitat quality. These practices also establish managerial traditions, and create a mindset that offers resistance to new ideas. Local dependence on a variety of forest resources once established tends to persist, and the activities diversify further. These forests have been managed under

working plans on a regular basis since the 1920s, with the principal interest in sal timber, and other timber species of economic interest such as khair (*Acacia catechu*), shisham (*Dalbergia sissoo*), and jaman (*Syzgium cumini*). The silvicultural practices varied from selection, to conversion to uniform, to improvement fellings, and a series of plantations were raised, mainly in the upland grasslands, of species such as teak (*Tectona grandis*) (40 sq.km), and eucalyptus (14.5 sq.km). Both are introductions in the Terai. There are also plantations of native species such as shisham and khair. There have been repeated attempts to regenerate tree species in the upland grassland patches (located within the forests) through a combination of silvicultural practices. When these failed to provide the desired results, plantations were resorted to (Rizvi 1979; Gaur 1983; Singh 1985). Between 1969 and 1979, an average of 30,458 cu.m fuelwood and 50,268 cu.m timber was produced annually in the south Kheri forest division (426 sq.km), in which the Kishanpur WLS (201 sq.km) is located. The minor forest products collected included thatch grass, (seven species of tall grasses from grasslands), honey and wax, approximately 80 tonnes/year of a grass species, *Eulaliopsis binata*, for making paper and rope, flowers of *Madhuca latifolia*, at least nine known species of medicinal plants, leaves of *Dyospyros melanoxylon*, fruits of *Mallotus philippensis*, seeds of *Shorea robusta* (average 1,500 tonnes/year), and hides and shed antlers (6 to 8 tonnes/year). Rhesus monkeys (*Macaca mulatta*) were sold for medical research (no figures available) up to 1977-78; fish in the swamps and rivers were auctioned annually (yield not known). Cattle grazing was allowed throughout the tract except areas under regeneration. Although there were adequate rules to regulate grazing, the overwhelming numbers of cattle made it impossible to enforce them.

Hunting in the forests outside the PAs was regulated under the provisions of three Acts and Rules until the Wildlife (Protection) Act 1972 superseded these. A moratorium was placed on hunting tigers all over India in 1970. Following that, several species were taken off the hunting list. By 1978-79, all licensed hunting came to an end. Between 1962-63 and 1968-69, 66 tigers, 6 leopards, and 5 sloth bears were killed in the south Kheri division alone. Four of the five deer species in the Terai (not the swamp deer), the antelope (*Antelope cervicapra*), nilgai (*Boselaphus tragocamelus*), and for some reason ten hyenas (*Hyaena hyaena*) were also hunted under license (Rizvi 1979; Singh 1983).

Current Wildlife Management Planning Issues and Needs

Management of forests in India has been driven by the institutionalised process of working plans since the 1870s (FRI 1961). The first attempt to bring wildlife management under a specific wildlife or Protected Area Plan came about in 1972 when this was made mandatory for the tiger reserves established under PROJECT TIGER (Government of India 1972b). Unlike the working plans (Mathur 1982), there was no code that enabled wildlife planners to follow a systematised process until the Wildlife Institute of India published a Manual for the purpose in 1995 to address the management of wildlife in PAs and in managed forests (MF) outside the PAs (Sawarkar 1995).

Working plans and wildlife management plans traditionally only addressed a specific notified area, a forest division or a PA. The concept of buffer zones

outside the PAs has enabled wildlife planners to extend management outside PA boundaries, and strategies are normally covered by ecodevelopment plans (WII 1995). Buffer zone management has still not been extended to PAs, beyond some selected range of areas, for various reasons. Now, in view of the fact that PAs cannot be seen in isolation from the interacting influences of other land uses in their surrounding tract, the planning needs to be based on the concept of a landscape in which the current buffer zone management strategies are integrated and planning is reordered taking the PA values and related issues in the particular landscape into consideration.

The current strategies to manage buffer zones, at least in practice, chiefly address the management and reduction of social and economic pressures on PAs and forest resources. This indeed is acknowledged as a primary function (Government of India, 1983), but there does not seem to be any serious attempt at maintaining habitats for wildlife in buffer zones, especially those which have natural ecosystems extending into them (Berkmuller and Mukherjee 1987; McNeely and MacKinnon 1989; Groenfeldt *et al.* 1990; Sayer 1991).

There is a clear need for the negative influences of habitat isolation to be countered. The conflicting land uses result in dramatic changes in environmental features along the PA interface (Carbyn 1979; Miller and Harris 1979). If the range of habitats outside PAs is not maintained, there is likely to be an increase in man-wild animal conflicts, a reduction in the ecological productivity of the natural systems, and further alienation of the human cultures that have evolved in forested/wilderness environments. Ecological surveys should thus be considered an integral part of socioeconomic surveys in such areas to enable balanced strategies to be developed. This applies especially to ecodevelopment planning outside a PA.

The principles of landscape ecology constitute an intersection between all the disciplines of 'wildlife science', viz. ecology, geography, forestry, wildlife biology, landscape design, sociology, and economics. In other words, they are integrative and interdisciplinary (Forman and Gordon 1986; Risser 1987). Landscape is a heterogeneous land area composed of a cluster of interacting ecosystems, i.e., ecosystems that are spatially related (Forman 1987). Landscapes do not have a specific size and may operate on a variety of scales depending upon a recognisable array of ecological processes working in harness over an area. None of the ecological processes act independently, rather they are mutually determining (Morrison *et al.* 1998). For example, agricultural practices combined with flooding patterns and fire escapes are suspected of encouraging exotic plants to invade favourable sites in tall wet grasslands, like *Cymbopogon martinii* and *Sesbania aculeata* in Dudwa.

Several hierarchical scales could be considered to simplify the concept for managerial application. Micro habitats, which are unique, could be addressed at site level; in grasslands especially, the next level could be vegetation and habitat characterisation in which few to several species might be present. This might also apply to upland forests. Similarly, the level of watershed/s in which populations of several species may be encountered can also be considered. The habitat corridors; the zones of influence (wildlife on people and people on the PA); the areas of administrative decisions relating to landuse or specific

resources that are likely to affect the PA values; and the level of biological organisation, i.e., distribution and abundance of individual species, populations, and communities, can also be considered. The best example is the concern for metapopulations and the relationships between 'sources' and 'sinks' (Gavin 1991).

Application of the Landscape Approach

Certain issues in this part of the UP Terai which attract the landscape approach to management planning will be discussed here to illustrate the idea.

The tiger (*Panthera tigris*) is one of the world's critically endangered species. The Terai has long since been known for the abundance of tigers. The hunting record statistics for one division cited earlier provide some indication. Current estimates suggest that there are 65-80 tigers in Dudwa tiger reserve. This is a very low number compared with the past. The decline in both population and range of distribution has occurred within the short span of a decade and a half. In the seventies and early eighties, tigers were distributed south of the national park through the sugar cane fields. There were several intact swamps within the stretch of agricultural lands. The surrounding tall grasses merged with the cane. Tigresses bred on several such sites (Sawarkar 1988a, b). Man eating tigers are not unknown in the Terai, but there was a sudden spurt of man eating between March 1978 and December 1981 during which 90 human kills were recorded, of which 12 were inside the park. A special committee was appointed by the Government of India to determine the causal factors and make recommendations. Forty one percent of the kills took place in the sugar cane fields when people unwittingly, mostly in the early mornings and evenings, came across a tiger in thick cover; 21% of the kills were thatch grass cutters, many illegally cutting inside the park; 12% of the kills were those of cattle grazers; and 28% for other assorted reasons. In all, seven identified man eaters accounted for 67 kills. All were proscribed and six were shot (Government of India 1982). The pattern of kills conformed to the intensity of spatio-temporal activity of people and the increasing presence of immigrant labour in an unfamiliar environment. To reduce the propensity of encounters, the committee, among several other measures, suggested strong anti-poaching strategies and the maintenance of thatch grass patches outside the park. These were fast disappearing and their decline had prompted people to enter the park illegally to collect thatch. Other suggestions included maintenance of corridor links with the south Kheri forests and shifting of a few villages for this purpose; maintenance of fuelwood reserves by regulating activities; and management of fish resources in swamps and rivers outside the PAs. In the mid 1980s the illegal trade in tiger bones and products picked up sharply (WWF 1998) and many tigers outside the PAs were poached. Sugar cane cultivation was intensified as sugar mills and their capacities went up. As a result, the large remnants of tall wet grasslands of Gholia and Gajraula outside the park were heavily encroached. The prey species were decimated. The north and south Kheri forests became progressively isolated and opportunities to reduce the interface problems rapidly declined. Later, tigers and people continue to be in trouble.

It needs to be appreciated that the opportunities to resolve the issues surrounding a single wide-ranging species and the interest of the people mainly lay in planning land use over a large tract outside the park.

The northern swamp deer (*Cervus duvauceli duvauceli*) is an obligate of the Terai grasslands and is one of the most endangered deer species in the world (Holloway 1973 and 1975; Schaaf and Singh 1976; Martin 1977; Schaaf 1978; Singh 1982; Sawarkar 1988a). In 1980 its population in Dudwa was estimated at nearly 2,100 individuals, in 1988 it was about 1,000, and by 1998 it was estimated to lie between 700 and 750 (WII 1998). In earlier times the major population, approximately 60% of the total, was in the north west section of the park, Sathiana. Just prior to the monsoonal flooding, this section of the swamp deer population disperses and goes south across the Suheli river into the upland grasslands of Ghola and Gajraula and the swampy grassland patches interspersed within the sugar cane. This coincides with the peak fawning during June and July. The deer remain outside the park till late January/early February. The rutting is completed outside the park in November/December.

What affected the tiger has affected the swamp deer. The fawning habitat and rutting areas were rapidly lost to encroachment. The deer were also exposed to increased poaching. When George Schaller visited Ghola and Gajraula in October 1963, he encountered a herd of 800 swamp deer (Schaller 1984). This approximately 52 sq.km of Terai grassland is estimated to be some 70% smaller now. There are no more than 150 swamp deer in Sathiana, compared with more than 900 in 1980. The swamp deer population of Kishanpur WLS has fortunately remained stable at around approximately 400-500, mainly around one large swampy grassland, Jhadital. But the flood plain grassland habitat of Ull river, extending well beyond the WLS, needs planned attention to secure the future of this species.

The elephant did not find any specific mention in this region during the 1970s. Since then the forests along the northern boundary of the park in Nepal have been cut for settlement and presumably important habitats and links across the Kheri, Bahiraich, and Pilibhit districts in India have also been lost. It is suspected that the elephant herds now range over much larger tracts. They are regularly seen in Kishanpur WLS and Dudwa National Park, more often than ever before. Crop raiding at these times has become serious. Elephants are reported seasonally in Royal Shukla Phanta Wildlife Reserve in Nepal (T. Maskey personal communication). Presumably they belong to one such disoriented metapopulation. This has increased the problem of ensuring conservation of elephants while maintaining the economic security of people across the range of elephant movement. This underpins the need for landscape/regional planning. Now that there is a better understanding of species-habitat relationships, and some bitter experience to go with it, the planning perspective can be reset and not just in consideration of long-ranging species. Depending on the issues, different spatial scales come into play and they are often all connected.

The forests outside the PAs are managed traditionally. Wildlife habitat management is not on their agenda, although legal protection of wildlife is. However, forest managers have a wide range of tools to manage habitat structure, composition, and conditions without prejudice to the production functions which managed forests need to serve. Working plan surveys and inventories are flexible enough to identify, locate, describe, and map micro habitat elements such as snags, den trees, down wood, breeding and fawning

areas, cubbing sites, heronries, other key and sensitive sites, sites of unique botanical interest, riparian forests, corridor connections (woodlands and grasslands), waterholes, swamps, groves, old growth forest patches, grasslands, and grassy openings. Silvicultural systems and tending operations can be built around these (Thomas 1979; Hoover and Wills 1984; Kelly and Braasch 1988; Hunter (Jr.) 1990, 1995; Sawarkar 1995; Morrison *et al.* 1998). The predation pressure of the tiger can be dispersed across the prey species to reduce the impact on the small population of swamp deer dwelling in the Terai grassland by managing the woodland habitat, with its interspersed grassy patches and edges, to manage, restore, or enhance the populations of species such as sambar (*Cervus unicolor*), spotted deer (*Axis axis*), barking deer (*Muntiacus muntjak*) and wild pig (*Sus scrofa*). Woodlands offer thermal cover to rhinos in winter and in the peak of summer (Sinha and Sawarkar 1992). Most species use more than one habitat (Morrison *et al.* 1998). Upland woodlands have a role to play in controlling the flooding pattern in the Terai grasslands. Interactions between ecosystems are often reflected in simple connections, and these present a good place to begin planning, which can then progress towards more complex interactions at different spatial scales. Most would be difficult to discern precisely.

There are 139 villages and hamlets in a belt of 5 km width surrounding the Dudwa National Park. In 1992, the fuelwood requirement per annum was estimated to be 22,800 tonnes; the annual requirement of thatch grass 64,700 tonnes; the human density was 129 per sq.km, and the cattle density 300 animals per sq.km (Qureshi *et al.* 1992). At the time there were opportunities to manage and harness substantial resources outside the government forests with the adoption of sensible land use practices. These, although now much reduced, still offer some chance.

Conclusion

The forest or wildlife departments may not have jurisdiction over the areas abounding PAs but they can identify opportunities. The only way to accomplish the desired set of practices is through building partnerships with other agencies such as the revenue, agriculture, animal husbandry, human health, tribal welfare, education, and fisheries agencies, who have programmes in and around the forested rural sector, and potentially have the capability of putting together programme packages that benefit people and natural ecosystems alike. This is easier said than done. However, a beginning has to be made to influence policies that might arbitrate the development of a synergy between land uses. Ecodevelopment or buffer zone management cannot succeed without partnerships and motivated and willing stakeholders, among whom the local communities are the most important. The local communities need to be enabled to make the connection between the proactive role of the managers of the natural ecosystems, and the increased benefits flowing to them.

Landuse management implications may transcend the state boundaries in a country, e.g., Pench National Parks across Maharashtra and Madhya Pradesh in India, or an international boundary, e.g., Manas World Heritage Site in Assam in India and Manas in Bhutan; Sunderbans Tiger Reserve, India, and Sunderbans World Heritage Site, Bangladesh; the Royal Bardia National Park,

Nepal, and the Katarniaghat WLS, India; the Valmiki Tiger Reserve, India, and the Chitwan National Park, Nepal; the Shukla Phanta WLS, Nepal, and the Lagga Bagga Reserve, UP, India. Notwithstanding the procedures needed to set the terms of bilateral cooperation between countries, there is no ambiguity in the planning principles that need to be followed to secure the mutual interest in ecosystem management.

Such needs and implications were discussed in the Millenium Tiger Conference, held from March 3-5, 1999, in New Delhi, in the session on Transboundary Cooperation. The landscape planning approach admittedly has many miles to go. The important need is that wildlife managers, planners, and decision makers are walking on that road.

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Status of Research and Monitoring in Protected Areas of the Indian Terai - An Overview

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Abstract

The east-west stretch of the vast northern alluvial flood plains of the rivers Ganges and Brahmaputra in the States of Uttar Pradesh, Bihar, West Bengal, and Assam is recognised as the Indian Terai. The characteristics of this tract include a high water table, annual flooding, and the synergistic influence of annual grassland fires. Once the Terai represented a lush belt of green vegetation comprising mainly moist deciduous forests dominated by sal (*Shorea robusta*) interspersed with tall, wet grasslands and numerous swamps. The tall grasslands were dominated by *Saccharum*, *Narenga*, *Sclerostachya*, *Imperata*, and *Typha* species. The complex woodland—grassland—wetland ecosystem harboured a variety of floral and faunal life, including several charismatic and obligate species. However, the highly diverse and productive Terai ecosystem witnessed a massive change during the country's post-independence era as a result of abrupt changes in land use policy, settlement of refugees, uncontrolled expansion of agriculture and the associated large-scale reclamation/conversion of grassland and swamp habitats, heavy deforestation, ever-increasing resource dependence and factors like fire, livestock grazing, and flash floods. These factors greatly reduced the once extensive Terai into smaller fragments. Some of these fragments were declared Protected Areas (PAs) in order to ensure conservation of representative biodiversity. As a result, what exists today are a few scattered PAs that experience high biotic pressure amidst a sea of extensive crop fields and human settlements.

In spite of the known significance of research and monitoring for sound and effective PA management, these PAs lack planned research and monitoring programmes. The existing research contributions are mainly in the form of check lists, inventories, ecological surveys (e.g., grassland habitats, turtles and tortoises, Bengal florican, cranes, swamp deer, Asian wild buffalo) and mainly species-oriented research on selected endangered mammals (*Rhinoceros unicornis*, *Bubalus bubalis*, *Cervus duvauceli duvauceli*) and birds (Bengal florican—*Houbaropsis bengalensis*, blacknecked stork—*Ephippiorhynchus asiaticus*). Sporadic studies also exist for selected PAs on resources mapping and land use changes. Up to now no baseline information has been collected on the structure, composition, and dynamics of forests, grasslands, and swamps in the rapidly changing landscapes. Likewise, well-planned and detailed experimental studies are needed on grassland diversity, succession, and the effect of burning, harvesting, and grazing. This paper highlights some of the constraints that have led to the present state of research and monitoring in these PAs, and recommends planned and co-ordinated multidisciplinary research including socioeconomic research; assessments at multiple hierarchical levels; application of modern technologies, viz. remote sensing and GIS; and management-oriented experimental research. The paper also recommends the adoption of a well-developed comprehensive approach for a long-term monitoring programme for each PA based on 'vital signs' and selected taxa.

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The Threatened Terai Ecosystem

India is fortunate in having a rich diversity of natural ecosystems ranging from the snow-capped peaks of the Himalayas in the north, to a vast hot sandy desert in the west, dense evergreen forests in the east, and biologically unique islands and coastal areas in the south. These result from the country's strategic location at the confluence of different biogeographic realms. Rodgers and Panwar (1988) in their biogeographic classification divided the country into 10 biogeographic zones and 26 biotic provinces. Like any other developing country, India too has witnessed a rapid growth of human and livestock populations in the past decades, and an ever increasing pressure of land encroachment and unplanned development have ultimately led to the decline and irreparable loss of the country's once extensive wilderness. Of the 10 biogeographic regions, probably the worst affected is the Terai, the east-west stretch of the northern alluvial flood plains of the rivers Ganga and Brahmaputra, which once harboured a lush belt of green vegetation dominated by sal (*Shorea robusta*) forests interspersed with tall grasslands and numerous swamps. This vast tract stretches across the northern Gangetic plains from Uttar Pradesh, through the southern Nepalese flood plains to Sikkim Dairs of northern West Bengal, to the floodplains of the Brahmaputra in north-west Assam and south of Bengal as far as Dakha (Wadia 1953; Oliver 1985; Lehmkuhl 1989, 1994; Sharma 1991; Bell and Oliver 1992; Peet *et al.* 1997, 1999; Kumar and Mathur 1998). The characteristics of this tract include a high water table, annual flooding, and the synergistic influence of annual grassland fires. This complex woodland—grassland—wetland ecosystem harbours a variety of floral and faunal life, including several charismatic and obligate species such as the tiger (*Panthera tigris*), Asian elephant (*Elephas maximus*), great one-horned rhinoceros (*Rhinoceros unicornis*), Asian wild buffalo (*Bubalus bubalis*), swamp deer (*Cervus duvauceli duvauceli*), Bengal florican (*Hubaropsis bengalensis*), hispid hare (*Caprolagus hispidus*), and pigmy hog (*Sus salvanius*).

The history of the area, coupled with severe human interference, has changed it into the fragmented landscape it is today. For a considerable time the area remained thinly populated except by local tribal people. However, the entire tract witnessed an immense change during the country's post-independence era as a result of abrupt changes in land use policy, the settlement of refugees, uncontrolled expansion of agriculture by large scale reclamation/conversion of grassland and swamp habitats for agricultural activities, heavy deforestation, increased levels of forest resource dependence, and the resultant abiotic factors like floods and forest fires. These biotic and abiotic factors greatly reduced the wilderness in the Indian Terai and it is now one of the most threatened ecosystems in India.

The Indian Terai PA Network

In recognition of the rapid decline of this highly diverse and productive complex ecosystem, and with the aim of protecting the endangered populations of prominent mega-herbivores, some large remnant patches of Terai forest in different states were declared as protected areas as part of a global network of biogeographically representative protected areas (GOI 1972, 1983; Mackinnon *et al.* 1986; UNCED 1992). The present network of India's protected areas

(PAs), including 85 national parks (NP) and 450 wildlife sanctuaries (WLS), covers an area of 1,449,788 sq.km, or 4.5% of India's geographical area. However, the Indian *Terai* has just 6 national parks and 38 wildlife sanctuaries covering an area of ca. 8,520 sq.km, or a mere 2% of the flood plains of the Ganga and Brahmaputra. The PAs in the Indian *Terai* are in four states—Uttar Pradesh (UP), Bihar, West Bengal, and Assam. The most prominent are Dudwa NP, Kishanpur WLS, Katarniaghat WLS, Suhelwa WLS, and Sohagibarwa WLS in UP; Valmiki NP and WLS and Kabar WLS in Bihar; Mahananda WLS, Gorumara WLS, Jaldapara WLS, and Buxa WLS in West Bengal; and Kaziranga NP and Orang WLS in Assam.

The average size of the PAs in the Indian *Terai* is about 185 sq.km, and like the majority of the PAs in India they also have villages within the PA and/or a large number of peripheral villages that are dependent on the natural resources of the PA. Furthermore, because of the prevailing severe biotic pressure and past management practices, most of these PAs are neither totally 'natural' nor stable (Mathur and Mathur 1999), rather they are largely 'semi-natural' or man altered. Many of the PAs lack contiguous managed forests or other categories of wilderness that can serve as crucial corridors. Thus they are isolated islands of wildlife habitats surrounded by people and incompatible land uses. The priority management issues facing the field managers of these PAs are often related to dependency of people—their rights and concessions; wildlife damage problems—crop depredation, cattle lifting, and even human injuries or kills; and aggravation of habitat loss and fragmentation—mainly by encroachments, flash floods, changing land use, hydrology, extensive farming, and the resultant habitat dynamics (Kumar and Mathur 1998).

Research and Monitoring in PAs

It is evident from the foregoing description that the existing PAs in the *Terai* are too small, in many cases isolated, severely altered, complex, dynamic, and heavily burdened by biomass dependent communities. Restoration, protection, and maintenance of these complex dynamic ecosystems will require effective management interventions, and these call for a better understanding of the various constituents and processes of the ecological systems under the jurisdiction of field managers. In light of the above, the relevance of research and monitoring as integral activities of PA management cannot be over-emphasised, keeping in view the multiple threats to the fragile ecosystem. Well organised rigorous scientific research and an integrated monitoring programme would ultimately help the PA management in several ways: it would enhance bench mark knowledge; facilitate decision making; reduce overall management costs; and enhance ecological integrity through increased public awareness and participation (Mackinnon *et al.* 1986, Mathur and Mathur 1998). It has been well illustrated that research and monitoring are two indispensable arms needed to support and strengthen PA management (Mathur and Mathur 1998). Developing and using an information base is the essential first step in deciding PA management goals and objectives. Evaluation of knowledge gaps helps determine research needs, while the research and monitoring outputs enhance the information base which further assists in redefining objectives, prioritising management issues, and evolving appropriate strategies.

Information Base on the Indian Terai — An Insight

In spite of the threats to the entire Indian Terai, PAs in this region have received very little attention from the research community; only in the recent past have they attracted some researchers. It is neither intended nor desirable to present here an exhaustive review of published or accessible research and monitoring activities in the Indian Terai. In this paper I will present a glimpse of the significant research contributions related to its diverse floral and faunal life and its spectacular landscapes. Most of the existing information is in the form of checklists, inventories, biological surveys, community ecology studies, and species-oriented research on selected endangered mammals and birds. Sporadic studies also exist for selected PAs on resource mapping, socioeconomics, and changes in land use. The most prominent studies and their contributions are described briefly below.

Surveys, Biological Studies, and Ecological Assessments

The majority of the PAs in the Terai were carved out from managed forests formerly under the control of State Forest Department(s); thus primary information about each PA comes in the form of old official Forest Department documents. This mainly means Forest Working Plans. These plans largely provide information on the type and extent of forests, taxonomic checklists (plants, birds, and mammals), forest management practices (silvicultural systems, plantations, rights, and concessions), habitat management, and to some extent socioeconomic profiles. Basically, they were management-related records with lots of facts and figures and not based on actual rigorous research. Often the plant checklists excluded lower and aquatic plants, grasses, and other herbaceous vegetation. In spite of this, such records are quite valuable for new managers and researchers to the area as important references. In addition to this, several floristic and faunal surveys have been undertaken throughout the Terai by survey organisations such as the Botanical/Zoological Survey of India and other scientific institutions.

Floristic Studies

Prominent floristic—forest/grassland surveys relevant to the Indian Terai are Duthie (1883, 1886, 1888), Cowan and Cowan (1929), Raizada (1931), Kanjilal (1933), Kanjilal *et al.* (1934a, b, c, d), Champion (1936), Bor (1941, 1960, 1982), Whyte (1957), Murthy and Singh (1961) Panigrahi and Ram Saran (1967), Panigrahi (1968), Champion and Seth (1968), Chaudhury (1969), Panigrahi *et al.* (1971), Dabadghao and Shankarnarayan (1973), Hajra and Shukla (1982), Singh and Tomar (1983), Chaudhuri and Naithani, (1985), Banarjee (1993), Uniyal *et al.* (1994), Sawarkar and Hussain (1995), and Rawat *et al.* (1997). A good beginning was made by the earlier foresters and botanists in providing checklists, flora, and illustrations, particularly in the case of grasses. However, much needs to be done in the field of community ecology—ecological description and vegetation assessment, classification, phytosociology, biomass production, harvest and use, and consumption by herbivores. Only preliminary research results are available on grassland succession and habitat dynamics. Extensive areas are affected by a variety of weed plants, yet no one has conducted research into this.

Faunal Studies

Faunal surveys and endangered species conservation oriented studies were also initiated a long time ago and these efforts continue. Such surveys and studies largely dwelt upon the status, distribution, and conservation priorities relevant to large mammals and birds. Prominent ones are Blanford (1888), Baker (1906, 1912, 1921), Gee (1964), Schaller (1967), Spillet (1967), Ali and Ripley (1969), Mallinson (1971a, b), Laurie (1978), Oliver (1979, 1980, 1984, 1985), Daniel (1980), Lahiri Choudhury (1980), Inskipp and Inskipp (1983), Singh (1984), Bell (1987), Rahmani *et al.* (1990), Sankaran and Rahmani (1990), Quershi *et al.* (1991), Ghosh (1992), Mathur *et al.* (1995), Javed (1996), Hussain (1997), and Maheshwaran (1998). Most of the recent species-oriented studies on large mammals and birds, *viz.* rhino, wild buffalo, swamp deer, and Bengal florican, highlight the distribution, status, population structure, habitat use, movement pattern and behaviour of the studied species. In many cases, findings are site specific. As the field situations are rapidly changing, constant monitoring and updating of information is mandatory to ensure conservation of such critically endangered species. There are only general accounts in these reports of the effect of grazing, grass cutting, and burning of grasslands on the species of concern. Many studies and reports advocate annual burning of grasslands, but such recommendations are not based on actual experimental studies. In general the published studies fail to provide any insight into ecological relationships and interactions among plants, wild animals, livestock, and humans.

Land Use, Resource Dependence, and Socioeconomic Studies

The entire *Terai* region is under tremendous pressure as a result of the ever increasing biomass-based demands of local people and intensive agricultural development. Even so, only a few sporadic studies have been made on changes in land use (using remote sensing) and a few preliminary assessments made of resource dependence and socioeconomic profiles of selected villages. The prominent studies are those by Parihar *et al.* (1986), Sharma (1991) and Wil (1997). In addition to these research studies, the State Forest Departments recently started collecting information for all internal and peripheral villages in and around PAs, on human and livestock population resource dependence and priority village needs using rapid assessment methods such as participatory rural appraisal (PRA) and micro-planning. Visible changes are taking place in tribal and rural systems as a result of sudden and massive inputs by the tribal development agencies, intensive agricultural development, and growing market forces and ecodevelopment activities. Clearly changes in attitude, perceptions, and the overall socioeconomics can be expected as a result. These need to be quantified. Increasingly, wildlife damage problems (crop depredation, livestock predation, and human injuries) are being encountered in and around each PA. It is difficult to find any comprehensive study which addresses this priority management issue in India.

Research Issues

Wildlife or protected area management research is of comparatively recent origin in the Indian *Terai*. The majority of the past investigations and research studies have been of short duration, at the most three to four years. Likewise, the various biological surveys were mostly undertaken only once and a

considerable time has lapsed since they were completed. Thus there is no up-to-date reliable information available on trends. The main research issues are common to almost all PAs in India and have been discussed in detail by Mathur and Mathur (1998) in their report on 'Research Strategy for Protected Area Management for the India Ecodevelopment Project Sites.'

The complexity of the terrain in the *Terai*, the poor field research infrastructure, and often the lack of desired management support, have seriously hampered expected research outputs. The concept of planned and coordinated, multidisciplinary research is gaining acceptance and support in other biogeographic zones in India. However, the PAs in the *Terai* region have yet to attract or implement such participatory, inter-disciplinary, and coordinated research activities, and to demonstrate their success and management utility.

Future Research Needs

The following priority research is recommended, taking into account the existing biodiversity patterns across the Indian *Terai* and the conservation challenges posed by them, while simultaneously recognising the merits and gaps in the available research information,

Flood Plain Dynamics

The majority of PAs in the *Terai* have been affected increasingly in recent years by frequent floods, siltation, inundation, and changes in river course, all of which result in changes in grassland and vegetation succession and in the dynamics of habitat use (e.g., Mohana, Suheli, and Sharda in Dudwa Tiger Reserve; the Torsa river in Jaldapara WLS, and the Brahmaputra in Kaziranga NP). Long-term multidisciplinary studies that can assess river-flow and dynamics, vegetational changes, and the factors responsible are required as a priority to facilitate management strategies for food, cover, and water management—at least for all prominent PAs.

Grassland Experimental Studies

Over the years, a combinations of tools and methods like grass cutting, harrowing, burning, and grass planting, have been used in different PAs to maintain grassland diversity and productivity. Unfortunately, the complexities of different management inputs and their effects on species of concern and overall biodiversity are poorly understood. Experimental studies on grassland management in the Indian *Terai* have been advocated for a considerable time in a large number of past research papers and reports. Some PAs are providing intensive management inputs at a high cost with potential ecological risks involved therein. In spite of this, systematically planned long-term experimental studies are lacking. It was only two years ago that the first experimental study on grassland burning was initiated by the Wildlife Institute of India at Dudwa National Park in UP with the support of the park management. Details of this new initiative are provided in a paper by Kumar in this Proceedings. Such efforts need to be multiplied elsewhere on a long-term basis in order to avoid *ad hoc* and expensive management inputs.

Biological Surveys

Considering the *Terai* grassland diversity and prevailing biotic pressures, it is important to undertake periodic grassland surveys in order to assess the

diversity, distribution, status, and threats not only to the grasslands but also to the associated faunal species. Earlier studies by the Bombay Natural History Society (BNHS), particularly on the Bengal florican, have made a significant contribution to this. However, such efforts need to be strengthened and other endangered species or taxonomic groups addressed (e.g., hog deer, hispid hare, pigmy hog, insects, and birds).

Weed Management

In the last decade, throughout the *Terai*, a variety of terrestrial and aquatic weed plants have gregariously invaded vast areas resulting in the decline of native herbaceous vegetation and overall habitat degradation. Appropriate weed control methods are required immediately. This calls for an assessment of weed types and extent, and specific research studies addressing their control either manually or biologically—as the option of using chemical herbicides has a limited scope in a PA.

Genetic Management

Endangered species that already have a small population or are confined to one or two distant PAs, of which there are a large number, may suffer severely in the future as a result of their potentially low genetic variability and associated genetic disorders. The situation could be further aggravated if the present level of biotic pressure continues in the PAs. A recent study on rhinos in Jaldapara WLS, West Bengal, indicated a high level of homozygosity in the confined population (Ali *et al.* 1999). The genetic interaction between domestic and wild buffaloes (*Bubalus bubalis*) in Kaniziranga National Park has been well documented (Mathur *et al.* 1995) and also established by preliminary DNA studies. Although wild buffalo is a species of the highest significance for conservation, much still needs to be done for its conservation in the field—genetic research and subsequent genetic management are needed to ensure the survival of this critically endangered species. While intensive grassland/habitat management is the current priority in several PAs, one can expect that genetic assessment and management of endangered species will become a necessity in the near future. Thus the species that may require such inputs need to be short-listed, selected, and studied for population genetics and genetic variability (using modern DNA technology) so as to provide timely and suitable answers to the complex management challenges while keeping the field realities and other constraints in view.

Resource Dependence and PA-People Conflicts

PAs in the Indian *Terai* are heavily exploited by resource dependent communities. Grass, timber, fuelwood, thatch, and other non-timber forest products, once extensively extracted, are either still removed in bulk legally or illegally or are suddenly not being collected at all, as a result of sudden imposition of restrictions and serious enforcement. A manager needs to understand the impact of both situations, continued biomass removal or sudden protection, on vegetation and fauna. There has been no comprehensive study addressing the issues of biomass production *vs.* consumption in terms of harvest and removal or even loss due to burning or other natural processes like herbivory. It is also necessary to discover what effect sudden protection has on vegetation and wildlife. Research addressing alternatives to biomass-based

demands is equally important. PA interface conflict is another major issue concerning almost all managers, and it will be difficult for them to control adverse situations if appropriate research addressing park-people conflicts is not undertaken on a priority basis and such issues tackled immediately.

The Impact of Changing Scenarios, Policies, and Programmes

In recent decades, many government and non-government agencies, particularly those related to tribal and rural development, have provided multifarious inputs to villages located in and around PAs. Likewise, at several places, the Forest Department or PA management has started providing ecodevelopment inputs. Thus there is considerable implementation of new policies and programmes. Moreover, there is an increasing trend of exposure to the modern world, with changing life styles and land use patterns and new market forces, that will ultimately bring about changes in attitudes towards, and perceptions of, the protected area and overall village development. There is a need to study these emerging park-people relationships, and also to standardise the methods used to assess such changes.

Long Term Ecological Monitoring

Depending upon the management needs, available resources and staff capabilities, and infrastructure, various kinds of monitoring activities on climatic, vegetation, and animal parameters (predominantly periodic census/population estimation of large herbivores and carnivores/predators), and to some extent socioeconomic aspects, have been initiated in different PAs and continue today. In the majority of cases, however, these studies are not 'diagnostic' in nature and the managers barely benefit from the exercise. Monitoring activities are being carried out in spite of the constraints of staff time and budget for the sake of monitoring, or as a follow-up action to administrative orders. Uniyal and Mathur (1996) and Mathur and Mathur (1999) have reviewed present monitoring activities in Indian PAs and highlighted the strengths and weaknesses of such programmes. There is a need to design and develop a comprehensive and integrated long-term monitoring programme based on 'vital signs', with periodic assessment of various parameters of the population dynamics of selected taxa as described by Davis (1992). At least the prominent PAs should adopt such an approach so as to make the entire monitoring effort interesting and meaningful for PA management. This would require multidisciplinary research inputs, at least at the initial stage of developing the integrated monitoring programme. Richard (1999) strongly recommends that "all research and planning should be part of a flexible and iterative framework, where research is action oriented and designed to monitor impacts of policies and programmes in addition to monitoring bio-physical resources". This lays the basis for emphasising participatory action research (PAR) and participatory monitoring activities involving local people.

Conclusions

The significance of action-oriented research and integrated long-term monitoring programmes as integral activities of PA management cannot be over emphasised. PA managers cannot wait indefinitely for the findings of long-term research; at the same time they cannot afford to ignore the importance of such research, instead they need urgently to recognise that today's investment in

research and monitoring activities will not only help them immensely in future crises but would also help safeguard the fast depleting unique and diverse floral and faunal life in the Terai. In short, research, monitoring, and management need to be blended. A concerted effort needs to be ensured at all levels to implement the priority research relevant to the Indian Terai successfully.

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Managing the Terai Grasslands in Nepal: Recent Research and Future Priorities

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Abstract

Recent research in the Terai grasslands of Nepal has provided important new information on their ecology and management. This paper briefly summarises key research and management priorities arising from this work.

Classification has revealed the structure, composition, and diversity of the grasslands within and between four protected areas. Maintaining the area and assemblage diversity of these grasslands will require further research into the effects of disturbance, particularly flooding, cutting, and burning, on grassland succession. In the absence of long-term data on the effects of fire, attempts should be made to leave areas of grassland unburned on a rotational basis.

Large mammal utilisation of the grasslands has been linked to particular grassland assemblages. Such associations need to be researched for other faunal groups and seasonal and management effects understood. For example, ungulates exploit the forage provided by grasslands resprouting after cutting and burning. However, widespread cutting and burning is deleterious to cover-dependent species. A management experiment in *Imperata cylindrica* grassland has indicated that patches of grassland can be left uncut and unburned on a rotational basis without causing major changes in species composition and abundance in the sward. These patches would then provide refugia for cover-dependent species.

Introduction

The tall grasslands of the Terai of Nepal and northern India are a unique habitat, dominated by dense stands of graminoids, up to six metres tall. They are host to a range of threatened fauna including the greater one-horned rhinoceros (*Rhinoceros unicornis*), tiger (*Panthera tigris*), swamp deer (*Cervus duvauceli*), and hispid hare (*Caprolagus hispidus*) (IUCN 1993).

In Nepal the grasslands are largely confined to four protected areas in the Terai: Koshi Tappu Wildlife Reserve, Royal Shukla Phanta Wildlife Reserve, Royal Chitwan National Park, and Royal Bardia National Park. Managers of these remaining grasslands face a number of management problems including harvesting of thatch, burning of grassland, grazing by domestic stock, loss of grassland area, and dam and irrigation schemes. In addition, key ecological data on the grasslands is limited as most studies have concentrated on the ecology of their fauna (Schaaf 1978; Laurie 1982; Mishra 1982; Smith 1984; Stoen and Wegge 1996). Relatively few studies have examined the structure and function of the grasslands themselves (Dinerstein 1979 a,b; Lehmkuhl 1989, 1994, Peet 1997; Peet *et al.* 1997, Peet *et al.* 1998).

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This paper briefly summarises some of the research, and conclusions on management priorities, arising from a recent research project in the *Terai* grasslands that investigated:

- botanical diversity across the protected areas;
- animal species - plant assemblage associations;
- the effects of cutting and burning on an *Imperata cylindrica* dominated grassland;
- the spatial and temporal responses of ungulates to cutting and burning; and
- the socioeconomics of grassland harvesting.

More detailed results and analysis and more complete management recommendations are given in Brown (1997); Peet (1997); Peet *et al.* (1997, 1998, in press). The results of the socioeconomic study are not given in this paper.

Grassland Organisation and Management

The complexity of the tall grasslands was first revealed by Lehmkuhl (1994) who identified eight grassland assemblages in Chitwan. Across the four *Terai* protected areas, nine grassland assemblages with eight phases have now been identified (Peet *et al.* 1998). These assemblages are characterised by a few highly dominant and structurally important grass species with the remaining species being of low abundance and frequency.

Early successional grasslands, maintained by annual flooding, are dominated by *Typha elephantina*, *Phragmites karka*, and *Saccharum spontaneum*.

Assemblages on drier and better-developed soils are dominated by *Narenga porphyrocoma*, *Saccharum bengalense*, and *Themeda arundinacea* and are maintained, at least in the short-term, by fire, cutting, and grazing. 'Phanta' grasslands are dominated by *Imperata cylindrica* and occur on old village sites and abandoned agricultural land within the protected areas. Assemblage diversity is highest in Chitwan, whilst Bardia and Shukla Phanta are of particular importance for their *Imperata cylindrica* grasslands. Assemblages in Koshi Tappu are limited to early successional grasslands maintained by flooding.

Whilst fire, cutting, and grazing are important in influencing the composition and structure of the grasslands on sites not maintained by flooding, the overall distribution and diversity of grasslands is primarily influenced by the action of rivers. Rivers can create new areas for grassland colonisation by depositing alluvium, leaving abandoned channels and ox-bow lakes, and removing areas of forest during floods. As rivers migrate across their floodplains they leave a variety of differently aged river terraces on which grasslands develop and are then maintained by disturbance. At the same time the mobile nature of the rivers feeding the protected areas means that existing grasslands are vulnerable to large-scale movements of the rivers either through the erosion of existing grassland or by leaving grassland isolated from fluvial disturbance and therefore open to succession to forest. Clearly regulation of the rivers that influence the protected areas, either for irrigation or hydro-electric schemes, would have severely deleterious effects on the area, distribution, and diversity of grasslands.

For protected area managers seeking to maintain the area and diversity of assemblages and the faunal species that utilise them, a research priority is to gain a better understanding of successional processes in the grasslands. This requires: i. investigating and predicting landscape dynamics, primarily controlled by rivers; ii. quantifying rates of succession between bare alluvium and early successional grassland, between early successional flooded grasslands and later successional dry grasslands, and between grassland and forest; and iii. gaining a clearer understanding of the role of fire, cutting, and grazing in the successional process.

Lehmkuhl (1989) developed exploratory models to predict changes in river course and alluvial deposition in Chitwan. These need to be further developed and extended to Bardia and Shukla Phanta so that protected area managers can predict likely changes in the spatial dynamics of flooding, erosion, and alluvial deposition, which has obvious consequences for the establishment of early successional grasslands.

A pre-requisite to investigating rates of succession between assemblages and changes in grassland area will be to identify the extent of grassland assemblages within each park. It should be possible to identify early successional grassland and later successional tall grassland from aerial photographs and to examine changes in area through time.

Rates of change between grassland types and between grassland and forest will be influenced by disturbance, particularly fire. In tall grassland assemblages, it would be expected that fire would retard succession to forest. Fuel loads are high as the grasslands are highly productive and little above-ground biomass is consumed by grazing herbivores (Lehmkuhl 1989). Under these conditions, high fire intensities would be expected, which should cause mortality in woody species or confine them to small individuals unable to escape the grass layer (Bond and van Wilgen 1996). However, Lehmkuhl (1989) suggests that fire cannot completely retard succession to forest as a result of spatial variation in fire occurrence and intensity. Long-term experiments should be used to examine the influence of fire and cutting on successional change in a variety of different assemblages. Identifying rates of successional change and changes in the area of grassland assemblages has obvious implications for the persistence and abundance of faunal species dependent on different grassland assemblages.

Whilst the impact of fire and cutting is poorly understood, cutting and burning of virtually the entire area of grassland within a protected area should be avoided. Instead, where possible, managers should seek to leave patches of grassland uncut and unburned on a rotational basis. This is of particular importance for grasslands that are not influenced by flooding.

Reaming *Imperata cylindrica* dominated 'phanta' grasslands are declining in area as a result of succession to tall grassland and forest. Immediate steps to monitor encroachment can be taken and invading tree saplings removed. The most suitable methods for maintaining patches of shorter grassland within the tall grasslands are currently unclear. Given the importance of these shorter grasslands for threatened species (Schaaf 1978; Dinerstein 1979b; Mishra 1982;

Inskipp and Inskipp 1983; Peet 1997), a priority should be to investigate experimentally methods of preventing succession to tall grassland.

Grassland Management and Faunal Conservation

Faunal associations with one or several grassland assemblages have been established for a range of species in the tall grasslands (Peet 1997; Peet *et al.* 1997). At this stage, research has concentrated primarily on larger mammals. For example, hog deer (*Axis porcinus*) and greater one-horned rhinoceros are associated with early successional assemblages dominated by *Phragmites karka* and *Saccharum spontaneum* (Peet 1997). There is a clear need to extend the present understanding of these associations to more faunal groups and to understand seasonal changes in assemblage utilisation.

Faunal species also respond to management of the grasslands, and the implications of annual cutting and burning for faunal utilisation of grassland needs to be more clearly understood. There are clear implications for faunal species conservation and reintroduction schemes. Cutting and burning of grasslands has been demonstrated to lead to temporary increases in the numbers of chital (*Axis axis*) and swamp deer (*Cervus duvauceli duvauceli*) utilising *Imperata cylindrica* grasslands (Dinerstein 1979b; Mishra 1982; Moe and Wegge 1997; Peet 1997). This appears to be a result of the high quality forage provided by the new grass shoots after cutting and burning (Moe and Wegge 1997; Peet 1997). The utilisation of burned grasslands by ungulates has led to widespread use of burning as a tool to maintain threatened ungulate populations and ungulate prey populations for threatened predators. However, it is not clear whether this ephemeral forage resource affects ungulate populations in the protected areas.

Whilst ungulates probably gain some benefit from widespread cutting and burning, studies of smaller cover-dependent species have indicated that they are deleteriously affected by the practice. Studies of hispid hare (*Caprolagus hispidus*) and pygmy hog (*Sus salvanius*) have shown that animals become confined to small patches of uncut and unburned grassland following fire where they are vulnerable to disturbance, predation, and hunting (Oliver 1980; Bell 1986; Bell *et al.* 1990; Oliver and Deb Roy 1993). Populations of both these species appear to have been affected deleteriously by widespread cutting and burning, and may indeed be limited by the extent of unburned habitat that remains in individual protected areas. Initial results of an ongoing study of small mammal communities in Bardia suggest that the abundance of animals in the grasslands declines dramatically after cutting and burning (T. Adhikari, personal communication). There is ample evidence from other systems that fire can influence species composition and species abundance in small mammal communities (Cheesman and Delany 1979; Fa and Sanchez-Cordero 1993; Friend 1993), herpetofauna (Fyfe 1980; Barbault 1983; Gillon 1983; Braithwaite 1987), and invertebrates (Gillon 1970, 1983; Ahlgren 1974; Majer 1984; Andersen 1991).

If management of the grasslands is to reflect the conservation of biodiversity other than ungulates and their predators, then it is important for managers to consider leaving uncut and unburned refugia. This would mean leaving patches

of grassland unmanaged on a rotational basis. In Bardia, a management experiment has demonstrated that patches of *Imperata cylindrica* grassland can be left unmanaged for two to three years without a major turnover in species composition, or succession to tall grassland or forest, occurring more rapidly than in cut and burned grassland. *Imperata cylindrica*, dominant in the cut and burned grassland, remains the dominant grass species when grassland is left temporarily uncut and unburned for three years (Peet *et al.* 1997, in press). If an unmanaged patch was then cut and burned a forage resource would again be available to ungulates and a thatch resource available to local people. These results allow managers to consider rotational patch management of the phanta grasslands, thereby providing refugia for cover-dependent species. Leaving some areas uncut and unburned would be unlikely to impact on the available forage resource for ungulates as forage would remain abundant in cut and burned areas.

Conclusion

Recent research in the Nepalese Terai has raised a number of important research and management priorities. In particular, there is a need to understand better the successional processes within the grasslands and the effects of disturbance, particularly cutting and burning, on plant species composition and species abundance in the grasslands. In the case of *Imperata cylindrica* grasslands, it is important to investigate methods of maintaining areas of shorter grassland within tall grassland. The effects of management on faunal utilisation of the grasslands needs clarification, particularly for poorly known groups such as small mammals and herpetofauna.

With data lacking on the long-term effects of cutting and burning on the structure and composition of the vegetation, and the conservation of a range of faunal species being deleteriously affected by widespread cutting and burning, managers should consider adopting rotational patch management regimes in the grasslands.

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The Organisation and Human Use of *Terai* Riverine Grasslands in the Royal Chitwan National Park, Nepal

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Abstract

I studied the landscape dynamics, organisation, and productivity of a tall-grass and riverine forest mosaic in the eastern portion of Chitwan National Park, Nepal. Aerial photograph interpretation, relevé sampling, experimental plots, models, and foraging studies were done. A model of landscape dynamics showed that fluvial action controlled landscape organisation. Ten grasslands and three forest associations were identified on edaphic and successional gradients. Above-ground net primary production appears to be among the highest in the world. Large herbivore consumption was estimated at 6% of above-ground production. Humans legally harvested 11,132 tonnes of grass worth NRs 10 million in 1987. Experimental testing of the effects of mechanical disturbance, staggered burning, and cutting to maintain, create, or restore habitat and provide for compatible human use is suggested. An adaptive management approach is proposed to engage managers and scientists in using scientific methodology to gain reliable management information.

Introduction

Little work has been done to describe the ecology and productivity of *Terai* riverine grasslands. Grasslands have been classified locally in dry regions of the subcontinent (see Yadava and Singh 1977 for a review), but the 1973 broad classification of Dabodghao and Shankarnarayan (DS) remains the commonly cited system for *Terai* riverine grasslands. The DS *Saccharum-Phragmites-Imperata* grassland type, however, is generalised for all of north India (Yadava and Singh 1977) and is not very useful for research or management of specific locales. Moreover, little is known about the floristic and successional relationships of these grasslands and the processes affecting pattern and productivity, particularly fire and wild ungulate herbivory (Lehmkuhl 1989, 1994).

The interactive effects of grazing and fire on grass production and quality have significant impacts on energy and nutrient cycling (McNaughton *et al.* 1982), and ecosystem productivity (Van Dyne *et al.* 1980). Fire is an important influence on grasslands worldwide (Daubenmire 1968; Vogle 1974), and particularly in south Asia where the climax vegetation is said to be forest (Puri 1960; Wharton 1968). Fires in Chitwan's recent past have been wholly anthropogenic, and nearly always started early in the dry season during late January or early February (Bolton 1975). Early season fires generally stimulate production, which is considered beneficial to important ungulates, but late season fires usually depress production (see reviews by Daubenmire 1968; and Vogle 1974). Little research has been done on the effects of fire on community dynamics and wildlife (Lehmkuhl 1989).

Grazing influences the composition, quality, and quantity of above-ground biomass. Grazing will usually reduce the standing crop of biomass (Heady 1975; Crawley 1983), and often reduces total annual productivity (Jameson 1963;

Younger 1972). However, some research has suggested that grass productivity is sometimes higher with moderate grazing than with lower or higher intensities of grazing (McNaughton 1979; Dyer *et al.* 1982). Regrowth after grazing is also of higher quality than ungrazed forage (Christensen 1977; McNaughton 1985). The result is a higher grazing capacity. South Asia has received little attention in the study of large ungulate herbivory (Lehmkuhl 1989).

Grassland productivity research on the subcontinent (reviews by Yadava and Singh 1977; Coupland 1979; Misra 1979) has overlooked *Terai* grasslands. Reported production estimates for four north Indian grasslands of the shorter (<2m) and dryer *Dicanthium-Cenchrus-Lasiurus* and *Sehima-Dicanthium* types were higher than estimates for 48 of the 52 temperate and tropical grasslands reported by Coupland (1979). Based on *Terai* grassland heights of four to seven metres and their occurrence on the most productive soils in Nepal (Carson *et al.* 1986), the *Phragmites-Saccharum-Imperata Terai* grasslands are potentially the most productive in the world.

Management of the grasslands for compatible human use, primarily grass cutting, is a major concern of the Park managers. The contribution of grass products from the Park to the local village and household economies has been estimated at NR 10 million (Mishra 1982b). Strategies to manage thatch grass inside the Park and to increase fodder supplies outside the Park are necessary to reduce conflicts with villagers (Mishra 1982b, 1984; Sharma 1986). Such strategies require good information on human use and attitudes (Lehmkuhl *et al.* 1988).

Research Objectives

This paper summarises my research in Chitwan National Park from 1985 to 1987, and describes potential adaptive management work that could be done to manage *Terai* grassland for conservation and compatible human use. The objectives of my work were to: (1) understand the landscape and disturbance ecology of Chitwan's riverine grasslands; (2) quantify the productivity of natural grasslands and village pastures, and the effects of fire and herbivory on production; and (3) quantify human use. Detailed accounts of the research can be found in Lehmkuhl (1989, 1992, 1994) and Lehmkuhl *et al.* (1988).

Methods

Location

The study area encompassed 2,300 ha along the north-central boundary of Chitwan National Park near the village of Sauraha—the largest area of grassland and riverine forest in the Park. The research area extended nine kilometres west from Itcharny to the Dumaria area, and about three kilometres south from the south bank of the Rapti River to the edge of the sal forest.

Organisation and Classification

Approximately two-thirds of the study area was sampled with 188 relevé plots (Mueller-Dombois and Ellenberg 1974) to study community organisation (Lehmkuhl 1989, 1994). Plot locations were mapped on aerial photographs in a 250 m x 250 m grid pattern. Minimum plot sizes (Mueller-Dombois and

Ellenberg 1974) were selected to include at least 90% of the total number of observed species in *S. spontaneum* and *N. porphyrocoma* swards (8.5 m x 8.5 m), and in the understorey of riverine and sal forest (11 m x 11 m) (Lehmkuhl 1989, 1994). All herbs, shrubs, and tree regeneration within sample plots were listed and cover/abundance was rated on the Domin-Krajina cover-abundance scale. Soil information was obtained from soil survey maps prepared by Carson *et al.* (1986). Sample plot classification and ordination was performed with the TWINSpan and DECORANA programs (Hill 1979a,b).

Landscape Dynamics

Black and white aerial photographs from 1964 and 1981 were used to quantify landscape patterns, then model landscape dynamics (Lehmkuhl 1989).

Landscape dynamics over historical time and projected into the future were estimated with a linear compartment model (Swartzman and Kaluzny 1987). The model was intended as a preliminary exploration of landscape dynamics because some model assumptions may not be valid for this highly dynamic system.

Productivity

Three experimental sites were selected in stands dominated by *I. cylindrica*, *S. spontaneum*, and *N. porphyrocoma* to estimate biomass production and the effects of fire and wild ungulate herbivory on annual production (Lehmkuhl 1989). The *N. porphyrocoma* site was meant to be representative of a "mixed tall grass" (MTG) type. Grazing treatments were grazed and ungrazed. Ungrazed plots for the two replicates were fenced with five-strand electric fence powered by a 12-volt car battery. Burn treatments were early burn (early February), late burn (mid-May), and no-burn. Each treatment combination was replicated twice with 20 m x 20 m plots in a randomised split-block design. The split-block arrangement was used for convenience in fencing, to save scarce fencing materials, and to reduce costs, while providing statistically valid results.

Primary Consumption

Primary consumption by rhinoceros and domestic elephants, the dominant ungulate herbivores, was estimated by multiplying the number of animals or grass cutting permits by the per capita harvest (Lehmkuhl 1989). Population estimates of rhinoceros were calculated using 1975 census estimates (Laurie 1978) as an initial population size, and a minimum 2.6% annual increase as estimated by Dinerstein (1985). Rhinoceros per capita grass intake was estimated from defecation rates and forage quality data from Laurie (1978) and Gyawali (1986) using the formula of Milner and Hughes (1968).

Elephant consumption rates were estimated by a year-long field study (Lehmkuhl 1989). The weight and species of fodder cut for night feeding and the amount consumed overnight were measured. Grazing intake was estimated by a bite-count technique.

Legal harvest rates of thatch and canes by grass cutters were estimated from a field study and attitudes toward the Park were gathered in a closed-questionnaire survey (Lehmkuhl *et al.* 1988). The weight of fodder illegally cut during the hot season of February through May was estimated roughly for the *S. spontaneum* cover type.

Village Pasture Production and Harvest

Annual production was quantified on a village pasture near the Park boundary, and the effects of different clipping frequencies inside a 22 m x 22 m enclosure were determined experimentally (Lehmkuhl 1992). Standing biomass was clipped at 5-weekly intervals from 0.5 sq.m plots inside the enclosure and outside the enclosure using the caged-plot method with moveable barbed wire enclosures. An experiment was done inside the enclosure to study the effects of four frequencies of cutting on production. Effects of defoliation every 11, 22, 45, and 90 days were compared to an undefoliated control. Six replicate 0.5 sq.m plots of each treatment were arranged in a randomised block design.

Results

Landscape Dynamics

The river was the focus of landscape dynamics: erosion, deposition, and channel meandering destroyed, created, and modified habitats constantly. During the 17-year period between photograph years, the river channel area increased 56% (Table 1). Floodplain sandbars increased 215% inside the Park, and 121% outside the Park. ~~The landscape was not stable, or a 'shifting mosaic', with constant properties.~~ Analysis of the photographs and model simulations indicated that three subsystems of landscape change existed in the dynamics (Figure 1) (Lehmkuhl 1989).

One subsystem consisted of the river channel and lands outside the Park that are influenced by river action. About 45 ha of agricultural and 52 ha of forest land within the study area were eroded into the river during the 17-year period, an average of 5.7 ha per year. The net loss of outside-Park lands was only 22 ha, because some of the lost upland remained in floodplain habitats outside the Park.

The floodplain and upland habitat inside the Park was the main landscape subsystem. This subsystem displayed dynamics different to those outside the Park, because the river channel was primarily cutting outside lands and depositing on the Park side of the river. *Saccharum spontaneum* floodplain habitat increased 73% after 1964 to become the most abundant vegetation type. Model simulations show that *S. spontaneum* habitat area will double over the next 50 years and dominate the landscape if current trends continue. The increase in *S. spontaneum* habitat was a consequence of faster creation of floodplain habitat than succession to mixed tall grass habitat.

The third landscape subsystem consisted of reclaimed agricultural land succeeding to natural vegetation. About 540 ha of wet paddy fields succeeded primarily to a stable mosaic of *N. porphyrocoma*, *T. arundinacea*, and *I. cylindrica*. Another 309 ha of dry fields reverted to savanna and woodland in mosaic with *I. cylindrica*. *Imperata cylindrica* dominated these lands in nearly pure swards after they were reclaimed; but after 25 years nearly all would have disappeared under tall grass. It was estimated that 66% of the area would revert to tall grass within 10 years.

Table 1. Area and percentages of grassland and forest habitat types identified from aerial photographs taken in 1964 and 1981 of the Sauraha area of Chitwan National Park, Nepal

	1964		1981		Change	
	Area ha	%	Area ha	%	ha	%
Non-Park Land						
Outside-Park Lands	97	3.2	0	0.0	-97	NA
Non-Park Floodplain	50	1.6	110	3.6	60	122
Non-Park <i>Saccharum spontaneum</i>	76	2.5	91	3.0	16	21
Park Land						
River Channel	157	5.2	245	8.1	88	56
Floodplain	52	1.7	165	5.4	112	215
<i>Saccharum spontaneum</i>	362	12.0	435	14.4	73	20
Mixed Tall Grass	546	18.1	393	13.0	-153	-28
MTG- <i>Imperata cylindrica</i> Mosaic	0	0.0	51	1.7	51	NA
<i>Themeda-Imperata</i> Mixture	133	4.4	459	15.2	326	244
<i>Bombax</i> -Tall Grass Savanna	207	6.9	509	16.8	301	145
Riverine Forest	405	13.4	473	15.6	68	17
Sal Woodland	6	0.2	6	0.2	0	0
Sal Forest	88	2.9	88	2.9	0	0
Reclaimed Agricultural Land						
Agriculture (treeless)	537	17.7	0	0.0	-537	-100
Agriculture (woodland)	309	10.2	0	0.0	-309	-100
Total	3,025		3,025			

Community Organisation

Ten grassland associations, with six phases, and three forest associations were identified (Lehmkuhl 1989, 1994). Types were classified on an edaphic and successional gradient indicated by the amount of shrub cover (Figure 2). *Themeda* and *Narenga* dominated types occurred on the wettest sites with the smallest shrub cover, and appeared to be relatively stable over time. The majority of types with *S. spontaneum* and *S. bengalense*, but also some with *N. porphyrocoma*, were considered stages in the succession to riverine forest.

Fluvial action was the controlling force of community organisation at the landscape level. At the lower among-habitats level of organisation, gradient analysis suggested that soil moisture and development, and fire were the primary factors underlying community organisation and succession. Succession was a complex function of species life-history characteristics (e.g., seed dispersal, competitive ability) and population processes, changes in soil moisture regimes, and increasing soil fertility over time. Large mammalian

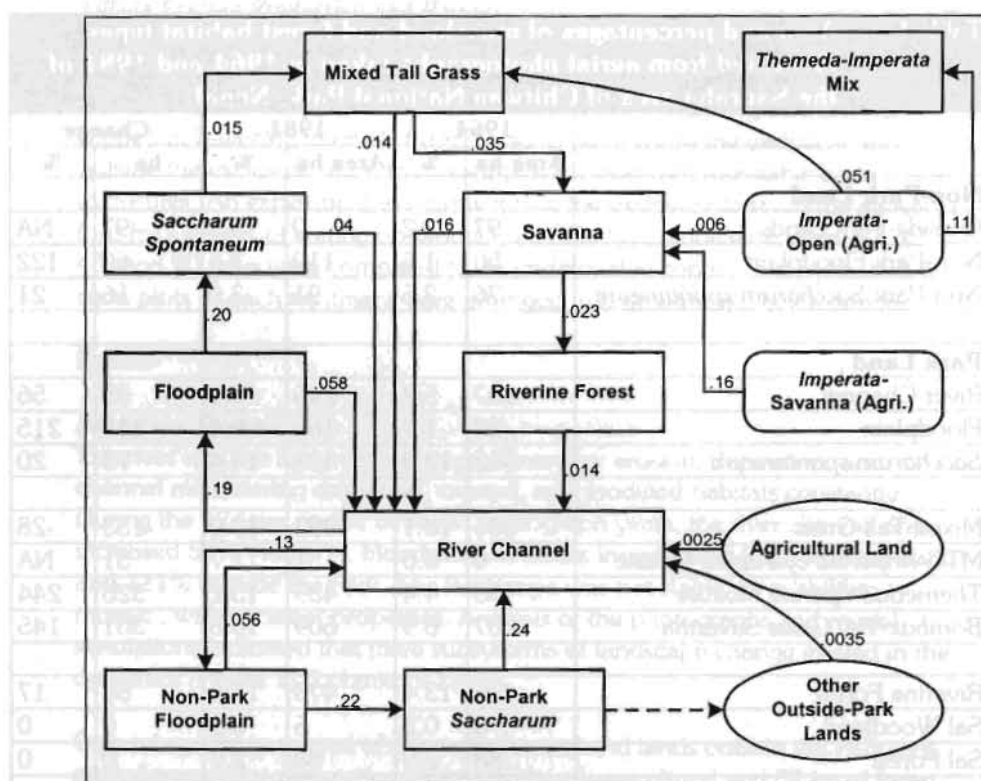


Figure 1. A model of landscape dynamics for natural upland and floodplain grassland and forest communities in Chitwan National Park, Nepal. Numbers are the instantaneous rates of area transfer estimated from aerial photographs taken in 1964 and 1981. The rates indicate relative changes in area from one type to one or more differing types over time.

herbivore feeding and fodder cutting for domestic elephants were secondary factors. Herbivores were probably most important as agents of site disturbance and plant dispersal, and thus regulators of community organisation, rather than as consumers, as only 6-10% of aerial net primary productivity was consumed by large mammalian herbivores.

Productivity and Consumption

Park grasslands

Fire and grazing had significant effects on the standing biomass of *I. cylindrica*. Early burning without grazing produced the greatest biomass (1.2 kg per sq.m). Late-burn production was 81% of early-burn production and unburned production was 38% of early burn production. Grazing removed the greatest biomass from the late-burn plots, probably because burned plots were surrounded by older and less palatable forage. Grazing after late-burning was strong for at least 15 weeks. Grazing after early burning removed an estimated 141g per sq.m, 12% of annual above-ground production. Humans harvested

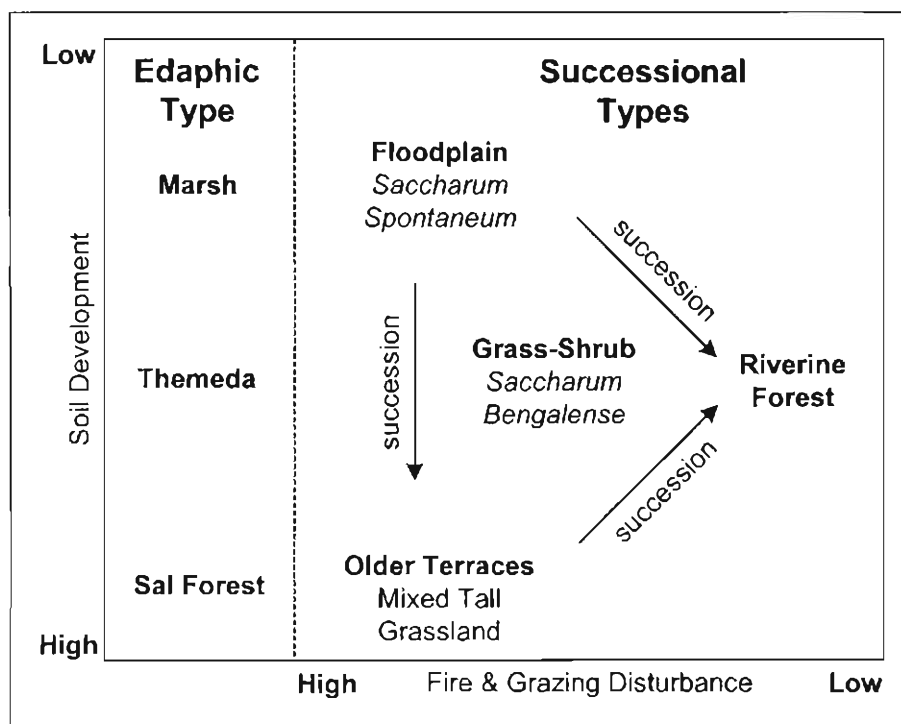


Figure 2. **Generalised riverine grassland and forest types determined from field sampling in Chitwan National Park, Nepal, and the hypothesised edaphic and disturbance gradients influencing grassland and riverine forest composition.**

nearly all of the remaining biomass during the January grass cutting season. Heavy grazing after early burning lasted for about 10 weeks, when forage apparently became unpalatable. *Imperata cylindrica* probably compensated fully for grazing by producing biomass equal to ungrazed production. Model simulations indicated little change in *I. cylindrica* biomass availability over the 20 years from 1987.

No significant grazing effects on production were found with *N. porphyrocoma*. Grazing was not evident on burned or unburned plots. Early burning resulted in the highest above-ground production (1.6 kg per sq.m), followed by unburned production (60%), and late-burn production (42%). Large herbivore consumption was estimated by model simulations as 4% of production. Humans harvested 26% of the above-ground production during the grass cutting season. Model simulations indicated a 28% decrease in mixed tall grass biomass over the 20 years from 1987 as a result of succession and erosion.

Problems were experienced with the *S. spontaneum* experimental plots. Villagers and elephant handlers surreptitiously cut grass from the plots, and ruined the treatment design. However, data were collected over the year to assess production in response to burning as well as possible. Late burning appeared to decrease production to 22% of the early and unburned production (1.65 kg per sq.m). Model simulations indicated that rhinoceros and domestic

elephants consumed 10% of annual production, and humans harvested 5%. The model of landscape dynamics showed a 15% increase in *S. spontaneum* biomass over the 20 years from 1987.

The above-ground net primary production of Chitwan's grasslands appears to be among the highest in the world. Tall grass production was surpassed by only five of 70 grasslands reported in the literature. Large herbivore grassland consumption in the study area averaged 6% of above-ground production. The literature reports less than 10% consumption for most natural grazing systems, except the Serengeti.

Village pastures

The grazed pasture composition was dominated by *Chrysopogon asciculatus* (45%), *Cynodon dactylon* (19%), and *I. cylindrica* (19%). The ungrazed pasture was quickly dominated by *I. cylindrica* after one year of protection from grazing.

Above-ground production of the pasture, also considered a surrogate for Park grazing lawns, was 872 g per sq.m. Grazed production was 39% less than the ungrazed production of 1,410 g per sq.m inside the enclosure. Consumption by livestock outside the enclosure was 100% of annual production.

Experimental defoliation every 11 days reduced production by about 29%, but defoliation every 90 days reduced production by only about 4%. Production models were fitted for three cutting schedules to estimate grass production for a stall-feeding program. Production was most rapid between April and September for all cutting schedules. Annual yield was an estimated 9,400 kg/ha, 10,440 kg/ha, and 12,970 kg/ha for the 2-week, 7-week, and 13-week cutting schedules (Figure 3).

Human consumption

About 60,000 grass cutting permits were sold, and there were about 216,000 visitor-days during 1985 and 1986. The harvest of thatch grass and canes for house construction was 6,406 tonnes and 4,726 tonnes, with monetary values of NRs 4.6 million and NRs 5.4 million (1986 values). Subtraction of labour and permit costs yielded a net value to the economy of NRs 5.5 million. Benefits accrued to the individual village family were NRs 2,500. Seventy-five percent of the villagers interviewed were dependent on grass products from the Park for their subsistence needs.

Domestic elephant consumption

An average daily fodder ration of 58 kg DW (dry weight; 153 kg wet weight) was cut for each elephant, of which they consumed 25 kg DW. Eighty percent of the fodder was the floodplain grass *S. spontaneum*. Six percent was tree fodder, mainly the limbs of young *B. ceiba* trees. Elephants were grazed for at least four hours each day, during which time they consumed an average 20 kg DW fodder for a total daily consumption estimated at 45 kg DW (135 kg WW). Intake increased during the summer, leveled during the fall through December, then increased through the remainder of the dry season.

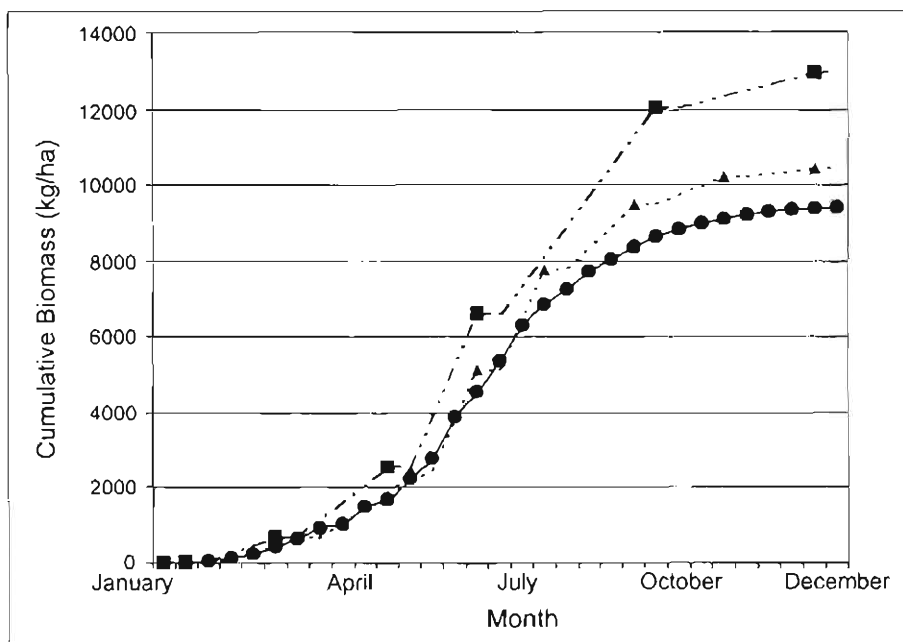


Figure 3. Cumulative yield of a native mixed-species pasture in lowland central Nepal from 2-week, 7-week, and 13-week cutting schedules. Lines are model estimates, and points are original data on above-ground production from an experimental defoliation experiment during 1986 and 87.

Conclusions

Disturbance and Succession

The increase in the *S. spontaneum* type is good for Park management. *Saccharum spontaneum* grassland is perhaps one of the highest quality habitats in the Park in terms of forage quality and use by wild herbivores (Mishra 1982a; Dhungel 1985). It is essential rhinoceros habitat (Laurie 1978), the major source of elephant fodder (80%), and is used heavily by deer species (Mishra 1982a). The Park may be able to play a larger role in the local economy by providing *S. spontaneum* for paper fibre via grass cutting permits. Such a programme would have to be carefully planned and managed, however, to avoid jeopardising wildlife conservation and other natural values.

Imperata cylindrica biomass will decrease only very slightly. Demand is extremely high for this grass, and will continue to rise as the local population and households increase. Judicious grassland management would not endanger, but could enhance, wildlife or plant conservation values and increase total *I. cylindrica* biomass at little cost. A programme to break up mechanically extensive tall grass stands that were formerly *I. cylindrica* into a patchwork of tall grass and *I. cylindrica* might benefit wildlife by increasing landscape diversity and thatch supplies, allow for better fire control and management by breaking up extensive stands of inflammable tall grass, and provide better opportunities for wildlife viewing.

Fire Management

Staggered burning of grasslands in small patches could provide fresh, high-quality forage for a longer time during the dry season than at present. Laurie (1978) and Dinerstein (1979) have suggested this practice to increase the carrying capacity for large mammalian herbivores in Nepalese reserves. Roy (1986) described a successful patch burning programme in Manas Wildlife Sanctuary in Assam. Rodgers (1986) provided a good review of fire management for wildlife habitat management in south Asia.

The results of my fire experiments indicated that staggered burning may foster the formation of pasture-like grazing lawns by concentrating grazing pressure on limited areas. Grazing lawns would produce high-quality forage year-round, may decrease crop depredation by attracting wild herbivores away from agriculture, and would increase herbivore carrying capacity. Patch size would be critical for success; a patch too large would be hard for herbivores to crop fast enough to keep the grass short, and a patch too small might be overgrazed and not provide adequate benefits to warrant management.

Patch burning would also increase cover for wildlife. Oliver (1980) concluded that widespread burning was one of the factors contributing to the decline of the endangered *Sus salvanius* (likely extinct in Chitwan) and *Caprolagus hispidus*. Roy (1986) claimed that his patch burning programme has been instrumental in increasing the population of *S. salvanius* in Manas, and managing high quality habitat for other species. Patch burning would also provide the essential spring nesting habitat for grassland birds in unburned sites that is now missing with widespread, uncontrolled fire (Rodgers 1986).

Pasture Management

Studies on the village pasture provide a base of data from which management studies and plans can be formulated. Although ungrazed pastures produced over 30% more forage than grazed pasture, the quality of ungrazed forage was lower (E. Dinerstein, unpublished data), and the carrying capacity would likely be lower. There would be some threshold to manage where production and quality are optimised. This is just one point to consider to increase livestock production around the Park. A complete analysis of grazing management that considers forage production, forage quality, introducing forage crops, stall feeding, tree plantation intercropping, and grass responses to grazing is beyond the scope of present studies, but is recommended for proper management.

Adaptive Management

Adaptive management marries scientific research principles with management objectives and practices to gain reliable information for managers (Holling 1984). The process is simple: define management objectives; design management treatments and their implementation using scientific principles of treatment randomisation, replication, and controls; monitor or measure the effects of treatments; analyse the results using statistically sound methods; and, finally, assess whether the outcome met the management objective, and adjust management if necessary. The approach is ideal for testing new grassland management treatments where results are uncertain, for example, the effects of patch burning or mechanical treatments on productivity and ungulate use.

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Grasslands and Large Mammal Conservation in the Lowland Terai: A Preliminary Synthesis Based on Field Research Conducted in Royal Bardia National Park, Nepal

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Abstract

In the lowland Terai of Nepal, two types of grassland are found, viz. riparian tall-grass floodplains, and wooded grasslands and phantas. The floodplain grasslands, which consist of tall, perennial grasses, are established and maintained by fluvial action and flooding; the wooded grasslands and phantas consist of shorter perennial grass and originated following human intervention (forest clearing, burning, grazing of domestic stock, and cultivation). Both of these types of grassland have traditionally been utilised by local villagers for different purposes. In addition, both types of grassland are periodically burnt, either intentionally by protected area managers or by local people. Field studies in the protected areas of Koshi Tappu, Chitwan, Bardia, and Sukla Phanta have documented the crucial role that both types of grassland play in the conservation of several wild mammalian herbivores, and thus in the conservation of their carnivore predators. In these grasslands, various management interventions such as burning, grass harvesting, ploughing, and uprooting of tree saplings are carried out by reserve authorities. Recent research suggests that rotational cutting and patch burning spread over a longer time during the dry season should be practised. Similarly, smaller wooded grasslands and phantas should be created within the surrounding sal forests in Royal Bardia National Park. Finally, it is suggested that long-term research should be conducted on the ecological effects of cutting and burning in the tall-grass floodplain and the effects on the productivity and mineral balance of the wooded grasslands and phantas. Research into grazing lawns and grazing pressure, and on proposed experimental clear felling in mature sal (*Shorea robusta*) and asna (*Terminalia tomentosa*) forest to create wooded grasslands and phantas is emphasised.

Background

The grasslands in the lowland Terai basically consist of two types: a) riparian tall-grass floodplains, and b) wooded grasslands and phantas. These types are quite different in origin, species composition, and ecological dynamics, and functionally in the larger-scale ecosystems in which they occur.

The floodplain grasslands consist of tall, perennial grasses (*Saccharum*, *Narenga*, *Themeda*, *Phragmites* spp.). They are natural in the sense that they become established and are maintained as a result of fluvial action and flooding during the monsoon; but they are successional and would develop into forest if periodic flooding ceased and the soil substrate become stabilised. In contrast, the wooded grasslands and phantas consist of shorter perennial grasses (mainly

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Imperata cylindrica and *Vetiveria zizanioides*); they originated following human intervention (forest clearing, burning, grazing of domestic stock, and cultivation); and they occur on more or less stabilised soils where monsoonal rains have little impact on the substrate. Both types share the characteristic of a high water table, which facilitates extensive grass growth and gives graminoids a competitive advantage over shrubs and trees under conditions of more or less uninterrupted insolation.

Traditionally, both types of grassland have been utilised by local villagers for different purposes. The tall grasses in the floodplain are cut and harvested mainly for canes, whereas the wooded grasslands and phantas were previously grazed by domestic stock and grasses cut and harvested for a variety of local uses. Grazing of domestic livestock is now prohibited inside the protected areas, but harvesting is permitted both in the floodplain and in the phantas during a short period in the early (cool) part of the dry season. At the same time of year and shortly thereafter, large parts of both types of grassland are burnt each year intentionally by Park staff as part of a habitat management programme. Fires are also set by others as a result of carelessness and for no defined purpose.

Grasslands and Phantas as Habitats for Larger Mammals

Field studies in the protected areas of Koshi Tappu, Chitwan, Bardia, and Sukla Phanta have documented the crucial role that both types of grassland play in the conservation of several wild mammalian herbivores, and thus in the conservation of their carnivore predators. The floodplain grasslands are particularly important habitats for the two megaherbivores rhinoceros (*Rhinoceros unicornis*) and wild elephant (*Elephas maximus*) (Laurie 1978; Dinerstein and Price 1991; Jnawali 1995; Fjellstad and Steinheim 1996), other mammals such as wild water buffalo (*Bubalus bubalis*) (Heinen 1993), hog deer (*Axis porcinus*) (Dhungel and O'Gara 1991), and barasingha (*Cervus duaucei*) (Schaaf 1978; Pokharel 1997; Moe 1994), whereas the wooded grasslands and phantas are critical habitats for chital (*Axis axis*) (Mishra 1982; Moe and Wegge 1996) and seasonally for barasingha (Pokharel 1997). Nilgai (*Boselaphus tragocamelus*) are also dependent on the short grasslands, although to a lesser extent than the other two ungulates (Khatri 1993). The successional pattern of floodplain grasslands (in the absence of flooding disturbance) is through intermediate stages of riparian sissou (*Dalbergia sissoo*) and khair (*Acacia catechu*) forest to a more or less stable semi-evergreen riverine forest (Dinerstein 1979). These intermediate stages are also prime habitats for chital and to a lesser extent for barking deer (*Muntiacus muntjak*).

Recent census data from the western part of Royal Bardia National Park (RBNP) show that the total density and biomass of wild herbivores (excluding megaherbivores) in the mosaic of grasslands and grassland-related habitats are among the highest recorded in Asia, with more than 200 animals per square kilometre. In the surrounding sal forest and other non-related grassland habitats that cover the largest portion of RBNP, the density is only a fraction of this (Andersen and Naess 1993, Wegge *et al.* unpublished). One of the main reasons for the extraordinarily high density and also diversity of ungulates in the grassland-related habitats of RBNP is probably the fine-grained pattern of habitat dispersion in which the landscape consists of a mosaic of different

habitat patches: animals do not need to move far to obtain seasonal high quality food and shelter (Moe and Wegge 1996).

The very high biomass of ungulates in the floodplain-phanta habitat complex constitutes the food base for a dense predator fauna. Recent investigations have disclosed a higher density of tiger in this mixed habitat complex of RBNP than in Royal Chitwan National Park and most other tiger reserves elsewhere (Pokharel *et al.* unpublished), and circumstantial evidence indicates that this local tiger population has a different social structure, probably as a result of the high prey base (Wegge and Storaas unpublished). A newly initiated study on leopards has confirmed that the Park also contains a viable population of this species, which in part is attributable to the presence of a prey base that is sufficiently diverse and dense for the two carnivores to coexist (Wegge and Odden, unpublished).

Management Considerations

In the south-western part of RBNP, the mosaic of grasslands—both the natural riparian floodplains and the man-made wooded grasslands and phantas—surrounded with and interspersed with seral forested plant communities, provide optimum habitats for an exceptionally dense and diverse assemblage of wild herbivores, and consequently for their main predators—the tiger (*Panthera tigris*) and the leopard (*Panthera pardus*). Several of the species in this area belong to the categories 'endangered' or 'threatened' internationally. From a conservation standpoint, this ca 100 sq.km of the Park should be considered a biodiversity 'hot spot', requiring special attention by management.

The two types of grassland together play a vital role in shaping the large mammal communities, but they are quite different ecologically and need different management interventions. Before suggesting options, some general comments are necessary. The strategy of 'no intervention - let nature take its course' would lead to the following scenario.

1. The natural tall grasslands of the floodplain would remain more or less intact; some new grasslands would slowly change through sissoo and khair forests into climax-like riverine forest, while at the same time forested river banks and islands would be disrupted by flooding and revert to grasslands. The local population of hog deer—a main prey for tigers—would remain more or less unaffected as would the seasonal habitat for barasingha and the two megaherbivores.
2. The shorter grass wooded grasslands and phantas dominated by *Imperata cylindrica* would change through shrub encroachment and succession into forest, mainly of the sal complex. Understorey vegetation would become shrub and seedling dominated—the grasses, except the less palatable *Desmostachya bipinnata*, would more or less disappear. This change would have a significant negative effect on barasingha and chital, and on the small population of nilgai. Because chital is by far the most important prey of tigers (Støen and Wegge 1996), a decline in the chital population would affect the local tiger population. At present the 'hot spot' area of the Park acts as a 'source' from which tigers disperse to peripheral habitats both inside and

outside the Park. Thus a decline in the local tiger population would reduce the capacity of the area to produce dispersers and maintain connectivity with other reproducing tiger units within the region.

3. The reduction of prey biomass through loss of wooded grasslands and phantas as a result of natural succession would also intensify the food competition between tigers and leopards. A likely result is that leopards would be further displaced to the periphery of the Park and increase their predation on small livestock. Depredation of domestic stock by tigers and tiger encounters with humans might also increase as a result of the reduced prey base inside the Park, at least temporarily.
4. The local populations of rhinoceros and wild elephants are currently increasing in RBNP, particularly in the hot spot in the western part. None of these species are dependent on the wooded grasslands and the open phantas. Instead, they feed on the tall grasses in the floodplain and on a variety of browse from shrubs and trees. A continued increase, especially of elephants, would modify the forests in the direction of more open-spaced forests with a higher proportion of grass in the understorey. This would to some extent counteract the negative effects of loss of the short grassland phantas, and thereby slow down the rate of habitat deterioration for chital and nilgai. It is less clear what the effect would be on barking deer and wild boar (*Sus scrofa*), but a reduction in the shrub understorey would probably affect barking deer negatively, and thus also reduce the natural prey base for leopards.

The Park authorities are already practicing a moderate 'human-intervention' management policy. Until recently, this consisted of permitting some 35 - 40,000 villagers to enter the Park during a short period in the early dry season to cut and harvest grasses, both in the phantas and in the floodplain (Sharma and Shaw 1993; Pokharel 1993; Sætre 1993; Brown 1997), and of burning large parts of the grasslands shortly thereafter. Recently, a programme of maintaining the wooded grasslands and phantas has also been initiated, in which encroaching shrubs and trees are removed through uprooting and cutting. Both of these interventions (grass cutting and phanta management) provide benefits to the local communities.

As is clear from the above, and from recent research (Moe and Wegge 1997; Peet *et al.* 1997), the cutting and burning of the grasslands have a positive effect for the larger herbivores, and hence on the predator fauna. Recently, however, the number of permits for grasscutting has increased, with a concurrent increase in the amount harvested. The density of chital also seems to be increasing following a temporary die-back in the early 1980s, leading to a higher grazing pressure and creation of preferred 'grazing lawns', that are now patchily distributed on the phantas (Karki 1997). With little grass left after harvesting and more conversion to grazing lawns, the fuel load is reduced. This may explain why the rate of invasion by shrubs on phantas has increased, as the post-harvest burns have not been intense enough to kill back the encroaching vegetation, particularly the fire-resistant *Callicapra macrophylla* (personal observation). Thus the recently initiated intervention of mechanically removing

encroaching shrubs and larger trees in order to maintain *Imperata*-dominated grass cover on the wooded grasslands and phantas seems well justified ecologically, and is probably required to maintain the high diversity and density of wild ungulate biomass as a food base for the predator community.

Management Guidelines

Wooded Grasslands and Phantas

Management guidelines for these short grassland types (both cutting and burning) have been suggested by Moe (1994) and Peet *et al.* (1997). Both suggest a rotational cutting and burning regime as is largely practised at present. Moe (1994) further suggests that patch burning be spread over a longer time during the dry season so that animals (mainly chital and barasingha) may have access to newly burnt grassland over a longer period of time. Because the early part of the dry season may be the most critical period in terms of nutrition for chital and barasingha, cutting and burning of grass should take place as early as possible, preferably before mid-January. Burning during the first half of February should be avoided as this is the main calving season for chital. In addition to cutting and burning of grasses, encroaching shrubs and younger trees should be removed every 2-3 years, and the present intervention of opening the wooded grasslands by cutting down trees should be continued. However, widely spaced trees with shading foliage like *Ehretia laevis* and *Mallotus philippensis* should be retained to provide rest areas.

Peet *et al.* (1997) recommend that the road be closed to traffic during the dry season because traffic might prevent the chital and barasingha from utilising the phantas optimally. Our observations do not support this: the animals are habituated to motorised transport, and their main foraging period is in the evening and early night, depending on the moon cycle, when there is little or no traffic anyway (Wegge unpublished).

Floodplain Grassland

Less research has been done on the ecological effects of cutting and burning of tall grasses in the floodplain. River action may maintain an equilibrium between the relative coverage of grass-dominated communities and later tree-covered successional stages by creating new grassland. Thus, a 'no intervention' policy may not result in any loss of these natural grasslands. Cutting and burning in these areas may have adverse effects, however, by reducing the cover for cryptic species like hog deer, thus making them more vulnerable to tiger predation. Ongoing research tends to support the notion that hog deer abandon tallgrass areas when more than 80 percent of the area is cut, but if smaller patches are left uncut in a mosaic pattern, the deer will remain in their original habitat (Wegge and Storaas unpublished). Until more research has been undertaken, it is reasonable to assume that cutting and burning will have the same positive effects on deer nutrition and arresting the invasion of shrubs as in the *Imperata*-dominated wooded grasslands and phantas.

Since the harvesting of grasses in the floodplain provides tangible benefits to the local villagers, the negative effects of disturbance are thought to be negligible, and the effects on habitat quality may be positive, the present practice of cutting

and burning should continue. However, the increased cutting pressure observed in recent years, where large stretches of uninterrupted tall grasslands are cut down almost to the soil line, should not continue. Instead, cutting should be monitored in such a way that about 1/3 of the grasslands consist of uncut patches. During the subsequent controlled burning operations, some of these patches should also be spared to provide cover after the rest of the grasslands have been burnt.

Creation of New Grasslands

It should be emphasised again that the high diversity and density of wild herbivore species in the 'hot spot' portion of RBNP is a result of the spatial arrangement of the many different habitats there; the presence of interspersed grasslands and the early successional stages from tallgrass floodplain play a vital role. The high ungulate biomass provides for a very dense tiger population, but this is confined to the very small area of the 'hot spot'. Preliminary data indicate that the tiger density is much lower, outside the grassland-forest complex presumably as a result of the much lower biomass of prey. In order to increase the food base for tigers—a species with priority conservation status in Nepal—Park authorities should consider creating smaller wooded grasslands and phantas within the surrounding sal forests. Clearfelling smaller blocks in sal (*Shorea robusta*) and asna (*Terminalia tomentosa*) dominated forests will increase the habitat quality for wild herbivores and thus expand the prey base for tigers and leopards. Depending on the soil conditions and use of fire, creating gaps in the tree overstorey through clearfelling of small blocks or selection cutting may also increase the shrub layer and stimulate regeneration of woody saplings. This is expected to improve the habitat quality for sambar (*Cervus unicolor*), which is considered a main prey species of tiger throughout most of the tiger's geographical range (Karanth and Sunquist 1995).

Such an intervention may at first glance appear rather drastic and not readily acceptable within national parks. However, in order to conserve viable subpopulations of tiger and provide dispersal habitat between existing protected areas, it is necessary to provide sufficient natural prey not only in smaller hot spots within the PAs but also in other parts of the PAs and in remaining forests outside the protected areas.

Research Priorities

Many studies have already been conducted and the current management practices appear ecologically sound, thus we see the following four themes as the priority.

1. Further studies on the ecological effects of cutting and burning of grass in the tallgrass floodplain
2. Studies on the long-term effects of cutting and burning on the productivity and mineral balance of the wooded grasslands and phantas
3. Further studies on grazing lawns and grazing pressure—how they are created and maintained—a follow-up of the recent study conducted by Karki (1997)
4. Experimental clearfelling in mature sal and asna forest to create wooded grasslands and phantas in order to increase and expand the habitat quality for deer, thereby improving the habitat for tiger

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Koshi Tappu's Treasure: Grasslands or Wetlands?

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Abstract

Koshi Tappu Wildlife Reserve, located on the Koshi river floodplain in the eastern Terai of Nepal, has a vegetation that comprises both riverine forests and a large tract of grasslands, most of which become flooded during the monsoon and remain wet for several months of the year. These seasonally flooded wet grasslands, together with the swamps formed in depressions on the floodplain, are the ideal habitat for the last remaining population of wild buffalo (*Bubalus bubalis*) in Nepal. These grasslands are viewed in different ways by different people. Livestock herders who practice their traditional profession of livestock grazing in that area see Koshi Tappu as a treasure that will never be exhausted. Landless people in the adjoining villages and those who have lost their land to the reserve or as a result of the shifting of the Koshi river, more than a quarter of the population, want to convert the grasslands into agricultural fields.

Conservationists see the wet grasslands and associated swamps and marshes, both within and outside the reserve, as a place of international importance in terms of staging and wintering sites for various trans-Himalayan migrating birds; the area has been listed as a Ramsar site (Wetlands of International Importance). The conflicting views of these different stakeholders are the root cause of the problems involved in the proper management of the reserve. An integrated management plan using a participatory approach is needed.

Introduction

There are different types of wetlands in the lowlands of Nepal varying from shallow lakes to rice fields. They include marshes, swamps, seasonally flooded grasslands, ditches, and any lowland depressions that are waterlogged for some part of the year (Sah 1993; BPP 1995; Bhandari 1998). Rivers, streams, canals, and paleo-channels are also considered as wetlands. Although wetlands possess economic, functional and existence values, they were considered until recently as wastelands by both the majority of people and by policy makers. In contrast, grasslands are seen by people as economically important resources for livestock rearing, which is an integral part of the agricultural system.

Conflicting uses of resources is very common in developing countries like Nepal. It becomes more common when the same resource means different things to different people. For industrialists, flowing water in a river is a means of diluting concentrated effluents; the same water is considered a means of livelihood by fishermen. Other wetlands are also used in different ways by different people. In contrast, conservationists see the wetlands as important ecosystems that should be conserved since they are rich in biodiversity and are important staging and wintering sites for migrating birds. Conflicts in use occur more frequently in a region where different units of a mosaic landscape are equally important in terms of economic, functional, and other ecological values. This is the situation in the Koshi Tappu region, located on the Koshi River floodplain in the eastern Terai of Nepal.

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A large part of the Koshi Tappu region is occupied by grasslands most of which become flooded during the monsoon. It thus falls into the category of wetlands (Dugan 1990). Associated with these grasslands are paleo-channels, ox-bow lakes, swamps, and marshes, all of which possess both economic and functional values. The grasslands in Koshi Tappu are considered by livestock herders as a treasure that will never be exhausted. On the other hand, the wet grasslands with associated lakes, swamps, and marshes are an ideal habitat for the sole remaining population of wild water buffalo (*Bubalus bubalis*), and of international importance as staging and wintering sites for various trans-Himalayan migrating birds (Suwal 1993; Sah 1997). Thus it has remained a matter of controversy whether Koshi Tappu is most important for the grasslands or the wetlands. The present paper describes the extent of the grasslands and wetlands in the Koshi Tappu region, their relative significance, and the management issues. Finally, some recommendations are made for integrated management using a participatory approach.

Study Area

Koshi Tappu Wildlife Reserve, gazetted in 1976, lies on the floodplains of the Koshi river in the eastern Terai of Nepal. The reserve covers an area of 150 sq. km and its altitude varies between 75 and 81 masl. It extends from 26°33' to 26°45' N and 86°54' to 87°04' E. The eastern and western boundaries of the reserve run along the eastern and the western embankments that were constructed to prevent floods from entering agricultural fields. The southern boundary is parallel to the Koshi barrage, 6.5 km to the south, and the northern boundary runs through the flood plain from the eastern embankment near Prakashpur to the village of Tapeshwari, north of the Trijuga River (Figure 4).

Koshi Tappu Wildlife Reserve is drained by the Sapta Koshi River, a major tributary of the Ganges, and the Trijuga river which joins the Koshi river in this region. Most parts of the reserve are flooded in the rainy season and an enormous amount of sediment is deposited at this time. The soil quality within the reserve varies greatly depending upon the degree of sedimentation and the establishment of vegetation on the sediment in subsequent years. In the reserve area, soils are sandy, loamy sand, sandy loam, loam, and sandy clay loam.

The Koshi Tappu region has a tropical monsoon climate with an average annual rainfall of between 1,300 mm and 2,051 mm. The average daily maximum temperature ranges between 23.5° C and 33.4° C, the minimum between 7.8° C and 25.3° C, and the mean monthly temperature between 15.7° C and 29.2° C. Humidity remains high all the year round with the monthly average varying between 76% and 94%.

The vegetation of the Koshi Tappu is mainly characterised by mixed deciduous riverine forest, *Acacia-Dalbergia* forest, grassland/savanna, and marshy vegetation. The mixed deciduous riverine forests are dominated by simal (*Bombax ceiba*); the *Acacia-Dalbergia* forest, locally called khair-sissoo forest, by *Acacia catechu* and *Dalbergia sissoo* in different proportions from almost pure stands of *Acacia catechu* in relatively moist places to pure stands of *Dalbergia sissoo* in dry uplands. About 40 per cent of the total area within the reserve is covered by grassland/savanna type vegetation most of which is flooded annually

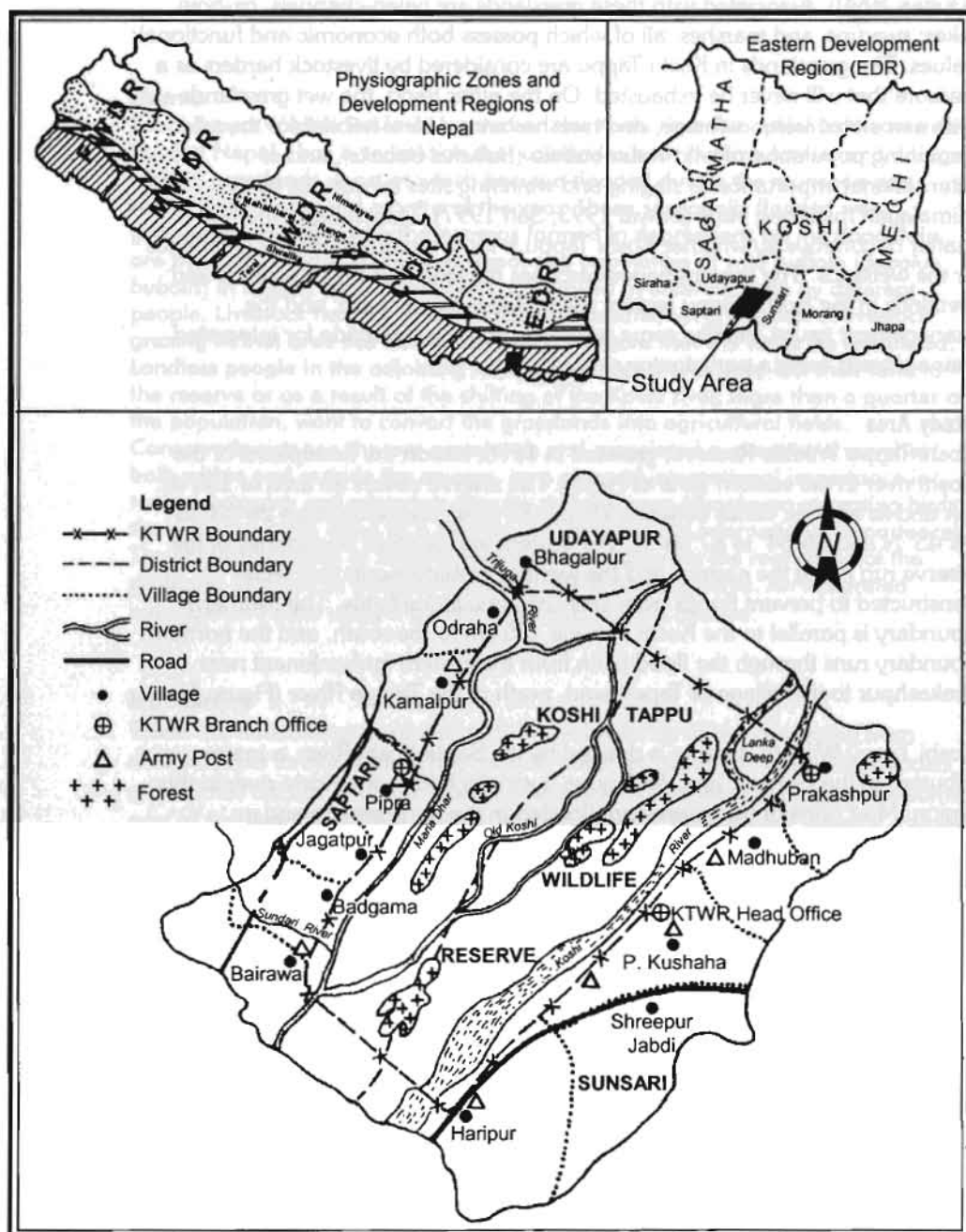


Figure 4: Map of the study area showing the location of Koshi Tappu Wildlife Reserve and surrounding villages

during monsoons. The major species are *Imperata cylindrica*, *Cymbopogon* sp., *Erianthus ravennae*, *Phragmites karka*, *Saccharum spontaneum*, and *Vetiveria zizanioides*. Marshy vegetation occurs at the fringes of ox-bow lakes along the eastern embankment of Kamal Daha, a naturally formed shallow lake near Kamalpur post, and in other lowland depressions inside the reserve. The marsh vegetation consists of all forms of aquatic plants from submerged (e.g., *Hydrilla verticillata* and *Ceratophyllum submersum*) to emergent (e.g., *Paspalum* spp., *Panicum barbatum*, *Typha angustifolia*).

Koshi Tappu Wildlife Reserve is surrounded by 12 densely populated village development committee areas (VDCs): to the east Haripur, Shreepur-Jabdi, Kushaha, Madhuban, and Prakashpur VDCs of Sunsari district; and to the west, Bairwa, Badgama, Jagatpur, Pipra-Purba, Kamalpur, and Odraha VDCs of Saptari district, and Tapeswari VDC of Udaypur district. Two wards of Prakashpur VDC, called Lanka Dweep, are located on the floodplain to the north of the reserve. People from these villages frequently visit the reserve to collect fuelwood, graze livestock, and fish.

Materials and Methods

The area of grasslands and wetlands in the Koshi Tappu region was calculated from a land use map of the area prepared with the help of aerial photographs taken in 1990-91 at a scale of 1:50,000 and Landsat TM Imagery from December 12, 1991 (path 140, row 42). The image data were supplemented by a two-month field survey in February and March 1993. Land use classification was done using a slightly modified USGS (United States Geological Survey) system (Anderson *et al.* 1976). The classification was mostly limited to level I, and in some cases to level II of the system. Since both the aerial photographs and the satellite images were obtained during the dry months, February and December, respectively, the area of wetlands might have been underestimated. The results might have been different if the data had been obtained during the monsoon period when most of the reserve area is flooded. Some parts of the seasonally flooded grasslands are very difficult to recognise as wetlands during the dry season even in the field, especially when they are burnt.

The significance of grasslands and wetlands in Koshi Tappu were assessed on the basis of their use by local people and the ecological functions they perform. To assess the use value, a household survey was carried out in some of the adjoining wards of all the 11 VDCs in Sunsari and Saptari districts that are adjacent to the reserve. Altogether 160 households were selected randomly from the list obtained from VDC offices and surveyed using a structured questionnaire. The focus was on the use of plant resources from the grasslands and wetlands of the reserve, and on people's attitudes towards the conservation of those resources in the reserve. In addition, large livestock herders who have been using the reserve to graze their livestock for many years, were interviewed informally to obtain an idea of their perception of the grasslands within the reserve. Information on other values of the grasslands and wetlands in the reserve was gathered from various sources. Finally, grassland and wetland management issues were identified from formal and informal discussions with reserve authorities and groups of local people, and personal observations.

Results and Discussion

Grasslands and wetlands together cover almost 92% of the total area of the Koshi Tappu Wildlife Reserve. Grasslands include both the dry grasslands of *Cymbopogon-Saccharum* and *Imperata-Saccharum* association type and the wet grasslands of *Saccharum-Typha* and *Saccharum-Phragmites* type. The latter are seasonally flooded and are also considered as wetlands (Dugan 1990). Other wetlands include permanent water bodies such as the Koshi river, the Trijuga river, and other streams; ox-bow lakes; marshes or seasonally flooded barren lands; paleo-channels; and swamps. Both wetlands and grasslands occur along a soil moisture gradient of very wet to very dry and are thus sometimes difficult to differentiate from each other. The main types of wetlands and grasslands found in Koshi Tappu and their prominent vegetation are described in the following under the sub-headings wetlands, wet-grasslands, dry-grasslands, and savanna.

Wetlands

The following types of wetlands are found in the Koshi Tappu region.

Rivers and streams—The perennial Sapta Koshi river, which is a snow-fed river originating in the Himalayas and Tibet, represents the main wetland habitat in the region. The Trijuga river originates in the Mahabharat region of Udayapur district and enters the reserve from the northwest. It is called Mariya dhar in the southern part of the reserve. At present, the main course of the Sapta Koshi river lies in the eastern part of the reserve, whereas the old channel of the Koshi and the Trijuga river still flow through the western part of the reserve. Two other small rivers, the Mahuli and the Sundari, originating in the *siwaliks* of Saptari district, enter the reserve from the west near the villages of Pipra Purba and Badgama, respectively.

A total water area of 1,426.5 ha (8%) was calculated from the land use map of the wildlife reserve prepared from satellite imagery taken in the month of December 1991. This represents the minimum water area. The area increases significantly after March, first as a result of the snow melting in the Himalayas, and later as a result of monsoon rains throughout its catchment area. A much larger area is under water during the monsoon floods. Furthermore, the Koshi river changes its course within the reserve between the two embankments and thus extensively modifies the area. In the middle portion of the reserve near Kushaha, the river recently shifted about 1 km to the west. The area which was under water in 1991 is nowadays barren land full of sands.

Barren Floodplain—The floodplain is a periodically flooded flat area between the river channel and the terrace or plateau delimiting the plain. The wildlife reserve is located on the alluvial floodplain, which receives alluvial deposits from the river in the form of sand and silt. A total area of about 2,300 ha (15.4%) was identified as barren floodplain from the land use map (dry season). The area has increased recently after the gradual shifting of the river to the west. The area becomes smaller in the rainy season when most of it becomes submerged following the rise in water level of the river and streams, and some acquires vegetation in the course of time. The barren floodplain is almost devoid of any vegetation, with the exception of some old sand-bars where *Tamarix dioica* and *Saccharum spontaneum* grow either in pure stands or in association.

Oxbow lakes, riverine marshes—Like any other floodplain, the Koshi floodplain is characterised by the presence of oxbow lakes and back swamp lakes with marshes on their fringes. The most important oxbow lakes are ‘Kamal Daha’, meaning ‘lotus pond’, located in the far west of the reserve near the village of Kamalpur, and three lakes in the eastern part of the reserve along the eastern embankment near the village of Kushaha. There is an extensive marshy area on the fringes of these lakes. Apart from these areas the majority of the important marshes, lakes, and reservoirs are situated outside the wildlife reserve between its southern boundary and the barrage. In addition, there is a seepage stream with a 100-250 m wide strip of marshes on its fringes east of the eastern embankment. There are several man-made ponds of 0.5 to 2 ha located along the embankment outside the reserve.

The vegetation in the oxbow lakes and marshes consists of aquatic plants from different groups: submerged (*Hydrilla verticillata*, *Ceratophyllum submersum*, *Potamogeton crispus*); free-floating (*Azolla pinnata*, *Lemna minor*, *Spirodela polyrrhiza*, *Pistia stratiotes*, *Eichornia crassipes*); rooted-floating (*Hydrocharis dubia*, *Hygorrhiza aristata*, *Ipomaea aquatica*, *Nelumbo nucifera*, *Nymphoides indicum*); and emergent (*Cyperus sanuguin*, *Fimbristylis aestivalis*, *Paspalidium* spp., *Persicaria barbata*, *Phragmites karka*, *Typha angustifolia*).

Swamps—In contrast to the relatively permanent water bodies, swamps are wetlands where the soils remain saturated with water long after the monsoons. About half of the area inside the wildlife reserve is grassland, dominated by combinations of *Phragmites*, *Saccharum*, *Typha*, and *Vetiveria* in different associations, which becomes flooded annually during the monsoons. This type can be recognised easily in the field by the presence of wetland vegetation dominated by *Typha-Vetiveria* and *Saccharum-Vetiveria* associations. Because of the dominance of *Typha angustifolia* and *Vetiveria zizanioides* this type of wetland is sometimes considered to be wet grassland.

Wet Grasslands

A large area inside the wildlife reserve is grassland, dominated by *Cymbopogon*, *Imperata*, *Phragmites*, *Saccharum*, and *Typha* in different associations. Some of these grasslands are wet grassland or ‘seasonally-flooded grassland’. Dugan (1990) included seasonally flooded grasslands as a sub-type of wetlands. Three different types of wet grassland are found in Koshi Tappu,

Typha-Saccharum—*Typha angustifolia* is usually found in shallow marshes. The association with other species, such as *Saccharum spontaneum*, indicates areas that dry up seasonally. Other associated species include *Persicaria barbata*, *Tetragstigma serrulata*, *Scoparia dulcis*, and *Sida rhombifolia*.

Saccharum—Pure stands of *Saccharum spontaneum* are found in the area with frequent flooding where there is a higher amount of sediment deposition. Associated species such as *Blumea lacera*, *Persicaria barbata*, *Desmodium* sp., *Diplazium esculantum*, and *Sida cordata* are far from being dominant.

Saccharum-Phragmites—This type of grassland is very common in the Koshi Tappu region. It is dominated by *Saccharum spontaneum* and *Phragmites*

karka, and found in diverse environments, such as on the relatively stabilised floodplain, in moist places, and in the riverine forest. Both species can withstand standing water, and grow as tussock-forming perennials. Their growth is favoured by inundation of the area for longer periods. Peet *et al.* (1999) thought that this type of association in Koshi Tappu represents degraded grassland from the more widespread *Phragmites karka* and *Phragmites karka-Saccharum spontaneum-Saccharum arundinaceum* associations. The associated species in this type of grassland include *Alternanthera sessilis*, *Sida rhombifolia*, *Tamarix dioica*, *Vetiveria zizanioides*, *Azeratum conyzoides*, *Calapogonium mucunoides*, *Centella asiatica*, *Lindernia pumila*, *Plantago major*, *Tetrastigma serruatum*, and *Uraria logopoies*.

Dry-Grasslands

The grasslands present in relatively dry areas comprise *Saccharum-Imperata*, *Imperata*, and *Saccharum-Cymbopogon* associations. This type of area is subjected to frequent burning and livestock grazing.

Saccharum-Imperata—This type of association is common in those areas that remain dry throughout the year or become inundated only briefly. This type of vegetation is common in open forests where grazing is common. The dominant species are *Saccharum spontaneum* and *Imperata cylindrica*.

***Imperata* stands**—Pure stands of *Imperata cylindrica* are formed in areas that are open, dry, and highly disturbed. In Koshi Tappu, this type of grassland is found in the northern and southern parts of the central portion of the reserve where the herds of livestock, that reside permanently within the reserve graze intensively, as in Chitwan and Bardia (Dinerstein 1979).

Cymbopogon-Saccharum—This type of association was found in relatively dry areas that are less disturbed. It is characterised by the dominance of *Saccharum spontaneum* and *Cymbopogon pendulus*.

Savanna Vegetation

Some portions of the grassland represent a savanna habitat (having been formed through degradation of the forest or regeneration of trees in the grasslands) with trees scattered throughout. *Dalbergia sisso*, *Acacia catechu*, and *Bombax ceiba* trees are found scattered in grasslands mostly of *Saccharum-Phragmites* and *Saccharum-Imperata* association types.

Significance of the Wetlands and Grasslands

Both the wetlands and the grasslands in Koshi Tappu are important resources that are used legally or illegally by local people. However, since extensive wetland areas also exist outside the reserve, the wetlands inside the reserve are used less intensively by people than are the wet grasslands and dry grasslands. The Wildlife Reserve Regulations 1977 (HMG 1977) do not officially allow the use of any resources from the Wildlife Reserve, thus it is hard to say that any object within the reserve has use values. However, here we assume that if permission is given to use products from the wetlands and grasslands, e.g., grass harvesting during the dry season, people will use them freely. Thus they can be considered as resources, reserves of commodities that have a use value to man,

either directly or indirectly (Ehrenfeld 1976). Many researchers have considered grasses in the protected areas to be important resources for local people (Lehmkuhl *et al.* 1988; Heinen 1993; Brown 1997). This means they possess some use values, which typically involves some human interaction with the resource (Barbier *et al.* 1996). It is important to consider the use values of the wetlands and grasslands because the local people in Koshi Tappu, legally or illegally, use their products.

Use values may be direct or indirect (Barbier *et al.* 1996). Direct use values include both commercial and non-commercial uses, indirect use values are generally regulatory ecological functions, which are sometimes considered as functional values (Dugan 1990). The indirect use values were difficult to quantify. In this study some indirect values were assessed subjectively. Existence values, a form of non-use values or non-economic values (Ehrenfeld 1976), help in evaluating the significance of wetlands and grasslands as they involve subjective valuations by individuals (Barbier *et al.* 1996).

Use Values of Wetlands

Fishing—Despite the ban on fishing inside the reserve, the Trijuga river and the old channel of the Koshi river are the main fishing sites for the fishermen living in the vicinity of reserve in Badgama, Pipra Purba, Kamalpur, and Odraha VDCs. About 90% of households of fisherman caste are landless in these VDCs. They are solely dependent on fishing within the reserve since there is no alternative site for fishing outside the reserve. Fishing, snail collection, and other human disturbances are high in Kamal Daha, despite its location near the Kamalpur post, because it is the only source of stagnant water in this area. Similarly, fishing is common in the main channel of the Koshi river near the northern and southern boundaries of the reserve. Outside the reserve, fishing is common in the Koshi river and associated marshes near the barrage and in the seepage stream flowing to the east of the eastern embankment. Altogether 115 households were found to be solely dependent on fishing. In this area, one fisherman catches 2-4 kg of fish per day and sells them in the local market.

Livestock grazing—Livestock grazing is also common in the wetlands, especially in the marshes which dry up in the dry season and the seasonally flooded grasslands. Grazing in wetlands is common in Madhuban, Kushaha, Shreepur-Jabdi, and Haripur VDCs, situated to the east of the reserve. People cannot cross the Koshi River daily from these villages, thus they take their livestock to the marshes along the seepage stream, the eastern embankment, and the swamps between the Koshi river and the embankment. The density of livestock grazing in this area peaked in the late afternoon, reaching 6 to 10 livestock units per hectare. Domestic animals from Badgama and Vardah villages also come to the south-western part of the reserve for grazing. In addition, thousands of cattle that reside permanently within the reserve regularly graze in the marshes located along the fringes of the Trijuga River and the southern border of the reserve.

Fuelwood collection—There is hardly any forest left outside the reserve in the adjoining VDCs, especially along the embankments in Sunsari and Saptari districts, and fuelwood is very scarce in this region. Because of the fuelwood shortage, people mostly use agricultural residues, cattle dung, and *dhadi* for

cooking. *Dhadi*, which is composed of dry weeds and dry minor woody products, is mostly obtained from the dry wetlands of the reserve. In addition, driftwood lying on the barren floodplain is also collected occasionally and used as fuelwood. A total of 1.4 tonnes/household per year of fuelwood and *dhadhi* was extracted from Koshi Tappu. The use of fuelwood and *dhadi* from the reserve was more intensive in the west (70.4%) than the east (29.6%) as a result of the easy access to the reserve from the west.

Irrigation—After the river shifted to the eastern part of the reserve, a seepage stream formed to the east of the eastern embankment. The water from this stream is used by the people of Madhuban, Kushaha, Shreepur-Jabdi, and Haripur VDCs for irrigation.

Recreation—Recreation in the wetlands is considered by Barbier *et al.* (1996) to be one of the direct use values. The wetlands in Koshi Tappu are regularly visited by bird watchers. Rafting from the Sunkoshi River to the barrage has also become popular in recent years. The number of nature tourists almost tripled from 150 in 1994 to 500 in 1999 (Koshi Tappu Wildlife Camp and Unlimited Aqua Bird: personal communication).

Other uses—Many wetland plants such as cattails (*Typha angustifolia*) and vetiver (*Vetiveria zizanioides*) were found to be harvested illegally from the swampy area of the wildlife reserve for commercial purposes. People legally harvest cattails from the marshes near the Barrage and export them to India on a commercial scale. Several other wetland plants, such as *Alternanthera sessilis*, *Ipomaea aquatica*, *Ludwigia adscendens*, *Scirpus kysoor*, and *Tamarix dioica* are regularly collected for household use. WMI/IUCN-Nepal (1994) has given a detailed account of the plants being used from the reserve.

Existence Values of Wetlands

Habitat of Water Buffalo (*Bubalus bubalis*)—The wetlands, seasonally flooded grasslands, swamps, marshes, and rivers in Koshi Tappu, provide a suitable habitat for the last remaining population of wild water buffalo (*Bubalus bubalis*) in Nepal. The establishment of the reserve in this area has helped to restore the population from a low of 40 (Gupta and Mishra 1972) to the present number of about 125 to 150.

Rich Biodiversity—The wetlands in Koshi Tappu support a rich biodiversity. Altogether, 236 plant species, 80% of which are estimated to be wetland plants, have been recorded so far (Sah 1997). Similarly, 84 species of fish (WMI/IUCN-Nepal 1994) and 23 species of mammals (BPP 1995) have been recorded from the reserve and adjoining wetland area. The five hectare Kamal Daha in the western part of the reserve has such a diversity of fish (29 spp. WMI/IUCN-Nepal 1994) that it can be considered as a living aquarium (Jeevan Shrestha; Personal communication). In addition, a few individuals of the rare gharial (*Gavialis gangeticus*), freshwater crocodile (*Crocodylus palustris*), and Gangetic dolphin (*Platanista gangetica*) species are also found in the Koshi river inside the reserve, as well as a small number of all three Nepalese otter species (*Lutra lutra*, *Lutrogale perspicillata* and *Aonyx cinerea*), and the fishing cat (*Felis viverrina*).

The Koshi Tappu region is considered a birds' paradise by bird watchers. A total of 461 bird species have so far been recorded from Koshi Tappu (Anonymous 1997), more than 180 of them wetland dependent species. It is not certain how many of these were recorded in the reserve itself. Many bird species visit the wetlands outside the reserve, especially the seepage stream to the east of the eastern embankment and the reservoir and marshes near the Koshi barrage. About 32 species found in this region are either threatened, rare, or endangered bird species. (Heinen 1986; WMI/IUCN-Nepal 1994). These include the swamp partridge (*Francolinus gularis*), Bengal florican (*Houbaropsis bengalensis*), white-tailed rubythroat (*Luscinia pectoralis*), and blue whistling thrush (*Myiophonus caeruleus*).

Cultural Heritage—The Koshi river, as a tributary of the Ganges, is considered a holy river by the local people. People take ritual baths in this river, especially south of the barrage, on many occasions such as Dashraha (celebrated in June) and Chhatha (celebrated in October or November). The people of this region have a cultural attachment to the river. Fishermen see the Koshi river as the means of their livelihood, indigenous people of other castes such as Tharus, Donbar, Jhangar, and Bantar depend on the Koshi river for their daily life.

Use Values of Grasslands

The results of the household survey showed that more than two thirds of local people residing in the vicinity of the reserve considered the grasslands of Koshi Tappu to be important and unlimited resources which would never be exhausted. They had strong attitudes about using these resources for different purposes. Grasslands in the Koshi Tappu region have the following use values.

Livestock grazing—People living in the vicinity of the Koshi Tappu region have been using the grasslands and forests to graze livestock for centuries. After the area was declared a wildlife reserve, such activities were legally banned. Nevertheless, livestock herders of different socioeconomic status have continued such practices to the present. Many large livestock herders, who mostly belong to the Yadav caste (literally milkmen), keep their livestock (cattle and buffalo) inside the reserve permanently. About 50 households own 10,000 to 12,000 livestock units; none has less than 100 units, while some have more than 500 units (Kherwar 1996; Sah 1997). They are mostly from different villages in Sunsari and Saptari districts. Some of their relatives from India also keep cattle inside the reserve. Many other householders take their livestock inside the reserve every morning and bring them back in the late afternoon. The total number of livestock taken to the reserve daily was estimated to be 15,000 to 17,000 in the west and 3,200 in the east from the livestock holdings per household and the proportion of households taking their livestock inside the reserve during most of the year except the rainy season.

Besides the availability of grasses, the other main incentive for livestock owners to keep their buffalo inside the reserve is that they prefer to cross-breed them with the wild population to get hybrids, which are more valuable in the Indian market. A second-year hybrid may be valued at 50-80% more than an ordinary buffalo.

Fodder collection—During the field survey, more than 90% of households in the villages located in the close vicinity of the reserve in the west and north were found to be bringing fodder from the reserve. Each household collected one to three bundles per day. In the east, this depended on the opportunities people had to enter the reserve. In one morning, 200 people were found between Kushaha and Prakashpur, 100 of them from Madhuban where there is an army post.

Fuelwood collection—People from the villages to the west of the reserve collect fuelwood in the form of *dhadhi* from the grasslands and savanna.

Thatch grass—The harvesting of thatch grass, locally called 'khar' and 'dhadhi', is legally permitted in the protected areas of Nepal. In Koshi Tappu, permission is given for a one-week period. Until recently this used to be 15 days. *Imperata cylindrica* is the most favoured thatch grass harvested by the local people. The other grasses harvested during this period are *Phragmites karka* and *Saccharum spontaneum*. During the grass-cutting season, swampy areas are visited by relatively few people because of the swampy conditions and the presence of a high proportion of less preferable grass species. No systematic research has been done on the amount of grass harvested since 1987, when Heinen (1993) estimated that its value lay between 3.7 and 5 million NRs.

Other uses—Many other plants found in the grasslands of the Koshi Tappu region are used by local people for different purposes. The most extensively used is a fern *Dryopteris chochleata*. This fern is harvested on a commercial scale from the western part of the reserve and is supplied to Kathmandu. Other plants include *Alternanthera sessilis*, *Diplazium esculantum*, *Eclipta prostrata*, *Leucas cephalotus*, *L. indica*, *Lippia nudiflora*, and *Vernonia cineria*, which are used as green vegetables. Similarly, wild varieties of vegetables like *Solena heterophylla* and *Momordica charainta* are also harvested from the grasslands.

Existence Values of Grasslands

Grasslands are also considered rich in biodiversity. No detailed study was made of the species composition in the grasslands during my field trip. However, in a study conducted by WMI/IUCN-Nepal (1994) more than 30 species of plants were found in different grasslands. Grasslands have an important role in Koshi Tappu as the habitat of wild water buffalo. Altogether, eight species of mammals were recorded in the grasslands and savanna by WMI/IUCN-Nepal (1994). Many bird species in Koshi Tappu are also grassland birds. Mr. Hem Sagar Baral of Bird Conservation Nepal (BCN) is conducting research into the population of grassland birds.

The above results show that both the wetlands and grasslands are valuable in the Koshi Tappu region (Table 2). However, under the present conditions, their relative importance in terms of their use and existence values differ. The grasslands are more intensively used by the local people than the wetlands. On the other hand, the wetlands seem to have more existence values than the grasslands if the adjoining areas are also included (Figure 5).

Table 2. Different values of wetlands and grasslands in the Koshi Tappu region under present conditions

Value	Wetlands	Grasslands
Direct Use Values		
1. Grazing	**	*****
2. Fishing	***	-
3. Fuelwood collection	*	***
4. Fodder collection	*	*****
5. Other products	***	*****
6. Irrigation	*****	-
7. Recreation	*****	*
Indirect Use Values		
1. Ground water recharge	*****	*
2. Flood control	*****	**
3. Sediment retention	**	*****
Non-use/Existence Values		
1. Biodiversity richness	*****	**
Cultural Values	**	-

Note: the number of stars shows the relative value

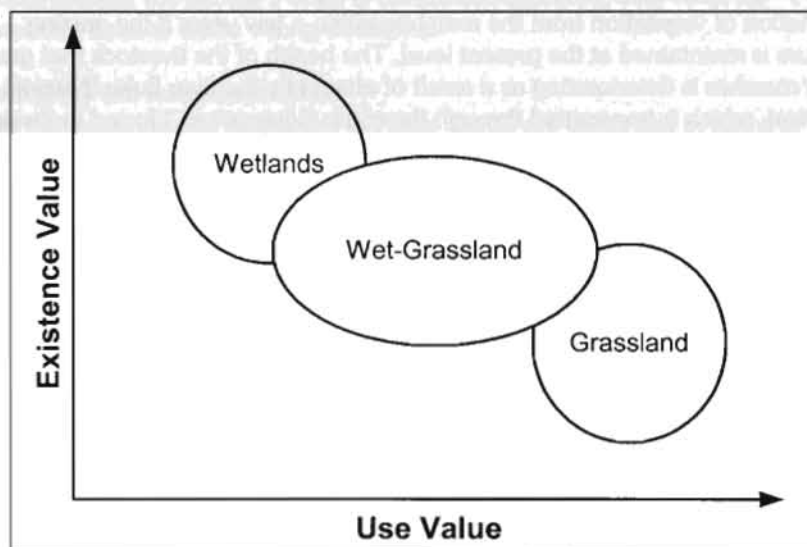


Figure 5. Relative use and existence values of wetlands, wet-grasslands and grasslands in the Koshi Tappu region under present conditions

Factors Threatening the Wetlands and Grasslands

Both the wetlands and grasslands in the Koshi Tappu region are important, but they are threatened both by natural calamities and anthropogenic disturbances. The main problems in managing the wetlands and grasslands in the Koshi Tappu region are as follow.

Flooding and Sedimentation—Frequent flooding in the Koshi river leads to a high mortality of the wild water buffalo which is the main target species of protection in this region. The mortality rates due to flood vary from 12% as in 1987 (Heinen 1993) to 40% as in 1968 (Dahmer 1978). Sedimentation in the Koshi Tappu region has increased since the barrage was constructed. Sedimentation causes the riverbed to rise and is thus the main cause of the shifting behaviour of the Koshi River in this region. Sedimentation also threatens the existence of the ox-bow lakes situated to the west of the eastern embankment. Furthermore, shifting of the Koshi river towards the west may result in drying up of the seepage stream located to the east of the eastern embankment.

Livestock grazing—Livestock grazing inside the reserve is seen as a chronic management problem. The intensive grazing in Koshi Tappu has adversely affected plant diversity in the grasslands and savanna, destroying the habitat and possibly creating problems of genetic erosion in the population of wild water buffalo (yet to be confirmed by research).

Intensive grazing in the marshes, especially in the eastern part of the reserve, is destroying the habitat of several important bird species, and may cause the elimination of vegetation from the marshes within a few years if the grazing pressure is maintained at the present level. The health of the livestock that graze in the marshes is deteriorating as a result of attacks by the liver fluke (*Fasciola hepatica*), which is transmitted through the snails (*Viviparis* sp.) found in these marshes.

The problem of livestock grazing in Koshi Tappu has its roots in the social structure of the communities, cultural practices, and lack of political determination. Further causes are lack of alternatives for the large livestock herders, and insufficient resources in the protection unit of the reserve. In addition, people living in Bairwa, Badgama, Pipra Purba, Kamalpur, and Odraha VDCs face problems of water scarcity and are dependent on the river inside the reserve as a source of water for their livestock. Once they take their livestock to the Trijuga or Mariya dhar to drink, they take the opportunity to allow them to graze as well.

Grass harvesting—Permission given to the local people to harvest grasses from the reserve once a year helps gain support for the reserve, but it also has some negative effects. For example, theft of fuelwood in this season is common, and is the reason why the grass-cutting period was shortened from 15 days to 7 days. In addition, many wild animals are killed or injured during this period when they find their habitat disturbed and try to flee (Sah 1993). During this season, people also burn the grasslands.

Fishing—Illegal fishing in the wetlands inside the reserve creates confrontation between fishermen and reserve staff. Fishing during the spawning period also affects the growth of the fish populations. As a result, the size and number of fish in the Koshi River are both lower now than in earlier times.

Development Activities—The Koshi Barrage has adversely affected the wild land of Koshi Tappu by accelerating the deposition of sediments on the floodplain. Similarly, the 132 KV line constructed through the reserve is posing a threat to the wetland birds flying in huge flocks.

Presence of a Transitional Zone—When land becomes barren following deposition of sand, pioneer species from the surrounding community invade the area and grow to represent early stages of succession. This may not reflect any particular type of community, particularly when the area remains open to human interference. On the other hand, vegetation such as grassland may become severely degraded and look like barren land as a result of intensive grazing and frequent burning. Land which is in transition from wetlands to grasslands covers almost one fourth of the area of Koshi Tappu (22.8%) and may be categorised as 'transitional zone'. This area may be more vulnerable to human disturbance and needs special consideration for management.

Socio-political Interference—When reserve authorities try to enforce the regulations strictly, the large livestock herders seek the help of a political leader to ask the authorities to be liberal. When poachers or miscreants are caught breaking the regulations, local politicians come to release them. Under the present system, the people's voice is considered supreme. This voice is sometimes used to make wrong decisions.

Conclusions and Recommendations

Both the wetlands and grasslands in Koshi Tappu are important in terms of use and existence values. However, the use values, especially the consumptive use, should be handled carefully without compromising the goals of conservation. Consumption of the resources may cause their deterioration (Lemons 1987). The competing goals of conservation and use cannot both be maximised (Hardin 1968) nor can either be abandoned because the area is not only the prime habitat of the last remaining population of wild buffalo (*Bubalus bubalis*) and the location of nesting and wintering sites of a number of birds, but also a site which provides local people with various products for their livelihood. Thus it is recommended that livestock grazing in Koshi Tappu should be phased out gradually but not abruptly. Abrupt reduction would damage the whole social and economic setting of the communities in the adjoining villages, where livestock rearing is not only an integral part of the economy but also a part of the traditional culture of some ethnic groups. The process and benefits of a gradual reduction in livestock numbers has been described elsewhere (Sah 1993 1997).

In the Koshi Tappu region, it is the existence value of the wetlands that has led the international community to include this region in the list of Ramsar Sites (Wetlands of International Importance). But what the region is recognised for lies mostly outside the reserve in areas such as the reservoir and marshes near

the barrage and the seepage stream with marshes to the east of the eastern embankment. That is why the extension of the wildlife reserve up to the barrage is widely advocated (WMI/IUCN-Nepal 1994; BPP 1995; Sah 1997). However, prior to any decision, the challenges and consequences of such extension need to be well evaluated.

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Effects of Management Practices on the Grassland Vegetation and Their Use by Ungulates in Dudwa National Park, Uttar Pradesh, India

Harish Kumar⁸

Abstract

A study on grassland management practices and their impact on wildlife habitats was started in Dudwa National Park in 1998-1999. In this area the tall wet grasslands are maintained as a natural community by annual flooding and higher moisture regimes together with the synergistic influence of fires. These grasslands are burnt annually during the early dry season (January-February). As a result of floods during the monsoon and the associated deposition of silt and high moisture content, these grasslands do not burn properly. Different management practices are undertaken by the park management to improve the habitat quality including cutting of grass, cutting and removal of grass, harrowing prior to burning, and burning. In this paper I describe the effect of four treatments on these grasslands: (i) grass cut and burnt; (ii) grass cut, removed, and burnt; (iii) grass harrowed and burnt; and (iv) grass burnt as standing. The treatments were tested on two different types of grassland: wet, tall grasslands—*Sclerostachya fusca*-*Saccharum spontaneum*; and dry, short grasslands—*Imperata cylindrica*-*Vetiveria zizanioides*. A split plot design was used in these two different grassland communities to study the different burning practices with six replicates, three in each grassland community. Data are presented on phenology, plant species composition, grazing intensity, phytomass, and ungulate use (based on pellet counts). The above ground phytomass was lower after harrow and burn treatment than for the other treatments, but the relative pellet occurrence was higher when this treatment was performed during April 98 and July 98. After the monsoon there was no significant difference in phytomass or height after the different treatments. The study is long term and will address basic questions related to the impact of grassland management practices on grassland diversity and productivity and the effect of burning in the protected area.

Introduction

The tall grassland habitats in the Terai of India are described as stages in the successional continuum between the primary colonisation of new alluvial deposits by flood climax grass and herbaceous species, and the non-flooded climax deciduous forest, which is predominantly composed of sal (*Shorea robusta*) (Champion and Seth 1968; Dabadghao and Shankarnarayan 1973; Lehmkuhl 1989 and 1994). Since the sal climax only forms on older, better-drained alluvium, it is replaced by tropical deciduous riverine forests in areas such as those subject to periodic flooding during monsoons. The latter typically comprises either Khair-sisso communities (*Acacia catechu* and *Dalbergia sisso*) or those with *Trewia nudiflora*. The primary successional grasslands in the area are maintained by prolonged inundation during the monsoon, and the seral grasslands by periodic inundation and by fire or grazing. Current management in the grasslands of Dudwa National Park involves annual burning during the

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early dry season (January-February) (Rodgers and Sawarkar 1988; Rahmani *et al.* 1990; Kumar and Mathur 1998). It is believed that the early burning of the grasslands promotes the growth of new shoots, which are a preferred food item for different herbivores; serves to prevent the loss of grassland habitats through the invasion of woody species or encroachment of grasslands by climax forest habitat; and reduces the incidence of spontaneous and more damaging large scale summer fires by removing accumulated combustible fuel. At the same time there has been regrettably little research into the effects of burning, or indeed any of the other disturbance factors like grazing and harvesting, on tall grassland habitats to support the above claims (Rodgers and Sawarkar 1988; Kumar and Mathur 1998). Grassland programmes are now needed to increase the amount of premium *Imperata cylindrica* to help meet the demand for thatch grass. Management would emphasise the creation of a mosaic of tall-grass patches and short *Imperata cylindrica* grass patches, rather than converting large areas of tall grass into an *Imperata cylindrica* monoculture. The extensive tall grass stands are little used for foraging by wildlife, but they have a high cover value. Short grass stands are worthless for cover for large animals, but provide more palatable forage than tall grasses for a longer period during the year. The increased edge effect provided by a more diverse landscape mosaic would be likely to increase the diversity of other wildlife at a site (Lehmkuhl 1994).

The investigations in this paper aimed at assessing grasslands, different management practices, and wild ungulate relationships. Four treatments are being tested: a mosaic of cut and burned grasses; grasses cut, removed, and burned; selective harrowing of grassland patches followed by burning; and grass burned as standing.

Study Area

The present study was carried out in Dudwa National Park (DNP). The area represents one of the few remaining examples of the highly diverse and productive *Terai* system and falls under the *Terai*-Bhabhar biogeographic subdivision of the Upper Gangetic Plains biotic province and the Gangetic Plains biogeographic zone (Rodgers and Panwar 1988). The DNP lies between 28° 18' and 28° 42' N and 80° 28' and 80° 42' E. The foothills of the Himalayas lie 30 km to the north (Figure 6). The altitude ranges from 150 masl in the farthest south-east to 182 masl in the extreme north, a rise of just 32 m. Several streams and tributaries drain through the DNP. The northern boundary of the park is contiguous with the international India-Nepal border and is largely determined by the Mohana river.

The most significant attribute of the DNP forests is the predominant and valuable moist deciduous sal (*Shorea robusta*) forest with interspersed tall, wet grasslands and numerous swamps. Sal forest occupies the major portion of the DNP, ca. 50%, while grasslands constitute more than 15%. The grasslands can be broadly classified into two types: the tall, wet grasslands in low-lying areas dominated by *Sclerostachya fusca*, *Saccharum spontaneum*, *Phragmites karka*, and *Arundo donax*; and the short, dry grasslands occupying higher grounds and dominated by *Imperata cylindrica*, *Veteveria zizanioides*, and *Desmostachya bipinnata*. The number of species currently documented include 77 grasses and grass-like plants, 79 aquatic plants, 75 trees, 21 shrubs, 17 climbers, 40

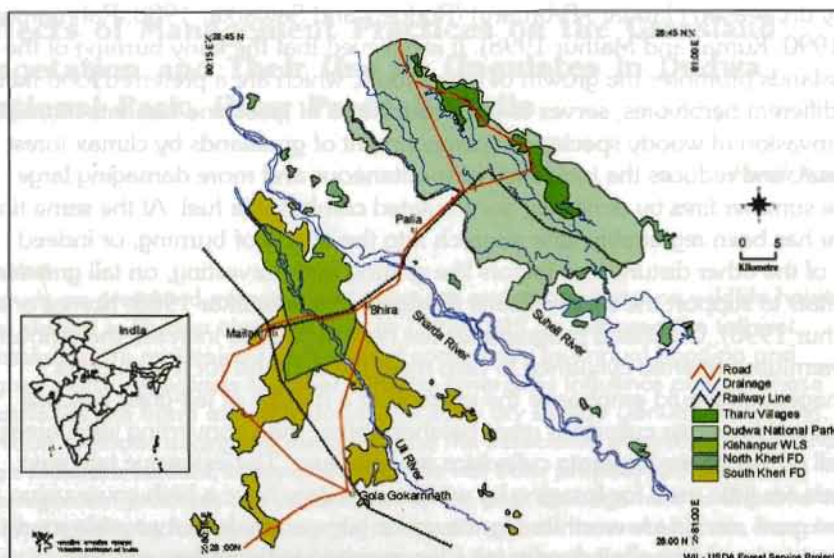


Figure 6. **Map of Terai Conservation Areas in Uttar Pradesh**

mammals, 90 fishes, 15 amphibians, 25 reptiles, and nearly 400 birds. The area harbours a significant population of tigers (*Panthera tigris*). Beside this, the most notable feature is the existence of five species of deer including a relict population of the highly endangered swamp deer (*Cervus duvauceli duvauceli*). The DNP is also home to other critically endangered species including the hispid hare (*Caprolagus hispidus*) and the Bengal florican (*Hubaropsis bengalensis*).

In the study area, the tall wet grasslands are maintained as a natural community by annual flooding and the associated high moisture regime with the synergistic influence of fire. Prior to 1978, a large number of domestic livestock used to graze the area and grass was cut and taken away for thatching. There is an unsubstantiated belief, notwithstanding the effect of fire and flood, that grazing and cutting used to maintain a layer of palatable grasses. Prescribed fires have been carried out in these grasslands for a long time. During floods, silt is deposited on the bed of these tall grasses. When they are burned the silt acts as an insulator and burning is incomplete. In order to improve the habitat quality, different grassland management practices are now being undertaken.

The main study area was a part of the DNP called Sathiana. This area used to be the main stronghold of swamp deer (Schaller 1967). During the summer of 1981 more than 2000 swamp deer were counted here (Sawarkar 1988). During the past few years, there has been a severe decline in the swamp deer population. The largest population of swamp deer seen in Sathiana in 1991 was 150 (Qureshi *et al.* 1991). The current estimate is 200 swamp deer in this area. Different grassland management programmes are now being undertaken in DNP to manage the monospecies dominant areas of the tall grassland habitats. An experimental study has been started to assess the effect of different management practices on the grassland vegetation and its use by wild ungulates.

Methods

For the purpose of the assessment two grassland communities were differentiated: short grasslands of *Imperata cylindrica*-*Vetiveria zizanioides*, with an average grass height of less than 1.5 m; and tall grasslands characterised by *Sclerostachya fusca*-*Saccharum spontaneum*, with an average grass height of more than two metres and a maximum of up to seven metres. Split plots of 100 x 200 m were used to study the different burning practices with six replicates of each split design, three each in the short grassland and tall grassland communities. Each experimental plot was split into four equal blocks (100 x 50 m) or treatments: (i) grass cut and burned; (ii) grass cut, removed, and burned; (iii) grassland harrowed and burned; and (iv) grass burned as standing. These treatments were randomly assigned in the split plots. The treatments were performed in January/February.

Habitat Use by Wild Ungulates

Prior to treatment and burning, the initial plant species composition, phenology, grass height, and phytomass were recorded, and pellet counts taken for swamp deer (*Cervus duvauceli duvauceli*) and hog deer (*Axis porcinus*). For vegetation assessment (species composition, height, and biomass), ten random sample plots (1 x 1 m) were laid in each treatment plot. For the assessment of phenology and grazing occurrence, ten 2 x 2 m quadrats in 2 rows of 5 quadrats were placed systematically in each treatment plot. Three placements were made of a 0.5 x 0.5 m frame with a 5 x 5 interior grid in each 2 x 2 m quadrat, to estimate the grazing intensity. Two belt transects (100 x 2 m) were marked at 17 m intervals from the left side in each split plot for the assessment of ungulate use through pellet counts. Total pellet groups of the two herbivorous animals were counted in two belt transects and later collected and removed. All the above measurements were repeated three times at intervals of three months after the different treatments had been carried out. In all, four sets of measurements were made of each parameter (one prior to the experimental treatment, and three after). The above ground phytomass was determined by clipping vegetation species-wise in 1 x 1 m plots and calculating the dry weight.

Analysis

Dunnet's t-test (two-tailed test) was performed to compare the control values with treatment values. The analysis was done using SPSS version 8.0 software (Norusis 1994) and biostatistical analysis.

Results and Discussion

The area was regularly grazed by wild ungulates during all seasons. *Imperata cylindrica* sprouted from the ground after harrow and burn treatment, after the other three treatments sprouting was from the remnant tussocks. Except in the harrowed and burned sections, the grasses began to flower in February and grass senescence started in March. In the harrowed and burned sections, *Vetiveria zizanioides* sprouted in February and was grazed intensively by herbivores during February and March, presumably because of the palatability and nutritive content. Flowering of grass started during March, but unlike in the other sections there was no senescence. *Saccharum spontaneum* sprouted in March (and in the monsoon), so that when *Imperata cylindrica* and *Vetiveria zizanioides* were flowering the ungulates fed on sprouts of *Saccharum*

spontaneum. The *Imperata cylindrica*-*Vetiveria zizanioides* communities supported grazing throughout the year in both harrowed and burned sections and sections subjected to burning alone. Hog deer grazed more heavily on harrowed and burned sections and sections subjected to burning alone, but preferred patches subjected to burning alone since this left more cover to hide in.

In the tall grassland communities, *Imperata cylindrica* sprouted from the ground in harrowed and burned sections during January, and there was intensive feeding on it during January and February. *Sclerostachya fusca* sprouted in February in all sections except the harrowed and burned and was moderately grazed. *Sclerostachya fusca* sprouted during March in harrowed and burned areas as did *Cyperus* species. Grazing seemed to be heaviest in relative terms in harrowed and burned sections. *Viccatia coenifolia* appeared as a dominant species in harrowed and burned areas during April. *Saccharum spontaneum* also sprouted in April.

In the tall grassland communities, the harrow and burn treatment areas were used relatively more by swamp deer because during the early dry season the tall grasses were replaced by short grasses which provided the preferred combination of food and cover as well as open areas for resting. Between January and April, 126 swamp deer were observed resting in the openings created by the harrow and burn treatments. The open areas presumably provide a good escape distance for the ungulates, and were combined with a mosaic of fodder areas and hiding cover. As the grass height increased the visibility decreased.

The above ground biomass before the start of treatment (January) and at three intervals of three months after the treatments is shown in Figures 7 and 8.

In the short grassland communities (Figure 7), the above ground biomass in the harrowed and burned areas was markedly lower than in the other areas three months after treatment, presumably as a result of the late response of species, the fact that grass had to sprout from under the ground rather than from tussocks, and that the intensity of grazing was higher. The difference was less marked in July. After the monsoon, in October, the above ground biomass was more or less the same in all treatment areas. Dunnet's two-tailed t-test showed a significant difference in above ground biomass between harrowed and burned and only burned treatments ($t = -105.75$; $n = 30$; $P < 0.001$); and between cut, removed, and burned, and only burned treatments ($t = -62.61$; $n = 30$; $P < 0.02$). There were no interaction effects between treatments and seasons on above ground biomass, i.e., the effects of the treatment and seasons were independent.

In the tall grassland communities (Figure 8) the above ground biomass three months after treatment was markedly higher after burn only treatment than after any of the other treatments, and was slightly lower in the harrowed and burned areas than in the cut, removed, and burned, and cut and burned areas. By July, the above ground biomass had increased somewhat in all treatment sections, but the differences remained similar to those in April. In October, after the

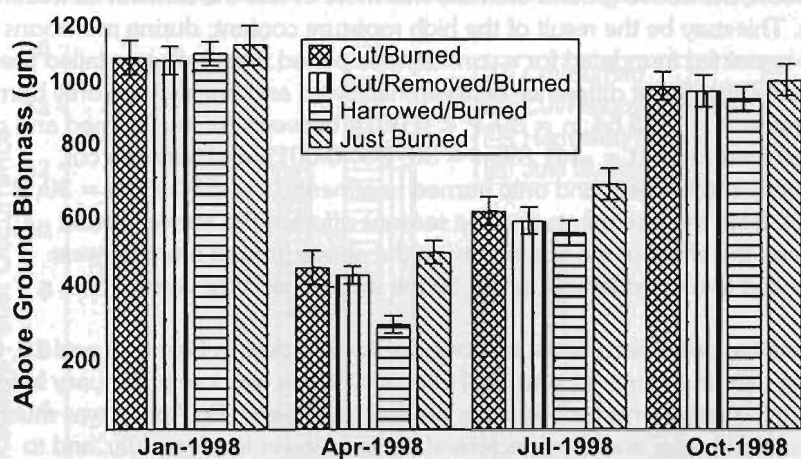


Figure 7. Above ground biomass in short grassland communities (g/m^2)

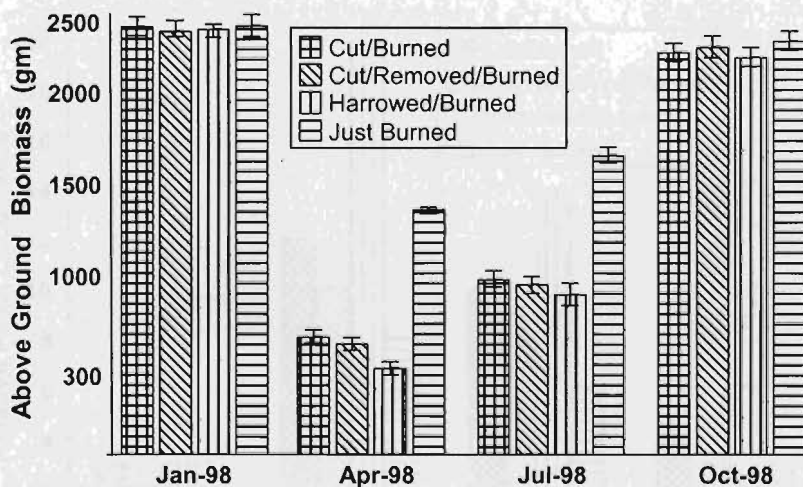


Figure 8. Above ground biomass in tall grassland communities (g/m^2)

monsoon, the above ground biomass was more or less the same in all treatment areas. This may be the result of the high moisture content; during monsoons the areas remained inundated for a considerable period. Dunnet's two tailed t-test showed a significant difference between harrowed and burned and only burned treatments ($t = -525.64$; $n = 30$; $P < 0.001$); between cut and burned and only burned treatments ($t = -441.89$; $n = 30$; $P < 0.001$); and between cut, removed, and burned, and only burned treatments ($t = -520.69$; $n = 30$; $P < 0.001$). Both the treatments and the seasons affected the above ground biomass; the effect of the treatments on the above ground biomass were influenced to a considerable extent by the season and vice versa.

The relative pellet occurrence is shown for swamp deer in Figures 9 and 10, and for hog deer in Figures 11 and 12. Pellet occurrence was low in January before starting the treatments for both animals and in all areas. By April it was much higher in all areas, and then decreased again to lower levels in July, and to levels closer to the original levels by October. These changes reflect the changes in grass height. Before starting the treatments the grass height was quite high; after the treatments the grasses were short and in the early months palatability was high; as time passed the grass height increased and the palatability decreased and this was accompanied by a decline in the relative pellet occurrence. The above ground biomass of different species has still to be analysed.

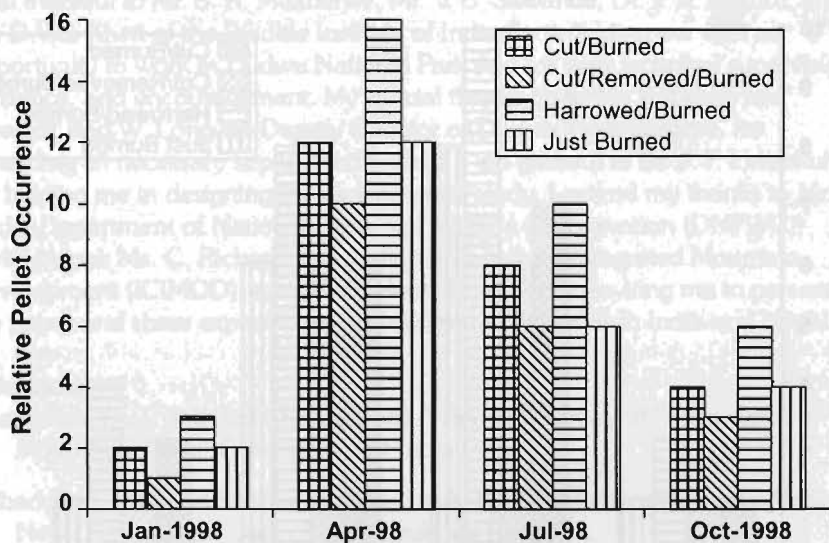


Figure 9. Relative pellet occurrence of swamp deer in short grassland communities

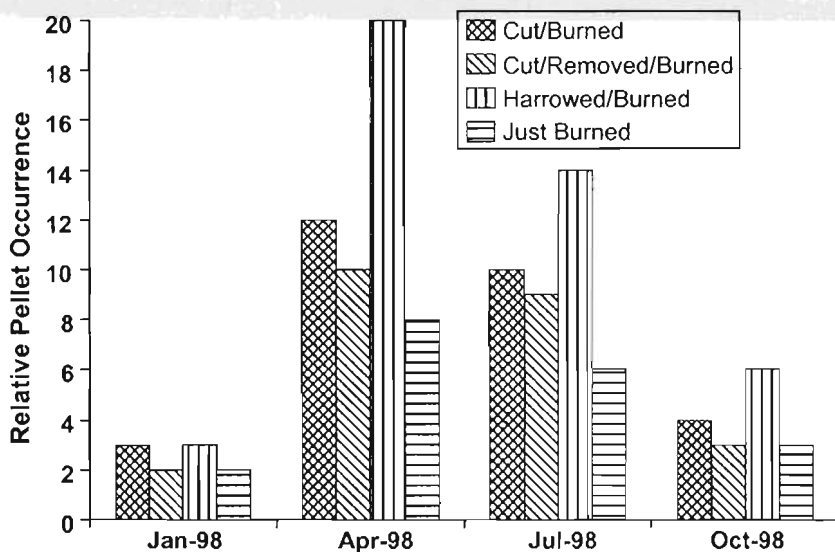


Figure 10. Relative pellet occurrence of swamp deer in tall grassland communities

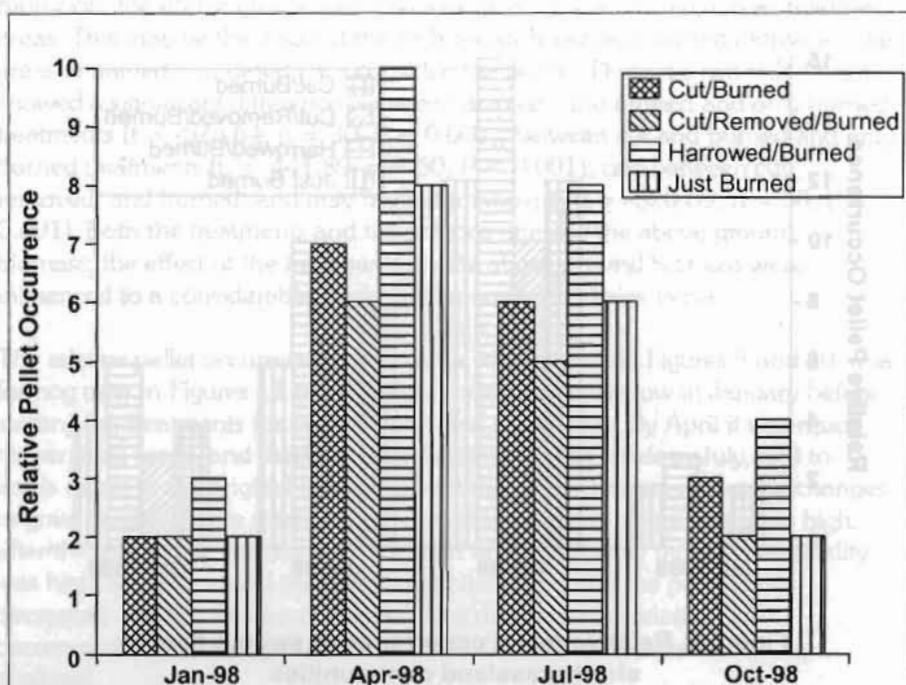


Figure 11. Relative pellet occurrence of hog deer in short grassland communities

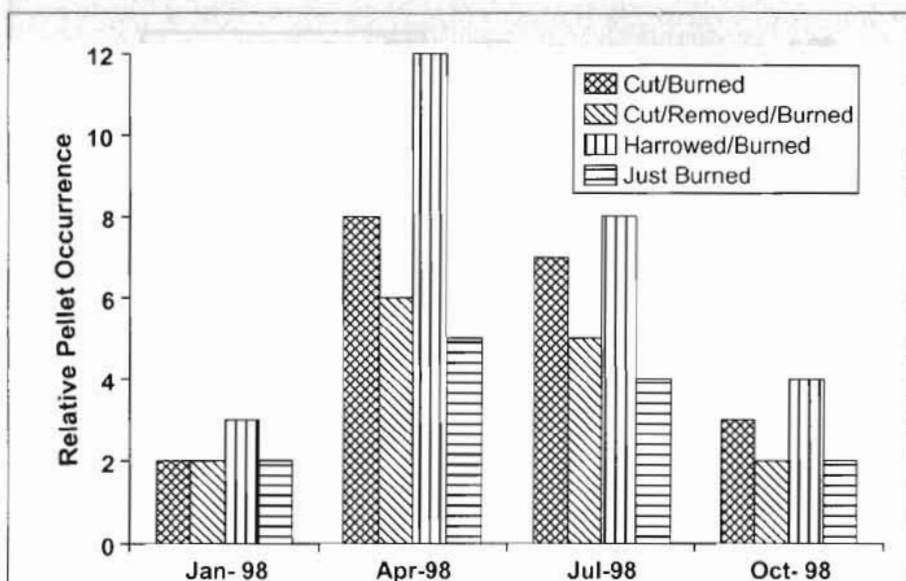


Figure 12. Relative pellet occurrence of hog deer in tall grassland communities

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Importance of Tall Grasslands in Megaherbivore Conservation

Shant Raj Jnawali⁹ and Per Wegge¹⁰

Abstract

In the lowlands of Nepal, tall grasslands once stretched throughout the southern alluvial floodplains, but now they are restricted to the river basins of protected areas. These tall grasslands provide refuge for a large number of wild mammals, including greater one-horned rhinoceros, wild elephant, tiger, swamp deer, hispid hare, hog deer, and wild water buffalo. The main objective of this paper is to assess the importance of the tall grassland ecosystem in megaherbivore conservation, with special emphasis on greater one-horned rhinoceros. In this study, which was carried out in Royal Chitwan National Park (RCNP) and Royal Bardia National Park (RBNP), microhistological analyses of animal faeces were used to assess the importance of grasses in conserving rhinoceros. Feeding data of rhinoceros clearly indicated that both the annual and the seasonal diets of rhinoceros in Bardia and Chitwan are dominated by the grass species growing primarily in the tall alluvial floodplain grasslands, which in these protected areas suffer encroachment from woody vegetation. Although the park authority in RBNP has recently initiated programmes of uprooting of woody bushes from phantas and wooded grasslands, which will help to create more open space for the large populations of medium sized ungulates that primarily graze on these habitats, no such interventions have been introduced so far to manage the tall floodplain grasslands. These grasslands are needed to accommodate an increasing number of megaherbivores as well as floodplain-dependent ungulates in both areas. Ironically, the dynamics of the floodplain ecosystem is still poorly understood, since no long-term scientific research has been conducted on its ecological processes. A comprehensive scientific research effort is needed before any management prescription can be made.

Introduction

The tall grasslands originating from fluvial action and monsoon floods are unique natural ecosystems. They are regarded as prime sites for biodiversity conservation. Previously, tall grasslands were distributed throughout the floodplains of the Ganges and Brahmaputra river systems of the northern Indian sub-continent including the southern lowland (*Terai*) of Nepal (Bell and Oliver 1992). Mainly as a result of lack of effective measures to control grazing by domestic stock, these habitats are now confined within the boundaries of protected areas in both Nepal and India.

In Nepal, tall grasslands once stretched throughout the southern alluvial floodplains of the perennial river systems, mainly the Mechi and Koshi river systems in the east; the Rapti, Rew, and Narayani river systems in the centre; and the Babai, Orai, Karnali, and Sarada river systems in the west. As a result of intensive rice cultivation and grazing, tall grasslands are now restricted to the

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river basins of four protected areas: Koshi Tappu Wildlife Reserve in the east, Royal Chitwan National Park in the central region, Royal Bardia National Park in the west, and Royal Shukla Phanta Wildlife Reserve in the far western Terai.

The tall grasslands are composed of a mosaic of a number of different tall grasses with a few sparsely scattered tree species. Dominant graminoids include *Saccharum spontaneum*, *Narenga porphyrocoma*, *Saccharum bengalensis*, *Themeda* sp., *Phragmites karka*, *Arundo donax*, and *Imperata cylindrica*. Important scattered tree species include *Dalbergia sissoo*, *Trewia nudiflora*, and *Acacia catechu*.

The tall grasslands provide refuge for a large number of wild mammals, including greater one-horned rhinoceros, *Rhinoceros unicornis* (Laurie 1978; Dinerstein and Price 1991; Jnawali 1995), wild elephant, *Elephas maximus* (Sukumar 1989), tiger, *Panthera tigris tigris* (Tamang 1982; Smith 1984), swamp deer, *Cervus duvauceli duvauceli* (Schaaf 1978; Pokharal 1996), hispid hare, *Caprolagus hispidus* (Bell et al. 1990; IUCN 1993), hog deer, *Axix porcinus* (Dhungel 1985), and wild water buffalo, *Bubalus bubalis* (Heinen 1993). In addition, a remarkable number of smaller mammals, birds, and reptilian species, refuge in this ecosystem.

The main objective of this paper is to assess the importance of the tall grassland ecosystem in megaherbivore conservation with special emphasis on the greater one-horned rhinoceros (henceforth referred to as rhinoceros).

Study Area

Data presented in this paper were collected from two national parks, Royal Chitwan National Park (RCNP) in the east and Royal Bardia National Park (RBNP), which is located ca 500 km west of RCNP. In Chitwan, a study area of ca 20 sq.km was selected in the northern floodplain (84° 20' E and 27° 30' N) along the Rapti river near Sauraha. In Bardia, the study area consisted of a narrow strip of ca 70 sq.km in the southwestern corner of the park (81° 20' E and 28° 35' N) along the Geruwa river, the eastern branch of the Karnali river system.

The climate of both study areas is subtropical monsoonal type. More than 80% of the precipitation occurs within the relatively short monsoon period. May and June are quite hot with average maximum temperatures around 40°C. Winter is chilly and the temperature drops below 5°C.

Vegetation in both areas is of subtropical type, ranging from a mosaic of early successional riparian vegetation on newly established riverbeds to the climax sal (*Shorea robusta*) dominated forest established on the dry uplands and slopes of the Churia ranges. There are five major types of vegetation in Chitwan: riverine; sal forests; khair-sissoo (*Acacia catechu*-*Dalbergia sissoo*) forests; bushy pasture; and tall floodplain grasslands—and seven in Bardia: riverine; sal; mixed hardwood forests; khair-sissoo forests; wooded grassland; tall floodplain grassland; and phanta.

Among the habitat types common to both areas, sal forest, tall grassland, and bushy pasture are similar floristically. The riverine forests in the two areas differ

in species composition with *Trewia nudiflora* dominating in Chitwan and *Mallotus philippinensis* in Bardia. The tall floodplain grasslands in both areas are dominated by *Saccharum spontaneum*, *Saccharum bengalensis*, and *Phragmites karka*. *Themeda arundinaceum* does not grow in Bardia's floodplain. In Chitwan, this species grows in large tracts between the Churia foothills and the Rapti river where surface water remains available all year round. *Arundo donax* is more common in Bardia's floodplain than in Chitwan. Furthermore, *Narenga pophyrocoma* is one of the dominant tall grass species in Chitwan, whereas in Bardia it is localised in the northern section of the floodplain. Detailed descriptions of the habitat types in both areas are given for Bardia in Dinerstein (1979) and Jnawali and Wegge (1993); and for Chitwan in Laurie (1978) and Mishra (1982).

The fauna in both parks is similar, except that some species are confined to one or other of the areas. Bardia has a small sub-population of rhinoceros translocated from Chitwan during 1986 (13 animals) and 1991 (25 animals). This newly-established population has increased gradually and has now reached a total of about 50 individuals (chief warden, personal communication). Other important wild mammals include Asian wild elephant (*Elephas maximus*), tiger (*Panthera tigris*), common leopard (*Panthera pardus*), sloth bear (*Melursus ursinus*), four species of deer (*Axis axis*, *A. porcinus*, *Muntiacus muntjack*, and *Cervus unicolor*), and wild dog (*Cuon alpinus*). The uncommon mammals include nilgai (*Boselephus tragocamalus*) and barasingha or swamp deer (*Cervus duvauceli duvauceli*) in RBNP, and gaur (*Bos gaurus*) in RCNP.

Methods

Microhistological analyses of faeces of Bardia and Chitwan rhinoceroses were used to assess the importance of grasses in conservation of this species (Jnawali 1995). For this, fresh dung samples were collected from both areas, sun dried, ground, and pooled. Every month, five microscopic slides were prepared from a pooled fecal sample. Identification of plant fragments was done using the morphological features observed by microscopic examination. Volumetric estimations of each food plant species were made for each month and later combined for three seasons—summer, monsoon and winter.

Above ground parts (leaf, flower, fruit, twigs, bark) of ca 200 plant species were collected to prepare reference slides. Microscopic structures observed on the reference slides were sketched to allow matching with the faecal plant fragments. A detailed description of the method is given in Jnawali (1995).

The relative importance value (RIV) of each plant species observed in the fecal samples was calculated as follows:

$$RIV_x = D_x (\sqrt{f_x})$$

Where,

- RIV_x = Relative importance value for species x
- D_x = Mean percentage of species x in fecal sample
- f_x = Frequency of species x in fecal sample

Results and Discussion

The rhinoceroses foraged a wide range of wild food plants, but >70% of the volume in the diet was contributed by less than ten species in both areas (Table 3). In Bardia, nine species (five grasses: *Saccharum spontaneum*, *Arundo donax*, *Cyanodon dactylon*, *Saccharum bengalensis*, and *Erianthus ravennae*—and four browse species: *Mallotus philippinensis*, *Dalbergia sissoo*, *Callicarpa macrophylla*, and *Calamus tenuis*) contributed more than 70% of the total volume in the annual diet. In Chitwan, seven species (four grasses: *Saccharum spontaneum*, *Saccharum bengalensis*, *Cyanodon dactylon*, and *Narenga porphyrocoma*—and three browse species: *Coffea bengalensis*, *Murraya paniculata*, and *Litsea monopatelata*) made up 85% of the total volume in the annual diet.

The diet of rhinoceros in both areas was dominated by grass species basically found in tall grasslands. Their proportion was higher in Chitwan (73%) than in Bardia (63%).

Browse species made up about 20%, and agricultural crop plants more than 6% of the diet in both areas. Other food plants, mainly herbs, forbs, climbers, horsetails, and pteridophytes, constituted ca 8%, with a slightly higher proportion in Bardia.

Of the different wild food plants recorded in the annual diet in both areas, the highest proportion was contributed by *Saccharum spontaneum*, with RIVs of 28.5 and 36.9 in Bardia and Chitwan, respectively. The other important grass species common in the annual diet were *Saccharum bengalensis* and *Cyanodon dactylon*. Uncommon species included *Arundo donax* and *Erianthus ravennae* in Bardia and *Themeda* species in Chitwan. The proportion of *Narenga porphyrocoma* in the annual diet was higher in Chitwan (RIV = 6.1) than in Bardia (RIV = 1.0). The higher proportion of this species in Chitwan was related to its availability. In Chitwan, this species is distributed in large patches throughout the tall floodplain grassland, whereas in Bardia *Narenga* is localised in the northern part of the floodplain.

The proportion of the different plant groups varied considerably between seasons, but the pattern was different in the two areas. Grass species constituted the highest proportion of the diet during the monsoon in Bardia (ca 92%) and during the hot season in Chitwan (ca 86%). They constituted the lowest proportion during the winter in both areas, about 42% in Bardia and about 57% in Chitwan. The higher proportion of grass species in the diet in Chitwan during the winter and hot seasons was probably related to the higher availability of water during these seasons. In Chitwan, substrate moisture is available for plant growth all year round. The most dominant grass species, *Saccharum spontaneum*, sprouts soon after grass cutting and grazing (Dinerstein and Price 1991) and burning (Laurie 1978) in winter, and a new flush becomes available early in the hot season. Hence, this species, is foraged during the dry season although to a lesser extent.

In Bardia, rhinoceros compensate scarcity of grasses during the winter season by foraging on the leaves of browse species. Laurie (1978) also recorded the highest proportion of browse species in the diet during the winter season.

Table 3. Relative importance values of main wild food plants in the diet of rhinoceros in Royal Bardia and Royal Chitwan National Park

Species	Relative Importance Value							
	Winter		Hot		Monsoon		All year	
	RBNP	RCNP	RBNP	RCNP	RBNP	RCNP	RBNP	RCNP
Grasses								
<i>Saccharum spontaneum</i>	18.9	25.7	21.2	43.1	45.4	41.9	28.5	36.9
<i>Saccharum bengalensis</i>	0.8	14.9	3.2	13.8	8.7	8.2	4.2	12.3
<i>Narenga porphyrocoma</i>	-	1.6	0.7	8.4	2.3	8.4	1.0	6.1
<i>Erianthus ravennae</i>	2.1	-	3.8	-	4.7	-	3.5	-
<i>Cyanodon dactylon</i>	4.4	4.3	4.7	7.6	3.1	8.2	4.1	6.7
<i>Imperata cylindrica</i>	-	0.4	4.4	2.3	1.2	2.6	1.9	1.8
<i>Themeda</i> sp.	-	3.1	-	2.2	-	2.8	-	2.7
<i>Cymbopogon</i> sp.	0.7	2.3	2.0	3.2	3.8	0.5	2.2	2.0
<i>Phragmites karka</i>	1.9	0.7	1.5	1.2	2.2	0.8	1.9	0.9
<i>Arundo donax</i>	5.6	-	5.4	-	4.5	-	5.2	-
Browse								
<i>Callicarpa macrophylla</i>	3.9	3.7	4.5	1.0	3.2	2.0	3.9	2.2
<i>Litsea monopatala</i>	-	5.0	-	0.1	-	0.6	-	2.0
<i>Coffea bengalensis</i>	-	6.5	-	0.4	-	3.0	-	4.1
<i>Murraya paniculata</i>	-	5.8	-	2.8	-	4.0	-	3.9
<i>Mallotus philippinensis</i>	7.9	2.6	5.9	2.1	0.6	0.4	4.8	1.1
<i>Dalbergia sissoo</i>	-	-	7.9	0.3	0.7	-	2.9	-
<i>Trewia nudiflora</i>	-	0.2	-	-	0.1	11.2	0.03	3.8
<i>Calamus tenuis</i>	4.4	-	5.0	-	0.9	-	3.4	-
<i>Bombax ceiba</i>	1.2	0.2	0.6	-	-	-	0.6	0.1
<i>Colebrookia oppositifolia</i>	1.6	0.1	0.8	0.1	0.1	0.2	0.8	0.1
<i>Ehretia laevis</i>	1.1	-	0.3	-	0.1	0.2	0.5	0.1
<i>Ficus glomerata</i>	1.7	-	0.1	-	0.3	-	0.7	-
<i>Ziziphus mauritiana</i>	1.0	-	0.1	-	-	-	0.4	-
<i>Acacia concinna</i>	1.3	0.1	0.4	-	0.2	-	0.6	0.03
Others								
<i>Triumfetta</i> sp.	0.4	0.4	0.1	-	0.1	0.2	0.2	0.2
<i>Urena lobata</i>	0.9	0.1	1.8	0.1	0.6	0.1	1.1	0.1
<i>Circium wallichii</i>	4.2	0.1	3.1	1.5	1.3	-	2.9	0.5

Important browse species in the annual diet included *Mallotus philippinensis* (RIV = 4.8), *Callicarpa macrophylla* (RIV = 3.9), and *Calamus tenuis* (RIV = 3.4) in Bardia, and *Coffea bengalensis* (RIV = 4.1), *Murraya paniculata* (RIV = 3.9), *Trewia nudiflora* (RIV=3.8), *Callicarpa macrophylla* (RIV=2.2), and *Litsea monopatala* (RIV = 2.0) in Chitwan. *Coffea bengalensis* and *Murraya paniculata* were not recorded in Bardia animals as these species do not occur in the Bardia study area.

Conclusions and Management Implications

The tall floodplain grasslands created by fluvial action and monsoon flood are prime habitats for bio-diversity conservation including megaherbivores like the greater one-horned rhinoceros. Once common throughout the floodplain of the Ganges and Brahmaputra river systems, the tall floodplain grasslands are now restricted to river basins within protected areas of the northern Indian sub-continent.

The feeding data from Chitwan and Bardia rhinoceros clearly indicated that graminoids make up the bulk of rhinoceros food. Both the annual and the seasonal diets of rhinoceros in both areas were dominated by grass species primarily growing in the tall alluvial floodplain grassland. Of the different wild food plants *Saccharum spontaneum*, a dominant grass species in the floodplain, contributed the greatest volume to the diet of both populations. Grasses become coarse and less palatable during the winter season. Rhinoceros compensate scarcity of green grass by foraging on green leaves of browse species: in winter mainly *Callicarpa macrophylla*, *Calamus tenuis*, and *Mallotus philippinensis* in Bardia, and *Murraya paniculata*, *Coffea bengalensis*, and *Litsea monopatelata* in Chitwan.

Within protected areas, tall floodplain grasslands (particularly old ones) suffer encroachment from woody vegetation. In Chitwan, *Trewia nudiflora* is aggressively invading grasslands where inundation by monsoon floods is not a regular phenomenon. *Trewia* seeds dispersed mainly by rhinoceros are easily established in open floodplains where substrate moisture is accessible (Dinerstein and Wemmer 1988). In Bardia, *Dalbergia sissoo* is a primary invader in newly-established *Saccharum spontaneum* dominated grassland, whereas *Murraya koinigii*, *Callicarpa macrophylla*, *Lantana camara* in association with *Dalbergia sissoo*, and *Acacia catechu* encroach the older tall grasslands.

In Bardia, the park authority has recently initiated a programme of uprooting woody bushes from phantas and wooded grasslands. This will help to create more open space for the large populations of medium-sized ungulates that primarily graze on these habitats. However, these habitats are far less important for rhinoceros, since their preferred food plants are not available there. So far, no such interventions have been made to manage the tall floodplain grasslands. But these are needed in both park areas to accommodate an increasing number of megaherbivores as well as floodplain-dependant ungulates.

Regular burning of grassland is regarded as an effective tool to control the invasion of woody vegetation. Today, burning of floodplain grassland is limited to areas with grass left over after grass cutting. Both parks are opened for local people to collect thatch grass (*Imperata cylindrica*) and grass reeds (mainly *Saccharum spontaneum*, *Narenga porphyrocoma*, and *Arundo donax*, needed for making the walls of traditional Tharu houses). In Chitwan, local people burn a few patches of the *Narenga porphyrocoma* growing on the dry uplands to remove the upper leafy part before the grass is cut off. This practice helps to some extent to control the invasion of woody vegetation into *Narenga*-dominated patches. In Bardia, the lower section of the floodplain is dominated

by *Saccharum spontaneum*, which is cleared by local people during grass cutting. Burning therefore has very little effect. Furthermore, fire has a very limited effect on *Saccharum* dominated floodplains with enough substrate moisture, as this species sprouts all year round in such areas.

The dynamics of the floodplain ecosystem are still poorly understood since no long-term scientific research has been conducted on the ecological processes. A comprehensive scientific research effort is needed before any management prescription can be made.

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Grassland Management Impacts on Small Mammals

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Abstract

Grasslands cover more than 13% of the total area of Nepal. They have declined very rapidly in area, however, and are now mostly confined to protected areas. Nepal has established 15 protected areas, however, excessive grass cutting, fire, and grazing continues. Villagers are allowed into the protected areas to harvest thatch grasses and reeds for 10 days annually. In Royal Bardia National Park, 21,000, 45,000, and 57,000 people entered the park in 1983, 1993, and 1999, respectively, to harvest grass. Grazing is rampant in the protected areas. Both park staff and local people set fire to the *Terai* grasslands in winter burning 70-90% of the total area. This form of management, however, has been shown to have deleterious effects on disturbance intolerant and cover dependent small mammals.

Introduction

Grassland covers more than 13% of the total area of Nepal (HMG 1992). A wide variety of grasslands are distributed across the country from the *Terai* (lowlands) to the highlands. Their distribution depends on the topography, soil type, and soil moisture (Tsuchida 1983, Peet *et al.* 1997). Nepal has established 15 Protected Areas, covering an area of 21,050 sq.km. However, several threats have been identified in these protected areas. They include excessive cutting of grass, forest fires, and grazing. Grazing is a year-round threat in the lowland protected areas, and generally a seasonal threat in the high pastures of the Himalayas. Cutting of grass and fire are seasonal (Yonzon and Heinen 1997). The *Terai* grasslands have declined very rapidly in area as a result of conversion to agricultural lands, grazing pressure from livestock, and natural succession. The *Terai* grasslands once extended across the northern Gangetic plain from Uttar Pradesh, through the Nepalese *Terai*, to Bengal in the valley of the Ganges and Brahmaputra rivers and their tributaries. They are now restricted to protected areas in Uttar Pradesh, Assam, and lowland Nepal (Bell and Oliver 1992).

Traditionally, local people have collected thatch grass and reeds in the areas that are now protected. In Nepal, villagers are allowed into the protected areas to collect thatch grasses and reeds for 7-10 days annually. This practice is allowed because suitable grasslands for harvesting are available within the protected areas, and the alternative materials for roofing and building are expensive (Lehmkuhl *et al.* 1988; Brown 1997). However, the grass cutting is massive and the number of grass cutters has been increasing. For example, in Royal Bardia National Park, 21,000, 45,500, and 57,000 people entered the park to harvest grasses and reeds in 1983, 1993, and 1999, respectively.

In addition to cutting of grass, burning is also common in the protected areas. Villagers set fire in almost all the parks and reserves of the *Terai* during the grass

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harvesting period. The main aim is to remove leaves and dead materials from the clumps of reeds so that they can be harvested more easily.

Park staff also set fire to the grasslands in the protected areas immediately after cutting of grass. They burn the stubble and uncut grass, supposedly to reduce the incidence of 'spontaneous' and 'more-damaging' large scale burning later in the dry season by removing any accumulated combustible material. Fire arrests succession, promotes the growth of new shoots, and provides ungulates with important forage resources from the regenerating grasslands (Mishra 1982; Moe and Wegge 1997). More than 70% of the area of grasslands in Royal Bardia National Park is burned annually (Peet *et al.* 1997). Lehmkuhl (1989) said that approximately 80% of the area of grasslands of the Royal Chitwan National Park was burned annually.

Small Mammals

Small mammals are an integral component of grassland communities, contributing to energy flow and nutrient cycling, and playing an extremely important role as seed predators, and dispersal and pollination agents (Fleming 1975). They eat varieties of vegetative materials (grazers, browsers, seed-eaters, nectivores), and a number of species are predators, preying upon insects, amphibia, fish, and others. Small mammals also form an important prey base for medium sized carnivores, birds of prey, and snakes (Emmons 1987; Golley *et al.* 1975; Hayward and Phillipson 1979). Some species can readily adapt to the micro-climates which are to be found in most environments. Most small mammals can cope with drastic changes in their environment, and can recover quickly from 'ecological disasters' because of their high rates of conception and fertility, short gestation periods, and large litter size.

The present paper reviews the impacts of grassland management on small mammals with reference to the *Terai* grassland of Nepal, and provides recommendations for their conservation.

Management Effects

Both cutting and burning can reduce litter inputs and lead to an increased floristic diversity (Peet *et al.* 1997) that appears to benefit a number of small mammal species. In Nepal, early burning, cutting of grass, and uprooting and felling of trees have been practised for some years in order to arrest succession and provide new shoots for ungulates. Cutting of grass and burning influence the stratification of grasses, plant species composition, and the height of standing crops in the grassland ecosystem. However, there is ample evidence that fire can also affect the species composition and species abundance of small mammals (Chesman and Delany 1979; Oliver 1985; Bell *et al.* 1990; Fa and Sanchez-Cordero 1993; Friend 1993). Kerney and Stubbs (1980) argued that mouse populations are severely affected by fire. Based on such findings, most conservation organisations oppose the use of fire in management (Ditlhogo *et al.* 1992).

Fire and Small Mammals

Only a very few studies have been carried out on small mammals in the Indian sub-continent. Data on fire effects are available for only two species, the hispid

hare (*Caprolagus hispidus*) and the pygmy hog (*Sus salvanius*). Both species occur in the tall grasslands of India and Nepal (Bell 1986; Bell and Oliver 1992).

Bell (1987) studied the biology and conservation problems of the hispid hare in the Sukla Phanta Wildlife Reserve in western Nepal. The results indicated that the hispid hares were confined to patches of unburnt tall grassland along streams, where they were vulnerable to predation. Similarly, Oliver (1980), in Barnardi reserve forest, Assam, found that the hispid hare and the pygmy hog were confined to small areas of unburnt tall grasslands in post-burn areas, where they were vulnerable to disturbances and poaching.

The populations of hispid hare have been declining over the previous range, as a result of widespread clearance of their tall grassland habitat for agricultural land and human settlements, together with cutting of grass, burning, and overgrazing. Oliver (1985) concluded that the long-term survival of the hispid hare population remained at risk as a result of the current management policies where tall grassland is burned or harvested for thatch and canes during the dry season.

Livestock Grazing and Small Mammals

Livestock can affect small mammals directly by trampling burrows, compacting soil, and competing for food; and indirectly by altering the structure or species composition of vegetation in a manner that influences habitat selection. The effect of grazing does, however, vary with the environmental conditions and type of plant communities. The vegetation cover influences the distribution and abundance of small mammals. Some species prefer tall grassland cover, whereas other species use short grassland or open areas more intensively.

It is very difficult to generalise the effects of grazing on small mammals. Hayward *et al.* (1997) reported that 50% more white-footed mice were found in ungrazed areas than in grazed areas. Grand *et al.* (1982) noted that the variety and abundance of small mammal communities depends on how grazers have utilised the grassland.

Conclusions and Recommendations

Widespread cutting and burning and grazing can have significant effects on disturbance intolerant or cover-dependent small mammals. Thus patch burning is recommended as a conservation measure (Fyfe 1980; Braithwaite 1987; Fa and Sanchez-Cordero 1993; Johnson 1997). Fire can reduce the input of litter and lead to increased floristic diversity (Peet *et al.* 1997).

Cutting of grass should be allowed under a patch management system in the protected areas. An alternative resource should be explored for thatch (Brown 1997; Peet *et al.* 1997). The patch management system could be effective if the buffer zone people are only allowed into the protected areas to harvest thatch and reeds. Such a system would provide opportunities to the local communities to generate income by selling surplus thatch and reeds, and provide them with an economic reason to protect the grasslands.

At the beginning of this century, burning would probably have produced a mosaic of burned and unburned grassland with different ages of post-burn regeneration. Today, with increasing human pressure on grasslands, virtually the entire area of grassland is cut and burned annually so that only a very limited area is left as a refuge for small mammals. This means that hispid hares and pygmy hogs are seriously threatened. Unfortunately, the ecological consequences on many of the small mammal species in the Indian sub-continent are unknown and inventories of these species in the grasslands are poor.

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Impact of Grassland Management on Avian Fauna

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Abstract

Tall moist lowland grasslands are by far the most threatened habitat in Nepal and probably in the entire Indian subcontinent. More than one third of globally threatened bird species in Nepal live in lowland grasslands. Tall moist grasslands were surveyed at different times of the year for three consecutive years in three protected areas of lowland Nepal. A total of 219 species of birds were found to be using lowland grasslands at different times of year. The effects of management regimes such as fire, floods, and grazing were studied. The grassland management in lowland protected areas differed in space, time, and habitat grain. The effects of grassland management on avian fauna were studied. Better understanding of grassland dynamics is recommended to facilitate effective grassland management.

Introduction

The tall grasslands in Nepal are found in the fertile Gangetic plain in the southern part of the country. In former times, the grassland habitat was more or less continuous from west to east Nepal, occurring mainly along the floodplains of rivers. Since 1954, the Government of Nepal has been actively engaged in the eradication of malaria in lowland Nepal with funding from USAID. The government encouraged people to cultivate the low-lying fertile plains in order to remove increasing pressure in the mid hills of Nepal and increase the agricultural productivity of the country. During the 1950s, hill people migrated in large numbers to lowland Nepal in the quest for agricultural land (Bhatt 1977). It was during this period that most grasslands and marshlands disappeared from the country as a result of cultivation. Previous to this period, movement of people was restricted to the winter months as malaria was prevalent in the summer. Grasslands soon vanished from many areas and today there are no tall moist grasslands of any size in Nepal outside the protected areas.

In many parts of the world, grassland research has now been given top priority (Collar 1996; Goriup 1996) and several studies have been conducted (Glover 1969; Goriup 1992; Leslie 1996). Grasslands in Europe have been highlighted as an important feeding and breeding habitat for birds (Goriup 1992). The grasslands in the Indian subcontinent are more significant on a global scale than those in Europe (Collar 1996). In India, a significant amount of information has already been collected on bird species (Narayan and Rosalind 1990; Javed and Rahmani 1991; Iqbal *et al.* 1994), grassland bird communities (Rahmani 1986, 1992; Majumdar and Bramhachari 1986), and grass cover types (Dabadghao and Shankaranarayan 1973).

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In Nepal, many of the large mammals found in grasslands (Schaff 1978; Laurie 1979; Mishra 1982; Dhungel and O'Gara 1985; Moe and Wegge 1997; Peet 1998) and the structure of these grasslands (Lehmkuhl 1994; Peet 1998) have been well studied. Comparatively little is known, however, about the avian fauna and the impact of management effects on avian fauna has been little studied in the context of the lowland grasslands. More is known about the socioeconomic issues related to grasslands and protected areas especially in Chitwan (Mishra 1984; Heinen 1993b; Sharma and Shaw 1993; Banskota *et al.* 1998).

At present there are five protected areas in the Terai region of Nepal, the name given to the plain that lies along the southern border of the country between 75 and 300 masl. One of the areas, the Parsa Wildlife Reserve, is a continuation of the Royal Chitwan National Park. All of the Terai protected areas lie within the same ecological zone. Together they comprise a total of 272,900 ha of land, of which roughly 50,000 ha is estimated to be grassland in various forms (Table 2). The Parsa Wildlife Reserve has very little grassland.

Study Area

Two of the protected areas, Royal Chitwan National Park and Royal Shukla Phanta Wildlife Reserve, were chosen for the study. Observations were also made in the easternmost reserve, Koshi Tappu, in 1996 and 1997, and Royal Bardia National Park was visited briefly in March 1998.

The Royal Shukla Phanta Wildlife Reserve (hereafter called Shukla Phanta) lies in the extreme south-west of the Terai (between 28°49' and 28°57' N and 80°07' and 80°15' E) and is the smallest of the protected areas. It covers 15,500 ha and ranges in altitude from 90 m to 270 m (IUCN 1993). Approximately 55% of the reserve—the southwest where soils are of recent alluvium—is covered by mixed deciduous forest, grassland, and marsh. The remainder is moist deciduous forest and savanna, supported by the better-drained soils on higher terrain in the northeast (IUCN 1993). The reserve possesses the largest grassland phantas in Nepal. There is a plan to extend the reserve at the eastern side. When this plan is realised and protection is afforded, more phantas will be created. After this extension, the total area of Shukla Phanta will be 30,500 ha (Tirtha Man Maskey, personal communication). The climate of Shukla Phanta is hot and dry. The grassland soil here is drier than in Chitwan. In April and May, warm and dry westerly winds blow across the phantas during the late afternoon generally settling before sunset.

A total of 30 species of mammals and 350 species of birds (Bird Conservation Nepal 1998) have been definitely recorded in the reserve. The grasslands at Shukla Phanta support a high population of *Houbaropsis bengalensis* (Inskipp and Inskipp 1983), *Francolinus gularis* (Baral 1998a), *Chaetornis striatus* (Baral 1997), and *Saxicola insignis* (Baral 1998c), all taxa that are considered to be threatened globally (Collar *et al.* 1994). Recently, two grassland birds found in Shukla Phanta were presented as new species to Nepal (Baral 1998b). One of these, *Ploceus megarhynchus*, is a globally threatened species (Collar *et al.* 1994) and previously described as endemic to India (Ali and Ripley 1987). Shukla Phanta also supports a large population of *Cervus duvauceli duvauceli*, a globally threatened ungulate species (Groomebridge 1993).

The Royal Chitwan National Park (hereafter called Chitwan) lies in the central Terai of Nepal (between 27°15' and 27°35'N and 83°45' and 84°58'E) between the Siwalik Hills in the south and the Mahabharat Hills to the north. Chitwan is an inner Doon valley situated between these two southernmost ranges of hills. All the other protected areas in lowland Nepal lie beyond the final range of hills. The total area of Chitwan is 93 200 ha. It is bordered by Parsa Wildlife Reserve (49,900 ha) to the east and is located in the drainage basin of three major rivers, the Narayani, Rapti, and Reu. Chitwan has numerous small patches of grasslands lying alongside the rivers. These riverside grasslands vary in width from a few metres to 1,500 m. Approximately 70% of the park is covered by sal forest (Laurie 1979), the remainder being grassland and riverine forest.

Chitwan is an important site for grassland birds, particularly for *Houbaropsis bengalensis* (Inskipp and Inskipp 1983), *Sypheotides indica* (Inskipp and Inskipp 1991), *Moupinia altirostris* (Baral and Eames 1991), *Turdoides longirostris* (H. S. Baral unpublished data), *Chaetornis striatus* (Baral 1997), and *Prinia cinereocapilla* (H. S. Baral unpublished data). Chitwan is the only place in Nepal where *Turdoides longirostris* has been recorded. Chitwan also supports a quarter of the world's population of *Rhinoceros unicornis*, a globally threatened mammal (Groomebridge 1993).

The Koshi Tappu Wildlife Reserve (hereafter called Koshi Tappu) occupies 17,500 ha of the Sapta Koshi River floodplain at the most northeasterly extension of the Gangetic Plain (between 26° 35' and 26° 40' N and 86° 56' and 87° 04' E). It ranges in altitude from 75 to 81 m (IUCN 1993). The reserve is located between two flood control embankments and is subject to annual flooding (Heinen 1993a). Approximately 70% of the reserve's land area is grassland (Heinen 1993b). During high flood years a large amount of grassland is destroyed to be replaced by new alluvial deposits.

The reserve contains Nepal's last population of *Bubalus bubalis*, and is further protected as a Ramsar Site, for its importance to migrating wildfowl (IUCN 1993). *Bubalus bubalis* is a globally threatened species (Groomebridge 1993). Beside being an important site for migrating waterfowl, Koshi Tappu is important for grassland birds like *Houbaropsis bengalensis* (Inskipp and Inskipp 1983), *Saxicola insignis* (Inskipp and Inskipp 1991), *Francolinus gularis* (Baral 1998a), and *Chaetornis striatus* (H. S. Baral unpublished data). The reserve faces problems like illegal grazing, collection of fodder, felling of trees, and hunting from the surrounding villages (Giri 1997; Petersson 1998).

Methods

Methods were made consistent and kept the same throughout the study period. In this paper, I have tried to summarise my observations on the dynamics of grassland vegetation in all the protected lowlands of Nepal since the mid-80s. This paper, presents some preliminary results of the study on the impacts of grassland management on avian fauna. A detailed report of this work will be published once the data analysis is complete.

Transect Counts

Linear transects were laid out in different grassland types in the three study sites. The length of the transects varied from 100 m to 1,300 m. Each transect was

divided into sections of 100 m to standardise observations. Habitat data were recorded for each 100 m section. For all observed birds, the exact distance along the transect and the distance to the right or left were estimated to calculate the density of birds (Bibby *et al.* 1992).

A data sheet was filled out for each visit in which all bird observations were recorded. The species, number, sex, location, behaviour, and overall height of the vegetation used by the birds were noted on the bird data sheet. Only positive identification to species level was used in the final analysis.

Environment Data

A data sheet on the habitat was prepared for each transect. If notable changes had taken place between two visits (either natural or human induced), a new habitat sheet was made. From the beginning, the importance was recognised of recording enough habitat variables to enable easy interpretation of the bird distribution in relation to the habitat (Laurie 1979). These variables were grass species composition, soil moisture, phenophase of grasses, average vegetation height, percentage of bare ground, presence of vegetation other than grasses and their percentage, type and average height of grasses, grazing pressure, data on whether the area had been burned or cut, disturbance by people, and proximity to water and forest. Data were collected in the morning or late afternoon.

Data Analysis

The data were stored in a relational database using the Paradox Database Program. The results presented in this paper are the results of simple queries performed in Paradox.

When the data have been fully analysed a consolidated report will be prepared (University of Amsterdam, Netherlands) outlining some suggestions for optimal grassland management for birds. Analysis of Variance (ANOVA) and TWINSPLAN programmes will be run to discover the bird communities associated with different grassland types using the MINITAB programme. Canonical Correspondence Analysis (CCA) and Detrended Correspondence Analysis (DCA) will be run to confirm these associations using the CANOCO programme (Jongman *et al.* 1995). The density and abundance of birds will be estimated using the DISTANCE programme (Bibby *et al.* 1992).

Results and Discussion

Some important information on grassland birds' ecology was collected during this study. More rigorous data analysis is expected to shed light on bird density, habitat association, and community structure in grasslands. Some preliminary findings on the grassland management and its effect on avifaunal life are presented. Fire, flood, cutting, grazing, and disturbance were recognized as the major ecological factors that effect avifaunal life in the grasslands. A total of 219 species of birds were identified as using lowland grasslands in various ways (H. S. Baral unpublished data). Of these 219, 10 species that depend exclusively on lowland grasslands are threatened globally (Table 4) (Collar *et al.* 1994, BirdLife International unpublished data). Species of global concern such as *Leptoptilos javanicus* and *Pseudibis palpebrosa* (Collar *et al.* 1994) were also observed

frequently in the short grasslands. Nine species found in the lowland grasslands are considered to be threatened at the national level (Baral *et al.* 1996). The present study identified *Cettia pallidipes* as another nationally threatened bird that also has a restricted world distribution.

Table 4. Threatened birds of the lowland grasslands in Nepal

English Name	Scientific Name
a. Threatened globally or in Asia	
Lesser Florican	<i>Sypheotides indica</i>
Bengal Florican	<i>Eupodotis bengalensis</i>
Swamp Francolin	<i>Francolinus gularis</i>
Sarus Crane	<i>Grus antigone</i>
Jerdon's Babbler	<i>Chrysomma altirostre</i>
Slender-billed Babbler	<i>Turdoides longirostris</i>
White-throated Bushchat	<i>Saxicola insignis</i>
Grey-crowned Prinia	<i>Prinia cinereocapilla</i>
Bristled Grassbird	<i>Chaetornis striatus</i>
Yellow Weaver	<i>Ploceus megarhynchus</i>
b. Threatened in Nepal	
Great Bittern	<i>Botaurus stellaris</i>
Black Bittern	<i>Dupetor flavicollis</i>
Yellow Bittern	<i>Ixobrychus sinensis</i>
Blue-breasted Quail	<i>Coturnix chinensis</i>
Small Buttonquail	<i>Turnix sylvatica</i>
Yellow-legged Buttonquail	<i>Turnix tanki</i>
Eastern Grass Owl	<i>Tyto longimembris</i>
Rufous-rumped Grassbird	<i>Graminicola bengalensis</i>
Striated Grassbird	<i>Megalurus palustris</i>
Pale-footed Bush-Warbler	<i>Cettia pallidipes</i>
Source: BirdLife International and Bird Conservation Nepal unpublished data; Collar <i>et al.</i> 1994; Baral <i>et al.</i> 1996.	

Chitwan and Koshi Tappu contained the largest number of globally threatened species, 18 and 17 respectively, followed by Shukla Phanta (14), Bardia (11), and Parsa (2) (Table 5). For its size, Shukla Phanta may be the most significant grassland reserve in the world as it contains internationally significant populations of many globally threatened taxa. Shukla Phanta has internationally significant populations of six globally threatened species, Chitwan of five species, Koshi Tappu of four, Bardia of three, and Parsa of one. At the national level, Chitwan and Shukla Phanta seem to be the most outstanding grassland reserves in Nepal, harbouring 10 and 9 nationally threatened species each. This simple analysis shows the importance of Shukla Phanta, Chitwan, and Koshi Tappu as the main grassland reserves in Nepal. As in other parts of the world (McCrea 1981), Nepal also needs to declare some protected areas as 'grassland reserves' to highlight the grassland and the fauna associated with it.

Table 5. Protected areas with grasslands and threatened species

Parks/Reserves	Total Area (sq.km)	Grassland Area (sq.km)	Threatened Birds		
			Global	Important Populations*	National
Royal Shukla Phanta WR	155	76	14	6	9
Royal Chitwan NP	932	185	18	5	10
Royal Bardia NP	968	190	11	3	3
Koshi Tappu WR	175	60	17	4	6
Parsa WR	499	<20	2	1	1?
Total	2,729	<531			

* Internationally significant populations of globally threatened species
 Source: Department of National Parks and Wildlife Conservation, BirdLife International, and Bird Conservation Nepal unpublished data

Grassland Fires

In many regions of the world the practice of burning grassland dates back many thousands of years. Fire has been recognised as an integral part of the grassland ecology in many parts of the world (Mentis and Bigalke 1981; Braithwaite 1987; Braithwaite and Estbergs 1987; Bell and Oliver 1992). Fire and floods have been described as the two main factors affecting the vegetation in Chitwan (Gurung 1983), and this is true for almost all the protected areas of lowland Nepal. Work on grassland management for mammals (Bell 1987; Moe and Wegge 1997; Peet 1998) and birds began only very recently in Nepal (Inskipp and Inskipp 1983; Weaver 1991; Baral 1998a,c).

When it is said that a particular grassland has been burned, it does not mean that everything present was turned into ashes. The extent of burning depends on such things as intensity of the fire, the grass species, soil condition, and phenophase of the grasses. Very intense fire can easily burn many grass species, leaving at most some lower parts of the grass stems of more resistant species. Usually fire is more intense in the early afternoon than in the morning and evening. Short grasses like *Imperata* are burnt wholly and almost nothing is left. In many grass species that have a thick stem like *Narenga porphyrocoma*, *Saccharum benghalensis*, and *Phragmites karka*, only the leaves and upper parts of the stem are burned even by intense grassland fire. The accumulation of moisture and the compact nature of the grass stem prevents the stem from burning. Generally, grasses growing in dry soils burn better than those in wetter soils. Old, dry, and dying grasses are burned better than young, developing, or mature green grasses. Some incompletely burnt grassland has to undergo repeated and irregular episodes of fire before it is completely burnt. Such repeated fires, which are prevalent in grasslands at the edge of and in forests, could prove fatal to some birds such as *Prinia cinereocapilla* and *Cettia pallidipes*. Both species are little known and threatened.

The Ecological Role of Grassland Fire

Gurung (1983) wrote: "Drongos follow the fires, often dangerously close, manoeuvring with amazing agility to catch the insects that fly off to escape the flames; hen harriers and other raptors hunt for rodents and lizards over the

newly-open, burned-out ground". His vivid observations while he worked during the late 70s and early 80s as a naturalist in Chitwan are the best remarks on the ecological role of the grassland fires that affect lowland grassland birds in Nepal.

Until the study is complete it is difficult to gauge the effect of fire because real effects can only be recognised from a long-term study. Generally, the immediate effect of fire appeared to be an increase in bird diversity and abundance. Fire seemed to encourage the growth of new grass shoots and thus provide an abundant food supply for many species such as drongos, *Artamus fuscus*, swallows, owls, bee-eaters, rollers, *Halcyon smymensis*, stonechats, and *Lanius schach*. *Houbaropsis bengalensis* were observed feeding on the new shoots of grass a couple of days after fire had swept through an area. Drongos, swallows, bee-eaters, and rollers were seen following the fire-front in grassland fires.

Burnt grasslands were mainly avoided by the species that needed dense and tall grasslands, such as *Prinia flaviventris*, *Timalia pileata*, *Saxicola jerdoni*, *Graminicola bengalensis*, *Megalurus palustris*, and *Chaetornis striatus*. There were many species, however, such as *Saxicola* species, *Luscinia* species, *Turdus ruficollis*, *Dicrurus macrocercus*, *Sturnus vulgaris*, and *Acridotheres* spp. that showed a marked preference for burnt grassland over unburnt areas. Generally, most of the birds that lived exclusively in tall grassland habitats showed a marked preference for unburnt grasslands. Species such as *Acrocephalus dumetorum* and *Prinia subflava* were absent from partially burnt grasslands (Table 6).

It is a proven fact that in some cases diversity will be highest at intermediate levels of disturbance; whereas large and frequent disturbance will tend to decrease diversity (Begon and Mortimer 1986). Partially burnt grasslands away from forests (>100 m) showed a slightly increased bird diversity and nearly double abundance (Table 7). Unburnt and totally burnt grasslands showed less diverse bird communities and lower abundance. Fire, if managed properly, may actually help the birds by maintaining the grasslands so that they are suitable for the species. Fire could be taken as a strong tool for conservation and management of grasslands. Various researchers have considered the importance of fire in the management of grasslands (Dinerstein 1979a, 1979b; Rodgers 1986; Roy 1986).

Along transect 25, which was partially burned, bird abundance was 125 before and 235 after the fire. The diversity before fire was 25 and after fire 28. After fire several bird species seemed to be exploiting the newly burned but resource rich ephemeral habitat. The most numerous among them were *Dicrurus macrocercus*, *Merops orientalis*, *Turdus ruficollis*, and *Acridotheres fuscus*.

A total of 1,690 birds, were registered prior to cutting and burning of grass (before 6 February 1998 in Chitwan) and 3,129 after cutting of grass. This was a near two-fold increase in bird abundance; but there was no significant change in bird diversity except in a few transects (Table 7). The increase in abundance could be attributed partially to the creation of more open habitat that perhaps also increased detectability for the observer. Grassland transects away from

Table 6. Birds seen during five visits before and after transect 25 was partially burned in Chitwan

Scientific Name	Abundance	
	Before fire	After fire
<i>Acridotheres fuscus</i> **		3
<i>Acrocephalus dumetorum</i> *	1	
<i>Amandava amandava</i>	18	42
<i>Centropus sinensis</i> *	4	
<i>Cettia brunnifrons</i>	3	3
<i>Cettia flavolivacea</i>	7	6
<i>Cettia pallidipes</i> **		2
<i>Chrysomma sinense</i> **		3
<i>Dicrurus macrocercus</i> **		1
<i>Ficedula parva</i> *	2	
<i>Gallus gallus</i> **		3
<i>Graminicola bengalensis</i>	4	7
<i>Lanius schach</i>	5	5
<i>Luscinia pectoralis</i>	7	9
<i>Melophus lathami</i>	3	5
<i>Merops orientalis</i> **		1
<i>Oriolus xanthornus</i> *	2	
<i>Orthotomus sutorius</i> *	4	
<i>Pavo cristatus</i>	1	8
<i>Prinia flaviventris</i>	3	7
<i>Prinia hodgsonii</i>	6	29
<i>Prinia socialis</i>	3	15
<i>Prinia subflava</i> *	1	
<i>Psittacula cyanocephala</i>	1	2
<i>Psittacula eupatria</i> *	4	
<i>Psittacula krameri</i> **		2
<i>Pycnonotus cafer</i>	5	9
<i>Pycnonotus jocusus</i> **		1
<i>Rhipidura albicollis</i>	1	1
<i>Saxicola torquata</i>	1	4
<i>Tephrodornis pondicerianus</i>	7	1
<i>Timalia pileata</i>	28	58
<i>Turdoides longirostris</i>	4	5
<i>Turdoides striatus</i> **		2
<i>Turdus ruficollis</i> **		1
* Species only recorded before fire		
** Species only recorded after fire		

forests showed trends similar to transect number 25. The grassland transects in and close to forest areas showed a general decline of bird abundance immediately after the fire.

Table 7. An overview of bird diversity before and within a month after transects were burned in the Chitwan grasslands

Transect No.	Before Fire		After Fire	
	Diversity	Abundance	Diversity	Abundance
4	18	115	25	85
5	27	134	37	303
6	6	40	9	45
7	12	44	19	119
8	23	99	33	230
10	38	317	24	202
12	32	144	22	114
16	6	10	18	98
21	42	261	51	384
25	25	125	28	235
26	25	139	25	176
27	17	41	12	27
28	12	64	16	73

Italicised figures show grassland transects close to or within forests, these had a lower bird diversity after fire.

The Role of Floods

Flooding occurs in all types of flowing waters during the monsoon in Nepal. The major rivers such as the Koshi in the east; Reu, Rapti, and Narayani in the central Zone; Babai, and Karnali in the west; and Mahakali in the far west contribute 90% to the formation of the existing major tall grasslands in lowland Nepal. The effects of flooding have been studied less than the effects of fire. Flooding, however, is an important natural factor that may have contributed more grassland areas than fire. The impact of flooding on grasslands and their associated fauna are no less than the effects of fire. Irrespective of grass composition, flooding affects all low-lying ground, very often sweeping over large grassland areas at one time.

Flood swept grassland areas were generally devoid of highly sedentary grassland specialist birds like *Timalia pileata*, *Graminicola bengalensis*, and *Chrysomma sinense*. As the flood receded from the grasslands, birds colonised the flood swept areas immediately from 'adjoining grasslands' as soon as the habitat was restored. The 'adjoining grasslands' were presumably on higher ground than the flood level. This seemed to be a common phenomenon in lowland flood affected grasslands. However, large areas of grasslands in Koshi Tappu were found devoid of species that were fairly common in Chitwan and Shukla Phanta in similar grassland types. A possible reason might be that there were no suitable 'adjoining grasslands' to provide refuge for these grassland specialists when most of the area in Koshi Tappu was flooded.

The grassland bird communities in Koshi Tappu, were highly influenced by annual flooding and excessive grazing by domestic livestock. Unfortunately, this study could not look into the details of the flood dynamics, although this is an important element in grassland management.

Grazing

Open fields of short grasslands were the result of intensive grazing, mainly from domestic livestock. Overgrazing in grasslands destroyed the habitat of many grassland specialists that required tall grasses, for example, *Timalia pileata*, *Graminicola bengalensis*, and *Saxicola leucura*. When grazing was stopped, the grasses resumed their original height. Low and moderate levels of grazing might be beneficial for bird communities. Similar effects have been observed in studies conducted in other parts of the world (Campbell-Kissock *et al.* 1984; Dale 1984).

Intensive grazing seemed to benefit some of the more common grassland birds, for example, *Anthus* spp., *Mirafra* spp., *Alauda gulgula*, *Motacilla* spp., *Acridotheres ginginianus*, *Turdus ruficollis*, *Acridotheres* spp., and *Sturnus* spp. However, most of the threatened grassland birds suffered from intensive grazing.

Grassland management is widely discussed and is a hot issue in many parts of the world. Grasslands could be managed both for wildlife and for the prosperity of villagers living nearby. A thorough study is important to discover the best way to manage grasslands for both wildlife, including birds, and people (Blankespoor 1980; Stuth 1996).

Cutting of Grass

Cutting alone resulted in a negative response from many species and only a few birds seemed to occupy cut plots when there was a choice of a burnt plot nearby. We noted *Fringilla gularis* frequently in such habitats. Once cut, many grassland areas became devoid of cover and unsuitable for feeding. Of all the regimes, cutting alone showed the worst effects on species. The long-term effects of cutting alone are not yet known, however.

Ploughing

Cutting and ploughing generally resulted in decreased avian diversity. Birds like *Anthus rufulus*, *Pavo cristatus*, *Alauda gulgula*, and *Streptopelia* spp. seemed to prefer ploughed areas for feeding. However, although ploughing created open areas suitable for many birds as feeding grounds, the absence of perches and suitable cover led them to avoid such areas. Experimental manipulation of ploughed grasslands in Shukla Phanta was attempted. In the winter of 1997 and 1998, ploughed grasslands that were devoid of tall perches were provided with perches. *Saxicola* spp. and *Merops* spp. seemed to use these artificial perches frequently. Similar studies have been conducted in grasslands of the north-eastern United States (Vickery and Hunter 1995).

Current Practices of Grassland Management

Grassland management was initiated in Shukla Phanta and Chitwan in 1996. As part of the management, many grassland areas that were listed as strongholds for *Houbaropsis bengalensis* (Inskipp and Inskipp 1983) were ploughed during 1996-98. There were two main reasons for the practice. The first was to prevent short *Imperata* grasslands from being encroached by taller, hardy, and coarse grass species; and the second to increase sightings of deer and other mammals for visitors.

Though started with good intentions, the results of this practice showed negative results in Chitwan. The natural succession of short grasses by the taller and hardier species was actually speeded up, in particular near Dumaria Guard Post. Within two to three years, most *Imperata* grasses had given way to other hardier and taller grass species. Chitwan is more humid than Shukla Phanta, thus the type of grass management practised had particularly negative effects where moist-loving invasive grass species such as *Narenga porphyrocoma* and *Saccharum bengalensis* were found in abundance.

The effect of management in Shukla Phanta was probably moderate and no obvious negative effects were noted during the study period. Long-term observations are needed.

It is vital that we first understand the nature and life cycle of the grasses that are found in lowland grasslands before management regimes are proposed. The results of studies from other regions and parts of the world should be reviewed when we manage grassland habitat for wildlife.

Conclusions

The present grassland areas are not sufficient to maintain the populations of several globally and nationally threatened taxa. Although in recent years attention in Nepal has been drawn towards active grassland management, some of the existing grasslands are still being rapidly succeeded by woody vegetation and this poses a threat for the future survival of many grassland bird species. Thus management interventions are necessary to conserve the grassland habitats in a manner suitable for the many grassland birds. Research in other parts of the world has shown that in carefully managed areas declining species can respond positively (Swengel 1996).

Recommendations for Conservation and Research

If protected areas in lowland Nepal are proposed for extension, considerable thought should be given to the inclusion of as much grassland area as possible. Highly grazed open areas, if given proper protection, are colonised naturally by either *Saccharum spontaneum* or *Imperata cylindrica* grasses. The colonisation is rapid and the results can be seen within a year.

Shukla Phanta and Chitwan should be declared as grassland reserves of international importance on the basis of the avian and mammalian taxa they contain. HMGN should take the initiative and then seek international support.

The open ground on the eastern side of Shukla Phanta Wildlife Reserve near Radhapur and Jhilmila could be converted to a grassland area of outstanding importance for both birds and mammals. This open area starts at Jhilmila, extends almost five km to the north, and has an average breadth of 500 m. This area is already inside the reserve and under proper protection it could be a safe haven for many grassland birds and mammals. It is quite likely that birds such as *Houbaropsis bengalensis*, *Sypheotides indica*, *Francolinus gularis*, *Chaetornis striatus*, and *Saxicola insignis* will find a suitable home in these grasslands. If the reserve finds it difficult to manage this, a community grassland approach could be tried. This latter approach is a replica of the community forestry concept that

is widely accepted all over Nepal. Reserve wardens and wildlife technicians should guide village communities to ensure the best utilisation of grasslands for both people and wildlife. This approach can be developed as a future conservation project in Nepal with support and guidance from organisations like BirdLife International. BirdLife International should collaborate with the government of Nepal and Bird Conservation Nepal in these kinds of projects.

Burning should be monitored regularly. It should not coincide with the breeding time of birds. Repeated fire in grasslands could be harmful for birds and other taxa. Instead of cutting large areas of grasslands at one time, an experiment with small patch clearing should be carried out. This might prove beneficial to certain birds. Patch ploughing should be experimented with rather than ploughing large areas of grasslands. A tentative suggestion for managing *Imperata cylindrica* grasslands is described stepwise below. This experiment should be carried out in areas where there are no known threatened bird inhabitants and limited to a small area. It can be stopped immediately if negative results or no significant positive changes are noted.

- Burn the plot between January and February
- Remove unburned reeds and woody vegetation manually
- Plough in such a way that the plough penetrates at least six inches (15 cm) into the earth
- Compact the ground with the help of the type of machine used in road works
- Leave the area for natural regeneration

Grassland management should be focused on providing more habitats for globally and nationally threatened birds. The current practice of grassland management in Nepal is mainly aimed at increasing the population of large mammals. This practice, which overlooks the threats to other smaller taxa, should be changed. With improved grassland management it may be possible to maintain a healthy population of all taxa within the ecosystem concerned. The DNPWC should consult researchers who have worked in the grasslands of Nepal and their suggestions should be taken into account in the management of grasslands.

Grassland research on such things as flora, succession, and fauna should be started as soon as possible. The socioeconomic side should be taken into account while conducting management studies of grasslands.

A grassland conservation forum should be formed under the aegis of DNPWC. This forum, consisting of technicians, researchers and planners, should be a formal group that acts as a watchdog for grasslands and their associated fauna.

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Parsa Wildlife Reserve, located in the Central Terai, was declared in 1984 as an extension of the Royal Chitwan National Park to provide additional coverage of the unique habitat for the increasing population of wild animals in the National Park. Since the reserve is primarily located in the Bhabhar region south of the Chitwan hills, the area is covered with dense forest and has hardly any natural grassland. However, a small patch of grassland has been created by clearing the acacia trees planted as a part of a reforestation project before the reserve was declared. There is a plan to create more grassland by clearing another acacia patch and by relocating some animals inside the reserve. The newly created grassland has provided a good grazing ground for wild animals and a patch of grass for the local people. The reserve is also the area where grasslands will be created in the future. The reserve is expected to help in the conservation of biodiversity within the Terai.

Status of Grasslands in *Terai* Protected Areas: Management Issues and Gaps

Status Paper of Parsa Wildlife Reserve

Surya Bahadur Pandey ^a

Abstract

Parsa Wildlife Reserve, located in the central Terai, was gazetted in 1984 as an extension of the Royal Chitwan National Park to provide additional coverage of the pristine habitat for the increasing population of wild animals in the National Park. Since the reserve is primarily located in the Bhabhar region south of the Churia hills, the area is covered with dense forest and has hardly any natural grassland. However, a small patch of grassland has been created by clearing the eucalyptus trees planted as a part of a research project before the reserve was declared. There is a plan to create more grassland by clearing another eucalyptus patch and by relocating existing settlements inside the reserve. The newly-created grassland has provided additional grazing land for wild animals and thatch grass for the local people. The same is expected from the area where grasslands will be created in the future. This change is intended to help in the conservation of biodiversity within the reserve.

Introduction

Established in 1984, and lying within 27° 15' - 27° 33' N and 84° 41' - 84° 58' E, Parsa Wildlife Reserve (PWR) protects 499 sq.km of habitat within Nepal's Terai, Inner Terai, and Churia hills. The elevation ranges from 150 masl to 800 masl (Chaudhary *et al.* 1995). The PWR extends from the Royal Chitwan National Park (RCNP) in the west to the Hetauda-Birgunj highway in the east; The northern and southern boundaries are demarcated by the Rapti River and main Churia ridge, and a 36 km long forest road, respectively. The park hosts an incredible amount of biodiversity

A proposed buffer zone for the reserve encompasses 369 sq.km in 19 village development committee areas (VDCs) in three districts, Bara, Parsa, and Makwanpur. Four small villages are located inside the reserve—two on the southern side of the Churia hills (Rambouri and Bhata with about 55 ha of agricultural land) and two in the inner Terai along the Rapti River (Ramouli and Pratappur with about 150 ha).

The total number of households in the buffer zone area is estimated to be about 10,500 with a population of 84,000 (unpublished data). The majority of the indigenous people are Tharu, Dhangar, Yadav, or muslims, with minorities of Mushar, Hazra, and Malaha. There are also a number of *pahadia*, people who migrated from the hills after the eradication of malaria in the 1950s.

The uniqueness of PWR lies in its distinction as being set aside exclusively for the wild Asian elephant (*Elephas maximus*). Approximately 35 individuals of this endangered species are found here, along with many other endangered mammals including the royal bengal tiger (*Panthera tigris*), striped hyaena (*Hyaena hyaena*), four-horned antelope (*Tetracerus quadricornis*), and,

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occasionally, the one-horned rhinoceros (*Rhinoceros unicornis*)—which crosses the boundary from RCNP to the reserve.

Altogether 33 species of mammals and 31 species of butterflies (Budha *et al.* 1998) have been recorded in PWR. The endangered giant hornbill (*Buceros bicornis*) is one of an estimated 300 species of birds in the reserve. There are also many reptiles such as krait (*Bungarus caeruleus*), banded krait (*B. fasciatus*), common cobra (*Naja naja*), king cobra (*Ophiophagus hannah*), and the endangered Asian rock python (*Python molurus*) and golden monitor lizard (*Varanus bengalensis*).

A total of 333 recorded plant species (327 of them angiosperms) has been recorded. The vegetation is broadly categorised into six forest types: mixed deciduous hardwood, sal, sal-pine, pine, acacia, and mixed deciduous riverine forest (Chaudhary *et al.* 1995). Sal (*Shorea robusta*) and its associated species are predominant covering about 90% of the reserve area. There are no natural grassland habitats.

PWR's ecological goals are the provision of additional habitat for offspring of the RCNP, securing the wild elephant habitat, and protecting the unique Churia range. These goals are encompassed by PWR's overall objective to enhance the conservation of the natural ecosystem in a sustainable way.

Grasslands: Status and Significance

The reserve has no naturally occurring grassland. However, in 1996 3.45 ha of shrubs, bushes, and eucalyptus trees were cleared to create grassland. These trees were planted under a research project (no longer in operation) several years before the area was declared a wildlife reserve. This new grassland lies just west of the headquarters in Adhavar and north of the reserve's southern boundary. The aim was to provide wildlife with a suitable grazing habitat. The main components of the grassland are kush (*Vetiveria zizanioides*) and siroo (*Imperata cylindrica*). Some of these grasses grow up to five metres high during the monsoon.

A nearby observation tower overlooks the grassland and thus enables easier viewing of wildlife. Throughout the year, herds of spotted deer (*Axis axis*), hog deer (*Axis porcinus*), and gaur (*Bos gaurus*) can be observed in this new grassland. Bird species are attracted too: so far nearly 80 species have been observed in and around the grassland. Commonly-sighted birds include red jungle fowl (*Gallus gallus*), spotted dove (*Streptopelia chinensis*), chestnut-headed bee-eaters (*Merops leschenaulti*), owls, pheasants, and warblers.

Grassland Management Activities

Since the conversion of the forest patch into grassland in 1996, controlled burning has been done once a year to help prevent invasion by trees. Similarly, villagers from outside the park are allowed to cut the grasses once a year in winter for their own use, thereby benefiting the local community.

Research Activities

Research has been done in PWR and its surrounding villages, on the biodiversity and cultural diversity (Chaudhary *et al.* 1995; Budha *et al.* 1998),

the status of gaur (*Bos gaurus*), and the status and behavior of chital (*Axis axis*). Although these research activities were not directly related to the grasslands, their results will help in monitoring the impact of the created and to be created grasslands on the status of biodiversity in general, and of wild animals in particular. In addition, the reserve authorities carry out regular monitoring of the movement of wild animals around the newly-created grasslands.

Management Issues

The reserve faces a variety of future challenges. Under the proposed management strategy framework and the grassland conversions, the four settlements Rambouri, Bhata, Ramouli, and Pratapur would be relocated. This will need the cooperation and commitment of several stakeholders including local people, politicians, and government authorities.

Research Gaps/Needs

No detailed systematic research has yet been done on the change in plant species composition in the created grasslands. Such research is needed so that interventions can be made at an appropriate time for better habitat management. Similarly, research needs to be done on the biomass production and carrying capacity of such grasslands so that the population of wild animals can be maintained at the optimum level.

Baseline data on the species composition in and around the fields of settlements should be gathered. Once the area has been evacuated, regular monitoring of the successional changes should be done.

The impact of grass harvesting by local people on the newly-created grasslands should be monitored carefully so that harvesting can be done at the optimum level.

Management Recommendations

As a result of the observations of the benefits accruing from PWR's newly-created grasslands, another grassland conversion is proposed that would expand the created habitat. This conversion would take place directly north and adjacent to the first grassland and would replace a four hectare plot of exotic eucalyptus trees. The rationale behind this recommendation is that the eucalyptus trees do not belong to the natural vegetation inside the reserve. The trees draw away an incredible amount of the precious water needed for the native species, thus eradication of the trees is important for the quality of PWR as a representative of the indigenous vegetation of Nepal.

Similarly, the extension of the grassland area would increase the amount of grazing land available for wildlife, and this should reduce the frequency of wildlife crop-raiding outside the reserve. Subsequently, predators will be drawn to the grasslands for their survival. Common leopards (*Panthera pardus*) have recently been sighted around the newly-created grassland. This would help to maintain the natural food chain in the area.

In the future, the village areas of Rambouri/Bhata and Ramouli/Pratapur could also become grasslands. The reserve considers these villages to be problems as

a result of their impact on the ecosystem from over-grazing by livestock and the collection of firewood and fodder. Relocation of these settlements is proposed under a management strategy framework, with conversion of the land into grasslands. Rambouri/Bhata would provide about 55 ha, and Ramouli/Pratappur about 150 ha of grassland area. The near proximity of water at both of these sites is also advantageous as it would allow the new grasslands to flourish.

A further plan proposed in the management strategy is to extend the reserve's eastern boundary up to the Pashaha River in Bara District. This would provide extended habitat and protection for wild animals, especially for elephants. Elephants and other wildlife are known to cross the Hetauda-Birgunj highway, overstepping the reserve's current eastern boundary. This extension would include an important wetland, Halkhoria Daha, in the PWR thus providing more protected water sources in an area where surface water is scarce throughout most of the year.

Although detailed systematic research still has to be done, the proposed management activities are intended to help accomplish the following objectives.

- To provide additional habitat for wildlife in the form of grazing land
- To remove the exotic eucalyptus trees so that only native flora are represented
- To reduce the conflict between people and wild animals that graze on crops
- To curb the problems of over-grazing by livestock and of firewood and fodder collection within the reserve
- To benefit people by making more grass available for cutting for local use, thereby helping to foster a positive relationship between people and the reserve.
- To promote tourism by making viewing of wildlife easier

Conclusion

The Parsa Wildlife Reserve's converted grassland has attracted several species of wildlife and helped provide thatch grass to the local community. Other sites, including an adjacent plot of eucalyptus trees and four settlements inside the reserve, have been designated for possible future conversion to grasslands. Although some problems like over-grazing by livestock and collection of firewood and fodder from the reserve would be reduced as a result of the planned conversion, the issue of the relocation of the village settlements is a major problem that still needs to be addressed.

The creation of new grasslands would provide grazing land for the wild animals within the reserve and thus help minimise park-people conflicts. The proposed buffer zone, and the participation of local people in its management, will help both the sustainable management of the ecosystems and their biodiversity, and the development of the surrounding communities.

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Status Paper of Royal Bardia National Park

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Abstract

Royal Bardia National Park is the biggest national park (968 sq.km) of the lowland *Terai* of Nepal. Tall floodplain grasslands created by the Geruwa, Babai, and Orai river system, and phantas—previously cultivated and re-vegetated short grasslands—are the main grasslands of the park. In terms of size, there are three major grasslands: Bagaura, Khauraha, and Lamkauli. Issuing of grass-cutting permits has been continued to provide twin benefits: socio-cultural and economic benefits to the local community, and a management tool for the conservation of biodiversity. Allowing cutting of grass has also helped to minimise park-people conflicts. All these grasslands are being gradually encroached by tree species and invaded by unpalatable species. Grassland in the Babai valley is also decreasing in area as a result of succession. *Bombax* and acacia have almost covered the valley. Several short-term research studies have been carried out to look at different aspects of the grassland in the park. Management intervention by the park has been done to maintain these grasslands by incorporating traditional practices adopted by the local community and recommendations of researchers. However, concrete management intervention and a system of continuous monitoring of the impact of intervention is essential for long-term management of the grassland ecosystem.

Introduction

Royal Bardia National Park (RBNP) is the biggest national park (968 sq.km) of the lowland *Terai* of Nepal. In 1969 part of the area was established as a Royal Hunting Reserve. In 1976 it was gazetted as the Royal Bardia Wildlife Reserve (area 348 sq.km). Later, in 1984, the area was extended to include the Babai valley in the north-east, and renamed the Royal Bardia National Park.

Seven major vegetation types—sal forest, khair-sisso, moist riverine forest, mixed hardwood forest, wooded grassland, phantas, and floodplain grassland—have provided suitable habitat for more than 38 species of mammals (including 9 endangered), 25 reptiles, 60 fishes, and more than 400 species of birds. The Babai valley and Karnali flood plains are prime habitat for the reintroduced greater one-horned rhinoceros and migratory wild elephants.

RBNP is surrounded by 25 village development committee areas (VDCs) of which 17 are within the buffer zone of the park. Ninety thousand people of 11,000 households reside in the buffer zone. After the protected area was established, access to grass and grass products was restricted. Authorised cutting of grass started again in 1983 (Table 8)

Grasslands: Status and Use

The tall floodplain grasslands, created by the Geruwa, Babai, and Orai river system are dominated by *Saccharum spontaneum*, *S. bangalensis*, *Arundo*

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donax, and *Phragmites karka*. Phantas, previously cultivated and re-vegetated short grassland, are dominated by *Imperata cylindrica* and *Vetiveria zizanioides*. There are three main phantas in RBNP namely Khauraha (Upper Khauraha 0.95 sq.km, and Lower Khauraha, 0.34 sq.km), Bagaura (Upper Bagaura 0.59 sq.km and Lower Bagaura 0.34 sq.km) and Lamkauli (1.11 sq.km). Mansuri Phanta, north of Lamkauli Phanta, was also a grassland upto 1976 but has converted to forest in the course of succession.

Traditionally, people collected thatch grass, binding material, and reeds from the area that is now protected. Free access was

refused in 1976 when the area was declared the Royal Bardia Wildlife Reserve. However, recognising the traditional dependence of local people on park resources for subsistence living, a process of issuing permits once a year has now been introduced so that local people can have access to grass and grass products.

Grass is an important natural resource that plays an integral role in the subsistence lifestyle. People use it for different purposes like fodder; raw material for household goods like rope, mats, storage baskets, and vessels; and fencing and thatching. Villagers generally collect thatch grass (primarily *Imperata cylindrica*), reeds (primarily the canes of tall grass like *Narenga porphyrocoma*, *Phragmites karka*, and *Aurundo donax*), and binding materials (*Eulaliopsis binnata* and *Desmostachya binnata*). Tharu people have traditionally used a wider range of products than other ethnic groups.

Harvesting of grass by local people has helped to provide forage for grazing ungulates and probably to maintain the grasslands. Thus, cutting of grass has twin benefits: socio-cultural and economic benefits for the local community, and conservation of biodiversity. Further, permission to cut grass has helped to reduce park-people conflict. In 1994, the duration of harvest was reduced to 10 days. However, the number of grass-cutting permits has doubled within the last ten years. The loss of grassland outside the protected area and the increase in population probably led to the increase in the number of thatch permits up to 1998. The reason for the sudden increase in 1999 is unclear, however, because since 1997 a few villages have a protected buffer zone and are self sufficient for their forage requirements. It remains to be discovered whether the increasing number of grass-cutting permits has increased the biomass harvest.

Table 8. Number of grass-cutting permits issued annually

Year	Number of permits
1983	21,081
1984	25,565
1985	27,824
1986	30,568
1987	29,161
1988	30,241
1989	33,142
1990	38,117
1991	37,962
1992	41,413
1993	na
1994	45,598
1995	43,539
1996	48,923
1997	50,838
1998	49,508
1999	57,255

Grassland Management Activities

In order to maintain the existing grasslands, RBNP has introduced some management practices based on traditional knowledge and recommendations made by researchers.

Traditional Practice

Grass cutting and fire

Bush firing has been adopted by local people as an efficient tool for the management of grassland. Villagers set fire to the area after cutting is over. In addition to human interference, seasonal flooding also influences composition, distribution of species, and size and shape of the grasslands.

Park Management Intervention (1978-1994)

After the establishment of the protected area, the park management authority started interventions to maintain existing grasslands as follows.

Cutting of grass

Cutting of grass was permitted once a year in January for seven days. The duration was later extended to 15 days. During this period, local people were allowed to collect grass from any part of the park.

Fire

Traditionally, villagers set fire after cutting was over. Park staff also initiated controlled burning in phantas.

Introduction of grass species

In order to manage the habitat for the black buck (*Antelope cervicapra*), reintroduced in 1978, dubo (*Cynodon dactylon*) was sown in Bagaura phanta. However, the area was flooded and covered by sand in 1984, which changed the composition.

Ploughing

Tractors were used to plough Bagaura phanta to create a habitat for the reintroduced black buck.

Uprooting of stumps

Small bushes and stumps were uprooted to open up Bagaura phanta to create an ideal habitat for black buck. Despite all these efforts black buck did not survive in the area.

Current Management Practices (1995-1999)

Management Strategy

The grassland management interventions carried out by the park to maintain existing grasslands include allowing local people to cut grass, removing tree species, and controlling invasion of unpalatable species. A joint approach of the traditional practices adopted by the local community, and research recommendations has been followed. However, monitoring of the impact of management intervention still needs to be developed.

Cutting and Burning of Grass

Currently management of tall grass involves widespread cutting and burning of the grassland during the dry season. Since 1994 the duration of permits to cut grass has been reduced to 10 days (in January). Following the harvest, the grasslands are burned by local people and park staff. Burning of grass by local people is done illegally and is also not systematic. Park staff set fire to the grassland in a controlled manner as described below.

1995	Khauraha Phanta	mid February- end of March	
1997	Khauraha	„	„
1998	Bagaura	„	„
1999	Lower Khauraha	„	„

Uprooting of unpalatable species

Invading unpalatable species such as *Lantana* sp. and *Colebrookia* sp. Have been uprooted in Bagaura and Khauraha but not in Lamkauli phanta.

Cutting trees and bushes

Small bushes and selected trees are being uprooted yearly to open up Khauraha phanta. The practice was started in 1995 and was done extensively in Khauraha phanta in February 1999.

Research Activities

Several research studies have been carried out in the grasslands of RBNP (Pokharel 1993; Moe 1994; Karki 1997; Peet *et al.* 1997). Similarly, research done on *Rhinoceros* (Jnawali and Wegge 1992) and buffer zones (Bhatta 1994) in RBNP are also related to grasslands. Some of the findings and recommendations of these research activities are given below.

- The park authority should have a proper monitoring technique.
- The park should try to keep the grass harvest within a sustainable level.
- The existing floristic composition of the grassland should be maintained.
- Organic matter is removed annually by cutting of grass and there is a loss of nitrogen as a result of burning.
- Patches of sal (*Shorea robusta*) forest along the Karnali river should be removed selectively in order to increase the area of grassland.
- Encroaching plant species should be removed.
- Patches of grassland should be left uncut and unburned in a two-year rotation.
- Plans to dam the river that enters the park should be strongly opposed to maintain disturbance from river action and annual flooding, which are important for the persistence of the grassland.
- Management experiments should also be established to investigate the effect of rotational patch management of the grassland.
- Disturbance to ungulates utilising regenerating phanta grassland should be minimised by closing roads.
- The input and output of nitrogen and phosphorus should be quantified.
- The grassland ecosystem can sustain the current level of nitrogen loss. However, several experimental plots would need to be monitored for several years to see whether or not continuous harvest and burning deplete grassland resources.

- The management strategy should include maintaining a mosaic of (tall grass) areas that are cut and burned, and unmanaged.
- Cutting should be done in two phases spaced 20 days to 1 month apart.

In addition to the research findings, some conclusions have been drawn from the ongoing regular management practices. However, systematic research remains to be done to discover whether these practices really improve the condition of the grasslands or not. The lessons learnt are as follow.

- Controlled burning should be done twice a year.
- Fire should be set immediately after October in the daytime when there is wind.
- Fire should be set again after cutting of thatch grass is over in January-February.
- Cutting of grass should also be done twice a year: in January by people, and after June by a park authority grass cutter.

Management Problems

Because of the continuous interventions, not all the grasslands have fully converted to forest, as happened to Mansuri phanta after 1976. However, some problems have been observed in almost all the grasslands. Any kind of management intervention in these grasslands needs to address the following.

- Succession throughout the grassland, such as by *Bombax* and *Acacia* in the Babai valley
- Gradual encroachment by tree species along the boundary of the grasslands in all grasslands
- Invasion by unpalatable species in Bagaura, Khaura, and other small grasslands
- Ungulates, ground nesting birds, and smaller mammals are affected by uncontrolled burning as well as harvesting of grass by local people
- Damage to infrastructure, signposts, and bridges, and harm to animals during the grass-cutting season
- Lack of a proper monitoring system

Research Gaps/Needs

Some research has been done on the species composition of the grasslands, grazing, burning, and cutting of grass. Management interventions have been done in the grasslands by the park authorities based on the recommendations of such research and the experience of local people managing the grasslands in a traditional way. However, long-term systematic study of the impact of such activities still has to be done. For example, the relationship between the increase in the number of permits for harvesting grass and biomass removal needs to be explored in order to limit the permits to the optimum level.

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Grasslands in Royal Shukla Phanta Wildlife Reserve: Status, Importance and Management

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Abstract

Royal Shukla Phanta Wildlife Reserve, located in the western Terai, is famous for having a large herd of swamp deer (*Cervus duvauceli duvauceli*). Within its relatively small area, the reserve has diverse types of habitat. A large tract of grassland, the Shukla Phanta, is the main habitat of 1,500 to 2,000 swamp deer, or 'barhasingha'. The park contains many other small to moderate-sized grasslands, some interconnected and others scattered, such as the Barkaula Phanta, Sundari Phanta, Karaiya Phanta, and Haraiya Phanta. (The open grassland in the forest is locally called 'phanta'). One of the main objectives of the reserve is to manage these phantas in a way that will maintain them as a suitable habitat for swamp deer and other wild animals. Several management activities, have been conducted within these phantas including regular burning, ploughing, uprooting, and construction of waterholes. Despite these activities, portions of many phantas, such as the south-eastern part of Sundari Phanta, the northern part of Shukla Phanta, and the south-eastern part of Karaiya Phanta have been invaded by tree species which are spreading fast and thus threatening the existence of the grasslands. Block-wise management activities need to be conducted with a long-term perspective in order to manage these grasslands of international importance within the reserve.

Introduction

The Royal Shukla Phanta Wildlife Reserve (RSWR) is one of five protected areas located in the Terai. This reserve was gazetted in 1976 when a network of protected areas was established throughout the country. RSWR is famous for having the largest herd of swamp deer (*Cervus duvauceli duvauceli*), locally called 'barhasingha', and is thus of international importance. Many other wild animals, such as tiger, leopard, wild elephant, spotted deer, hog deer, and wild boar, are also found within the reserve. Shukla Phanta, a large area of grasslands located in the southern part of the reserve, is the main habitat of the barhasingha. The reserve also contains many other grasslands, such as the Barkaula Phanta, Sundari Phanta, Karaiya Phanta, and Haraiya Phanta. However, these grasslands are not devoid of trees, rather trees are scattered throughout making them more like a savanna type of vegetation than a pure grassland.

The grasslands within the reserve have been subjected to different kinds of management activities such as regular burning, ploughing, up-rooting, and construction of waterholes. These activities are carried out to prevent invasion of trees, to promote the growth of palatable short grasses, and to provide drinking water for wild animals in the dry season. However, except for burning, all the activities have been limited to a small portion of the Shukla Phanta because of

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the limitations of resources and manpower. As a result, parts of Shukla Phanta and the other grasslands have been invaded recently by many trees, which are growing fast. If management activities do not address the problem seriously, these grasslands will soon be replaced by trees in the course of succession, and will lose their significance as a habitat for the many wild animals, including swamp deer and birds, that prefer grasslands habitat.

The present paper describes the physical features and the history of the reserve, the importance of grasslands as the habitat of swamp deer, present management issues, and management activities that have been carried out in the grasslands. Finally, some recommendations are given for the management of these grasslands in the long-term.

Physical Features of Royal Shukla Phanta Wildlife Reserve (RSWR)

Location

RSWR is located in Kanchanpur district in the Far Western region of Nepal. The reserve is situated between 28°45'16" and 28°57'23" N and 80°06'04" and 80°21'40" E. The total area of the reserve, including its recent extension to the east, is 305 sq.km, and its altitude varies from 150 to 184 masl. The western boundary of the reserve runs along the western bank of the Mahakali river; the southern boundary runs along the Nepal-India boarder for 15 km and then eastward along the canal through the Beldandi Village Development Committee area (VDC). The reserve extends up to the Syali river in the east and to the Siwaliks in the north-east corner. Mahendranagar Municipality, the headquarters of Kanchanpur district, is situated to the north-west of the reserve.

The headquarters of the reserve is located at Majhgaon, which is to the south of the airport and about 6 km from the Mahendranagar market area. There are nine guard posts, one each located at Malumela, Barnikhera, Champapur, Beldandi, Dhaka, Radhapur, Singhpur, Shukla Phanta, and Piparia. There is one elephant camp located at Piparia near the Mahakali river. Army posts are located at Majhgaon, Mangalsera, Jhilmila, Singhpur, Barkaula, and Piparia.

Climate

The area has a tropical monsoon climate with four different seasons: winter, spring, summer, and monsoon. The mean monthly minimum temperature varies from 10° to 12° C in winter, gradually rising to 17° C in the spring and 26° C in the summer. The maximum temperature varies from 22° C to 36° C, reaching as high as 42° C in the pre-monsoon period. December and January are fairly cold and misty with occasional frost. This part of the country receives less rain than eastern Nepal, even so the average annual rainfall ranges from 1,300 mm to 2,300 mm, 80% of which falls during the monsoon, i.e., during the months of July to September. The relative humidity remains fairly high throughout the year except in the dry months of the pre-monsoon period.

Soil

There are five different types of soil in the SPWR. The soils in the riverine forests of khair (*Acacia catechu*) and sissoo (*Dalbergia sissoo*) along the Mahakali River are loamy-sand with small gravel and stones; in the mixed forests they are

sandy-loam; in the sal (*Shorea robusta*) forests, they are loam to sandy-loam with a high organic content; in the grasslands in lowland areas, they are clay-loam and sticky, and in the Siwaliks the soils consist mainly of sandstone, conglomerates, quartzite, shales, and micaceous sandstone.

History of the Reserve

The far-western Terai of Nepal, which includes the present RSWR, was covered by dense forest with grassland openings until the early 1960s and was inhabited by the aboriginal Tharus (Balson 1976). The forests and grasslands of this region were noted for an abundance of big game and the rulers of Nepal used to visit this area to hunt during the relatively cool and dry winter months. This area remained a famous hunting site for many years and in 1965/66 an area of 131 sq.km, including the Shukla Phanta, was declared a Royal Hunting Reserve by a decree of the late king Mahendra Bir Bikram Shah Dev. Fairweather tracks were then cleared to facilitate the hunt and several villages were removed from the reserve area.

In 1976, the Royal Shukla Phanta Hunting Reserve was gazetted as the Royal Shukla Phanta Wildlife Reserve with minor changes in the boundary, giving an area of 150 sq.km. A special unit of the army was assigned to protect the reserve, replacing the forest guards formerly responsible. Thereafter several villages, including Singhpur, were removed from the reserve area. Later, an additional area of 155 sq.km was added to the reserve in 1984, making a total area of 305 sq.km. The extension area lay to the east of the previously gazetted reserve. Several villages, including Jhala, Bichhwa, Bhatapuri, Tarapur, Paraw, and Hirapur, were included within the extension area. The people from the villages of Arjuni and Hirapur have already been resettled, and those from the other villages are in the process of being resettled. The extension area has four guard posts, one each at Barnikhera, Beldandi, Dhaka, and Champapur. There are no army posts in the extension area yet.

Vegetation

Two thirds of the previously gazetted reserve area is covered by forests and one third by grasslands, in contrast more than 90% of the extension area is forested and the remainder includes agricultural lands and settlements. There is hardly any natural grassland within the extension area.

Forest Types

There are different types of forest within the reserve. The riverine vegetation comprises khair-sissoo (*Acacia catechu-Dalbergia sissoo*) forests present on the Mahakali floodplains, and pure stands of sissoo on the banks and gravel bars of the Mahakali river. Sissoo trees are also found scattered in grasslands. Khair trees are components of the mixed riverine forests found at various sites along the river.

Mixed deciduous forests occupy about 20 sq.km of the lowlands. The major tree species in this type of forest are guthail (*Trewia nudiflora*), jamun (*Syzygium cuminii*), simal (*Bombax ceiba*), sindure (*Mallotus philippinesis*), *Celtis australis*, *Ficus* spp., *Cedrela toona*, and *Murraya koenigii*. Ground cover is poor in this type of forest, consisting only of leaf litter where the canopy is dense and

dominated by *Ageratum conyzoides* and ferns in other places, especially moist areas. Grasses are very infrequent in this type of forest.

Approximately 80 sq.km of the originally gazetted reserve, and most of the extension area, is occupied by different stages of sal forest (*Shorea robusta*). In many places this species forms pure stands, while in others it is associated with *Lagestroemia parviflora*, *Embllica officinalis*, *Terminalia belerica*, and *Terminalia chebula*. Ground vegetation is very poor in the mature forest where there is a closed canopy, while grasses like *Narenga porphyrocoma*, *Themeda arundinacea*, *Saccharum bengalense*, *Saccharum munja*, *Eulalipsis pinata*, *Desmostachya bipinata*, *Thysanolaena maxima*, *Apluda mutica*, and *Eulalia* spp. are present in the immature forests which have a relatively open canopy.

Grasslands

The RSWR is famous for large tracts of grasslands, among which Shukla Phanta is the largest. Shukla Phanta covers an area of 54 sq.km south-west of the Bauni river and south of the forest. Other grasslands include the Sundari Phanta, Barkaula Phanta, Karaiya Phanta, Singhpur Phanta, Haraiya Phanta, and Mangalsera Phanta. The Haraiya Phanta lies on the floodplain of the Chaudhar river; the Mangalsera Phanta is a relatively small opening in the sal forest near the Mangalsera post; Sundari Phanta and Barkaula Phanta are in lowland areas to the north-west of Shukla Phanta; Karaiya Phanta lies in the south and is bounded by a strip of forest along the Nepal-India boarder; and Singhpur Phanta is in the lowland area to south of the Singhpur post at the former site of Singhpur village.

Some of the grasslands, especially those on the slightly elevated lands with sandy-loam soils, are relatively dry. Central Shukla Phanta, west Seta Khera, and parts of Karaiya Phanta have this type of grassland. *Saccharum bengalense*, *Saccharum spontaneum*, *Imperata cylindrica*, *Narenga porphyrocoma*, and *Desmostachya bipinata* are the dominant grasses. Other grasslands lie at lower elevations and are seasonally flooded. This type of grassland is present in the north-eastern part of Shukla Phanta, most of Sundari and Barkaula Phantas, and almost the whole of the Singhpur and Mangalsera Phantas. The dominant species in these grasslands are *Saccharum spontaneum*, *Vetiveria zizanoides*, *Narenga porphyrocoma*, and *Imperata cylindrica*.

The grasslands in the Barkaula Phanta, Sundari Phanta, Karaiya Phanta, Haraiya Phanta, and southern part of Shukla Phanta contain a number of scattered trees, and thus form a savanna type of vegetation rather than pure grassland. The dominant trees in the savanna are *Dalbergia sissoo*, *Acacia catechu*, *Butea monosperma*, *Bombax ceiba*, *Cedrela toona*, and *Sterculia villosa*. The relative abundance of these trees varies in the different phantas.

Grasslands: Status and Significance

The grasslands in the RSWR have both national and international importance. Grasslands in this reserve are the habitat of swamp deer (*Cervus duvauceli duvauceli*), which is one of the world's endangered large mammals. The population of swamp deer in Shukla Phanta is estimated to be 1,500 to 2,000, probably the world's largest herd.

Swamp deer used to be present in other parts of the central and western Terai but are now mostly confined to the SPWR with a very few in Royal Bardia National Park. This loss of range is attributed mainly to habitat loss and other pressures exerted by the ever-increasing human population in this region since the eradication of malaria in the late fifties.

In the reserve, swamp deer prefer the dry grasslands present in the central part of Shukla Phanta and the north-western part of Karaiya Phanta in all seasons except the very hot months in the pre-monsoon period, when they prefer seasonally wet grasslands. This preference results from the presence of preferred grass species such as *Imperata cylindrica*, *Narenga porphyrocoma*, *Saccharum bengalense*, and *Saccharum spontaneum*. These grasslands are also the preferred habitat of hog deer and spotted deer. However, while swamp deer and hog deer avoid forest as a habitat, spotted-deer are found abundantly in forest areas as well.

In addition to swamp deer, five other mammalian species that are found in the grasslands of Shukla Phanta, including hispid hare (*Caprolagus hispidus*), are listed by the IUCN (1993) as threatened species. The grasslands of Shukla Phanta are also an important habitat for a number of bird species. A total of 345 species of birds has been recorded in the reserve (Chaudhary 1997; Baral 1997). Most of them are found in grasslands and savannas. Among the several species of birds that primarily depend on grasslands, Bengal floricans (*Houbaropsis bengalensis*), swamp francolin (*Francolinus gularis*), white-throated bushchat (*Saxicola insignis*), bristled grassbird (*Chetornis striatus*), lesser florican (*Sypheotides indica*), grey-crowned prinia (*Prinia cinereocapilla*), Jerdon's bushchat (*Saxicola jerdoni*), and Finn's weaver (*Ploceus megarhynchus*), are either regionally or globally endangered. Many other bird species that are threatened at national level are found in the grasslands of Shukla Phanta. They include the black bittern (*Dupetor flavicollis*), yellow bittern (*Ixobrychus sinensis*), tawny eagle (*Aquila rapax*), small buttonquail (*Turnix sylvatica*), yellow-legged buttonquail (*Turnix tanki*), grass owl (*Tyto capensis*), striated grassbird (*Megallurus palustris*), rufous-rumped grassbird (*Graminicola bengalensis*), jungle prinia (*Prinia sylvatica*), and rufous-bellied babbler (*Dumetia hypertyra*).

The grasslands in the Shukla Phanta are also rich in plant diversity. Only one detailed report exists of the floral composition of the grasslands, the study by Schaff (1978). He reported 54 species of grasses and sedges but did not include dicots in his list. More recently a total of 125 species was recorded (unpublished data) in a preliminary survey of species in different grasslands, including Shukla Phanta, Singhpur Phanta, Barkaula Phanta, and Haraiya Phanta.

The grasslands have been very important sources of thatch grass for the local people. Harvesting of grass from the reserve is legally permitted to local people for seven days once a year. A total of 36,000 people entered the RSWR to cut grass in 1998. The availability of grass from the reserve is considered an incentive for local people to develop a positive attitude towards the reserve.

Grassland Management Issues

Despite several management interventions, some management issues still exist in the grasslands of RSWR.

Inaccessibility in the monsoon period—Although there is a network of roads in Shukla Phanta, the area becomes difficult to reach by vehicle in the rainy season and for one month after. This is because of the bad state of the roads near the Bauni River between Singhpur and Shukla Phanta, near Barkaula post, and near the Headquarters in Madhgaon. As a result, patrolling and other management activities are difficult to carry out during the rainy season.

Invasion by trees—Despite the grazing by swamp deer and other wild animals and regular burning, some areas of grasslands, such as the northern part of Shukla Phanta, Karaiya Phanta, Sundari Phanta, and Barkaula Phanta, have been heavily invaded by trees like *Dalbergia sissoo*, *Bombax ceiba*, *Acacia catechu*, and *Butea monosperma*. If management interventions are not carried out in time, these trees will colonise the area and the grasslands will be lost.

Scarcity of water—During the hot season, marshes in the grassland area dry up. Swamp deer and other wild animals move further south in search of water to places where the deer's life is in danger.

Livestock grazing—Since the villages along the Chaudhar river in the extension area are still present, livestock graze in grasslands like the Haraiya Phanta and the eastern part of Singhpur Phanta. Thus wild animals have to compete with domestic animals. The grassland quality has deteriorated in this area as a result of over-grazing.

Uncontrolled burning—Every year grasses are burned in the dry season. The uncontrolled burning of grasses is thought to be one of the factors contributing to the deterioration of grass quality.

Management Activities

The reserve authorities carry out different kinds of activities for the management of the grasslands within RSWR, such as construction and clearing of access roads, regular burning, ploughing, and construction of water holes, in close cooperation with the army. For the last few years, a UNDP funded project, the Park People Programme, has also helped the reserve administration to conduct management activities in order to improve the condition of the grasslands as the habitat of swamp deer and other wild animals. The different management activities are as follow.

Construction and Clearing of roads—A network of roads has been constructed within and around Shukla Phanta since the declaration of the area as a wildlife reserve. One road runs parallel to the Nepal-India boarder in the south, passes through Karaiya Phanta and Seta Khera, and continues to Jhilmila in the south-east. Another road passes through Barkaula Phanta on the way to Shukla Phanta from the north-west side of the reserve. Mangalsera Phanta is situated at the side of the road leading from Majhgaon to Malumela post. Haraiya Phanta has no road passing through it. Work is in progress to construct a road from Singhpur through Haraiya Phanta by clearing the vegetation.

All the access roads are cleared manually after the monsoon every year. Clearing is done to facilitate the movement of both official vehicles on patrol and visitors' vehicles. Clearing is also done with the idea that the roads can act as fire breaks in the dry season.

Burning—Since swamp deer are primarily grazers, they find young grass highly palatable. Burning is one of the management tools used to promote the growth of tender shorts. In Shukla Phanta, regular burning of grasslands causes *Imperata cylindrica* to produce tender foliage, which is highly preferred by grazing animals. All the burning activities in the grasslands are done from mid-November to mid-February. It is after this that swamp deer in herds of hundreds are seen grazing in the grasslands.

Ploughing—Non-palatable tall grasses were seen to be growing in all the grasslands including Shukla Phanta. Ploughing is used to break up swards of tall grasses and promote the growth of short grasses. Ploughing has been included as a grassland management activity for the last four years. Altogether 110 ha of grasslands have been ploughed by tractor since 1996. Five ha were ploughed twice, the others only once. Table 9 shows the details of ploughing since 1996. Ploughing could not be done at a particular time of the year because of reasons like shortage of staff and lack of timely availability of the budget. There has also been no research programme to discover the most suitable time for ploughing.

Table 9. Ploughing activity in Shukla Phanta grassland since 1996

Year	Month	Location	Area (ha)	Programme
1996 (2054)	Sept	North-east of the viewing tower	10	PPP
1996 (2054)	Sept	West of the viewing tower	5	PPP
1997 (2055)	Apr	North-east of the viewing tower	30	PPP
1997 (2055)	Apr	Central part of Shukla Phanta	40	PPP
1997 (2055)	Apr	East of viewing tower	15	HMG
1997 (2055)	Jan	West of viewing tower	10	HMG
1998 (2056)	Jan*	East of viewing tower	5	HMG

* In previously ploughed area

Uprooting—The grasslands in Shukla Phanta, Barkaula Phanta, Sundari Phanta, and Karaiya Phanta have been invaded by several tree species, such as *Dalbergia sissoo*, *Bombax ceiba*, and *Butea monosperma*. Once these trees become established in the grasslands they produce seeds which germinate. As a result, succession proceeds towards complete colonisation by the species at a later stage. For example, there were no sissoo trees in Shukla Phanta to the north of the viewing tower before 1982 when one of the reserve staff planted a tree. Later, many sissoo trees were found growing in the area (personal communication). It is better to prevent these species from becoming established, but if they do become established the only option is to them when uprooted young, or fell if they are mature. Simal (*Bombax ceiba*) saplings were uprooted in a five ha area in 1998.

Construction and Repairing of Water Holes—During the hot season, the marshes situated along the periphery of Shukla Phanta dry up. Even the Rani Tal, which is seven kilometres from Shukla Phanta and occasionally used by swamp deer for drinking water, has dried up every summer for the last three years. A continuous supply of water needs to be maintained in the vicinity of the habitat of the swamp deer in order to keep the herds healthy. Two ponds were dug near the viewing tower in Shukla Phanta and a third one renovated with the help of the Park People Programme in 1996. These ponds were filled with the help of boring and pumping sets. Renovation of these ponds was repeated in 1997.

Research Activities

Very little research has been carried out on the grassland ecology of Shukla Phanta. Schaff researched the population size, structure, and habitat relations of the swamp deer (*Cervus duvauceli duvauceli*) in 1978. In the same year, Bhatt and Shrestha (1978) published a book entitled 'The Environment of Shukla Phanta', in which they gave a brief history of the area, vegetation types, and animal diversity. Their book was based on a very brief visit of the area and did not include any detailed study. Later, Peet *et al.* (1997) classified the grasslands of Shukla Phanta based on species composition as part of a larger study of the ecology of Terai grasslands. There has been no systematic research on the impact of management activities.

As a result of the realisation of the national and international importance of the area, many researchers have recently started studying the grasslands of RSWR.

Mr. Hem Sagar Baral selected the grasslands in Shukla Phanta as one of his study sites to study grassland birds for his Ph.D. He is collecting data on birds along several transects passing through the grassland.

Mr. Jay Prakash Sah is doing his Ph.D based on fieldwork within the reserve. Although his work is mostly related to the wetlands, he is also working in grasslands like the seasonally flooded grasslands in Mangalsera Phanta. He has also surveyed the volume of grass being harvested during the grass-cutting season, socioeconomic conditions, and the attitude of the people who come to the reserve to harvest grass.

Mr. Mahendra Shrestha has started research on the habitat of tigers in the western Terai, including Shukla Phanta Wildlife Reserve.

Recently, two students, Bindu Sharma and Shrijna Poudel, from the Central Department of Botany, Tribhuvan University, have started research into the impact of ploughing on grasslands under the supervision of Mr. J. P. Sah.

A Peace Corps volunteer, Timothy M. Croissant from the USA, has been doing research on the population of swamp deer and birds in the Shukla Phanta area.

Research Needs

Research is still needed into the following.

- The carrying capacity of phantas

- The water quality and status of wetlands in and around the grasslands
- Prey and predator relationships in grasslands
- Flooding patterns and their effect on grasslands
- The effect of burning on grassland quality and wild animals
- The ecology of swamp deer

Management Recommendations

The following recommendations are made for management.

- Roads should be properly maintained so that the movement of vehicles is smooth throughout the year. The roads near Barkaula post, the Bauni river, and the Headquarters should be repaired by filling with gravel.
- To ensure a regular supply of water in the Shukla Phanta area, the existing ponds should be renovated and filled. Three pumping sets should be bought and kept in running condition.
- Saplings of simal (*Bombax ceiba*), sissoo (*Dalbergia sissoo*), and other trees growing near the viewing tower, north of the access road, near the Barkaula post, and in Sundari Phanta, should be uprooted in a timely fashion so that further colonisation by these trees is checked.
- Growing trees of sissoo (*Dalbergia sissoo*), simal (*Bombax ceiba*), and palans (*Butea monosperma*) should be killed by girdling so that further colonisation is checked, but at the same time the dead intact trees can still provide a habitat for several bird species.
- Uncontrolled and illegal burning by people during the grass-harvesting season should be checked by employing temporary guards and making people aware of the damage caused by such burning. Similarly, fire fighting equipment should be made available to control uncontrolled and untimely burning.
- The villages along the Chaudhar River should be removed as soon as possible. This will help check livestock grazing in Haraiya Phanta, and add additional grassland habitat suitable for swamp deer and even rhinos.
- The location of the army post near the viewing tower in Shukla Phanta, which is a sensitive area in terms of the habitat of swamp deer, needs to be assessed and appropriate measures taken.
- Regular monitoring programmes should be conducted to monitor the impact of management activities so that necessary changes can be made.

Conclusion

Grasslands are an important habitat for wildlife. Management interventions will improve the status of grasses. Burning grassland in blocks can help to maintain bird life and reptile species. The focus should also be on wetland management, which will help maintain the wildlife diversity in the grasslands.

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