OCCASIONAL REPORT NO. 12

SILENT STRANGLERS

Eradication of Mimosa in Kaziranga National Park, Assam

Joseph Vattakkavan, N. K. Vasu, Surendra Varma,
Nidhi Gureja, Ambika Aiyadurai

Wildlife Trust of India

Assam Forest Department

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The Wildlife Trust of India (WTI) is a non-profit conservation organization committed to help conserve nature, especially endangered species and threatened habitats, in partnership with communities and governments.

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FOREWORD

Alien invasive species have been a matter of great concern for wildlife managers who have been trying their best to protect species and their habitat, which are already threatened by ever increasing human population and their never ending demands for resources. Invasive species that first threatened our parks was eupatorium, followed by lantana, parthenium, mikania, and of late, mimosa. Mimosa is considered to be the worst because it is learnt to be toxic to herbivores.

The Assam Forest Department has been making an all-out effort to conserve the habitats of elephants and rhinoceros and their typical alluvial grasslands and forests. Alert and vigilant staff have been successful in protecting the species from poachers and other offenders to a great extent. We have also succeeded in containing loss of habitat through encroachment and other means. However, of late, the invasion of mimosa from the tea estates nearby has emerged as a threat to the herbivore habitat in Kaziranga National Park. We started an immediate action to control the weed using the traditional method of uprooting the stock. The Wildlife Trust of India (WTI) and its partner the International Fund for Animal Welfare (IFAW) were also quick in responding to our request by extending financial assistance and organizing a field team to investigate the weed problem.

Fortunately, the collaborative effort of the Forest Department, WTI and IFAW has been able to contain the menace to a limited extent thereby saving the habitats of the endangered elephants, rhino and wild buffalo along with innumerable number of other species living in the area. However, further assistance from the NGOs is required to continue this operation for some more time.

The programme is a good example of a successful collaborative effort between voluntary organizations and a government department to save wildlife, which is the ultimate objective. The joint venture has also opened up new avenues for further collaborative programmes involving the Park officials and also the experts, thereby giving the opportunity to the staff to be up to date with conservation efforts all over and to get involved in the monitoring of the habitat in a systematic manner.

I wish the attempt for eradication of the weed from the Park and adjacent areas a complete success.

M.C. Malakar
Chief Wildlife Warden, Assam
Rehabari
Guwahati-8

PREFACE

Invasive alien species have become a major threat to wildlife habitats the world over. These are accidentally, or more often, purposefully brought in for certain beneficial characteristics, overlooking the procedure to be followed while making such introductions. Historically, all the introductions both accidental and purposeful have turned to be disastrous to native habitats and species.

The recent stress on mikania, lantana, parthenium and mimosa eradications call for immediate action to prevent such erratic introductions leading to endangerment of species and their habitats.

Mimosa has spread to Kaziranga National Park from adjoining tea estates, spreading to parts of the park and threatening the habitat of the already endangered rhino population. Mimosa species is reported to be poisonous to herbivores and is considered to be one of the most serious alien invasive species. The present report describes the first ever attempt to control the spread of the weed with an ultimate aim of bringing it under control. The programme is the beginning of a long term procedure for saving Kaziranga National Park from the threat of an alien poisonous invasive species.

Dr. P.S. Easa
Wildlife Trust of India

ACKNOWLEDGEMENTS

The authors are grateful to the Assam Forest Department for extending support throughout. Mr. M. Malakar, Chief Wildlife Warden permitted the field work and joint publication of the report. The Asst. Conservator, Mr. Dey and the Forest Range Officers, Mr. Boro, Mr. Tamuli and Mr. Alam and other field staff were co-operative in the field. Ms. Sarah Scarth and Kelvin Alie of the Animals in Crisis and Distress department and Ms. Grace Gabriel of the Wildlife and Habitat department from the International Fund for Animal Welfare were quick in sanctioning the financial support for the programme.

Dr. I.C Barua, Sr. Scientist, Assam Agricultural University, Jorhat, gave inputs on the mimosa weed menace and confirmed the identity of the mimosa species. The director and scientists at the Tea Research Association, TOCLOI, Jorhat provided information on mimosa species, their use and management in tea gardens. Dr. P.C. Bhattacherjee of Guwahati University helped in co-ordination of the work.

Mr. S. Singsit, Director of the Wildlife Institute of India, Dehradun permitted the use of the Institute's facilities for analysis and report writing. Dr V. B. Mathur, Professor and Shri. Panna Lal, Programmer in particular helped in the preparation of the GIS maps for the report. Dr. K. V. Sankaran, Scientist, Kerala Forest Research Institute provided references and commented on the work.

Mr. Vivek Menon initiated the project and spent some time in the field. The first author is thankful to him for providing the opportunity to work in Kaziranga. Aniruddha Mookerjee was instrumental in getting the financial assistance from IFAW. Dr. P. S. Easa edited the report and provided references and inputs especially at the incipient stage.

EXECUTIVE SUMMARY

A survey of the alien invasive weed mimosa was carried out in March 2003, by the Wildlife Trust of India (WTI) in collaboration with the Assam Forest Department and in partnership with the International Fund for Animal Welfare (IFAW) at the Kaziranga National Park (KNP), Assam, India. This followed close on the heels of an intensive weed eradication measure undertaken in the park by the Forest Department soon after the threat of the weed was first identified to the park's critical grassland habitat. The eradication effort was started in the mid 90s in the Baguri range of the park after the weed was first noticed. Since 2002-03, WTI and IFAW had been providing monetory assistance to the Kaziranga National Park authorities for manual eradication of the weed. The park holds 85 per cent of the global population of the endangered greater one-horned rhinoceros (*Rhinoceros unicornis*) and significant populations of the Asian elephant (*Elephas maximus*), swamp deer (*Cervus duvauceli*) and the tiger (*Panthera tigris*). The park is also a World Heritage Site. The objectives of the survey were to identify the species of the weed, assess its distribution and estimate the extent of area infested. The survey also assessed the management strategy adopted to control the weed. Visual estimation was done to estimate the extent of the mimosa patches. GPS locations of the patches were recorded and plotted on an area map. Quadrates were laid in burnt mimosa patches to estimate seedling germination. The preliminary patterns observed are as follows:

1. **Mimosa was distributed more along the boundary of Kaziranga National Park.**

   Rivers flowing near park boundaries, the annual occurrence of floods, the peripheries of the park being more exposed to people, seeds sticking to the tyres of vehicles passing on the National

Highway 37, cattle straying into the park and the presence of several 'bheels' (water bodies) and small streams within the Park that provide moist conditions, facilitated the spread of the weed from its original source, which were the adjoining tea gardens that had introduced the plant as a nitrogen fixer into their planta tions.

2. Prompt action limited infestation to only 0.5 per cent of Kaziranga National Park.

The survey determined that due to the prompt action of the park authorities, assisted by WTI and IFAW, the extent of mimosa in the park was limited to about 0.5 per cent (2.13 km^2) within the tall grassland areas while the weed had not yet taken root in the short grassland areas, which is one of the main food sources for mega herbivores of the park. Of the four ranges of the park, the Baguri Range was the most infested (58 per cent of the total infested area), followed by Kohora (39 per cent) and Agratoli (3 per cent) and priority (effort, time and funds) for control measures should be in the Baguri Range. The seedling germination density was the highest in Baguri with 55 seedlings/m^2, Kohora with 20 seedlings/m^2 and Agratoli with 12 seedlings/m^2.

3. Two varieties of mimosa were found to be present.

There were differences in the variety of mimosa across the ranges; the Baguri Range had *Mimosa invisa* (thorny variety) and Agratoli had the thornless variety *Mimosa invisa inermis*; Kohora had both the varieties though the thornless one was predominant. This could be due to the soil or microclimate characteristics or type and the variety of mimosa grown in the tea gardens adjacent to the ranges.

With the backing of our findings as well as similar efforts attempted elsewhere, the following measures are suggested for aiding in the eradication of mimosa from KNP:

1. **The control measures are to be carried on annually for at least three more years to ensure complete eradication from within the park.**
2. **The plant be completely uprooted and not cut at the base and this has to be followed by burning to achieve the best results.**
3. **Eradication be done twice a year: once in October - November and early December before the seeds are mature and once in May - June when young regenerated plants carpet the ground.**
4. **An integrated, management plan involving biological control, herbicide application, mechanical removal, controlled burning and pasture management be put in place to ensure that further infestation does not occur from the tea gardens and that complete eradication is achieved in the Park.**
5. **A targeted awareness campaign be conducted among tea-related organizations and other planter's bodies to educate them about the menace of mimosa.**
6. **Interruptions in the control program to be avoided, since this allows mimosa to recover from the past treatment.**

Prompt action by the park authorities and the two partnering NGOs has ensured that the spread of mimosa has not seriously affected this World Heritage site. In 2002, about 56 per cent of the mimosa were removed by cutting, 41 per cent by uprooting and 3 per cent area was not cleared of the weed.

1. INTRODUCTION

Human intervention in pristine ecosystems has helped some species cross ecological barriers and spread. Alien invasive species are recognized as the second largest threat to biological diversity (Singh, 2001; IUCN, 2000). Recent developments in trade, travel and other fields have rendered every precaution taken, through customs and quarantine practices, ineffective. IUCN (2000) defines an alien invasive species as an alien species, which becomes established in natural or semi-natural ecosystems or habitat, as an agent of change, and threatens native biological diversity. This is distinctly different from an alien species, which only connotes a non-native, non-indigenous, foreign, exotic species, subspecies, or lower taxon occurring outside its natural range (past or present) and has dispersal potential and includes any part, gametes or propagule of such species that might survive and subsequently reproduce. The implications of intentionally or unintentionally introduced alien species have not been fully understood. The impacts of alien species on the native ones and the naturalness of the ecosystem is immense, unpredictable and often irreversible. Economic loss could be enormous affecting the crop yield, promoting pathogens and pests and increasing the cost of production. Alien species are aggressive colonists (invaders) and have a damaging effect (Sandland *et al.*, 1996) on the ecosystem as a whole.

Kaziranga National Park (hereinafter the Park), Assam is infested with mimosa. It is a straggler that chokes the native grassland habitat in the Park and has established itself mainly in small patches (Figure 1). It produces minute seeds profusely, which are easily spread across the Park during the rains. The weed was reported to be spreading rapidly across wildlife habitat, hampering access to food and other resources and the movement of wildlife.

Mimosa is a native of tropical America and was imported by neighboring tea gardens from East Asia in the 1960s, as a nitrogen fixer prior to planting tea. Since many of the tea gardens are at a higher elevation than the Park, mimosa seeds are carried by running water into the Park during the monsoons. This weed is believed to be a serious threat to the Park, and attempts have been made to control its spread since the mid 1990s. The Forest Department has, since then, been mechanically removing the weed with the help of hired laborers and tractors. Removal is not an easy job due to the thorny nature of mimosa, and the Forest Department has very limited resources to tackle this problem.

Figure 1: Mimosa strangling the tall grasses

Sankaran (2001) reported *Mimosa invisa* as a threat to the forest areas of South India. The thornless variety of *Mimosa invisa* was brought by the planters to the hilly tracts of Kerala to prevent cattle from entering the estates (Rajan *et al*., 1986). Rajkhowa *et al.* (2003) reported occurrence of the species in sugarcane fields in Assam. When consumed, the toxin in the plant causes vascular endothelial damage, nephrosis, necrosis of the heart and liver, leucopaenia and anaemia in herbivores (Rajan *et al*., 1986). Alex *et al.* (1991) reported a case of *Mimosa invisa* poisoning in a heifer. There are indications that Mimosin - (à - N - [3 - hydroxyl - 4 - pyridone] - à -aminopropionic acid)—a non-protein amino acid in mimosa is hazardous to animals (Rajkhowa *et al*., 2003). Therefore it was feared that rhinos and other herbivores could consume it, with fatal effects.

Wildlife Trust of India and its partner, the International Fund for Animal Welfare, extended financial support to the Kaziranga National Park authorities for controlling the weed and initiated a programme to assess the extent of infestation and to look at the factors favoring the spread of the weed. The funds were released at short notice by WTI in 2002 and this assistance helped considerably to clear the weed from most of the Park. During the initial phase of the survey, it was also understood that sufficient information was lacking on many aspects of the problem. Two species, *Mimosa invisa* and *Mimosa rubicaulis* were reported to be present in the area. This had to be confirmed and other species if present, to be identified, with their characteristics and ecology, especially their flowering and seeding period, etc. This would help designing control measures that were to be carried out at the appropriate time. There was no information on the locations of mimosa patches and therefore no map available of its extent. There was also a need to evaluate the control measures adopted during the past year or so.

To look into all these aspects and to generate more information on the problem, a survey was required and this was carried out in March 2003, with the major objective of understanding the source of the problem, collecting information on the species concerned and its effect on the habitat and the mega-herbivores of the Park. This Occasional Report is a result of the survey and not of all the work that has taken place to eradicate the weed.

2. OBJECTIVES

This survey was specifically carried out to:

1. Identify the weed species and understand its autecology
2. Collect primary and secondary information on the species, its area of origin and habitat
3. Obtain GPS locations of the infested patches/areas of mimosa in the Park and to plot these locations on a GIS-based digitized map of the Park showing range-wise distribution
4. Estimate the area infested with mimosa in different ranges in the Park
5. Evaluate the control measures adopted thus far
6. Propose a strategic and integrated management plan to con trol and eradicate the weed.

3. PROJECT AREA

Kaziranga National Park (between 26°30'–26°45'N and 93°05'–93°40'E), Assam is a World Heritage Site covering an area of about 430 sq. km. It is situated in the southern floodplains of the River Brahmaputra (Figure 2). It was declared a National Park in 1974 with the objective of conserv-

ing the greater one-horned rhinoceros (*Rhinoceros unicornis*) and currently harbors the largest global population of this species. The National Park has a mean altitude of about 65 m and has a flat terrain with a gentle slope from east to west. The Park has rich alluvial deposits due to floods, and about three-quarters or more of the Park is submerged annually by the flood waters of the Brahmaputra. It has numerous water bodies ('beels'), which have often been formed due to the changing courses of the tributaries of the Brahmaputra. One such tributary, the Mori Diphlu makes up most of the southern boundary of the Park.

The Park is managed under four Ranges: Kohora (Central Range), Agratoli (Eastern Range), Baguri (Western Range), and the Burapahar

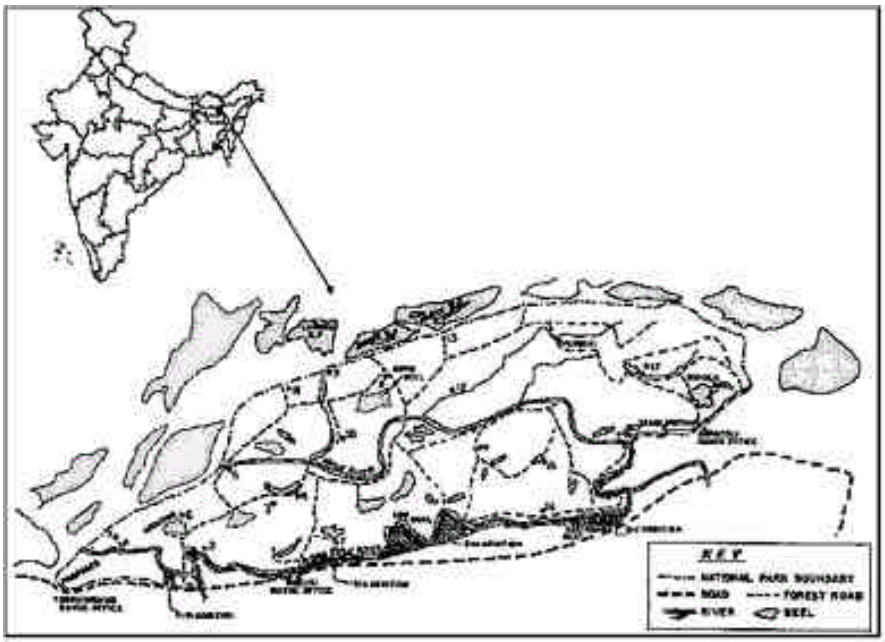

Figure 2: Map of Kaziranga National Park

(far-west Range). A regime of controlled burning of the grasslands is one of the significant and established management practices of the Park. Fire helps in the maintenance of the grasslands by arresting succession to woodlands, and provides high quality forage which is preferred by herbivores (Banerjee, 2001). Keeping this in mind, almost the entire grassland area of the Park is burnt during the post-flood season between January and February, which may extend up to April, depending on moisture regimes and grass phenology.

3.1 Vegetation types

The vegetation of KNP comprises primarily of alluvial grasslands interspersed by tropical moist to semi evergreen forests (Champion & Seth, 1968). The grasslands are of two types, the tall and the short. The tall grasslands, commonly referred to as elephant grass, occupy more than 40 per cent of the Park, and are used by animals mainly as cover. They consist of species such as *Saccharum arundinaceum*, *S. spontaneum, S.procerum*, *Phragmites karka*, *Erianthus ravennae*, *Arundo donax*, *Imperata cylindrica*, *Vetiveria zizanioides* and *Themeda arundinacea*. There are also patches of *Alpinia allughas* (Family: Zingiberaceae) between the tall grasses. The tall grasses are burnt every year during winter to prevent woodland succession. The new growth that comes up after burning is relished by ungulates especially rhinoceros and hog deer (*Axis porcinus*). Short grassland areas surround the 'beels' and are the preferred grazing grounds for all the major herbivores of the Park. Grasses include *Cynodon dactylon*, *Chrysopogon sp*., *Andropogon sp.*, *Cyperus sp*., *Fimbristylus sp.*, *Carex sp.*, etc. Woodlands make up about 30 per cent of the area of the Park and are found in the highlands and elevated areas. Dominant trees include *Bombax ceiba*, *Albizzia procera*, *Dillenia pentagyna*, *Careya arborea*, *Trema nudiflora*, *Bischofia javanica,*

etc. The park also supports luxuriant impenetrable thickets of cane.

3.2 Fauna

The Park, besides supporting the largest population of the greater one-horned rhinoceros (*Rhinoceros unicornis*) and the Asiatic wild buffalo (*Bubalus bubalis*) in the subcontinent, also has significant populations of the Asiatic elephant (*Elephas maximus*), gaur (*Bos gaurus*), swamp deer (*Cervus duvauceli)*, hog deer (*Axis porcinus*) and a small population of barking deer (*Muntiacus muntjak*) and sambar (*Cervus unicolor*). Livestock are seen grazing on the fringes of the Park. Carnivores include the tiger (*Panthera tigris*), leopard (*Panthera pardus*) and jackal (*Canis aureus*), while primates include the hoolock gibbon (*Bunopithecus hoolock*) and capped langur (*Trachypithecus pileatus*). The river has dolphins (*Platanista gangetica*). Monitor lizards (*Varanus salvator*) are common.

4. METHODS

The survey was conducted in March 2003, in Baguri, Kohora and Agratoli Ranges of Kaziranga National Park. The Burapahar Range was reported free of mimosa and was not included in the survey. Different areas of the Park were visited mostly in vehicles. Elephants were used on terrain that was inaccessible by vehicles and some patches were even covered on foot. The team had the field assistance and guidance of the Assistant Conservator of Forest (Kohora) and the field staff throughout the survey. Field staff from the locality assisted in the location of mimosa patches. This also helped to investigate or gather information on the methodology adopted for the removal of the weed. Since most of the grassland includ-

ing the cleared mimosa patches were already burnt, it was not possible to determine the extent of the patches without help from these guards.

4.1 Identification of location, area and other details of mimosa patches

GPS locations were taken at the approximate centre of each patch and the dimensions of the patches were estimated. Visual estimations were made to determine the approximate area of the patches, after estimating the length and width of the patch. Distance estimation was first practiced with the help of a measuring tape before attempting in the Park. Information was also collected on the species, whether it was a cleared or un-cleared patch, the methodology adopted for removal, whether the patch was burnt or un-burnt, species regeneration, germination and other aspects before and after removal of the weed.

4.2 Germination estimation

To estimate the density of seedlings (germination at a given point or point of time), 2m x 2m quadrates were laid in the burnt patches and individual seedlings were counted. A minimum of three and a maximum of five quadrates were laid for each patch depending on the size of patches and the logistical support available. No germination was observed in un-burnt patches and these were thus not considered for estimation of seedling density. However, in the Baguri Range, plants were counted in un-burnt, cut patches to estimate their density. This was possible only in Baguri due to the methodology adopted to remove them. In other Ranges, there were either no plants left to be counted or when present, were difficult to be counted due to their extremely tangled nature.

4.3 Taxonomy and other related information

Mimosa specimens including flowering and seedling stages were collected from different parts of the Park and preserved by preparing herbariums. These were later used to confirm their identity. Identification of the species was done mainly with the help of flora (Saldanha, 1984), and other literature which has descriptions of the mimosa species in the Southeast Asian regions (Waterhouse, 1994). Experts on the subject were also consulted with the specimens for species identification.

The research team also approached Tea Research Association, TOCLAI Experimental station at Jorhat, the Assam Agriculture University and some tea managers around the Park to obtain further information on the species, viz. the species preferred in tea gardens, their management, substitutes being advocated, their advantages and limitations, etc.

4.4 Mapping and data analysis

The GPS locations of the mimosa patches were plotted on a GIS-based map of Kaziranga National Park using ARCVIEW Software. The locations of the patches in the three Ranges were plotted using different colored symbols to aid in their identification. Density of regeneration was calculated for each burnt patch and then averaged to get the density of saplings coming up in burnt patches for each Range. The same was done separately for plants in un-burnt patches, except Baguri Range, where it was done for cut patches.

4.5 Constraints and limitations

Due to sporadic showers, some of the roads had become slushy and

some areas were difficult to access by vehicle. These areas had to be covered on elephant-back and on foot. Visual estimation of the area of the patches was often difficult as most of the mimosa patches were burnt along with the grassland. In such patches, the help of the forest guard, who knew the extent of the patch before it had been cleared, was sought. However, an idea of its boundary could be obtained as the cleared mimosa patches stand out even in the burnt landscape. Estimation was also difficult in some areas due to the scattered nature of plants. Besides these, some of the relatively minor, small-sized patches were left out of the survey, due to their remote locations. Therefore, these minor patches are not represented on the map and the actual area could be slightly greater than that estimated in this survey. It must also be considered that the density of seedling regeneration estimated is for that particular period in burnt patches and that it may increase with the rains. However, some estimate of the germination for that period in the burnt patches could be made.

5. RESULTS

5.1 Origin and distribution of mimosa

Mimosa invisa is native to tropical America. It is found from Brazil to Paraguay and tropical northeast Argentina, and also in the lowlands of Central America. It is today widely distributed in the Southeast Asian region, including India and Sri Lanka (Waterhouse, 1994). Sankaran (2001) has reported that *Mimosa invisa* is widespread in the central and southern parts of Kerala, India.

Figure 3: Profuse Mimosa flowering in the Park during March 2003

5.2 Characteristics of the species

Mimosa invisa is a fast-growing abundantly thorny, biennial or perennial shrub with an angular branching stem that becomes woody with age. The leaves are alternate, bi-pinnate and compound. The pink to purple globular flowers are borne on short prickly stalks arising from the leaf axils (Figure 3). The seed pods are covered with stiff bristles and they separate at transverse grooves into two to four single-seeded segments. *Mimosa invisa* folds its pinnate leaves when touched but it is not as sensitive as some other species, such as *Mimosa pudica*. The leaves fold at dusk. Unlike the situation in the more tropical regions such as Philippines, where *M. invisa* flowers all year round, in central and southern Brazil it flowers only from the end of January to mid-April. The seed production ability of *Mimosa invisa* and *M. prainiana* are in the range of 8000-12000 and 9000-20000 per sq.m. respectively (Rajkhowa *et al*., 2003).

Seeds mature from February to the end of May and the plants then senesce, losing most of their leaves; although a few green leaves remain at the stem base. For two to five months, green plants are difficult to find. Senescence is not due to water shortage as well-watered plants in the laboratory also senesce. However, germination occurs when moisture is available, so young plants may appear after showers of rain.

The thorn-less variety of mimosa is possibly a variety of *Mimosa invisa. Mimosa invisa inermis* appears similar in all morphological characteristics to the thorny variety except for the lack of thorns (Figure 4).

The thorn-less variety *M. invisa inermis* is capable of reverting to the thorny variety. The thorn-less variety has been suggested as a tropical pasture legume, but its tendency to revert to the thorny variety and the fact that it is potentially toxic, has discouraged its use (Waterhouse, 1994).

Figure 4: *Mimosa invisa inermis*, the thorn-less variety

5.3 Significance of the weed

Mimosa invisa scrambles vigorously over other plants, forming dense tangled thickets up to 2 m high. It is a nitrogen fixer and its extremely rapid growth smothers useful plants and other weeds. It is commonly seen along roadsides and in moist places (Waterhouse, 1994). Sankaran (2001) reports that the species is an annual but it can also grow as a biennia wherever water is available year round. The weed produces a large number of seeds, which have a long period of viability. It is heliophytic in adaptation and cannot grow well under a closed canopy. It is reported to be at its best where fertility and soil moisture are high and it prefers full sunlight.

In evergreen and semi-evergreen forests, infestation is seen only on the fringes where the canopy is fully or partially open. It is also moderately drought-resistant.

The fact that it can invade the ground completely, competing with other plants and smothering herbaceous growth implies habitat degradation

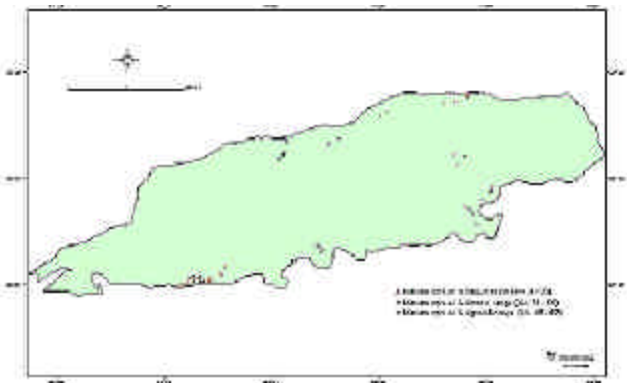

Figure 5: GIS locations of Mimosa patches in Kaziranga National Park

and loss of biodiversity. Areas infested with *M. invisa* are impenetrable because of its characteristic thick growth and its stem being armed with sharp thorns (in case of the thorny variety). It is also known to be toxic to cattle (Rajan *et al*., 1986; Alex *et al.*, 1991; Sankaran 2001). The plant has a minimum generative time of one year for reproduction. Its seed production is prolific (>2000/sq.m). The seeds are dispersed by water, by animals externally, and in some places (Australia) the seeds are dispersed unintentionally through high vehicle movement.

5.4 Taxonomy of the species in the Park

The species that is currently invasive in Kaziranga National Park was identified to be *Mimosa invisa.* It is also known as *Mimosa diplotricha* and *M. rhodostachya*. It is commonly referred to as the 'Giant sensitive plant', the 'Creeping sensitive plant' or 'Nila grass'. A biotype or a variety named *Mimosa invisa inermis* was also observed. Both types of mimosa were observed to be in flower in the Park during the period of the survey.

Range	# Patches visited	# Patches sampled	Remarks
Baguri	23	10	3 burnt, (7 un-burnt*)
Kohora	32	15	15 burnt
Agratoli	12	11	11 burnt
Total	67	36	29 burnt, 7 un-burnt

Table 1. Details of mimosa patches surveyed in different Ranges
** only mature plants were counted*

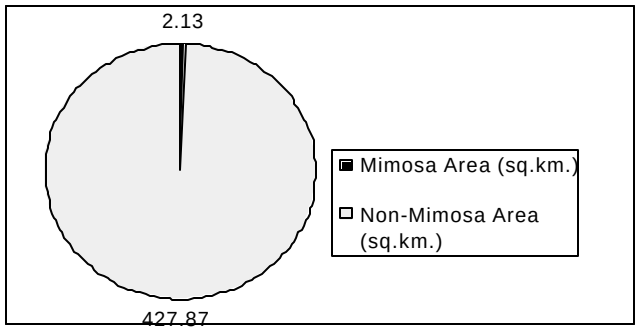

Figure 6: Representation of Mimosa & non-Mimosa area (sq. km) in KNP

5.5 Locations of the mimosa patches in the Park

During the survey, a total of 67 patches were visited of which 36 were sampled for specific information (Table 1).

5.6 Distribution of the weed in the Park

The GIS map of the plotted GPS locations of mimosa patches shows a distribution mostly on the periphery of the Park (Figure 5). The area

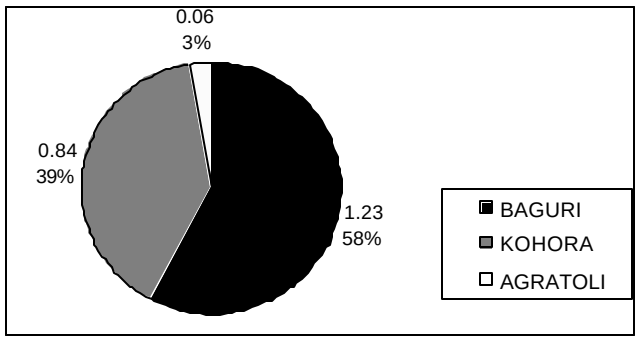

Figure. 7: Range-wise distribution of Mimosa area (sq.km)

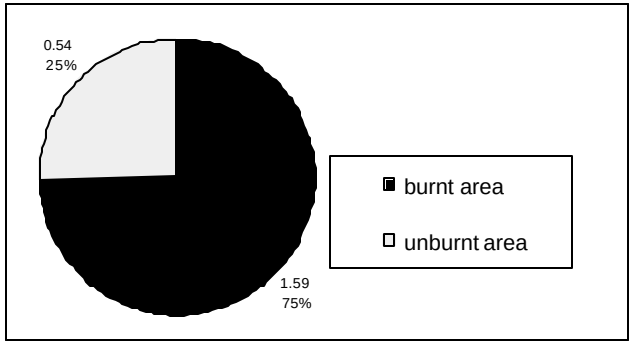

Figure. 8: Representation of burnt and un-burnt areas in KNP

infested with mimosa after control measures is about 2.13 km^2, which is about 0.5 per cent of the Park area (Figure 6).

5.6.1 Range-wise distribution of the species

A Range is an administrative unit of the Park that is managed by a Range Officer. It represents a distinct area and therefore was taken as a basic unit of division of the park for the purpose of analyses. A range-wise analysis shows that Baguri was the most infested of the three ranges, fol-

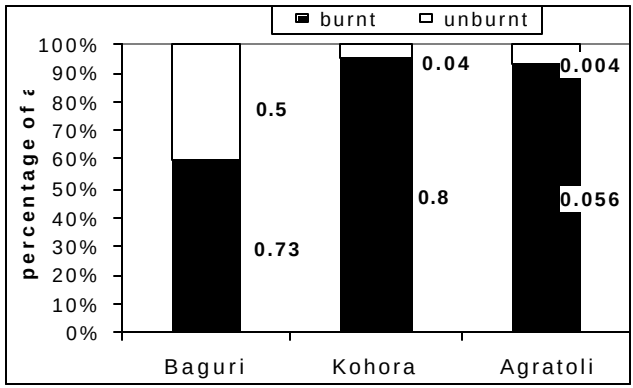

Figure 9: Range-wise representation of burnt and un-burnt areas in KNP

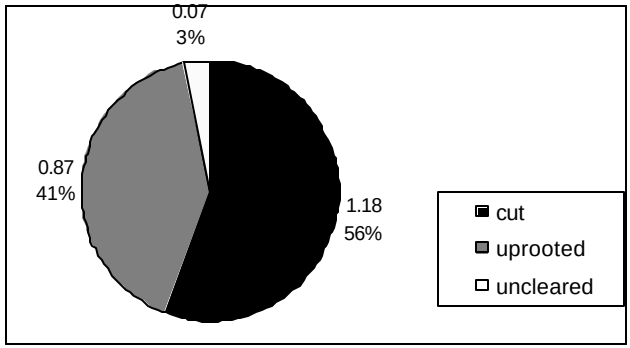

Figure.10: Representation of cut, uprooted and cleared patches in KNP

lowed by Kohora and Agratoli. (Figure 7). An analysis of burnt and un-burnt areas for the entire Park shows that 75 per cent of the mimosa area in the Park was burnt (Figure 8). A Range-wise analysis shows that almost all the un-burnt area was in the Baguri Range. In Baguri, 40 per cent of the Mimosa area was left un-burnt whereas in the other two Ranges, the area was comparatively much less (Figure 9). The measures adopted to control mimosa in KNP showed that mimosa was uprooted in 41 per cent of the infested area and cut in 56 per cent (Figure 10). About

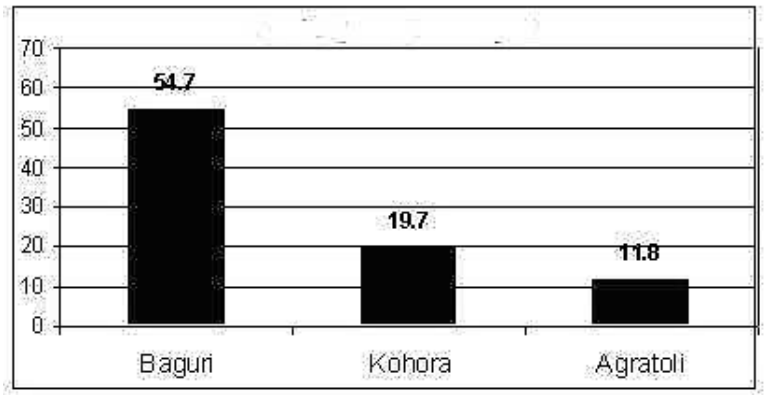

Figure.11: Density of seedlings determined per square metre for each Range

3 per cent of the area was left un-cleared.

An analysis of the data on germination from sampled areas, collected from burnt patches, showed that KNP had an average of 20 (± 5.1) seedlings/ m^2., with a maximum of 1050 seedlings and a minimum of zero plants per square metre. A Range-wise analysis showed that Baguri had the highest germination of 54.7 (± 34.5) seedlings/m^2 followed by Kohora with 19.7 (± 5.2)/m^2 and Agratoli with 11.8 (± 8.5) seedlings/m^2 (Figure 11). Density of mature plants estimated from cut, un-burnt patches in Baguri Range gave a density of 21.7 (± 9) plants/ m^2 with a maximum of 967 plants and a minimum of zero plants per square metre.

6. DISCUSSION

6.1 Distribution of mimosa patches

The distribution of mimosa patches in the Park shows that areas along the boundary are the most affected. It is known that the tea estates bordering the Park brought in mimosa as a nitrogen fixer. These tea gardens, situated at higher elevations, acted as the source. The annual floods of the Mori Diphlu River on the southern boundary and the River Brahmaputra along the northern part facilitated the dispersal of the seeds to the low-lying areas in Kaziranga National Park.

The boundaries, being close to habitations are accessed by people, who unintentionally disperse the barbed seeds that cling on to their clothes and footwear. The existence of a road along the boundary also helps in the dispersal of the seeds that stick on to tyres of passing vehicles.

There is a school of thought that the weeds would be confined to the outer boundaries. This is unlikely in a place like Kaziranga, where the grasslands are burnt annually and the Park becomes open. The seeds would definitely spread to other areas through streams during floods. Presence of several 'beels' and small streams in the Park also provide ideal moist conditions that encourage such a spread. This is vindicated by the finding of the survey that the weed had indeed spread to the interior, as seen in Agratoli and in the Aremara beat of Kohora Range. mimosa infestations are all in tall grassland areas and are absent from the short grassland areas.

This is possibly because the plant is a strangler and needs tall grasses as a support (Figure 12). The weed is reported to be a light demander, and the grasses do not fully cut off the light. When these areas are burnt, mimosa also gets the chance to grow together with the grass, using it as a support and then smothering it. This is not possible in short grassland areas. In fact, it is possible that the soil in other areas in the Park already harbors mimosa seeds, which could germinate in time and smother more areas.

Mimosa patches in Baguri were of the thorny mimosa variety (*Mimosa invisa*) and all mimosa patches in Agratoli were of the thorn-less variety (*Mimosa invisa inermis*). Patches in Kohora had both the varieties of mimosa with the thorn-less variety predominating in areas nearer to Agratoli Range. A few thorny plants were seen in Agratoli but these were very few. This could be due to the type of mimosa being grown in the tea gardens adjacent to the Park. The gardens near the eastern range of the Park could be using the thorn-less variety as a nitrogen fixer. This fact needs to be confirmed. Another possible reason for this could be the soil properties or microclimate of these areas that account for the two mimosa

varieties. The thorn-less variety is preferred as a nitrogen fixer and the Tea Research Association, TOCKLOI, Jorhat also advocates the thorn-less variety as the better one. However, there are hardly any visual differences between the two varieties, except for the lack of thorns in one and it is reported that the thorn-less one can even revert to the thorny one under certain conditions (Waterhouse, 1994).

Although only two types of mimosa were reported from the Park, a more thorough study on the taxonomy by a specialist is needed to follow up this

Figure 12: Mimosa strangling tall grasses

effort. *Mimosa rubicaulis* was not observed in the Park during the present survey. Collection of more specimens at different seasons needs to be done to identify other species, if any and the inherent in species variation. A management strategy for these weeds also must take into account the inherent variation within the population because the weeds may consist of several biotypes (Murphy, 2001).

6.2 Extent of mimosa patches in the Park

Although only 0.5 per cent (2.13 km^2) of the Park is infested after control measures, it represents a potentially dangerous source and the situation can reach practically unmanageable proportions if left unattended. Even small infestations can be a cause for worry. Herbivores have been observed nibbling the tender leaves of mimosa and this could be harmful to them as the weeds contain the toxin called mimosin that Rajan *et al.*, (1986) and Alex *et al.*, (1991) have reported as toxic to cattle. Cattle are also reported to die a few days after eating the weed in villages close to the Park. However, this is not likely to be a problem in the Park at this stage as the area left uncleaned is very small, and wild herbivores may instinctively adapt to avoid them if found harmful. In any case the short grassland areas, which are the main feeding grounds of herbivores in the Park, are free of the weed.

However, lack of knowledge on the impact of the weed should not prevent action (IUCN, 2000). The IUCN guidelines also state that lack of scientific or economic certainty about the implications of a potential biological alien invasion should not be used as a reason for postponing eradication, containment or other control measures. Control measures for eradication or containment of an alien invasive species will be most effective in the early stages of invasion, when populations are small and localized.

A Range-wise analysis of distribution of mimosa patches show that Baguri Range is the most infested accounting for 58 per cent of the weed area in the Park followed by Kohora Range (39 per cent). In Agratoli Range, the weed accounts for only 3 per cent. This gives us an idea of the proportion of effort, time and funds to be allotted to management in the Ranges. This would logically require more resources and priority be given to Baguri Range to control the weed. However, the guidelines in IUCN (2000) state that priority for eradication must be given to sites where an alien invasion has occurred and is not yet well established. Thus eradication attempts are more likely to be successful in Agratoli Range where the weed is not yet well established and the area infested is relatively less.

6.3 Assessment of control measures adopted before this survey

The Forest Department has been manually removing mimosa from the Park for the past couple of years before the seeds set in, i.e. between September and December. Manual or mechanical removal was adopted besause the method was more familiar and considered safe in the Park as compared to chemical and biological controls.

Mechanical control could be implemented either by uprooting by hand or with tractors or by cutting the plants. The uprooting shows fairly good results because the root-stock is removed and mimosa can come up only from the seeds present in the soil. However, it must be ensured that all the plants are cut before seeding and that this should not wait up to the end of December when some of the plants may have seeded.

Although cutting is useful in preventing the plants from seeding, *Mimosa invisa* sprout vigorously from the cut base soon after the onset of mon-

soons (Sankaran, 2001). Cutting was observed to enhance regeneration in parthenium (Sushilkumar and Saraswat, 2001) and in lantana (Sawarkar, 1984). The cut mimosa were observed to sprout and flower during the survey. The seeds that set in had to be removed again. Thus, cutting is not recommended as a control measure.

The Forest Department started systematic removal operations only in 2001, though there were attempts for several years in Baguri in the 1990s as well. In Kohora, removal operations have been carried out for some years. Some areas were left un-cleared in Baguri because the operation commenced a little late and there was no point in clearing the plants after they had flowered.

Some areas with mimosa were left un-burnt in Baguri to see whether germination could be prevented. This helped to check the germination and practically no germination was observed in the un-burnt patches at the time of survey. The burnt patches, on the other hand, showed profuse germination of seedling and were used for estimating the seedling density (Figure 13). Although leaving mimosa patches un-burnt helps in controlling germination for a short period, the seeds in the soil can anyway germinate over a period of time. Hence, it may be better to burn these patches as well and remove the germinated seedlings after they have all come up. In this way the seed stock in the soil can be exhausted.

In Baguri, some innovative methods of controlling mimosa growth were tried out. These included uprooting a patch of mimosa and then rolling

over the area with a log. However, mimosa was seen to germinate in such patches too (Figure 14). The Park administration also plans to cover some of the mimosa areas with mulch to cut off the sunlight.

The result of this method is awaited. It was observed that several other species are coming up in the patches cleared of mimosa apart from the fresh growth of grass. The predominant species include *Solanum sp., Parthenium sp., Heliotropium sp., Oxalis sp., Mikania sp., Allughas sp., Gynura sp.* and *Cadiospermum sp.* In the eastern Range, mikania was seen growing profusely between the grasses. They were also observed to be more in the patches cleared of mimosa in Agratoli. Mikania was also seen growing together with mimosa strangling the grasses (Figure 15). The former was also seen smothering some ber (*Zizyphus sp.*) trees. Sankaran (2001) states that *Mimosa invisa* is found to overgrow and smother mikania in most parts of Kerala. According to him, the potential of a combined impact of these two weeds cannot be overestimated. Grasses will hopefully replace the species seen coming up in the cleared mimosa patches over a period of time. However, it needs to be looked into if mikania can be a threat. Since such cleared areas with weeds are relatively small, there is no need to replant such areas with grasses.

Figure 13: Mimosa seen germinating in a burnt patch after the showers

Figure 14: Mimosa germinating under a log used to level cleared patches

Replanting as an option in cleared areas will only arise if large areas of the Park are infested and the grasses have difficulty in establishing.

Variation in the density of germination could be due to different reasons. Higher germination in Baguri may be due to the greater germinating capacity of the thorn-less variety seen in the area as compared to the lowest germination of the thorn-less variety in Agratoli. This can be confirmed only after a controlled experiment. Variation in germination could also be due to the different soil characteristics, such as moisture in the two areas. These need to be tested. Another reason for the higher germination in

Baguri, as compared to Kohora, could also be that the removal operations were carried out for the first time and hence the soil could have a greater seed bank as opposed to Kohora where removal operations were carried out a couple of times, thereby reducing the seed bank also.

Although more detailed studies need to be done to confirm these, it gives us some basis to speculate on the percentage of seeds germinating in the Park conditions at that point of time. This estimation has to be done for a longer period of time to reach a reliable conclusion of the germination in the Park under different conditions. It would also be important to know the percentage of these germinating seedlings surviving to maturity. Density of germinating seedlings in the Park should also be estimated in other seasons for comparison.

Figure 15: Mimosa seen together with another weed *Mikania macaranta*

However, with the present data, we may speculate that since a greater number of seedlings are coming up in Baguri a greater effort would also be needed to eradicate them, as compared to Kohora and Agratoli.

7. MANAGEMENT PROSPECTS AND RECOMMENDATIONS

7.1 Experiences from other locations

Even after an alien invasive species has monopolized an environment, it is not clear if the invasion is problematic or not. This can make the formulation of management policy difficult (Murphy, 2001). Not much information on management of weeds in National Parks or Sanctuaries and very little information on *Mimosa invisa* is available. Some of the management practices followed to control other weeds in similar situations may be looked into.

In Kruger National Park, *Opuntia stricta* was a problematic alien weed invading about 3000 ha. of the Park. Rivers spread it, especially during floods (Lotter and Hoffman, 1997). Herbicidal control of the weed was the main method attempted and was supplemented by biological control, using a moth. Mechanical control by uprooting the plants was too expensive and time-consuming to be considered as an option as was herbicidal control, for which funds were also scarce. A management plan for the Park was developed to optimize control operations against the weed. The infested region of the weed was divided into 18 management units, each of which was to be treated in turn. During the first three years, control operations would clear the weed from the peripheral units to prevent the spread of the weed into other areas of the Park, after which the central

units would be tackled. The objective was to destroy all mature fruiting plants and those nearing maturity to curb the long-range seed dispersal of the weed. Small juvenile plants, which were difficult to detect, were to be controlled by the moth (biological control). Non-infested areas were to be continuously monitored for the weed and newly discovered isolated foci of the weed were to be treated immediately. After five years, it was hoped that the weed would be controlled to a great extent after which a lesser effort would be required, to keep the weed in check.

Several measures were used for controlling *Lantana camara* in the Melghat Tiger Reserve in Maharashtra (Sawarkar, 1984). These included controlled burning, cutting and uprooting, use of weedicides and biological control. Controlled burning of the weed has been considered ineffective (Sinha, 1976). Further, if burning was not followed immediately by uprooting, the weed tended to grow thicker. Manual uprooting and cutting of lantana and the use of elephants with dragging chains were tried in the coupes, but this method did not solve the problem since root suckers gave rise to new shoots and covered the area quickly. Only a limited area of the Park could be covered and the operation was expensive. Chemical use was not considered a good option due to adverse ecological effects and the economic costs involved for a large area. Biological control using insects was on a trial and testing stage and results are awaited.

Management options proposed to control lantana in Chinnar Wildlife Sanctuary, Kerala included chemical, biological and physical means (Chandrasekhara, 2001). However, it was concluded that herbicides could be used in PAs only after detailed studies confirmed their safety. Biological control also could have long-term adverse effects on the ecosystem. Physical removal too may not ensure the recruitment of native species. Biological control measures are not effective in controlling

lantana infestation. Mechanical methods are most often ineffective and involve heavy expenditure. Chemical control is environmentally damaging and cannot be practiced on a long-term basis. Sushil Kumar and Saraswat (1999) considered integrated management as the only viable option for managing lantana.

Several efforts to manage *Parthenium hysterophorus* in India have been tried, but since each method suffers from one or more constraints, such as high cost, impracticability, environmental hazards and temporary effect, so far no single method has proved to be satisfactory. Cutting of parthenium manually, enhances its regeneration; manual uprooting done after flowering is a waste. Biological control of parthenium is also not as simple as in some other cases due to its high regenerative capacity, immense seed production, ability for germination throughout the year and high adaptability in a wide range of ecosystems. Although chemical methods of control are effective, this alone is not justifiable as the effect of herbicides on the weed will be of a temporary nature and repeated operations are required which are not cost effective and ecologically friendly. To overcome the parthenium menace, integrated management has been considered to be the only viable option (Sushilkumar and Saraswat, 2001).

In recent years, the extent of degradation caused by invasive species has been recognized and many management actions taken, often addressing the effect rather than the cause(s). This is the case for the thorny shrub *Mimosa pigra* that has now become a weed in many tropical wetlands. Herbicides like glyphosate, 2,4-D and paraquat were found effective for control (Rajkhowa *et al.* (2003). Atrazine, diuron, hexazinone, sodium arsenite, 2,4-D plus atrazine were also found to be effective.

A risk assessment procedure for managing the tropical weed *Mimosa pigra* has been developed from the wetland risk assessment framework (Storrs and Finlayson, 2001). This framework can be adopted in the case of *Mimosa invisa* also, if it needs to be done again in future. It entails six steps described as follows:

1. Identification of the problem: Identify the nature of the problem and develop a plan for the remainder of the assessment, including the objectives and scope (e.g. site assessment, site-specific information on stress on the environment).

2. Identification of the adverse effects: Evaluate the likely extent of adverse changes (e.g. through monitoring, surveys etc.).

3. Identification of the extent of the problem: Estimate the likely extent of the problem (e.g. spatial and temporal distribution).

4. Identification of the risk: Integrate the result from the above steps by comparison of the effects with the extent using a GIS framework.

5. Risk management and Risk reduction: Make decisions to minimize the risks without compromising other societal, community or environmental values, i.e. by managing inputs and altering practices.

6. Monitoring: Verify the effectiveness of the risk management decisions (e.g. by use of early warning and rapid assessment indicators or a GIS-based approach.

Some of these have already been incorporated in this report, but can be improved, if the survey needs to be done elsewhere. In northern

Australia, the recommended strategy for controlling mimosa is to prevent initial invasion, eradication of small infestations by physical or chemical means and, for large infestations, to adopt an integrated approach involving biological control, herbicide application, mechanical removal, controlled burning and pasture management. All the above require some level of training and logistic support. Interruptions in control programs tend to waste time, resources and funds and allow mimosa to recover from the past treatment. Common problems in controlling mimosa are a lack of awareness on the effect and discontinuity in control programmes (Storrs and Finlayson, 2001). When a potential or actual alien invasive species has been detected, in other words, when prevention has not been successful, steps to mitigate adverse impact include eradication, containment and control (IUCN, 2000).

Early detections of alien invasive species together with the capacity to take rapid action is often the key to successful and cost-effective eradications (IUCN, 2000). The best opportunities for eradicating or containing alien invasive species are in the early stages of invasion when populations are small and localized. Immediate eradication of new or alien invasive species is preferable, more environment friendly and more cost effective than long-term control, particularly for new cases. Eradication should not be attempted unless it is ecologically feasible and has the necessary financial and political commitment to complete. Controlling further spread of the alien species should be considered as an appropriate strategy when eradication is not feasible, but only where the range of the species is limited and containment within defined boundaries is possible. Regular monitoring outside the containment boundaries is essential with quick action to eradicate any new outbreaks.

The control methods should also be socially, culturally and ethically

acceptable, efficient, non-polluting and should not adversely affect native flora and fauna, human health and wellbeing, domestic animals or crops. Biological control agents may sometimes be the preferred choice over physical or chemical methods, but require rigorous screening prior to introduction and subsequent monitoring. Physical removal can be an effective option for clearing areas of alien invasive plants. Chemicals should be as specific as possible, non persistent and non accumulative in the food chain.

The control strategy adopted should clearly state the gains for native species. Badly focused and half-hearted control efforts can waste resources, which might be better spent elsewhere. A formal control strategy should be drawn up which includes the areas for control, the methodology and the timing of operations. It must be evaluated whether long-term reduction of an alien invasive species is more likely to be achieved by adopting one action or a set of linked actions (multiple action control) (IUCN, 2000). There is a need to develop and implement an Integrated Weed Management (IWM) project involving an objective assessment of the problems and the use of effective elements of control integrated with biological control.

There needs to be a strong extension and education component to the program to ensure the adoption of management practices (Murphy, 1999). The integrated management strategy proposed for parthenium, involves several methods. Mechanical methods include uprooting, cleaning and spraying before flowering. Chemical control is by pre- and post-emergent application of herbicides before and after rains. Biological control includes the use of an insect or/and plant. Besides these conventional methods, the proposed integrated management strategy includes legal control, wide publicity and utilization of the weed (Sushilkumar and

Saraswat, 1999). We suggest a risk assessment to be conducted for mimosa in the park and to put in place an Integrated Management Plan for the Park.

7.2 Preventive measures to manage mimosa in the Park

Based on the control measures mentioned here and adopted in different places and the IUCN (2000), control measures suitable to tackle *Mimosa invisa* in KNP are suggested with discussion and justification.

The control measures have to be initiated from the source of infestation of mimosa in KNP, the tea gardens around the Park. The tea estate managers need to be made aware of the seriousness of the problem and an alternate to the species suggested for nitrogen fixing. At present, it is learnt that some of them have shifted to Guatemala grass as an alternative to mimosa. But mimosa still remains the preferred nitrogen fixer by most managers. Besides, mimosa is also preferred since it is not eaten by elephants whereas Guatemala grass is eaten by the elephants which tend to pass by these gardens. The Tea Research Association (TRA), Jorhat also recommends mimosa as the best nitrogen fixer. Seeds are available easily with suppliers in the markets and the thorn-less variety is reportedly the most preferred.

The use of mimosa in the gardens has to be stopped as soon as possible as there will be an annual supply during the floods. Pressure also needs to be mounted on the corporate tea management to give up the practice of using mimosa. The tea garden management needs to be weaned away firmly with a specifically targeted campaign to achieve this. This would include making the public more aware of the problem through the print and electronic media. Seminars and presentations will help in

the effort. Alternate measures to solve the mimosa problem will also need to be devised. Tea garden managers and staff, forest department staff, concerned NGOs, political leaders and local people should be brought together and the seriousness of the problem and control measures discussed.

Legal action should also be contemplated against non-compliant estates using mimosa around the Park. Legislation may also be needed for the effective management of the mimosa problem on the lines of the management of parthenium weed, first tried out in Karnataka. Based on the Act, the government of Karnataka declared parthenium a noxious weed in the year 1975 (Sushilkumar and Saraswat, 1999). This may also have to be done for mimosa in Assam. However, although the Act was in place and the municipal corporation issued notices to remove parthenium, there was apparently no follow-up and this failed to control the weed. Lack of publicity and failure in educating the people on the importance of implementing the Act added to it. It will be pertinent to mention that in India, rules and acts to suppress weeds exist but their proper implementation has always been problematic (Sushilkumar and Saraswat, 1999). This aspect will have to be remembered even if legislation for mimosa is put in place.

7.3 Control measures

The weed will have to be directly tackled in the Park. This can be done by mechanical, chemical and biological methods. It is therefore recommended to conduct a targeted awareness campaign among the tea gardens around Kaziranga (North and South bank) and to educate the organizations related to tea estates and other planter's bodies about the menace of mimosa.

7.3.1 Mechanial control

This would involve uprooting from the infested areas manually and with the help of tractors. The help of elephants can also be taken for removal of the weed, if they can be spared for the purpose. Mechanical removal needs to be done before the seeds set in and could be by October or latest by November every year. A second removal should ideally be done after the first showers in the month of April to remove the germinating seedlings and saplings. This would also reduce the efforts required in subsequent attempts.

7.3.2 Chemical control

Exisiting chemical options to control the weed need to be tested and proven before being recommended for a unique habitat like the Park. A hasty decision always involves the risk of disturbing some aspect of the ecological balance in the sanctuary The weed is susceptible to translocated herbicides including sodium arsenite, 2,4-D plus atrazine, fluroxypyr and probably glyphosate at standard rates (Swarbrick, 1997). An attempt to control it using 2,4 D and dinitrobutyl phenol (Denoseb) in Brazil was not very successful (Sankaran, 2001). Experience has shown that herbicide use is unlikely to be cost-effective (Murphy, 1999).Chemical control is not recommended unless extensive *ex-situ* tests are conducted and mechanical control proves to be a failure.

7.3.3 Biological control

At least 70 species of insects attack mimosa in Brazil and related species elsewhere. Detailed studies have been made on two hemipterans (*Heteropsyla spinulosa* and *Scamurius sp*.) and a moth (*Psigida walkeri*). *H. spinulosa* has caused extensive damage to *Mimosa invisa* following its establishment in Australia and has shown promising early results in Fiji, Papua New Guinea and Pohnpei, but disappointing results in Western

Samoa, where *Scamurius sp*. failed to become established and *P. walkeri* is still under investigation. The prospects for biological control of *M. invisa* appear to be good, although additional natural enemies may have to be considered (Waterhouse, 1994). Biological control using insect enemies is showing success in Queensland and attempts to control this weed through biological means are highly warranted in India (Sankaran, 2001). The option could, again, be tried out only after proper *ex-situ* tests , and if there is ample proof that the rich biodiversity of Kaziranga will not be affected by it.

7.3.4 Integrated weed management

It is recommended that an integrated approach, using all the available control measures could be more rewarding. However, the mechanical control could be continued till other methods are tested and proved to be effective and harmless to the ecosystem.

7.4 Monitoring

Regular monitoring will also have to be done to see if mimosa is spreading to other regions of the Park. The Park can be divided into compartments and periodic patrolling by forest guards can be done to check for spread of the weed. The spread of the weed could be prevented only if the forest guards report new infestations whenever encountered in their patrols and immediate action taken to eradicate these. The control measures being used should also be reviewed from time to time to verify their effectiveness. A study on the rate of spread of the weed in the Park should also be done so that we know how quickly it can take over a habitat, which will also help in planning its check within a time frame. A close monitoring of tea gardens in the surrounding areas will also have to be planned.

A survey of other Protected Areas in Assam and other parts of North East India must follow this study to check the spread of mimosa.

Control operations need to be planned and done well on time before the plants are in seeds. Mechanical control of the weed must be done only by uprooting and not by cutting and the operation must be well coordinated in all the Ranges. Other control measures such as biological, chemical, legal etc should also be explored, and an integrated management plan put in place to control or eradicate the weed from the Park in the most effective manner. The mimosa area in the Park can also be divided into units, with each unit assigned to specific guards or watchers. Periodic monitoring of these units need to be done to see the status of mimosa infestation and the impact of control measures on them. Any spread of mimosa infestation outside these units must be immediately reported to the concerned staff and action must be taken quickly. The success of this will depend on the timely reporting on spread by the forest guards and quick action taken. It is recommended that the integrated management plan has a clearly defined monitoring section so as to detect spread of the weed as quickly as possible.

7.5 Research

Information on various aspects of mimosa in India is lacking. This may be generated through research on the taxonomy, biology and ecological requirements of the plant. Stress could be on its germination requirements, seed viability, seed dormancy, habitat preferences, rate of spread, taxonomy, etc. and could lead to the formulation of a better control strategy. Research could also be on biological control. The research findings and information generated with recommendations for implementation should then be extended to the forest departments and other concerned

organizations. Co-ordination with various research organizations is recommended to ensure that any research being done finds management applications.

7.6 Future role of Wildlife Trust of India

The Trust could support the programme by providing scientific and financial supports. The Trust could also be involved in monitoring along with the forest department and give inputs on the methods being used. Survey and monitoring should also be extended to the tea gardens to know the status of mimosa use in the gardens and to generate more information on the problem. Legal measures could also be thought of for control of intentional introduction of such plants and for successful implementation of the existing Rules and Acts. A campaign among tea gardens can also be done and legal action contemplated in case of non-compliance.

Rapid surveys in other Parks in the North East, especially those with tea gardens around could be taken up immediately so that the problems, if any could be contained before it becomes serious. This will also help in formulating a strategy for the country in general and the North East in particular.

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Kaziranga National Park is one of the last strongholds of the greater one-horned rhinoceros, the Asiatic wild buffalo, the Asian elephant and the swamp deer. All these are greatly dependent on the grasslands of the park for food and cover. The threat of the exotic *Mimosa invisa* that is strangling these grasslands has to be tackled quickly and scientifically. This is the story of how WTI and IFAW are assisting the Assam Forest Department to eradicate mimosa in Kaziranga.

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