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CHAPTER 7

MANAGING INDIAN FORESTS FOR BIOLOGICAL DIVERSITY AND PRODUCTIVITY

By

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ABSTRACT

We describe an approach for integrating protected areas, managed forests, community-owned forests, and the intervening human-dominated matrix to conserve biodiversity and to provide economic and social benefits to urban and rural sectors in forests of India. The Wildlife Institute of India, US Forest Service, Indira Gandhi National Forest Academy, and several state Forest Departments began this work in 1995. We identified four pilot Conservation Areas (CA) that represent major Indian ecosystems: Terai (north India), Garo Hills (northeast), Satpura Range (central), and Anaimalai Hills (south). In each CA we did a biodiversity assessment, compiled wildlife-habitat relationships information, evaluated forest practices and human use, developed management strategies, and worked with field staff to identify management opportunities. A 6-volume management guide (www.wii.gov.in) presents the approach, wildlife-habitat relationships, and results of the four CA case studies. Primary lessons learned were to think broadly across landscapes; coordinate inventory data and analyses; integrate management across ownerships and allocations; consider cumulative effects; refocus silvicultural and other management practices toward biodiversity issues, as well as meeting human needs; and work with field managers and local user communities of the forest. The transition to "biodiversity-based forestry" will require continuing education for professionals and experimentation using adaptive management.

Key Words: biodiversity, conservation, forest management, India, landscape ecology

INTRODUCTION

Biological diversity worldwide is threatened by pressures from an ever increasing human population that places huge demands and burdens on natural systems. India shares these problems with the rest of the world (Marcot and Nyberg 2005), with a large and rapidly increasing population whose needs for food, fuel, fodder, recreation, and economic development must be met from a fixed land base (Parikh 1977). These human needs exert great pressures on Indian forest resources as evidenced by species endangerment and declines in forest area, forest productivity, and in the biodiversity and healthy functioning of forests (UNEP 2001). Nevertheless, the biological diversity of India remains remarkable. India occupies about 2.4% of the world's land area yet supports about 8% of the world's total species, including 47,000 species of flowering plants (12% of world flora), 4833 vertebrates (10.4% of world), and 68,389 arthropods (6.9% of world) (UNEP 2001).

Despite the severity of these problems, India is committed to maintaining forests and their biological diversity. The cultural traditions of India place a high value on nature in the form of sacred animals and places (Bhagwat *et al.* 2005a; Tiwari *et al.* 1998). The establishment of a network of Protected Areas (PA), launched under Project Tiger in the 1970s, was a first key step in preserving the biodiversity of India's forests (Sawarkar 2001). Currently, 597 protected areas cover about 4.7% of the total land area of India and about 20% of the land is classified as forest (Wildlife Institute of India 2006). The National Forest Policy (1988) includes a formal mandate to provide for biological diversity in the management of all forested areas. Under this policy, tree harvesting in classified forests can only proceed when forest management plans fully incorporate the Policy's requirements for biological diversity.

To fully capitalize on the value of protected areas as a network supporting biological diversity, their management must be integrated with surrounding managed forests (MF), and even with non-governmental lands (Bhagwat *et al.* 2005b). A few PAs in India are thousands of square km in extent, but their average size is less than 300 km^2, and 70% of them are smaller than 200 km^2 (Sawarkar 2001). This integration is necessary to enhance connectivity among habitats; buffer the negative effects of fragmentation on habitat patches; capture the full variety of habitat types, quality, and settings; provide additional habitat area to support viability of widely distributed species; encompass key sites for all threatened, endangered, rare and endemic species; and maintain key ecological functions (Shi *et al.* 2005).

At present, separate processes are used to prepare plans for MFs and PAs. Working plans for MFs are prepared according to provisions of the All India Working Plan Code, whereas plans for PAs follow the Manual for Planning Wildlife Management in Protected Areas and Managed Forests (Sawarkar 1995, 2005). Because plans have been prepared separately for MFs and PAs, they have not provided integrated management guidance for all resources across logical landscape units (Rodgers and Panwar 1988). Such an integrated approach could better achieve objectives for both resource production and the maintenance of biological diversity (Sawarkar and Panwar 1987). It would help facilitate the role of MFs as corridors between PAs, ensure that provisions for major elements of biological diversity were included in prescriptions for MFs, provide for appropriate management in PAs when necessary to achieve desired ecological conditions, and allow a broader landscape to be viewed as the operational base for meeting ecological goals and human needs.

Following an initial collaboration during 1990-91 that aimed to improve management of wildlife in managed forests, the Wildlife Institute of India, the US Forest Service, and Indian central and state forestry agencies initiated in 1995 a 7-year project on "Management of Forests in India for Biological Diversity and Forest Productivity: A New Perspective" (hereafter, the Project). The goal of the Project was to demonstrate methods for doing integrated science and management assessments across jurisdictional boundaries of PAs, MFs, and community forests (CF). Such large-scale assessments make possible the identification of key areas for both protection and active management of habitats and species, and will facilitate the development of management plans at scales ranging from individual stands to biogeographic regions (Rodgers and Panwar 1988).

The Project had six objectives to accomplish in four demonstration landscapes, which we called Conservation Areas (CA):

- Assess, document and map plant and animal diversity.
- Develop information about wildlife habitat relationships for selected vertebrate species.
- Evaluate the impact of existing forestry practices, including the use of forest resources by local people.
- Rapidly assess the social and economic systems of surrounding villages in terms of land use and forest resource dependency.
- Use modern ecological concepts to develop potential management tools and practices.
- Develop the assessment information into a field guide, and transfer technology through publications, workshops, seminars, and development of forestry and wildlife training curricula.

Here we describe the Project study areas, the methods used to assess plant and animal diversity and identify management issues, the results in terms of outputs and key anthropogenic stressors to the ecosystems, and lessons learned and management opportunities.

STUDY AREAS

The project was field based and conducted in each of the four CAs (Fig. 1). Each CA included PAs (National Parks, NP, and Wildlife Sanctuaries, WLS), MFs (official Reserved and Protected Forest categories), and intervening government, community, or private forests and agricultural land (Table 1). We selected the CAs to represent a very wide diversity of ecological conditions, site histories, cultural situations, and management challenges across India. The four CAs were: the Anaimalai Conservation Area (ACA) in south India, the Garo Hills Conservation Area (GCA) in northeast India along the Bangladesh border, the Satpura Conservation Area (SCA) in central India, and the Terai Conservation Area (TCA) in north-central India along the Nepal border.

Anaimalai Conservation Area

The ACA is located in the Anaimalai and the Palani hills of northwestern Tamil Nadu state in the Western Ghats mountain range, which is one of 25 ‘biodiversity hotspots’ of the world (Myers *et al.* 2000). The 2200 km^2 ACA is in the 5B - Western Ghats Mountains biotic province of the Western Ghats Biogeographic Zone (Rodgers and Panwar 1988). Topographic, edaphic and climatic variations within the ACA create an exceptional array of vegetation types including Tropical Dry Thorn forests, Temperate Wet Montane Shola Grassland systems, semi-evergreen forests, and evergreen tropical forests (Champion and Seth 1968). The high number (15) of vegetation types recorded in the ACA are indicative of the region's exceptionally high floral and faunal diversity.

Plant and animal endemism is high (Tewari 1995). It is a stronghold of the Nilgiri tahr (*Hemitragus hylocrius*) and the lion-tailed macaque (*Macaca silenus*). Fourteen of the 15 endemic bird species in the Western Ghats are found in the ACA. Likewise, 14 (32%) species of reptiles, 30 (63.8%) species of amphibians, 18 (64%) species of fishes, and 13 (9%) species of butterfly are endemic to this region. The endemism of the vegetation is equally rich. The ACA possesses some of the best quality teak (*Tectona* *grandis*) in southern India and has greatly contributed to the revenue generated by the forest department through timber production. The region also supports cash crops of tea, coffee and cardamom. The tribal economy is largely dependent on non-timber forest products found abundantly in the forests and grasslands of the ACA.

Garo Hills Conservation Area

The GCA is in the western part of Meghalaya state in northeastern India. The GCA is in the 9B – North-East Hills biotic province of the North-Eastern India biogeographic zone (Rodgers and Panwar 1988). The GCA covers about 2000 km^2 of extremely rugged and undulating Tropical Evergreen and Semi-Evergreen forests (Champion and Seth 1968) that are known to harbor rich biodiversity and endemism. The GCA harbors one of the densest population of Asian Elephants (*Elephas maximus*) in the Indian subcontinent. Endemic plants, such as the pitcher plant *(Nepenthes khasiana*) and many *Citrus* species, occur in the region.

Most of the GCA forests are owned by tribal Garo and other communities, who mostly practice shifting cultivation, locally called '*jhum*' (Momin 1995). Increasing area devoted to *jhum* and the shortening of the *jhum* cycle are important land use issues. Collection of non-traditional forest products (NTFP) is an important source of food, medicine, and construction materials.

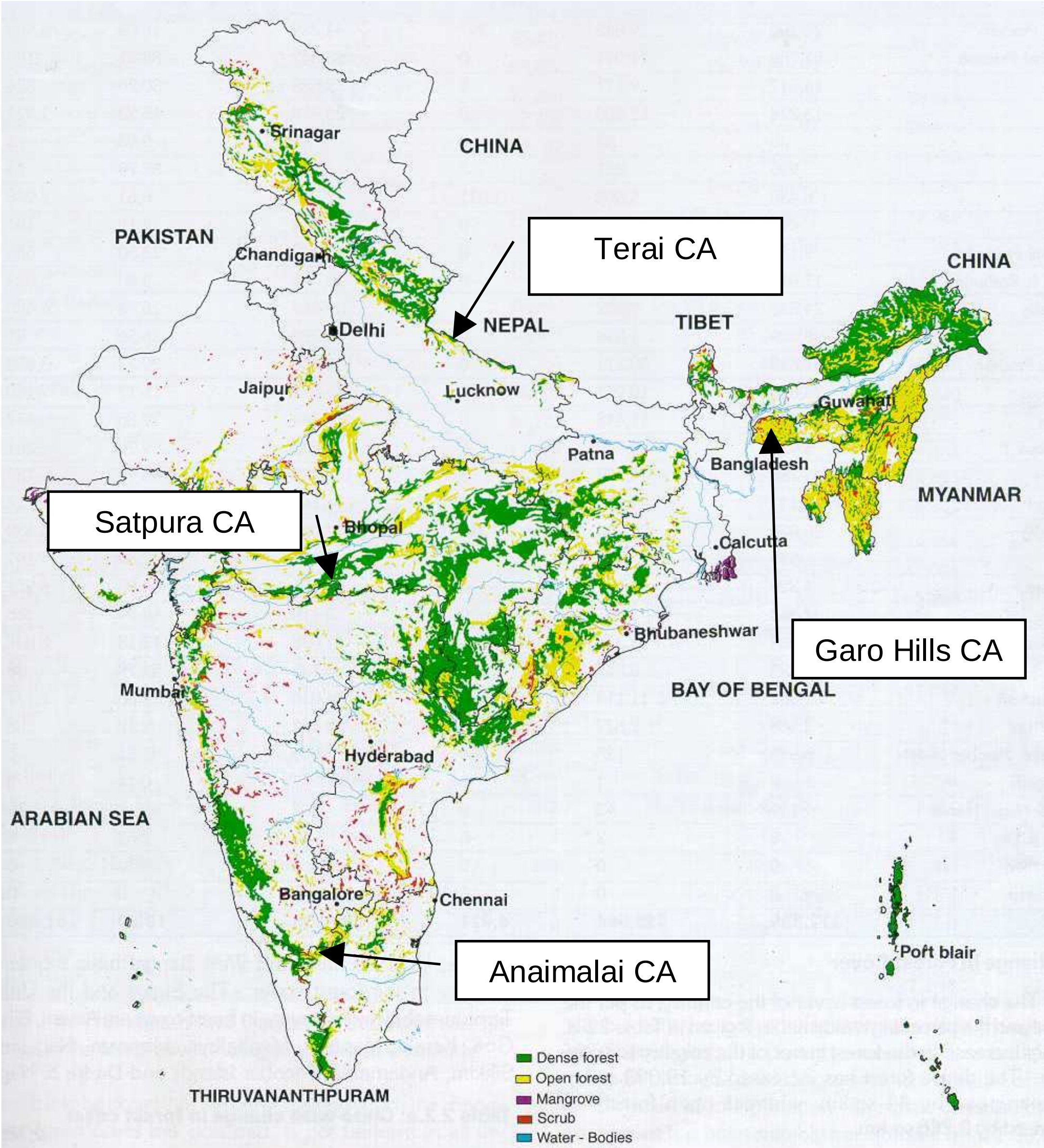

Figure 1. Forest cover map of India (Forest Survey of India 1999) and locations of Conservation Areas chosen to demonstrate an assessment and management planning approach that integrates Protected Areas and managed forests for conservation of biodiversity and human use.

Table 1. Area of Protected Areas and managed or community forests in Conservation Areas created to demonstrate a landscape approach for integrated forest planning and management in India.

Conservation Area	*State*	*Constituent areas*[*]	*Area (km^2)*
Anaimalai (ACA)	Tamil Nadu	*PA:* Indira Gandhi NP, Anaimalai WLS	958

		MF: Kodaikanal and Dindigual FDs	1,207
			2,165
Garo Hills (GCA)	Meghalaya	*PA:* Balpakaram NP, Nokrek NP, Siju WLS, Pitcher Plant WLS	406
		MF: Baghmara Reserved Forest	89
		CF: Baghmara CF	1,505
			2,000
Satpura (SCA)	Madhya Pradesh Maharashtra	*PA:* Satpura NP, Gugamal NP, Pachmarhi WLS, Bori WLS, Melghat WLS.	3,065
		MF: Hoshangabad FD; North,West and South Betul FDs; East, West and South Melghat FDs	6,239
			9,304
Terai (TCA)	Uttar Pradesh	*PA:* Dudwa NP, Kishanpur WLS;	884
		MF: North and South Kheri FDs	843
			1,727

[*] Protected Areas (PA), Managed Forests (MF), National Park (NP), Wildlife Sanctuary (WLS), Forest Division (FD), Community Forest (CF)

Satpura Conservation Area

The Satpura Conservation Area (SCA) represents the 6A - Central Indian Highland biotic province of the Deccan Peninsula biogeographic zone (Rodgers and Panwar 1988). The SCA covers some 9000 km^2 of forest in Madhya Pradesh and Maharashtra states. It is one of the largest contiguous forest areas in this central part of India. The forests in the SCA are economically the most valuable of the dry deciduous forest type. Teak is the principal timber species and is intensely managed. A small tract of sal (*Shorea robusta*) forest represents the most southerly occurrence of this dominant northern Indian forest type. A large number of endangered and threatened plant species have been documented from the region. The SCA has one of the largest contiguous populations of the critically endangered tiger (*Panthera tigris tigris*) and supporting prey species in India. The local forest-dwelling tribals and non-tribal communities are mainly dependent on the forests for their sustenance and livelihood. The SCA has the regionally important hill stations and outdoor recreation centers of Pachmarhi and Chikaldhara. There are old forests and other sites of historical, religious and pilgrimage attraction.

Terai Conservation Area

The Terai Conservation Area (TCA) covers 1700 km^2 of mostly Moist Deciduous Sal forest (Champion and Seth 1968) and interspersed grasslands and swamps in Uttar Pradesh state along the Indo-Nepal border. It is the single best representative in India of the 7B – Upper Gangetic Plains biotic province of the Gangetic Plains biogeographic zone (Rodgers and Panwar 1988), and harbors a rich and unique flora and fauna. The TCA is a stronghold of several threatened or endangered species, including the swamp deer (*Cervus duvauceli duvauceli),* Bengal florican *(Hubaropsis bengalensis),* hispid hare *(Caprolagus hispidus),* and Indian one-horned rhinoceros (*Rhinoceros unicornis)* (Dinerstein 2003). The TCA forests are historically famous for mechanized timber working and production of sal railroad sleepers (ties). The TCA is home to important *Tharu* tribal communities that have a rich cultural heritage and traditional resource dependence on TCA forests and grasslands.

The agricultural matrix, with its dense village population and intensively farmed sugarcane fields, separates the primary PAs and creates a landscape connectivity issue that is unique among the CAs. The landscape faces severe management challenges from rapid transformation of natural land into agriculture, and an ever-increasing human and livestock population. The landscape also experiences high biotic pressure from across the Indo-Nepal border.

METHODS

Here we present a summary of methods used to assess biodiversity in each CA. Methods for field ecological assessment, in particular, varied among CAs because of ecological or logistical reasons; details are in the respective Project reports for each site (Mathur *et al.* 2002a).

We first reviewed and collected available information in research publications, forest working and wildlife management plans, maps, reports, policy statements, and guidelines for each CA. The literature review was followed by reconnaissance visits to each CA to survey the ecological and management situation, interact with field managers, and plan specific field methods.

We next created a map library using geographic information systems (GIS) with the objective of consistently mapping vegetation conditions and resources across each PA and MF unit in each CA. Imagery from the IRS IB LISS II satellite for each site was procured from the National Remote Sensing Agency, Hyderabad. We combined Survey of India toposheets, forest thematic maps, and satellite imagery to generate land-use and land-cover maps that we validated in the field. We generated maps of elevation, hydrology, habitations, soil types, geology, agriculture, transportation networks, and vegetation fragmentation (e.g., A. Kumar *et al.* 2000). We used Forest Department stock maps to generate current and past information on forest site quality, age class distribution and allotment of forest working circles in standard management units (compartments, beats, blocks and range).

We undertook limited field studies in each CA, emphasizing vegetation attributes stratified by cover type. A researcher was hired for each CA, and they established randomly-placed transects and quadrats to assess vegetation structure, composition, distribution, and frequencies of plants of conservation and economic importance. Vegetation sampling techniques followed standard methodologies described by Mishra (1968) and Mueller-Dombois and Ellensburg (1974). The researchers characterized tree and shrub communities in detail, whereas grass and herb communities were described in terms of key assemblages and sensitive sites. The important tall riverine and upland dry grasslands in the TCA, however, were described in detail. Along with plants, researchers recorded the distribution and abundance of larger vertebrates by indirect evidence within the quadrats and from sightings along the transects. Special projects or analyses were done in some CAs. In Dudwa National Park in the TCA, the researcher carried out an experimental study on grassland burning, cutting and harrowing practices. In the SCA, detailed studies were conducted on the population structure of tree species important for non-timber forest products. Landscape pattern was analysed in the TCA and GCA. Fishes and birds were surveyed in the ACA.

We assessed the kind, extent, and potential impact of past forestry practices for their impacts on stand composition, structure, and microhabitats such as snags and logs. Practices evaluated were silvicultural treatments, marking rules, fuel wood harvest, harvest systems for non-timber forest produce (NTFP), and spatial allocation of management actions across the landscape. We also collected information on the impacts of infrastructure development (e.g. roads, fire lines, water holes, hides, etc) and forest administration practices.

We tallied the number and distribution of settlements within each CA and investigated villagers' lifestyles and influences on forests variously through standard techniques such as questionnaires, household surveys, rapid assessment and micro planning (e.g., A. Kumar *et al.*, in press). We often relied on acquiring data from completed or concurrent ecodevelopment and community forestry projects in or near the CAs. Socioeconomic assessment topics included agricultural practices in enclave and peripheral villages, impacts of crop depredation, predation on livestock by wild carnivores, injury and death of humans from wildlife encounters, and poaching. Industrial activities such as mining, quarrying, collection of sand, and irrigation were also described along with their potential impacts on biodiversity.

RESULTS

Here we present the major accomplishments of the Project, and a summary of the key stressors affecting biodiversity conservation within the CAs. Detailed results of the study can be found in the respective volumes for the ACA (Sajeev *et al.* 2002), GCA (A. Kumar *et al.* 2002), SCA (Pant *et al.* 2002), and TCA (H. Kumar *et al.* 2002).

Accomplishments

Resource Maps. Resource maps were created for each CA using remote sensing and GIS technologies. A spatial database is now available for each CA with information on watershed boundaries, administrative and management units, land use and land cover, vegetation, distribution of selected animals, village sites, and infrastructure.

Baseline Ecological Information. Baseline data were collected from 1997 through 2001 on patterns of plant and animal distributions and diversity, land use, historical development and management impacts, socio-economic conditions, wildlife–people conflict, and key stressors.

Wildlife Habitat Relationships (WHR). A list of 141 vertebrate species of conservation concern was developed to start a WHR database for India. A concise account of the species' status and distribution, ecosystems used, habitat requirements, and key citations was written. All species were listed in an easily-referenced table that tersely listed the taxonomy, legal status, residency and endemism, abundance, conservation issues, vegetation and structural types used, microhabitats (e.g., snags) used, key ecological functions, and sensitivity to human disturbance.

Capacity Building. Training curricula at the Wildlife Institute of India for the Post-Graduate Diploma Course in Wildlife Management were revised for middle staff (Assistant/Deputy Conservator of Forests) of the forest departments, and for continuing education courses for middle- and senior-level forest managers and planners. Changes also were made to the basic training module for new foresters being trained at the Indira Gandhi National Forest Academy. Chapters in the draft National Working Plan Code (1999) on assessment of biodiversity and wildlife and habitat management planning were largely based on the lessons learned from this project. The landscape approach adopted by this collaborative project is being increasingly advocated in all capacity-building programs and also used for planning, implementation, and management of conservation related projects in the country.

Study Tour for the Indian Delegation. A 13-member Indian delegation of forest managers and scientists visited a number of national forests, parks, and other areas throughout the U.S.A. on a study tour during 1999. A prime focus for the tour was understanding the lessons learned by U.S. counterparts in conducting large-scale ecological assessments in the eastern and western U.S. The entire experience was extremely relevant to the situation in India and addressed the vital areas of training, research, monitoring, planning, and management.

Management Guide. Results and recommendations of the project were presented in a 6-volume report (www.wii.gov.in). Volume I (Mathur *et al.* 2002a) contains a description of the Project purpose and background; concepts underlying landscape analysis and planning; a summary of the results for the four CAs and the lessons learned in them; and a proposal for next steps to be pursued. Volume II (Mathur *et al.* 2002b) presents wildlife habitat relationship information for 141 selected vertebrate species in the four CAs. Volumes III through VI (cited above) describe the assessment results, lessons learned, and management opportunities to maintain and enhance biological diversity in each of the CAs.

Key Stressors

Despite the great diversity of species, habitats, ecosystems, management issues, and human cultures among the four CAs, a common set of key anthropogenic stressors on resources and biodiversity were identified. We categorized stressors into six main groups.

Resource consumption. Resource consumption includes changes in the structure, composition, and extent of forests related to forest management activities, tree cutting, grazing, fishing (including use of pesticides), farming and invasion of exotic species in draw-down areas, and collection and poaching of animals and plants. Changes in forest structure, composition and extent have reduced late-seral and old-growth forests and structures such as dead trees associated with those forests. Such forest changes also have resulted in replacement of native forests with plantations, replacement of open grassland inclusions (blanks) with plantations, disturbance of understory vegetation, reduction in tree density in managed forests, and increased levels of disruption associated with human activities. Excessive collection of rare and medicinal plants threatens populations of those plants. In the GCA, large-scale coal mining and extraction has recently become a major impact on community-owned forest lands.

Nonconsumptive resource amenities including tourism and religious visitations. In the SCA, especially in the hill stations of the Pachmarhi plateau and Chikaldara, recreational tourism is a major stressor. Annual pilgrimage by millions of devotees to the Mahadev Temple and Nagdwari sites puts major stress on water and wildlife, and is accompanied by increases in anthropogenic fire, illegal collection of firewood and bamboo, and dumping of rubbish. Tourism and film production in the ACA, especially in the hill areas of the Kodaikanal District, has damaged sensitive ecosystems and strains the capacity of the small administrative staff to manage conflicts. In contrast, the GCA has little tourism due to its remoteness and other factors affecting safety and ease of travel (local agitation, lack of basic transportation infrastructures, etc.), so tourism pressure is not a factor. In fact, the GCA could benefit economically from growth in sustainable ecotourism if the basic problems of visitor access, accommodation, and safety were solved.

Transportation and habitation infrastructures. Irrigation canals and dams, roads and railway lines, and traffic of cars and trains are barriers to movement of wildlife, sources of mortality and disturbance, and corridors for the spread of invasive plants. These negatively affect wide-ranging herbivores (elephants) and carnivores (tigers, leopards), and other species principally through direct collision of vehicles and trains and indirectly through fragmenting forest cover habitats and encouraging the presence of people in areas better left undisturbed. In the GCA, roads likely are not causing major stress on wildlife, although elephant populations are far lower in areas near urban centers such as Tura.

Tribal village enclaves are a significant management issue. For example, the Indira Gandhi Wildlife Sanctuary of the ACA contains 36 tribal settlements. Traditionally, the tribals depended on various forestry operations such as logging, thinning, and NTFP collection. With the declaration of the area as a protected area, these tribals have been deprived of their source of livelihood and are now confined to a primitive style of agriculture and only seasonal employment with the Forest Department and adjoining estates. These tribal settlements have now become the source of anthropogenic disturbances including illicit NTFP collection, fire, grazing, and cattle penning.

Effluents. Water and air pollution from nearby industrial or urban areas are fouling the water and air. In the SCA, the Pachmarhi Plateau is under tremendous and increasing pressure from tourism which has resulted in the draining of pollutants into the drainage system of Satpura National Park. In the GCA, massive coal mining, extraction, and transportation activities are likely producing high levels of water effluents. Specific effects of these pollutants are unknown.

Other human activities. Illegal fires and excessive collection of medicinal plants and other non-timber forest products are serious problems in most CAs. In the SCA, extraction of non-timber forest products and extensive collection of some medicinal plants and fruits has had a detrimental effect on some plant species and frugivorous birds. Pachmarhi has many rare and endangered plant species that are under threat from botanical collections by large numbers of visiting students, researchers and traders. Burning to aid collection of 'mahua', 'tendu', and other plants disturbs wildlife populations and the forest floor understory, and eliminates dead wood from forest floors. Illegal fires also are eliminating fire-sensitive plant species from the area and reducing cover used by wildlife. Many wildlife species are affected by a combination of these and other human activities and by other stressors, such as loss of forest cover from timber harvesting coupled with poaching or disturbance from tourism. Shared and competitive use of water sources can result in disruption of populations of large ungulate species and crocodiles.

Human-animal conflicts stress both humans and wildlife. In the ACA, elephant depredation of crops is a problem, especially coconut plantations adjacent to PAs. This is exacerbated by the loss and fragmentation of forest habitat. The ultimate result is loss of human life and property and deaths of elephants from human harassment or poaching for tusks. Poaching directly affects populations of tigers and leopards, ungulate prey of large predators, elephants, porcupines, pangolins and monitor lizards. Poaching of ungulates, in particular, has a large indirect impact on tigers and leopards, and on ecosystem processes like seed dispersal of fruiting species that are ungulate foods.

Legal and illegal felling of forest has resulted in habitat loss. Illicit cultivation of the narcotic ganja (*Cannabis indica*) in the ACA has resulted in the clearing of large tracts of primary forest and the destruction of habitat for closely associated wildlife. Illicit removal of sandalwood is an issue. In the GCA, forest produce is illegally sold across the international border in Bangladesh. Much of the native forest cover in the ACA has been converted to tea plantations, resulting in the fragmentation and isolation of remaining evergreen forest tracts. This has disrupted movement corridors of elephants and reduced and fragmented available habitat of forest species requiring dense tree canopies, such as the lion-tailed macaque.

Other land use policies. Land use policies of non-forest agencies sometimes are in conflict with forest department policies. Most of the GCA area is under Schedule 6 of the Constitution of India, which provides for governance by District Councils that are authorized to make decisions for the control and management of forest areas within their jurisdiction. However, the management priorities of District Councils are distinctly different from those of the Forest Department, and there is essentially no coordination between these two bodies. This has created conflict in conserving forest biodiversity in GCA.

DISCUSSION

Lessons Learned

Following are a set of overall guiding principles and lessons learned from this project, which may be usefully applied to other areas when assessing and managing forests for biological diversity and forest productivity:

- *Think broadly across major landscape areas.* Think "outside the box," that is, account for conditions beyond the boundaries of the specific forest areas of interest. It is the broad context within which the management area resides that greatly affects conditions within the area and success of management actions. Consider the spatial and temporal cumulative effects of land use, conditions, and trends within, among, and beyond the boundaries of immediate interest. This would include, for example, the combined effects of such activities as forest management, grazing, tourism, road construction, and collection of non-timber forest produce on a given land area. Cumulative effects in buffer areas or in zones of influence outside existing protected areas, or even along state and international borders, are also to be taken into account when developing site-specific management plans.

- *Integrate management plans across administrative boundaries and between forest and wildlife management.* This principle suggests the need to coordinate data, analyses, and technical aspects of resource planning across forest and wildlife management areas, and with revenue land management, including agricultural lands. Some strategies to encourage voluntary public participation in such coordination are wildlife watches to thwart poachers, conservation easements, and other monetary incentive programs. One approach suggested for the TCA was the definition of Landscape Management Units based on common management issues, regardless of managing agency.

- *Think in hierarchical spatial scales.* An integrated resource management approach applied consistently across spatial scales is seen as the best way to avoid conflicts in resource use and to plan for appropriate ways to conserve biodiversity in managed forests. A useful approach to accomplish this is to evaluate conditions within a conservation area across delineated land ownerships and allocations, which then serves to help prioritize areas and identify the most efficient actions needed to meet more site specific biodiversity objectives. Consider connections needed across landscapes. For example, consider how thinning and other forest harvest operations may be defined or modified to meet both local and broader biodiversity conservation goals, as in the adage "think globally and act locally."

- *Use local knowledge and needs in the conservation strategy.* Local resource experts and lay people often have a wealth of experience, knowledge and wisdom in understanding the natural and human histories of an area, as well as what kinds of management actions may work and which may not. Attending to local knowledge also means being sensitive to cultural values of resources. In some cases, forests can be conserved for wildlife by recognizing their religious value, as in the case of sacred groves in GCA. The cultural and social values of organisms can be represented in the Wildlife-Habitat Relationships (WHR) Matrix as categories of "key cultural functions." The current WHR database does not explicitly list key cultural functions but they can be an important addition in future work. In this way, the WHR database could be used to identify the collective habitat conditions needed to manage for wildlife for both their ecological and social functions and values.

- *Consider a fuller array of flora and fauna.* The traditional focus in wildlife management on charismatic or "flagship" species such as elephants and tigers serves well to rally support for forest and wildlife conservation. Such wide-ranging species may also serve as "umbrellas" by which other species and environments may be conserved as well. However, management for flagships and umbrella species does not guarantee that all organisms will be provided for. Conservation planning should also explicitly provide for habitat and environmental conditions required by less charismatic species, including many plants, smaller mammals, reptiles and amphibians.

- *Consider ecosystem and anthropogenic processes and the ecological roles of organisms.* Providing environments for plants and animals entails accounting for the longer-term influence of anthropogenic and ecosystem processes that influence organisms and their habitats. A successful integrated forest-wildlife management plan would address disturbance regimes such as effects of insect pests, pathogens and disease, naturally-generated fire, floods, and other factors. It would also address major anthropogenic activities such as intentional fire-setting, diversion of water, grazing, lopping of trees for fodder, and many other activities. Also pertinent is the set of ecological roles played by organisms; these are referred to as "key ecological functions" (KEFs) of wildlife. KEFs are the roles that wildlife play that influence habitat conditions for other species, such as cavity excavation in trees, creating soil burrows, dispersing seeds, pollinating flowering plants, and many other roles. Because biodiversity is ultimately "the variety of life and its processes," to provide for biodiversity means attending to not just habitats and species but also their KEFs.

MANAGEMENT OPPORTUNITIES

How can the manager ameliorate effects of stressors identified and use the lessons learned in this Project? A major readjustment of administrative and organizational procedures may be in order to use the lessons learned and to effectively reduce the key stressors summarized above. We view such changes in management as positive opportunities that would move toward more integrated forest and wildlife resource planning for long-term sustainable biodiversity and forest productivity. Following are some changes that could be instituted.

Managed forests. Improve coordination of management between MFs and PAs. Some examples include delineating wildlife habitat corridors among PAs, retaining existing old-growth forests, retaining snags and hollow trees, maintaining grassy openings, providing for weed control, and balance removal of exotic shrubs such as *Lantana* with restoration of native shrubs.

Management of forest structure and composition jointly for timber, wildlife habitat, and other resources, is most efficiently accomplished by considering all such objectives simultaneously. Only in this way can silvicultural prescriptions for forest stand treatments be devised that help meet all goals, and only in this way can the extent to which all such goals can be met simultaneously be identified. The onus is on clearly describing the specific conditions of forest structure and composition needed to meet well-defined wildlife habitat management objectives. This is where the Wildlife-Habitat Relationships database on wildlife species' requirements can greatly help, by identifying specific habitat and substrate requirements – including forest structure and composition – for each species.

Managers currently recognize the need to manage key wetland and grassland habitats. In forests, fruit-bearing trees traditionally have been recognized in management plans and operations as important wildlife trees. Managers also are beginning to recognize the ecosystem and wildlife values of defective and dead wood (snags and down logs), instead of their value just for salvage. Defective trees and snags provide key cover and foraging habitats for cavity-excavating birds and secondary cavity-nesters that use woodpecker holes, for example. Down logs are key habitats for invertebrates, reptiles, and small mammals, which are prey to many birds and other small mammals.

Identifying natural conditions and native biodiversity. In all CAs, existing forest and grassland conditions are far from pristine, that is, formed by natural processes alone. People have been part of these ecosystems for thousands of years and have influenced ecological processes for centuries. This makes it difficult to describe desired future conditions of forest and grassland vegetation using "natural" conditions (i.e., without significant anthropogenic disturbance) as a baseline or management target. The assumption is that natural stand conditions and their pattern across the landscape will maintain the full range of native biodiversity, i.e., species and their interactions with each other and the environment. If those conditions are unknown, or if there is high variation in the composition and structure of a vegetation community or landscape as a result of the environment or disturbance processes, then a range of conditions, or states, is used to bracket acceptable future conditions.

Where "natural" conditions cannot be described, it is unknown the degree to which the full extent of native biodiversity would be provided by a set of management guidelines. In that case, the best the manager can do is to describe current conditions and, if data permit, at least recent historic conditions, and use these as baselines. The manager should also pay attention to the array of stressors and specifically identify which anthropogenic stressors have the greatest adverse effect on the species or habitats of interest, and then manage to reduce such stressors. This focuses on the desired outcomes and is a useful approach where identifying native biodiversity and natural conditions is not possible.

Riparian areas. Institute comprehensive management of riparian areas and corridors. This might include such activities as establishing no-disturbance buffers along stream channels; maintaining down logs within streams for fish and wildlife habitats; encouraging growth of native grasses and sedges in degraded riparian areas; managing and reducing contamination of water by controlling discharge of pollutants into streams or wetlands; eliminating use of pesticides, other poisons and explosives for harvesting fish; establishing specific guidelines for permissible human activities that are consistent with conservation and restoration objectives; and restricting agriculture in reservoir draw-down areas.

Roads and transportation systems. Manage existing transportation systems and design future transportation systems to minimize impacts, particularly to reduce or eliminate wildlife collisions with vehicles and trains, to reduce impacts over stream and river crossings, and to reduce or eliminate the severing and fragmenting effect on forest and grassland habitats for wildlife.

Tourism. Increase coordination among entities responsible for tourism development, to reduce negative impacts on biodiversity. Promote sustainable and low-impact ecotourism to help promote environmental education and to replace or reduce higher-impact recreational and exploitative tourism. In the SCA, this is a major challenge, as tourism (and religious visits) have impacted the area around the Pachmarhi plateau. However, low impact tourism has been accomplished in the Melghat Tiger Reserve in the SCA. Among the CAs, promoting tourism will be most challenging in the GCA because of its remoteness from tourism centers. Recent major improvements in some highways to the region are a good first step, however.

Rare species and communities. Rare species and communities have often been identified in the past, but little research has been done, except on some flagship species such as tiger and elephant, and specific management guidelines are lacking. Knowing the geographic locations of rare species will remain a challenge, but effort should be made to survey areas for such species before additional disturbances are permitted.

Vegetation community types that are rare and sparsely distributed may nonetheless provide vital habitat for many plants and animals. Examples include the wet meadow inclusions in the ACA, mixed deciduous forest in the TCA, riparian environments in the GCA, and deep-canyon forests in the SCA. In most conservation areas, "blanks" are grassland habitats quite important to wildlife. In some cases, manipulative management practices need to be carefully considered in light of the ecology and wildlife values of these relatively rare and important vegetation types.

Wide-ranging species. Habitat corridors help maintain interactions among population units and thereby maintain effective population size of wide-ranging wildlife such as tiger and elephant. For example, in the GCA a series of seven forest corridors has been proposed to link the few PAs and MFs of the area; these corridors would serve to help maintain the greatly-declining elephant populations there (Marcot *et al.* 2002), and would likely benefit a wide array of other plant and animal species as well. However, in cases where the matrix lands are heavily converted, disturbed, and occupied with villages, creating such habitat corridors may be difficult, as in the TCA. In such a case, new approaches for providing incentives to owners or managers of the matrix lands to contribute to conservation goals need to be developed. Approaches might include purchase of conservation easements wherein ownership of the land remains in private hands but concessions are made by the owner to create or maintain wildlife habitat. "Conservation districts" or “community reserves” (e.g., in GCA; A. Kumar *et al.*, in press) could be formed to enlist support of private landowners by providing incentives to maintain cover or other habitat elements during all or part of the year. Similar community groups could be organized to protect animals while in the area, similar to the Tiger Watch or Tiger Guardian programs (De 2001). On a regional scale, bold programs like the Terai Arc Project for linking PAs with forested corridors across the entire "arc" of the Indian and Nepalese Terai region (Johnsingh *et al.* 2004) will be necessary to ensure the long-term viability of species like tigers and elephants.

Collection and poaching of species. Control of poaching will require development of interagency programs to locally control poachers and engage local people in conservation activities (e.g., Nepal and Weber 1995), and international programs to control the consumers in the market. In the TCA, for example, threats from poaching need to be controlled through a concerted effort of Indian and Nepalese civilian and border authorities. Markets in Tibet and China need to be controlled to cut demand (Wildlife Protection Society of India 2005). In the ACA, recommended antipoaching measures include developing and strengthening intelligence networks among enforcement agencies, conducting security audits with the help of tribal communities, monitoring the methods and seasonality of poaching, providing insurance coverage for protection of forest staff, engaging tribals as anti-poaching guards, and providing a system of rewards and incentives to thwart poaching.

To reduce or eliminate stressors associated with hunting and collection of animals and plants, including medical plants, fruits, seeds, and other non-timber products, the manager can monitor collection rates and the range of impacts of harvest systems, interview local peoples to determine their use and needs, survey market demands and influence, and study the rates of production and distribution of such organisms and resources within the conservation area (Tewari 1999). Knowing the production capacity allows setting extraction rates to ensure long-term sustainable use (Appasamy 1993). Maps of villages and their zone of influence would indicate areas most at risk of resource damage and those areas free from current risk that might serve as refuges. Government could denationalize the collection scheme and allow collectors and villagers the right to sell NTFPs in the open market. This might encourage local people to participate in Joint Forest Management ventures.

Participation by local people. Several of the conservation areas are benefiting, or could benefit, from participation by local peoples formally organized to conserve wildlife, forest, grassland, and other resources. As an example, the state Government of Madhya Pradesh has launched an extensive program of Joint Forest Management (JFM). In the SCA managed Forest Divisions in Betul and Hoshangabad, JFM has improved protection of forests by helping to institute a better fire protection strategy, to institute self-help programs to monitor the status of local people, and to aid the sale of forest produce to forest cooperatives.

NEXT STEPS

Some next steps in implementing the guidelines and lessons summarized above have already been taken, and other steps are yet to come. The five field-level workshops held during 2005-2006 in each CA provided further technology transfer, helped renew local interest in the landscape conservation approach, and identified major priority activities needed in each CA

Technology Transfer. The Project's annual reports, maps, and data have been substantial assets for managers, who have used them to prepare management plans. For example, project concepts and data were incorporated in the first management plan written for the Dudwa Tiger Reserve (De 2001) in the TCA, and used in the GCA to write a proposal to establish an Elephant Reserve in the State of Meghalaya. Three Ph.D. dissertations came from the project. Presentations by Project scientists have been made at a number of regional, national, and international research and management meetings. Workshops for senior and field forestry and wildlife staff, outside scientists, public interest groups, and concerned citizens were conducted in 2005 and 2006 at each CA to present Project findings, discuss the issues and opportunities for implementing this new strategy, and to identify a primary issue for immediate attention.

Conservation activity priorities. Major priorities were identified in each CA for implementing results of the Project. A few examples follow. In the TCA, priorities included continued restoration and protection of rare species, particularly swamp deer, tiger, hog deer, hispid hare, and other Terai species, and establishing a second reintroduced population of one-horned rhinoceros. Studies are needed on the effects of habitat changes on swamp deer demography and on other wetland species. In the GCA, priorities might include designation of forest corridors between PAs and MFs; designation of Siju Cave as a bat sanctuary; updating PA management plans and increasing field staff; adding forest buffers to increase areas of PAs; inventory MFs for amounts and use of NTFPs; registering sacred groves in community forests for conservation; and nominating the GCA for UNESCO World Heritage Site status. In the ACA, priorities would include establishing antipoaching camps; designating riparian areas for conservation; mapping NTFPs; and development of comprehensive tribal and ecotourism development plans. In the SCA, priority management might include identifying wildlife corridors; improving grazing management; mitigating wildlife mortality along transportation corridors; and targeting remnant old-growth forests for special management.

Research, monitoring, and adaptive management. In all four CAs, management could benefit by research that would fill major knowledge gaps on basic species ecology (including the less conspicuous species), species distributions, population trends, specific effects of stressors, and effects of specific management activities. Research can take the form of adaptive management, whereby researchers and managers both learn from management actions that follow scientific experimental design standards of replication and control. Conducting activities as adaptive management research may require developing a new administrative approach and structure.

Basic ecological understanding also is necessary to modernize silvicultural systems by moving them from a focus simply on the production of wood and other human goods and services, to the production of both human and ecological goods and services while restoring or maintaining forest ecosystems. The transition from old to “new forestry” will be critical for integrating PAs and MFs to meet ecological goals described for conservation areas. The transition likely will require a period of adjustment of attitudes and experimentation with new methods.

It is clear that India is moving toward wildlife and forest conservation at a broader spatial scale and by incorporating more land use conditions than ever before. By focusing both within boundaries of PAs and MFs, and outside to community, revenue, and other lands, conservation guidelines will better use concepts of landscape ecology and conservation biology to help ensure protection and restoration of forests in India for future generations.

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