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The practice of weed control and vegetation management in forestry, amenity and conservation areas

Vegetation Management in Wildlife Protected Areas in India

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SUMMARY

The subject of vegetation management in the National Parks and Wildlife Sanctuaries of India is reviewed. Protected area history often includes management as Reserve Forest for produce exploitation. Since development for wildlife more emphasis has been given to animal populations, and management and monitoring inputs into the tree layer have decreased. Much effort goes to controlling still high levels of exploitation of timber, fuel, forage and minor products.

Two topics are considered in detail : the maintenance and development of grasslands within an environment largely dominated by woody components, and the problem of reduced tree regeneration due to heavy browse pressure and other factors.

INTRODUCTION

Wildlife Protected Areas (PA) in India have had a relatively long history of vegetation management. The majority of PAs were originally declared and managed as Reserve Forest (RF) dating back to the last century. The Indian Forest Service was one of the earliest to develop scientific management, geared to the production of timber and other products of commercial value. Management and silvicultural systems were intended to create even-aged stands of exploitable species, and frequently led to plantation development or enrichment planting as commercial species were depleted.

Such policies are not compatible with objectives of conservation of natural communities and one problem of PA management in India is to restore naturalness both in policy objectives and in the vegetation cover. India has adopted a two tier conservation structure, in that National Parks (NP) legally prohibit all exploitation, and a lesser category of Wildlife

Sanctuary (WLS) may allow exploitation and development of timber, fuel wood, grazing resources etc. provided such activities do not detract from wildlife values. This multiple function of WLS has frequently led to a dual control and management of resources, with a wildlife warden concerned with animal populations and a forest officer supervising the vegetation cover.

Indian forests have long been exploited by local people for many products including fuelwood, graze, browse, fruits, leaves, resins, medicinal products etc. Much PA management effort is directed towards regulating and reducing the growing impact of such exploitation (Panwar, 1985) following rapid rise in population this century.

Wildlife protected areas in India are small (average of 327 km^2, Rodgers and Panwar, in press) and frequently have a high boundary : area ratio. Internal villages and plantations mean that management cannot afford a 'let nature take its course' conservation policy, but has to actively intervene to prevent resource degradation.

This paper reviews the present vegetation management situation by giving examples of the range of problems and possible solutions found in Indian protected areas. Two topics are treated in more detail, which serve to show the complexity of problems across an enormous diversity of habitats :- unwanted woody regeneration in grasslands, and inadequate regeneration in forests to replace existing cover.

These problems are of interest in that they show different approaches to their solution. Grassland maintenance is a new concept for wildlife managers from a forestry background, in many PAs it is being undertaken vigourously. Inadequate regeneration of forest species is an old problem to forest managers, but it tends to be ignored by managers of wildlife areas. Most management inputs in Indian Protected Areas are involved with regulating people's activities. Rarely is vegetation a limiting factor on its own; given protection, vegetation can continue. Other habitat factors, such as water, can be limiting for wildlife and much effort is directed towards increasing water supplies.

Much information presented here is not available in the literature; we do not attempt to list local reports but suggest interested readers contact the authors for further information on sources. The locality of PAs mentioned in the text is shown in fig. 1.

THE RANGE OF VEGETATION MANAGEMENT PROBLEMS AND PRACTICES IN INDIA

a) Changing Concepts of Vegetation Management in Wildlife Protected Areas.

In the early days of wildlife conservation, policy was to manage an area for featured large mammal species (tiger, bison, etc.). The habitat was seen as a substrate which could be modified to suit particular species. In one park even the replacement of stands of natural vegetation by grain and legume crops as dry season forage was considered. Whilst nothing this drastic has been implemented, there have been many instances of planting fruit and fodder trees, reseeding grasslands and even sowing of Stylosanthes in PAs, all in the name of forage development for selected herbivores. The planting of grassy 'blanks' with trees is a hangover from forestry management, and is still practised today, often as a result of dual control.

It is increasingly realised that vegetation has conservation value both as part of a biotic community (Project Tiger approach, eg. Panwar, 1985), and in itself as a natural entity (the Biosphere Reserve approach). Whilst few PAs have been declared solely for vegetation values, eg. Valley of Flowers NP in the Himalayas, more are planned (Rodgers and Panwar, in press), and several PAs do give prominence to vegetation in their stated goals and management plans (eg. Kalakad WLS in the Western Ghats).

Added to this problem of changing concepts of vegetation is an occasional difficulty in framing rational conservation objectives. Palamau Reserve in Bihar for example has a goal of 'conserving the ecosystem for the tiger' Now after 12 years of protection there has been a great increase in vegetation cover and some authorities believe prey populations are declining as a consequence. There are now suggestions to open up much of the vegetation cover.

b) The Regulation of Resource Exploitation - Forest Working.

Commercial wood extraction from PAs is usually considered in terms of its effects on wildlife populations (eg. Johns studies in Indonesia, 1981), although measurement of logging damage indicates working can seriously affect forest growth and regeneration (Hall and Rodgers, 1985). Logging in India is governed by the silvicultural systems described in working plans and their prescribed marking rules. Rules are designed to protect catchment capability, to leave a canopy structure adequate for regeneration of favoured species (eg. Andamans Lifting Shelter wood System) and, as a consequence of wildlife interest, to leave a certain number of fruit, fodder and nesting trees including hollows and snags, as well as so much fallen wood per unit area. These rules may or may not be rigidly applied, but rarely do the rules refer to vegetation considerations. Many actions are taken to decrease plant community diversity : climber cutting, competitor removal and enhancement of selected species, and rarely are measures taken to increase genetic flow such as the maintenance of intact natural corridors within intensively worked forests. Sanitary felling is often considered necessary to reduce pathogen infestation, stimulate regeneration, reduce fire hazards and improve catchment capability etc. all unsupported by hard evidence (Saharia and Sawarkar 1982). Sanitary felling results in a young forest, without the complexity of epiphyte, climber and decomposer communities. Disturbance and large gaps are the rule, rather than the smaller gaps of natural tree fall. More research is needed to determine optimum working practices.

c) The Regulation of Resource Exploitation - Minor Produce and Firewood.

The extraction and preparation of Minor Forest Produce gives a livelihood to millions of people in India. Pressures can be so high that one area is burnt (ground layer and litter) three times a year to facilitate the collection of sal (Shorea robusta), Madhuca fruits and to stimulate Diospyros coppice for local cigarette manufacture. Cattle grazing and lopping of trees for fodder again is widespread, Livestock densities in forest areas may be over 200/km^2 (Rodgers in press), numbers usually increase in the growing season. These pressures have an obvious depressant effect on wild herbivores (carnivores may benefit). We estimate that a circle of radius of 2 km around each cattle camp or settlement has much lower large animal densities (unpublished data from Sariska Tiger Reserve). This is a consequence of habitat change : reduction in available water, loss of tree and ground cover, loss of plant diversity, loss of regeneration, increased weeds, increased erosion as well as physical disturbance. On a larger scale population pressures have led to forest fragmentation.

A major goal of PA management is the reduction of this detrimental impact on wildlife habitat. The management of people needs political goodwill and the ability to offer people alternative life styles; these are often factors out of reach of the professional wildlifer. Attempts to regulate exploitation levels by fees, permits, blocks, seasons etc. have all met with considerable opposition. Many conservationists believe that there can be no compromise between 'all in' or 'all out'. In theory National Parks are supposed to be free of settlement and exploitation. This is often not the case, and many National Parks have large numbers of villages e.g. Sanjay National Park has over 50 in 1800 km^2, Kanha National Park, one of India's best known wildlife areas, has 11 in the eastern 400 km^2 although 22 were shifted in the 1970s, an example of what can be done given proper inputs. Plans to resettle these still growing villages are nearly always bogged down due to inadequate land elsewhere, lack of finance and lack of political goodwill.

The larger WLS frequently have existing or planned core zones, free of exploitation. The rest of the area, known as a buffer, generally is intensively exploited. Protection of core areas and regulating buffer use takes up much of the duty time of management staff.

d) Fires and Vegetation in Indian Protection Areas.

This subject has recently been reviewed from the management action viewpoint (Sawarkar, 1986) and for the ecological implications (Rodgers, 1986).

Much effort is spent on preventing and fighting wildfires. This involves fire line cutting and back burning, use of watch towers fire fighting force etc. Little use today is made of prescribed early burning to prevent more catastrophic late summer fires and there is still debate on its usefulness. In some areas fire is viewed as such a potential disaster that grasslands are cut by hand to stimulate new growth, rather than management burning (Palamau Tiger Reserve).

It is only in the moister areas with a potential for grassland development that fire is used as a management tool, this is discussed later in this review. Elsewhere in India fire is rarely used today, although there is increasing discussion of its value in creating better wildlife habitat. Rodgers, Bennett and Sawarkar (1986) suggested that by reducing shrub layer height the occasional fire could increase browse availability for wildlife.

e) Eradication of Weeds.

This is one aspect of vegetation management where the plants themselves are manipulated, although weed abundance is usually a function of over-exploitation, and successful long term removal does depend on the reduction of adverse impacts on the environment. Many species of weed are recognised in India's forests and PAs, a partial list is shown in table 1. Lantana camara a pantropical invader originally from America is the most pernicious. Lantana rapidly colonises disturbed and overgrazed areas, and, being almost non-palatable, quickly spreads to the exclusion of virtually all other species. Lantana thus eliminates palatable forage for wildlife, although it does offer cover, and some birds are attracted to the fruits (Sawarkar, 1985). Regeneration of forest species is greatly delayed, although some species will slowly emerge through the Lantana canopy and ultimately shade it out, including the bamboo Dendrocalamus strictus. Some form of Lantana

control is practiced in a large proportion of Indian PAs. Little practical success has been achieved with biological control, or with chemicals (but not really desirable in natural PAs any way) and most operations involve manual uprooting, which in terms of employment generated is of great social benefit. Root removal is necessary to prevent immediate dense coppice regrowth and this forms some 75% of the cost.

Field trials in some areas, eg. Bori WLS in Central India suggest three consecutive years of cutting, uprooting and burning slash may be necessary to control Lantana. This can be justified in potential teak plantation, but is more difficult to fund in financially non-productive parks. Corbett National Park has achieved control in wet alluvial areas by clearing and planting a rapidly growing tall grass (Arundo donax) which dominates and excludes the coppice growth by the third year.

There is a need for more careful monitoring and publicising of control efforts with realistic portrayals of costs involved. Some observers believe that as Lantana does provide reasonable soil cover and a soil binding function it has a useful role to play in eroded areas. This may be so outside the PA network but long term planning for major PAs must stipulate its eventual exclusion by both clearing and protection.

THE DEVELOPMENT AND MAINTENANCE OF GRASSLANDS.

India has little natural grassland and much of that has long been taken over for cultivation (Whyte, 1964). The grasslands however do provide essential habitat for many of India's large mammals, including the blackbuck in the arid west, several sheep and goats in the high Himalayas and a variety of species including rhinoceros, buffalo and swamp deer in the alluvial valleys of the Ganges - Brahmaputra drainage (Rodgers in press). In addition, anthropogenic grasslands in peninsular India carry the densest and most easily visible populations of typical woodland and edge species, eg. chital (spotted deer) on Bandipur NP meadows (John Singh 1986); and Kanha NP (Kotwal 1979). Most of these grasslands, including those above the tree line, are subject to normal processes of succession involving increase in woody species and loss of grass cover. There is clearly a need for management effort to maintain existing grasslands and in some areas there is growing interest in creating new grassland by forest clearing.

I. Natural edaphic and climatic grassland communities.

a) The Brahmaputra valley grasslands in Assam carry a very tall grassland interspersed with swamps and evergreen forests on higher lands. Dry season fires have long been a feature of their ecology, and many authorities belive such burning necessary to maintain grazing large herbivore populations, (Laurie 1978). Management authorities of two major PAs, Manas WLS and Kaziranga NP do burn large areas every year (Deb Roy 1986) but this is rarely to specifically formulated plans, and is not well documented. The practice may be deleterious to pygmy hog and hispid hare populations in Manas, and the widespread tree of the grassland edges, Bombax malabarica shows little recruitment from the seedling stages due to repeated annual fires. To date Laurie's call for experimentation and monitoring is virtually unheeded.

b) The arid grasslands of Velavadar NP on the saline soils of coastal Kathiawar Peninsula in Gujarat, has one of India's largest and densest blackbuck populations largely due to the productive pastures of a Cynodon-Sporobolus pasture originally maintained as a 'royal grassland reserve'.

In the 1950s an inflow of cattle followed the collapse of royal control. This and an invasion of exotic Prosopis juliflora, caused dramatic decline in black buck populations. In the last decade protection has allowed the population to grow but Prosopis has become firmly established in one third of the park and management every year clears seedlings from the main pasture, another third.

Seedlings are dispersed throughout the park by the faeces of blackbuck and illegal cattle, both of which eat the pods of the largely non-palatable Prosopis. This seedling extraction consumes 25% of the parks operating budget. Mature Prosopis does provide some benefit : in pods which nutritionally are valuable dry season food, in shade, and in giving protection to some grass plants, allowing them to flower and set seed. Prosopis clumps offer protection to the Indian wolf, a threatened species. Management is debating the extent to which Prosopis should be eradicated. Should it be replaced by native Acacia nilotica ?

c) The alpine meadows of the Himalayas are a mix of typically temperate grass sedge and forb species, seemingly well adapted to some level of grazing but are extremely heavily exploited by transhumant domestic livestock (Rawat and Rodgers in press). Most Himalayan PAs are sanctuaries which still permit grazing, but there is little regulation and the less steep productive pastures are devoid of wildlife. Total protection may bring further problems in that reduced fire and fuel wood cutting may allow the spread of prostrate alpine species of Juniperus, which are not palatable. This is happening in Dachigam National Park in Kashmir for example (pers. obs. 1986).

II. The anthropogenic grasslands of peninsular India.

The meadows of Kanha NP are among the most well known grasslands in India eg. (Kotwal 1979) and are the only habitat of a relict race of Swamp deer. The meadows are believed to be old shifting cultivation sites, maintained by frost, fire, grazing and cutting. Many of the lower meadows have year round high grazing pressures. Where there is less grazing pressure, meadows rapidly produce a grass cover of tall, coarse, relatively unpalatable species and herbivore densities stay low. Meadows of flat hill tops have seasonal water shortages and densities are lower.

In nearly all cases there is the beginning of obvious invasion of meadows by tree species, firstly Lagerstroemia and Butea which are frost resistant, then Shorea.

There are three problems for management to deal with, overgrazing on some meadows, underutilisation of others and woody species invasion. Fire is being considered for the two latter, and a mixture of corridor openings, alternative water and grazing exclosures for the former.

III. New grasslands for wildlife.

Several PAs have started to develop new grasslands to increase and improve the habitat for edge species generalist herbivores such as chital and bison and to allow their observation by growing numbers of tourists. Totally new areas are being cleared in Palamau, abandoned and resettled village sites are to be maintained in Satpura, and roadside viewlines are to be greatly extended in places in Nagarhole. Management has to contend with three problems, preventing succession towards forest cover ensuring

grass cover remains in palatable condition for a long period of the year, and preventing take over by weeds. For roadside view lines, such management is straight forward, the area is cut by hand or tractor once or twice per year and in fire prone areas, back burned as a fire break. For other circumstances a number of approaches have been tried including hand cutting of tall grass, cutting in strips and manual uprooting of woody species. Experience in Palamau suggested that weed eradication (Cassia tora etc.) was necessary for three years after grassland openings were made, after this grass density was sufficient to suppress weed cover.

THE PROBLEM OF INADEQUATE REGENERATION OF DOMINANT TREE SPECIES

Traditional forestry has long noted the difficulties of obtaining adequate regeneration to restock natural forests (Troup, 1931; Champion, 1933). Such problems occur in several major communities including Sal (Shorea robusta), teak (Tectona grandis), and bamboo (Dendrocalamus strictus), because of excessive livestock pressures, fire, frost and unsuitable canopy and ground conditions. Whilst there has been some recent attempt to understand these problems and suggest management actions (Prasad, 1985), in many cases forestry has turned to plantation or coppice systems to replace or complement natural regeneration.

Whilst these solutions may be practicable in commercial forestry situations they are not usually compatible with normal conservation goals of PAs where replanting is usually only acceptable as a means to restore badly degraded areas or to provide shared resources in buffer zones. Few management plans address the question of inadequate canopy replacement, most comment on perceived fodder plant shortages. Wildlife managers are concerned with animal censuses; forest enumerations, inventory and stock mapping, standard procedures in RF, and which could show changes in vegetation type and structure, are no longer implemented, although the need for habitat mapping is often expressed.

Where the problem is due to excessive browing or fires, traditional forestry has been able to protect specific forest blocks by walls and ditches. Such measures are expensive and can often only be implemented when projected benefits can justify construction.

Sariska Tiger Reserve is typical of the semi-arid (6-700 mm pa) ancient Aravalli mountain forests of eastern Rajasthan and is dominated by Anogeissus pendula on the hill slopes and Butea - Ziziphus Acacia in the valleys. Anogeissus was worked and protected for fuel wood, but since declaration as a sanctuary all forest protection walls have become derelict. Table 2 shows the pattern of size class frequency in woody individuals and seedling abundance in two sites, one near to a cattle camp and one in the reserve centre. The data clearly show there has been regeneration in the recent past (abundance of stems in the 5 to 15 cm girth classes) but there is virtually no regeneration today in the unprotected site. High dry season wildlife and livestock densities in valleys with artificial water supplies can prevent all seedling development and recruitment. Table 3 shows population data for Butea and Ziziphus from two valley sites. There has been no regeneration at either site for a very long time. Site 2 has been free of cattle for eleven years but wildlife densities of over 70 large ungulates per km^2 (Rodgers, unpublished data) prevent seedling growth.

Dudhwa National Park in the moist sal (Shorea robusta) forests of north Uttar Pradesh has been stated to have some of Indias finest sal stands which were extensively worked prior to park formation in 1976. Management allowed

cattle grazing, and specified the occasional cool burn to clear the ground litter to aid seedling germination. Canopy opening by selection felling was thought to be beneficial to regeneration. Since park inception, cattle have been removed and the incidence of fires in the forest habitats greatly reduced. The shrub layer has become very dense, including a scrambling climber Tiliacora, which effectively hinders seed fall and germination. The pattern of recruitment to adult size classes is shown in table 4, and is compared with the same area in the 1950s. Seedling density today is very low.

Corbett National Park has a drier sal community in the Himalayan foot hills, and long term wildlife protection has allowed the development of dense herbivore populations in favoured locations, such as in the vicinity of Dhikala grasslands. The mature sal forests around these grasslands show no present seedling regeneration or pole crop recruitment, although some recruitment is evident in areas of lower wildlife numbers (see table 4). However, areas with a thick Lantana weed infestation do show sal seedlings which are protected from browsing animals. It remains to be seen if these seedlings will penetrate the weed cover.

In Bori WLS in Central India teak regeneration is now relatively rare and management depends on plantation and enrichment planting. Examination of a Bori preservation plot shows that there has been adequate, recruitment up to a few years ago as frequencies are high in the smaller girth classes (table 5). The reasons for the lack of regeneration are not clear, suggestions include changed fire regimes and livestock trampling. The earlier plantations of teak and bamboo do support high populations of sambar deer and bison but there is now only a small area of reasonably natural moist teak forest left. Conservation objectives as to whether to produce animals, natural teak, or timber and in what proportions are ambiguous and the subject of debate.

Gir National Park and WLS in Gujarat with some 700 mm rain is at the lower limit of precipitation for teak, and regeneration is now extremely scarce,although other species such as Acacia do show seedling and sapling crops. Increased aridity and livestock trampling are mentioned as possible reasons. The current drought with consequent increase of cattle using the area can only exacerbate the situation.

CONCLUSION

This brief review cannot do justice to the extent and magnitude of vegetation management problems in India's Protected Area network. Several things do stand out however, and warrant further discussion.

Firstly, is the need to spell out very clearly the objectives of conservation and only then can non-ambiguous management options be agreed upon. Once management moves beyond the protection phase, this problem will become increasingly prevalent, as in Palamau, Bori and Kanha today.

Secondly, is the overwhelming importance of human and livestock pressure on the environment. Many common vegetation problems stem specifically from such disturbance, such as reduced regeneration and spread of weeds. It is pointless to treat the symptoms, unless the "illness" itself is curbed.

Thirdly, is the low level of quantitative monitoring of the vegetation resources and the effects of management action. Even in cases where there

is monitoring, the results are not finding their way into the accessible literature. There is a great need for management publicity and for disseminating ideas and results. Only when this is done can the management of vegetation take a much needed 'giant step forwards'.

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Table 1. Some major weed species of India's Wildlife Protected Areas.

Scientific Name	Habit	Localities etc.
Prosopis juliflora *	Woody shrub to 4 m	Drier western India
Lantana camara *	Woody shrub to 3 m	Widespread in peninsula
Tiliacora racemosa	Woody climber	Mainly in north
Eupatorium adenophorum *	Herb to 0.8 m	Himalayas
Eupatorium odoratissima *	Herb to 2.0 m, scandent	South peninsula
Mikania scandens *	Climber	Moister east
Parthenium spp	Annual herb	Widespread
Cassia tora	Annual herb	Widespread to 1500 m
Achyranthes aspera	Annual herb	Widespread to 1500 m
Strobilanthes spp.	Gregarious perennial acanth.	Widespread in hill ranges
Adhatoda vasica	Woody subshrub to 2 m	Mainly in north
Imperata cylindrica	Cotton grass, perennial	Moister areas

Species marked * are exotic to India.

Table 2. Girth class and seedling height distribution for Anogeissus pendula in Sariska WLS.

Girth class (in cm)	Site 1 Open to cattle	Site 2 Open to Wildlife
5 - 10	6 %	11 %
10 - 15	14	17
15 - 20	13	14
20 - 25	15	8
25 - 30	14	5
30 - 35	13	5
35 - 40	7	4
40 - 45	7	3
45 - 50	3	3
50 - 55	2	4
55 - 60	3	2
60 - 65	1	3
65 - 70	1	5
70 - 75	2	5
75 +	0	4
Seedling height		
0 - 50 cm	8 per ha	216 per ha
50 - 100	2	182
100 - 150	2	42
150 - 200	4	144
Total	16	584

Table 3. Girth class distribution for two prominent tree species of valley habitats in Sariska WLS.

Girth class	Butea monosperma	Ziziphus Site 1.	Mauritiana Site 2.
10 - 20	0 %	0 %	0 %
20 - 40	0	0	0
40 - 60	0	20	23
60 - 80	5.0	27	22
80 - 100	16.5	24	29
100 - 120	14.0	18	11
120 - 140	12.5	7	6
140 - 160	11.5	2	5
160 - 180	9.0	2	3
180 - 200	8.5	0	1
200 - 220	6.0	0	0
220 - 240	4.5	0	0
240 - 260	2.5	0	0
260 - 280	3.5	0	0
280 +	2.5	0	
n	200	100	100

Site 1 is open to cattle and wildlife browsing, site 2 to wildlife only.

Seedling counts are virtually nil for both species.

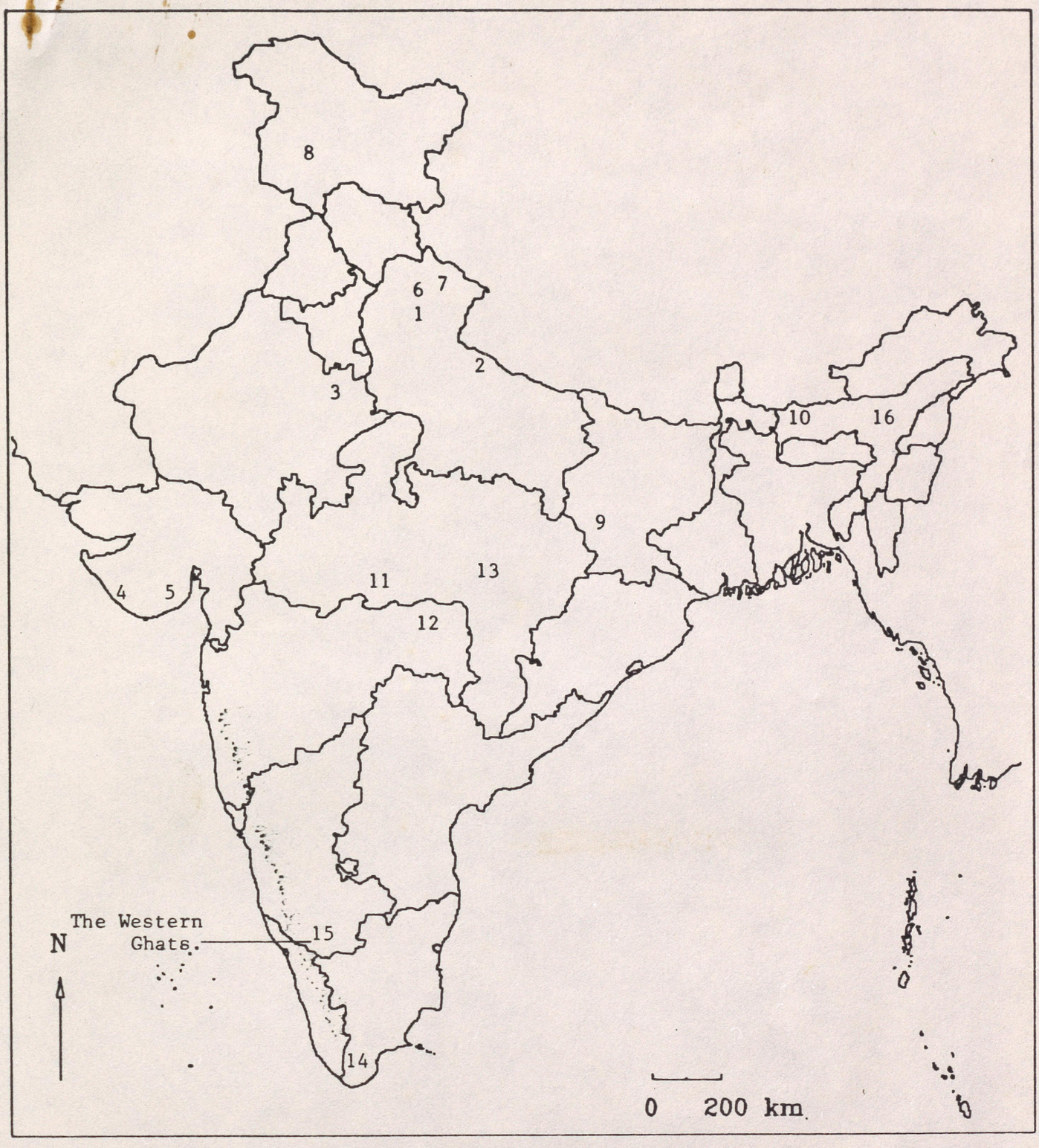
Table 4. Girth class and seedling height distribution for Shorea robusta.

Girth class in cm	Dudhwa National Park			Corbett National Park	
Date or Locality	1985	1986	1950s.	Khinauli 10A	Sultan
20 - 40	0 %	0 %	Abundant	0 %	9 %
40 - 60	1	0		0	23
60 - 80	8	0	44 %	1	9
80 - 100	14	8	36 %	7	12
100 - 120	14	14		16	17
120 - 140	13	15	15 %	13	11
140 - 160	15	20		21	10
160 - 180	15	28	3 %	29	4
180 - 200	13	8	2 %	8	3
200 - 220	4	5		3	1
220 - 240	2	1		0	0
240 +	1	1		0	0
n	278	100	large	300	400
Seedling height					
0 - 30 cm	low	1200/ha		500/ha	7,800/ha
30 - 60	nil	0	Abundant	0	1,025
60 +	nil	0		0	0

Data for 1950s taken from North Kheri Forest Division Working Plan.

Table 5. Girth class distribution for two dominant tree species in particular localities.

Girth class (in cm)	Bori WLS (teak) (Tectona grandis)	Kedarnath WLS (oak) (Quercus semecarpifolia)
20 - 40	2 %	0 %
40 - 60	5	0
60 - 80	5	5
80 - 100	10	16
100 - 120	6	19
120 - 140	11	11
140 - 160	17	4
160 - 180	18	7
180 - 200	15	5
200 - 220	6	4
220 - 240	3	5
240 - 260	0	4
260 - 280	2	5
280 - 300		8
300 - 320		7
n	151	50



1. Corbett NP
2. Dudhwa NP
3. Sariska WLS + NP
4. Gir WLS + NP
5. Velavdar NP
6. Kedarnath WLS
7. Valley of Flowers NP
8. Dachigam NP
9. Palamau NP + WLS
10. Manas WLS
11. Bori WLS
12. Tadoba NP
13. Kanha NP
14. Kalakaad WLS
15. Bandipur NP
16. Kaziranga NP

Fig. 1. Map to show the location of protected areas mentioned in the text.