INTERNATIONAL ELEPHANT CONSERVATION AND RESEARCH SYMPOSIUM

October 21-22, 2006
Copenhagen Zoo, Denmark

PROCEEDINGS

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Words of Welcome

Bengt Holst

Director of Conservation and Science
Vice Director
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These following pages feature the papers and posters presented at the 2006 International Elephant Conservation and Research Symposium hosted by Copenhagen Zoo, Denmark. The symposium took place from October 21 - 22 in Gilleleje.

It was a great honour to welcome you to the 2006 International Elephant Conservation and Research Symposium in Gilleleje. It was great to see that all of you found your way to Gilleleje. 85 participants have arrived (veterinarians, researchers, field researchers, biologists, curators) from 16 different countries from all over the world. Some of you have travelled as far as from the US, Asia and Africa. I believe it was the second time the symposium was held in Europe – making it easy for the Europeans to attend. I thank you all for coming and it was a interesting symposium with presentations and posters ranging from veterinary medicine and reproduction to *in situ* conservation and management as well as other research topics.

Organising the symposium was an exciting task and it has been a great pleasure to collaborate with the International Elephant Foundation represented by Debbie Olson, IEF executive director, and Harald Schwammer, vice director at Vienna Zoo in Austria. They put tremendous efforts into selecting presentations and posters. I take this opportunity to thank Debbie, Harald and the Copenhagen Zoo staff for making this symposium possible.

I trust that you found it rewarding to be part of the symposium and the information exchange that took place during the days of the symposium. We need that sort of information exchange, and I am happy that Copenhagen Zoo can contribute to that.

I also hope that you have enjoyed your stay in Denmark and found time to stroll along the coastline of Gilleleje during breaks.

Words of Welcome

Michael Fouraker

President
International Elephant Foundation

The International Elephant Foundation is pleased to partner with the Copenhagen Zoo in the hosting of the 2006 International Elephant Conservation and Research Symposium. This important annual symposium provides a forum for individuals interested in elephant conservation, management and care to share their ideas and learning while making new contacts and re-establishing prior relationships.

As in previous years, the results of scientific studies in veterinary care, health and welfare, conservation, and human-elephant conflict presented during the symposium are offered in this document. These papers represent years of study and contribute to the ever expanding body of knowledge of the African and Asian elephant.

The human population is multiplying at an astounding rate as is their perceived need of increased material goods creating the demand for more land and resources. Humans must develop a respect for the environment including developing strategies and techniques that will allow elephants and humans to co-exist. Our wildlife and resources must be actively managed for there to be a hope for survival of elephants and their natural habitats. As many of the presenters demonstrate, there is not just one solution that fits every situation. We need to work together, develop partnerships, comunicate a wide variety and combination of ideas if we are to meet our goal of the long-term conservation and survival of the African and Asian elephant.

I would like to thank Deborah Olson, Executive Director of IEF, and Dr. Harald Schwammer, board member of IEF, for their assistance in developing the symposium program. I would especially like to recognize and thank on behalf of the International Elephant Foundation the Copenhagen Zoo for organizing this symposium, which has brought the world's attention to the conflicts we face. Lastly, I would like to recognize our many distinguished colleagues from all over the globe and I thank you for your dedication and attention to this crisis.

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ORAL PRESENTATIONS

Resolving human-elephant conflict in the northern areas of Asom, India – a discouraging endeavour

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Abstract:
The Northeastern Region of India has been a stronghold for Asian Elephants. The region contains a sizable wild elephant population presently distributed in the north and south bank areas of river Brahmaputra in some fragmented patches. The elephant population in the north bank represents about 10% of the species total population and thus the area is considered as a priority elephant habitat. But due to ever growing rural human population, land conversion and urbanization the elephant habitat have been very rapidly shrinking, creating survival threat for the species and invoking serious human-elephant conflicts. Manas National Park of Asom represents an important elephant habitat of the north bank, sustaining a significant Asian elephant population. Unfortunately, this important park had also experienced similar problems of rapid forest loss, encroachment and also seriously disturbed by an ethnic unrest in the local areas. Massive shrinking of habitat and blocking of corridors resulted wide scale elephant depredation in the fringe of Manas. Though the ethnic unrest had subsided, forest destruction is still on, regularly eating up new areas thus making the situation hopeless for elephant conservation. The affected people have already started retaliatory killing of elephants, endangering the pachyderm population of the park. Dolphin Foundation with support from US-Fish & Wildlife Service, started a human-elephant conflict mitigation program in the fringe of Manas to address the situation. The main aim of the program was to develop and execute an effective conflict mitigation strategy with both long-term and short-term measures. Extensive field researches had been carried out and on the basis of the findings an Elephant Raid Prevention System (ERPS) was developed and executed. The study showed about 39 fringe villages were affected by elephant depredation in the western part of Manas. The raiding trials in the area were identified, thoroughly studied and mapped. The different herd sizes of the raiding elephants and use of different trails were studied thoroughly. About 5113 hectors of cropland in the 39 villages were observed to be regularly affected by elephant depredation. The reported crop damage is up to 60%, besides property destruction, stored grain raiding, injuring and killing of human beings. The ERPS developed by the program is essentially a chain of coordinated activities involving the villagers and forest personnel. The ERPS includes formation of anti-depredation groups from the villagers, training on anti-depredation procedures, providing anti-depredation equipments, Early Alarm System (EAS) for the fringe villagers to prevent the ensuring elephant raids, study of trails and nature of conflicts etc. The ERPS developed by the program showed up to 70% success in controlling the elephant depredation in the project area. The long-term measures of the strategy were – greening of peripheral areas by promoting community plantation, education & awareness, community support program etc.

Introduction:
The Asian elephants all over its range of distribution in the wild are now facing extinction. In the face of fast growing need of human habitation area, the elephant habitat throughout Southeast Asia is shrinking rapidly. Asian elephant populations living in the wild now are mostly small and isolated, their traditional migratory routes been cut off by human settlements. Wide scale confrontations between human and elephants are thus inevitable. Furthermore, as a result of their isolation the animals though manage to breed successfully, suffer from a depleted gene pool as a result of in breeding. Importantly, Asian elephants live in the regions of the world with the densest human population that is growing at a rate of over 3% per year. The growing conflict between humans and elephants is one of the most urgent challenges and is one of the highest conservation priorities.

The northeastern region of India has got a special place in the world map for its rich biodiversity. It is considered as biodiversity hotspot and comes under the Eastern Himalaya Eco-region complex. A home of many globally important and endangered species and the important among them is the Asian Elephant. The animal is a keystone biological species for the area and an integral part of the religion and culture of the people of the region from ancient times. A significantly large population of Asian Elephants occurs in the region, especially in the Northern bank area of river Brahmaputra, one of the most important sites for the Asian elephant conservation. It contains the largest elephant population in NE India and among the five largest elephant populations in Asia. The north bank of river Brahmaputra, comprising northern parts of Assam and adjoining southern areas of Arunachal Pradesh, may contain up to 10% of the species' total population. But in this entire habitat area the pachyderms have become highly threatened because of rapid shrinkage of habitat, indiscriminate poaching and most importantly the ever-increasing human-elephant conflict. As result the species become discontinuously distributed. Rapid shrinkage of habitat has fragmented the elephant population of the entire area, which not only exposed the animals to the risk of being killed by human being, but also have exposed the human population to large scale confrontation with settlement coming on their way of movement. Elephants can be a major destructive force to land owners and users.

Manas National Park of Asom represents an important elephant habitat of the north bank areas of Brahmaputra, sustaining a significant Asian elephant population. The World Heritage Site Manas is famous for its pristine natural ecosystem and unique for its diverse forms of flora and fauna with tiger, elephant, Pigmy Hog, Golden Langur, Hispid Hare etc. as its flagship species. The park has got enormous value for the Nation and so it has been conferred with different statuses – Tiger Reserve, National Park, Biosphere Reserve and Elephant Reserve (Ripu-Chirang). The Manas National Park area is overlapping with the Ripu-Chirang Elephant Reserve area, thus enhancing the protection level for the elephant population. Unfortunately, this important park had also experienced similar problems of rapid forest loss & encroachment and was mainly because of ethnic unrest in the areas. In demand for an independent state the agitation program by a local tribe ultimately led to insurgency problem by budding out to some rebel groups. And the worst part of these was that the virgin forest of Manas became the major hideouts for these rebel groups who started taking control of the area. The poor local people were very badly affected by losing all of their existing livelihoods based on the Manas, which ultimately indulged them to do all sorts of unfair to the park. This also made them extremely hostile for the outsiders, a major setback for the park management. Massive shrinking of habitat and blocking of corridors resulted wide scale human-elephant conflict in the fringe of Manas. Though the ethnic unrest has been subsided now, forest destruction is still on, eating up new areas regularly thus making the situation hopeless for elephant conservation. The affected people have already started retaliatory killing of elephants, endangering the fate of the pachyderm population of the park.

Dolphin Foundation with support from US-Fish & Wildlife Service, started a human-elephant conflict mitigation program during 2005 in the fringe of Manas to address the situation. The main aim of the program was to develop and execute an effective anti-depredation strategy with both long-term and short-term measures, to help the affected people and thereby to reduce the possibility of conflict killing of elephants and loss of human life & property and to have the local people onboard the elephant conservation program.

Study Site:
Out of the three Ranges of the Manas National Park area, elephant depredations have been mostly reported from the fringe areas under the Western and Central Range. A preliminary study showed that the problem was more acute in western Range areas of Manas than the central Range. Hence the project was first launched in the western Range of Manas National Park with its adjoining areas.

Methodology:
To achieve the overall goal, the project had undertaken various activities. They were - extensive field research on the elephant depredation in the project area, develop an affective anti-depredation strategy based on the findings of the field research, gather up-to-date information on human-elephant conflict in the area to make future anti-depredation strategy effective, take up small-scale community support program for

creating goodwill among the affected fringe villagers, greening of the peripheral non-forest fringe areas of Manas by promoting tree plantation (Promotion of Community Forest) for decreasing the pressure of firewood and logwood extraction from the elephant habitat and target specific educational & awareness program for elephant conservation.

The project was executed by setting up a Field Office in the project area. The activities were primarily carried out by filed survey, training programs, village meetings, awareness camps etc. As the village areas were in remote locations, depending on accessibility various means were adopted for carrying out the field research, they were – survey by vehicle & motorbike, by bicycle, on elephant back and on foot. First hand information about the location of the affected villages, raiding tracts of elephants, conflict sites etc were gathered through interviewing the locals. A questionnaire was developed and used to gather the required information. All the raiding tracts coming out of the park were identified, tracked with its full length with help of GPS and mapped. All the identified tracts were studied and profiled individually in respect to their various aspects. The activeness of the identified tracts was reviewed periodically. To confirm the use of a particular tract by elephant, both direct and indirect methods were adopted. In the direct method evidences like sightings, fresh footprints, fresh droppings, sign of crop damages were considered. In the indirect method interviewing the locals to get the information was adopted. Generally, the tract survey was done during the morning hours to locate the fresh footprints and droppings. The conflict sites were identified, studied and profiled in the similar way. The crop damage patterns in the fringe villages affected by elephant depredation were studied in respect to different seasons. As the entire project area was lacking of electricity facility, Solar Street Lamps were installed in the village sites (critical areas affected by elephant depredation) to facilitate anti-depredation operations during the night hours and thereby to boost up the morals of the affected people. For greening of the peripheral areas of Manas a tree plantation drive was organized. The plantation program was done in two different methods – (1) donation of seedling of commercially important and fast growing indigenous species to the interested fringe villagers for plantation in their private land ; (2) plantation program in the unused public land in the fringe villages with the involvement of local bodies, schools & organizations. Fast growing species were selected with help of the State Social Forestry Department and the seedlings were procured from both Govt. and private nurseries. Arrangement of unused public land was done with help of the local NGO partners, village committees, village school authorities etc. The Conservation Education program was carried out in two different levels with different standard of deliberations. They were – at school level & at village level. For school level - the educational and awareness programs were carried out by organizing different types of competition like - Essay writing competition on Manas and its wildlife, extempore speech, painting and drawing competition on Elephant etc in the fringe village schools. For awareness at village level – meetings, group discussions etc were organized in fringe village sites for the awareness of the general people. Various types of awareness and educational materials like – signboards, banners, posters, booklets were produced on elephant conservation for display and distribution among the target people.

Results and discussion:

The Manas National Park, which represents a major and important portion of the Ripu-Chirang Elephant Reserve, is presently a home of about 500 Asian Elephants. The area of the Ripu-Chirang Elephant Reserve is extended up to the River Sankosh in the west and to River Barnadi in the east, covering an area of 2600 sq km, out of which Manas National Park represents 500 sq km. As per findings of the preliminary study, the problem of wild elephant depredation is presently happening in the fringe areas under Western and Central Ranges of Manas National Park, with severity in the Western Range. After one year of extensive field research carried out in the Western Range areas and its adjoining parts in the southwest, it became evident that the problem of wild elephant depredation was a serious problem for the people living in the areas. Wild elephants from Manas use to regularly come out to the nearby human use areas and creating havoc by heavily raiding crops, vegetables, stored grains and destroying property and human life. The socio-economic status of the people living in these areas is very poor as these areas are very remote and underdeveloped. Most of the people are agriculture dependent with very insubstantial landholding pattern, thus fighting for their survival. And on the top that they have been facing extensive crop damage by wild elephant, a big blow to their ever-bad economy. There had been significant increase in the wild elephant depredation in these areas during last one decade and this was observed to be mainly because of

the indiscriminate destruction of forests for illegal timber extraction and other livelihood pressure, which had been rapidly shrinking the habitat of pachyderm and blocking their migratory corridors.

Raiding Trails of Elephants:
The present study revealed that about 39 villages, situated between 0-15 km radial distances from the forest boundary (both fringe and neighboring villages), were badly affected by wild elephant depredation. Out of those, 22 villages were observed to be the worst affected (Table-1 & 2). The project had identified 20 elephant trails coming out of the Western Range of Manas and up to Kuklung area of contiguous Manas Reserve Forest. These trails were regularly used by the elephants to raid the identified villages (Fig-1). Depending on the availability of preferred food crops and accessibility, the trails were observed to be of various lengths, ranging from 1-2 km up to 11-16 km, joining the elephant habitat areas inside the park with the affected villages. Out of the 20 trails, 8 were found to be originated from the National Park area and the other 12 from the contiguous Manas Reserve Forest area (Fig-1). About 12 of them were marked as major trails and the remaining 8 as minor. However, use of these trails by the elephants varies in different seasons and crops. The herd size of the raiding elephants were also found varied depending on seasons, ranging from 3 to 25, along with few loners. Each of the identified trails was observed to be of various potentialities, responsible for affecting 2 to 9 villages, with an average of 4 to 5 villages. The mode of use of these trails was about 95% for overnight trip. General tendency had been seen as to go out of the forest for raiding during the late evening and come back before early morning. However, there were some long trails leads to some specific places. These places were used by elephant as temporary shelter during the day hours. They used these shelters for raiding in the nearby crop fields. Beginning from the park boundary towards different directions, the length of the raiding trails were seen depending upon the following factors –

(1) Availability of preferred food in different seasons.
(2) In search of temporary shelters near the areas with preferred food crops.
(3) Human interferences.
(4) Inaccessible physical barriers.

Crop damage pattern:
Under Asom climatic type, generally two types of paddy are grown as major crops. They are summer paddy (*Ahu*) and autumn paddy (*Sali*) along with vegetables and other crash crops. In the project areas the winter crop is not successful due to water scarcity. Only a small fraction of the villagers (10%) practice winter paddy where there is facility for natural irrigation. Wherever the cultivation of winter crop is possible, the farmers have to suffer even a higher loss (more than 50%) because of frequent visits by comparatively more numbers of elephants. So, the major crop of these areas is the summer paddy (*Ahu*), with other minor crops like- pulses, jute etc. But the only major crop of the villagers is being regularly destroyed by the wild elephants, a further setback for their poor economy. The total calculated cropland in the identified 39 villages was 5113 hectors. The summer paddy is being practiced in 41% and autumn paddy is in 34% of the total village cropland. The calculated crop damage by elephants during the study year was 40% for summer paddy and 50% for winter paddy (Fig-2). Winter paddy had been recorded with high damage as it was practiced only in areas where irrigation facility was available and hence experienced with more number of elephant visits. About 20-30% of the total croplands in the area had already become wasteland due to high elephant depredation. The cropping patterns of the affected villages were observed to be changed due to regular elephant depredation. In most of the areas the people were seen growing crops which were generally not preferred by the elephants (viz. sesame, colocasia etc).

Elephant Raid Prevention System (ERPS) developed and executed:
An Elephant Raid Prevention System (ERPS) was developed and executed as a short term measures to control the elephant depredation in the project area. The strategy adopted was based on the findings of the field study carried under the present project.

The Elephant Raid Prevention System (ERPS) involved:

i) Formation of Anti-depredation Groups in the affected villages and trained them on the anti-depredation measures and other safety procedures.
ii) Each Anti-depredation Group consisted of ten members. The members were mostly the educated village youths from the fringe villages, who had certain level of knowledge about the problem and had real interest to work for the issue.
iii) A system was worked out to control the activities of these groups involving the village committees headed by the Village Heads with involvement of the local forest department.
iv) The general public of the affected villages were closely intimated about the ERPS by organizing meetings, discussions etc.
v) The anti-depredation groups were equipped with basic equipment like searchlights, sounding devices, fire crackers etc. Due to lack of electrification in the villages, a solar charging system was developed to regularly charge the searchlights.
vi) These groups were generally placed in strategic locations near the entries of the raiding trails in the village areas.
vii) These anti-depredation groups also worked as an Early Alarm System (EAS) for the fringe villagers to prevent the ensuring elephant raids. Out of the 10 members of each group, one member worked as a messenger to pass on information about the arrival of raiding elephant to its neighboring group, to the local forest personnel on duty and the general public of the village. Each messenger was provided with a School Bell to make people alert about the presence of wild elephant in villages. The messenger had to use a bicycle for his fast movement with the School Bell hanging in it.
viii) The other members of the group were responsible to contain the elephant by preventing them in entering the village and try to drive them back through the same path with the help of searchlights, crackers etc. The duty of the local forest personnel had been to guide and help the groups in driving back the elephants.
ix) The group members were also responsible for collecting data on current elephant depredations in the area.
x) Periodic review of the ERPS were done to judge the success or failure and to further develop the technique.

Effectiveness of the ERPS:
The success rate of the ERPS adopted at the start was not encouraging. But gradually after two / three weeks the system started showing its results. However, all the anti-depredation groups formed were not equally efficient in handling the situation. The success of each group was largely depended upon the location and topography of the villages, nature of raiding trails etc. But all of them in all most all the instances were observed to be successful in making the people alert about the entry of the raiding elephant in the village.

After the Elephant Raid Prevention System (ERPS) was executed, a total of 457 instances of wild elephant intrusion were recorded in the project area and were studied. Out of that in 372 (81%) instances the technique used in ERPS was observed to be successful. This was in terms of protection to the property, human injury/death and crop damage. The rests were observed to be unsuccessful because of incompetence or lack of timely action, lack of willingness among the group members, too complex situations, experienced raider elephants etc. The overall results of the ERPS were very encouraging. After the execution of the ERPS, the crop damage had come down significantly. A current assessment done on crop damage indicated that after execution of ERPS, about 40% of the crop damage had been reduced. The people had become enthusiastic to reclaim their abandoned crop field for regular cultivation.

Community support Program:
The Solar Street Lamps installed in the human-elephant conflict areas, in the premises of the local partner NGOs / bodies were indeed of much help. During elephant raid at night hours people used to gather near the Solar Lamps for strategy discussion. Most importantly, the facility of solar lamps has been boosting up of the morals of the people and greatly encouraged them to cooperate with the project.

Greening of the peripheral areas of Manas:
This was a long-term measure of the project for protection of elephant habitat in Manas. The purpose of greening of peripheral areas of Manas was to provide a sustainable source of firewood and other forest based produce for the fringe villagers and thereby to reduce the pressure on the park resources. This also helped in restoring the degraded ecology of the park and its peripheral areas by creating contiguous green belt around the elephant habitat. The program received very good response from the communities. About 15000 seedlings were already procured and distributed among the interested villagers for plantation in their private land. Simultaneously, the plantation of fast growing tree species was also carried out in the unused public lands of the fringe village areas. For this 5 plantation plots were developed and about 10,000 seedlings were planted. The necessary land for developing plantation plots had been arranged with the help of local NGOs, bodies, school authorities and general community. Besides, plantation programs were also carried out in School premises, community centers etc. Schools children were largely involved in the plantation program.

Educational & awareness Program:
The awareness program had always been a major part of the project activities. The project had developed various types of awareness materials like books, leaflets, banners, signboards, T-shirts etc. An Information Book on Manas was developed in local language and widely distributed among all the concerned people, especially among the school children.

The school awareness program had covered 30 fringe village schools under the project area. The signboards, banners were displayed in different places of the project area. Village meetings were organized in the fringe villages to generate awareness among the people. Explanations about the root causes of the gradual increase of the elephant depredation in the fringe areas, potential value of the park for the local communities, National and global significance of Manas and Elephant etc were the subjects of the awareness drive. The trained anti-depredation group members were also encouraged to participate in the educational and awareness program carried out in the project area.

Recommendations:
The efforts being made through this project is very small in comparison to the huge dimension of the problem all across the north bank of river Brahmaputra in particular and the state Asom in General. Human-elephants conflict in Asom has now become a social problem and is related to the socio-economic status of the people living at the vicinity of the forest areas. Lack of sustainable livelihoods compelled these people to become more and more dependent on the forest resources, which is the root causes for fast shrinkage of elephant habitat. In this circumstance, human-elephant conflict is inevitable. Conflict mitigation or anti-depredation activities can only minimized or control the problem to a certain extent for a limited period only. The root cause of the problem, i.e. forest destruction, has been continuously remaining un-addressed, making the scene hopeless for elephant conservation. There has to be coordinated efforts with the required political will, proper policy & practice and the resources for implementation, and only that can protect and restore the forest areas and give a chance to the pachyderms to reclaim their lost habitat.

Acknowledgement:
We are grateful to the CCF-Wildlife, Asom for his kind support to the project. The Field Director, Manas Tiger Project, had extended all the required helps for the smooth execution of the project activities, our sincere thanks goes to him. We are thankful to US-Fish & Wildlife Service for providing financial assistance to take up the project. Our special thanks goes to Dr. Meenakshi Nagendran of US-FWS (AsECF) for her invaluable inputs to the project. We would like to thank our all the colleagues for their tremendous support during the project execution.

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Human elephant conflict mitigation in North Bank Landscape, north east India

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Abstract:
The Kameng and Sonitpur Elephant Reserves (ER), in North East India, harbor a significant population of Asian elephant (*Elephas maximus*) numbering over a 1000 individuals. These two largely contiguous elephant reserves form a core for elephant conservation in the north of the river Brahmaputra in the states of Assam and Arunachal Pradesh. This large tract of elephant habitat is referred to as the North Bank Landscape (NBL). This landscape is experiencing a serious threat from Human Elephant Conflict (HEC) largely attributed to deforestation that took place in the 1990s. Surveys of conflicts carried out by WWF in NBL revealed that Sonitpur district within the landscape recorded the highest incidences of HEC. In 2001 alone, 25 people were killed by elephants and over 20 elephants were poisoned in retaliation. The surveys confirmed the urgent need for conflict mitigation. Accordingly, a HEC mitigation strategy was designed in 2004 for immediate implementation along a forest-human interface boundary stretching for over 100 Kms in Sonitpur district.

The strategy has two major components : a) to enhance the capacity and infrastructure of the forest department (FD) to address HEC, and b) to build capacity among the affected communities to help themselves. In Year One, fifty anti Depredation Squads (ADS) comprising of village volunteers were formed and trained at different strategic locations of the district. These locations were based on elephant raiding hotspots based as indicated by the ground surveys. The forest department was supported by providing additional 4 WD vehicles for faster response and *Kunkis* (trained captive elephants) for elephant drives. Both the ADS and the FD were provided equipments like searchlights and sounding materials (fire crackers). The FD and ADS worked in coordination to conduct frequent and systematic drives of elephants from human settlements/plantations into the adjoining forests. All elephant drives conducted were documented and categorized into *major* (cost ca. $100) and *minor* (cost ca. $50) drives depending on the resource requirements, the size of elephant herds and the distance covered during the drives. In 2004 and 2005 a total of 115 and 125 elephant drives were conducted respectively (in Sonitpur west forest division) with an average success rate of 85%. Adaptive management enabled the modification of Year two operations resulting in a steady increase in the success rate of the elephant drives. The Impact was measured by several parameters like human and elephant deaths, crop damage and attitudinal surveys. A decrease in elephant and human deaths and crop damage was recorded while attitudinal surveys indicated that more people are willing to try non-lethal methods to mitigate the conflict and also work towards addressing the root cause of the problem – habitat loss. We will discuss our key findings as well as plans for scaling up of the work up in a sustainable manner.

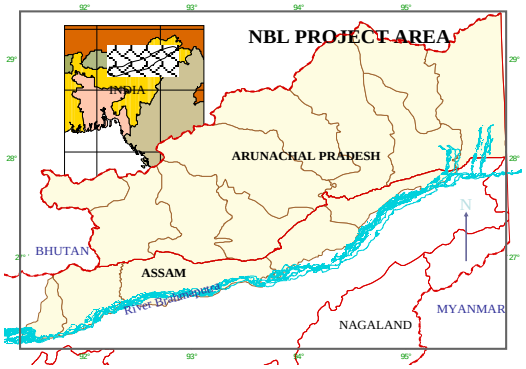
Introduction:
The Kameng elephant reserve and Sonitpur elephant reserve are the two contiguous elephant reserves in north east India that still are strongholds of Asian elephants. These two reserves constitute a core area for elephant conservation in the north of the river Brahmaputra in Assam and Arunachal Pradesh. This space is

referred to as North Bank Landscape (NBL), which is one of the priority areas of Asian Rhino and Elephant Action Strategy (AREAS) of WWF.

But due to severe loss of elephant habitat over a decade of time, this area has become one of the most conflict prone areas of the country, resulting in loss of life on both sides - human as well as elephants. Field survey in NBL shows that Sonitpur district is the worst hit in terms of HEC where 85 human beings and 60 elephants lost their lives during the period 2000 to 2003. HEC attained a serious dimension in the year 2001 when more than twenty elephants were poisoned and twenty six human beings were also killed by elephants in Sonitpur. After analyzing the ground situation it was understood that no conservation work could take root unless the issue of HEC was addressed properly. More importantly, it was felt that successful conflict mitigation would not only reduce the retaliatory killings but also bring people on board conservation programs.

As a part of the AREAS NBL program, a *Human Elephant Conflict Mitigation Strategy* was developed in 2003 to create a favorable atmosphere to ensure long term conservation of the species in the landscape. The strategy was implemented in the year 2004 and 2005 in collaboration with the Forest Department (FD) and the Community during which many aspects of the anti depredation measures were streamlined and many lessons were learnt to improve on the existing strategy in the years to come.

Figure 1: NBL Project Area



Material and methods:

Detailed databases were created and uploaded on GIS domains (which are regularly being updated) for analysis and for designing the strategy as well as for monitoring the effectiveness of the implementation. The databases created were on:

- Updated data on raiding tract and movement pattern of elephant herds, data on ADS location, data on possible strategic deployment sites for the *kunkis* considering factors like availability of fodder, water source etc.
- Data on the drives undertaken by the FD during the season and the collateral damage caused by raiding elephants to monitor the effectiveness of the strategy implementation
- Data on people's perception about the effectiveness of the strategy implementation and their suggestions collected through a series of PRA exercises in a number of randomly selected villages.

Results and discussions:

Developing the strategy for HEC mitigation

Based on the generated data on elephant movement and the raiding tracks, and analysis of the data collected, the strategy was developed in collaboration with the FD and local communities. It was planned that WWF would provide the required resources for conducting elephant drives and for protection, while the FD would implement the drives in the field with support from community based Anti Depredation Squads (ADS) formed by WWF**.** To involve the community and gain their support for better implementation of the strategy and conservation of the species at large, Anti Depredation Squads (ADS) were planned in affected areas.

Implementation of the strategy:

The HEC mitigation strategy was implemented for the first time in 2004 in collaboration with the State Department of Environment & Forests, Government of Assam (FD) in the Sonitpur district and is being continued with necessary modifications. During the implementation period the following activities were undertaken for effective and coordinated mitigation of HEC in the district.

The capacity of the FD was enhanced by providing two vehicles to two forest divisions for better movement. *Kunki* elephants were also provided to drive out wild raiding herds of elephants. Twelve *kunki* elephants were used in the Sonitpur district to mitigate HEC. The FD was also provided with high powered search lights and crackers when required.

After formation of the ADS, capacity building of the local community was also carried out by providing them with basic orientation on some major aspects of HEC mitigation like anti depredation technique, elephant psychology, use & maintenance of equipments, communication and information networking.

Elephant drives:
Elephant drives were conducted in the project area as a major activity of the HEC Mitigation Strategy implementation. Elephant drives are conducted by the FD either on their own or in collaboration with the ADS of the concerned area. In some of the major drives other agencies like Police department also provide support for proper execution of the drives.

The NBL Program helped the FD in planning the drives through monitoring of raiding elephant herds. Also the project played a role for better coordination between the FD, ADS and other agencies like the police department.

During the 2004 and 2005 HEC mitigation season in Sonitpur west division 240 elephant drive operations were organized out of which 170 were major drive and 70 were minor drive. Major and Minor drives were classified on the basis of the following criteria:

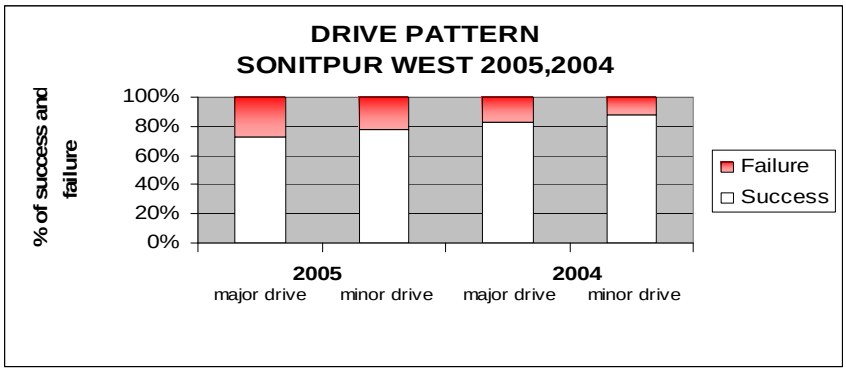
Table 1: Classification criteria of major and minor drives

DRIVE TYPE	HERD SIZE	KUNKI USED	OTHER RESOURCES USED	DISTANCE DRIVEN
Major drive	>20 nos	>5 nos.	Vehicle, Manpower, Lights all	>3 k.m.
Minor drive	<20 nos.	<5 nos.	Vehicle, Manpower, Lights all or any	<3 k.m.

As apparent from the table above (Table. 2) minor drives required fewer resources because the distance and duration of the drive were shorter.

In Sonitpur West the drive records during the year 2004 showed a good success rate[1] (see Fig. 2). A total 115 drives were conducted, out of which 84% or 97 drives were successful. Out of the 115 drives, 83% of the 81 major drives were successful and 87% of the 34 minor drives were successful. In 2005 the results were slightly poor compared to that of 2004. In 2005 a total of 125 drives were conducted of which 74% or 93 drives were successful. Of the 125 drives, 73% of 89 major drives were successful and 78% of the 36 minor drives were successful.

Figure 2: Elephant drive pattern Sonitpur



A drive is said to be successful when the raiding herds are driven to a desired location.

The cost of the elephant drives were worked out by considering the costs of hiring *kunkis*, vehicle running cost, sounding materials and cartridges used by the FD. The cost of all major and minor drives were calculated separately and the average was worked out by dividing by the number of drives of each type to get the cost involved per drive in each category of major and minor drives. However, the staff time of FD and WWF personnel were not included in the calculations.

Table 2: Cost involvement for Major and Minor drives in Sonitpur west Division

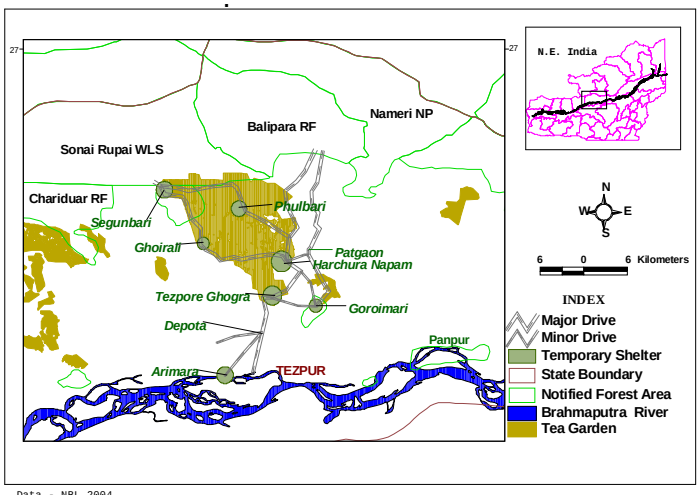
TYPE OF DRIVE	AVERAGE COST INVOLVED IN INR SONITPUR WEST DIVISION
Major Drive	5000/- (ca. $100)
Minor Drive	2500/- (ca. $ 50)

Elephant drive data for 2004 & 2005 raiding season's shows that elephant drives were conducted by the FD from the month of May to December (see Table. 3). However the number of drives during May-August was less compared to the period between September-December.

Table 3: Month wise number of major and minor drive (Sonitpur west division)

MONTH	2004 DRIVES		2005 DRIVES	
	MAJOR	MINOR	MAJOR	MINOR
May	Nil	1	0	1
June	Nil	2	1	2
July	1	4	7	3
Aug	1	6	0	0
Sep	22	9	24	8
Oct	20	10	32	6
Nov	23	2	15	7
Dec	14	Nil	10	9

Figure 3: Elephant drive pattern in Sonitpur West Forest Division



Since the launch of WWF's HEC Mitigation Strategy, the FD has started conducting frequent and sustained elephant drives due to availability of *kunki* elephants and other required resources placed at their disposal by the NBL program.

As apparent from the tables above (tables 3 & 4) the number of elephants visiting revenue areas showed a rise from September onwards. This rise in elephant number could be attributed to the fact that large number of elephants tried and ultimately succeeded in crossing the first *kunki* barrier along the southern periphery of Sonai-Rupai Wildlife Sanctuary (WLS) and Balipara Reserve Forest (RF) (See Figure 3).The FD in collaboration with the ADS managed to drive the elephants into some undisturbed pockets inside the tea gardens and some large open scrublands in the forest division. Also major herds of elephants were pushed back into the forest areas several times by conducting frequent elephant drives. However, the elephants managed to return into the revenue areas within a few days because the *kunkis* used as barriers had to be relocated to other areas where there were ongoing elephant disturbances.

But an overall control over elephant depredation was maintained by conducting frequent drives which was reflected in an overall decrease in the crop damage trend in the project area (see fig: 5 & 6). It was found that inspite of the presence of 100-150 elephants (see tables 3 & 4) in Sonitpur west division from September to December the loss to crop was reduced compared to the previous couple of years.

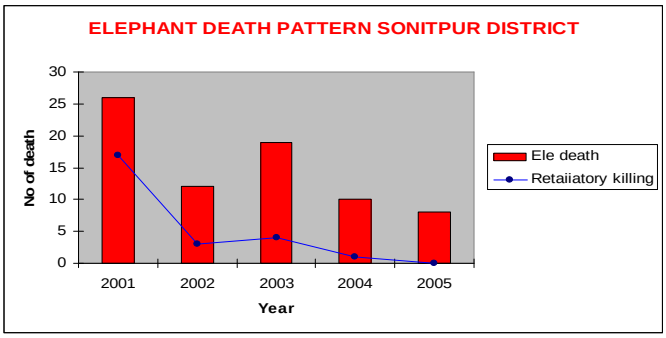
Table 4: Month wise pattern of herd size

MONTH	HERD SIZE (APPROX.)			
	MAXIMUM		MINIMUM	
	2004	2005	2004	2005
May	3	3	Nil	Nil
June	Nil	45	1	Nil
July	65	55	1	11
Aug	35	Nil	1	Nil
Sep	150	150	4	3
Oct	120	150	1	15
Nov	100	100	25	8
Dec	150	25	Nil	12

Figure 4: Elephant death pattern, Sonitpur district

DAMAGE ASSESMENTS

After implementation of the strategy during 2004 and 2005 a damage assessment of certain parameters was carried out to find out the effectiveness of the strategy. Parameters like retaliatory killing of elephants, crop damage and peoples' perception towards long term solution of the problem were also assessed.



As compared to the figures of retaliatory killings in 2001 and 2003 which were 17 and 4 respectively, the number came down to one and zero in 2004 and 2005 respectively after implementation of the HEC mitigation strategy. Although human and elephant deaths are not always good indicators of the effectiveness of the strategy, but decrease in the retaliatory killing of elephants can just be indicative of peoples' growing confidence on the HEC mitigation methods.

A reduction in crop damage during 2004 and 2005 has been observed while the HEC mitigation strategy was being implemented. During 2004, 56% of the villages sampled have shown decrease in crop damage compared to the previous year. During 2005, 68% of the sampled villages have shown a decreasing pattern. But 24% and 27% of the sampled villages in 2005 and 2004 respectively have shown an increase in crop damage. Whereas 17% and 8% of sampled villages in 2004 and 2005 respectively have shown no change in crop damage trend.

Peoples' perception towards short term and long term measures of HEC mitigation was studied. As a short term measure it was found that people in the villages in Sonitpur East preferred search lights, but the villagers in Sonitpur West had a mixed preference (see figure 7). Regarding long term measures more than 90% of the sampled villages preferred restoration of lost elephant habitat to mitigate HEC (see figure 8) in the year 2004. In 2005 there is a huge demand for the search light in both the forest division as a short term measure for HEC mitigation (see figure 9). Again in 2005 90% people in the surveyed village want restoration of lost elephant habitat as a long term solution of the problem (see figure 10). Although the program have been using the *kunki* elephants to drive out the wild elephants from the revenue areas of the district but it does not reflect as a most preferred means of HEC mitigation. It may be due to the fact that the *kunki*s are being used by the forest department and community has not direct control over the management of the *kunkis*.

Figure 5: Crop damage 2005

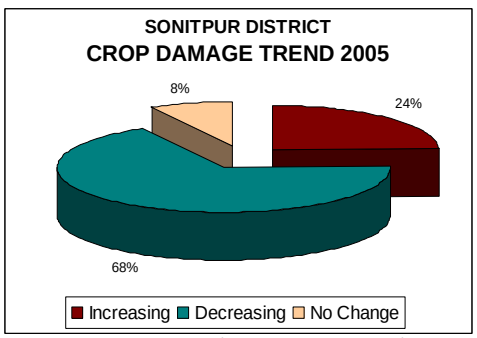


Figure 6: Crop damage 2004

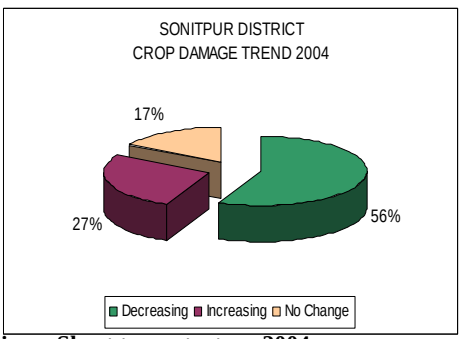


Figure 7: Community Perception – Short term strategy 2004

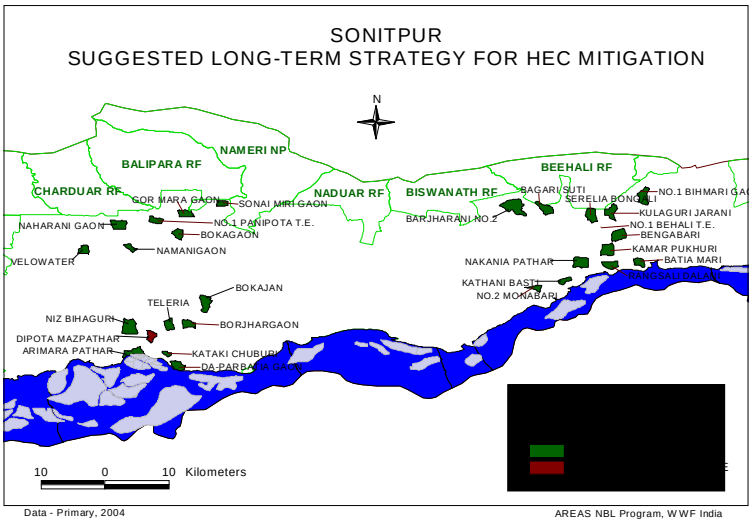


Figure 8: Community Perception – Long term strategy

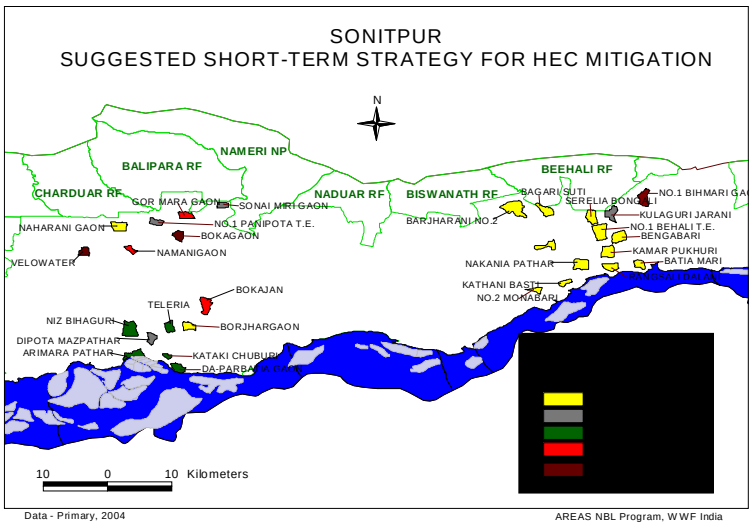


Figure 9: Community Perception – Short term strategy 2005

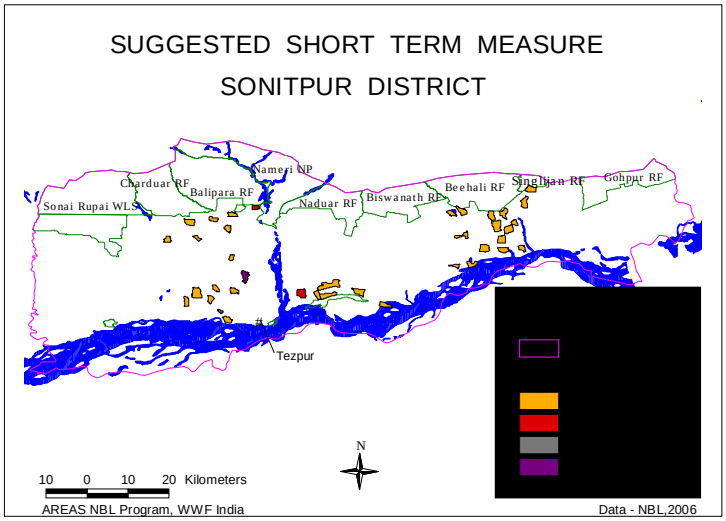
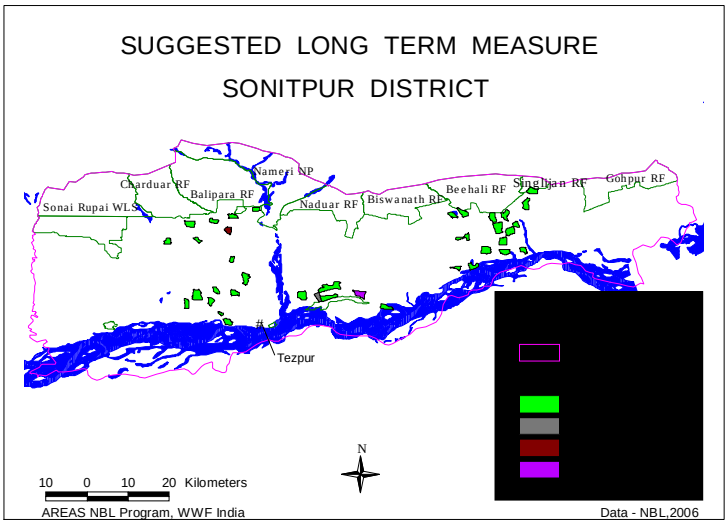


Figure 10: Community Perception – Long term strategy 2005



Limitations:

Sonitpur district has different ethnic communities with various perception towards the elephant. The existing ethnic and political conflict in the region is one of the major impediments in implementation of conservation objectives. Among the local communities while some people still revere the elephant as Lord Ganesha (a Hindu deity), others are sometimes violent against elephant usually during crop raiding season.

Other limitations like cooperation from the tea garden managements, which is sometimes crucial for conflict mitigation work, some time is lacking. At times lack of cooperation among the different stakeholder like among villagers, among different government departments, and sometime among different forest ranges also create problem. The elephant drives sometime fail due to lack of discipline among the *kunki* mahouts.

Lesson learnt:
After implementation of the HEC Mitigation Strategy 2004 and 2005, the project achieved some successes, met with some failures and also learnt new lessons. Some basic observations and learning during the phase are:

- All the drives conducted during the last two seasons were not successful because in cases of emergency, drives could not be planned properly due to shortage of response time available.
- The ADS are loosely structured groups which need to be institutionalized in the years to come.
- It was also realized that the *kunki* elephants need to be professionally managed to save the staff time of the project team.
- Strategically there is also a need of putting up a few temporary camps for the members of the ADS and the FD staff.
- Tea gardens constitute a major proportion of the land area of the Sonitpur district and hence strategic collaboration with the tea companies is a necessity for the purpose.
- The program also needs to look at the behavior of the loner elephants and the calves during the drives which may actually change the course of the drives.
- For a long term conservation plan to succeed, it is essential to urgently address the major threats like rapid forest cover and habitat loss.

Based on these observations and understanding the project looks forward to improve the endeavor to minimize HEC in the project area.

Acknowledgement:
We are also thankful to all the officials and staff of the Forest Departments of Assam and Arunachal Pradesh,and Department of geography of Gauhati university . Thanks are also due to our active civil society partners in the field namely SERDO, Nature's Bonyapran and all the Anti Depredation Squads. The project team is thankful to the donors namely WWF Netherlands, WWF US, US Fish and Wildlife Service, MacArthur Foundation and Smithsonian Institute.
Special thanks go to Sanjay Gogoi for his constant cooperation and help during the implementation period of the program. Thanks also go to Sushila Basumatari, Suren Bora and other members of the team. Last but not the least the team is thankful to Dr.Kushal Konwar Sarma for his contribution towards the healthcare of the *Kunki* Elephants.

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Preliminary results of a cabergoline trial in captive elephants with hyperprolactinemia

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Introduction:
An Asian elephant (*Elephas maximus)* at Busch Gardens Tampa Bay (BGT) was diagnosed with hyperprolactinemia, with a persistently elevated serum prolactin concentration greater than 15 ng/ml, by the Conservation & Research Center (CRC) laboratory in January 1996. She also had a number of other problems, including uterine disorders that resulted in consistently elevated progesterone. In March 2002, she was given cabergoline orally at a dose of 1 mg twice weekly p.o. for 6 mon. Cabergoline is a long-acting dopamine receptor agonist with a high affinity for D2 receptors. It exerts a direct inhibitory effect on the secretion of prolactin. Cabergoline (Dostinex®, Pfizer Inc. Kalamazoo, MI 49007, USA) was purchased from a local pharmacy. Serum prolactin concentrations declined almost immediately after treatment initiation, followed about one month later by a drop in progesterone to baseline. Progesterone secretion remained low until November 2002 when she resumed cycling based on the observation of a normal luteal phase based on serum progesterone profile.. From November 2002 through January 2004 she exhibited four normal estrous cycles. Prolactin secretion also remained within the normal range for elephants,[1] over one year after treatment withdrawal. This female suffered no adverse effects due to the cabergoline treatment. There were no behavioral changes noted or changes in appetite. Given the need to increase reproductive rates of African elephants *(Loxodonta africana*) to prevent captive extinction, it might be efficacious to treat genetically valuable females with cabergoline in the hope it will reinitiate reproductive cyclicity. Nearly 1/3 of African elephants with hormone data are not cycling normally, and in an earlier study 1/3 of these (11 of 30) were found to have increased serum prolactin levels.[1]

Methods and Materials:
A clinical trial was undertaken with six captive African elephant females that were identified as good candidates for a cabergoline treatment study (i.e., they are acylic and had mean prolactin concentrations of >15 ng/ml). The treatment consisted of 1 mg cabergoline given twice weekly p.o. for 6 months. Serum was banked and then analyzed at the CRC for progesterone and prolactin.[1] All elephants were thought to be otherwise healthy. Because prolactin is known to be an inflammatory marker,[4] all candidates were required to have a negative lateral flow immunochromatograpy (Rapid Test) and multiple antigen immunoassay (MAPIA) for *Mycobacteria tuberculosis*[5].

Results:
A summary of the results is given in Table 1. The treatment period is complete for three elephants, all of which showed a decrease in prolactin levels. Elephant 1 showed a good response while on treatment, but did not cycle and serum prolactin has subsequently risen to pre-treatment levels. Increasing the dose in Elephant 2 and 3 reduced prolactin to baseline levels, but again did not result in a return to ovarian cyclicity. Elephant 4 was taken off the study after only a few doses due to increased aggressive behaviors. This is believed to be due to changes in the group social dynamics and not related to the cabergoline, as this behavior has continued after withdrawal of the drug. Based on these findings, the two newest candidates, Elephant 5 and 6, with very high prolactin concentrations have been placed on 2 mg/twice weekly for one year pending continuation of this project.

Discussion:
Normalization of prolactin levels facilitated the return of normal cycles in an Asian elephant, but none of the African elephants have resumed cycling so far. Thus, while the use of cabergoline shows promise in reducing elevated prolactin levels in both Asian and African elephants, other factors may need to be considered or a longer course at higher doses may be required for treatment to be successful in reinitiating ovarian activity. The latter suggestion is supported by two of the animals (Elephants 2 and 3) in this limited trial, in which a decline in prolactin occurred after the dose was increased. Understanding the etiology of hyperprolactinemia in elephants may also help in returning females to normal cycling. Relapse of hyperprolactinemia is more common in humans with micro- or macroprolactinomas.[2] Chronic estrogen stimulation is also known to increase prolactin levels.[3] A proposed pathophysiology is that elevated estrogen levels from persistent cycling will lead to elevated prolactin levels and acyclicity. A difference between the two species in the causes of and potential treatment options for hyperprolactinemia should also be evaluated more closely.

Acknowledgments:
We would like to thank the participating zoos for their cooperation and patience during this trial.

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Table 1.
Treatment dates, doses, and responses to cabergoline treatment in captive elephants.

Elephant Number	Dates of Treatment	Dose	Response
1	2/05-1/06	1 mg (2X/wk)	Prl averaged ~15 ng/ml . After treatment, Prl declined to normal baseline (~6 ng/ml) until 9/05 and now has returned to slightly elevated concentrations (~13 ng/ml). No change in cyclicity status.
2	6/04-2/05	1 mg (2X/wk)	Prl averaged ~30 ng/ml, but had started to decline before treatment. During treatment, prl averaged ~10 ng/ml, with occasional spikes of 20-50 ng/ml. No resumption in cyclicity. Decided to increase dose.
	2/05-Current	2 mg (2X/wk)	Prl decreased further to ~5 ng/ml from 2/17-4/27, but then surged for 3 weeks in May 2005, followed by now baseline levels (<10 ng/ml). No change in cyclicity status.
3	8/04-12/16/04	1 mg (2X/wk)	Prl averaged ~40 ng/ml pretreatment, decreased to ~25 ng/ml, but still considered elevated and no change in cyclicity status, so increased the dose.
	12/17/04-4/14/05	2 mg (2X/wk)	Within 2 weeks, prl declined to normal baseline (<10 ng/ml) and remained low until treatment withdrawal. After 2 weeks, prl started to rise, peaked at 70 ng/ml, and now remains elevated at ~30 ng/ml. No change in cyclicity status.
4	5/28/05-6/14/05	1 mg (2X/wk)	Stopped after a couple of weeks due to aggressive behavioral change
5	pending		Variable Prl, ranges from 20-80 ng/ml. **Recommend 2 mg twice weekly for 1 year.**
6	pending		Very high average prl (off curve) >80 ng/ml. **Recommend 2 mg twice weekly for 1 year.**

Prl = serum prolactin

Status and management of captive Asian elephants in northern West Bengal, northeastern India

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Abstract:
The status and management of captive elephants maintained by the Forest Department at Jaldapara Wildlife Sanctuary, West Bengal, India, were assessed in 2004. The sanctuary managed 48 captive elephants kept at thirteen locations. The overall male to female ratio of these animals was 1:2; the Forest Department favoured females as they are easier to manage as compared to the males. Adults (38%) and sub-adults (35%) were almost equal in number. Although there were no calves (<1 yr old) in 2004, juveniles (1-5 yr old) constituted a significant (27%) proportion of the population.

The reproductive status of 16 adult females showed that most of them were breeding regularly with the exception of three cows aged 45, 48 and 49 years that had never calved. Among the breeding females, age at first calving was between 13 and 28 years (mean 19.5 yr). Females born in captivity, calved at a relatively younger age (17.2 yr) compared to females brought or caught from the wild (21.7 yr). No instance of twin births was observed. Sex ratio of 48 calves born in captivity showed a male-biased sex ratio (1.7:1). Middle-aged mothers (25-35 yr) produced more male calves than female calves compared to younger or older mothers. Although calves were born throughout the year, a distinct seasonality in calving was observed between November and March. An inter-calving interval of 4.8 years was estimated from 33 instances (ranging from 2.4-15.0 years). This is thus a healthy, breeding population.

Behavioural data of calves showed that on average calves suckled 0.85 times/hr and the mean suckling duration was 93 sec/hr with a mean bout time of 42 sec/bout. The suckling behaviour in terms of frequency of suckling and bout decreased with increase in age of calves. Mothers were the nearest neighbours of calves more often (68%) than allomothers (24%) while feeding in the grassland. At the tethering site, however, where mothers and allomothers were restrained with chains, calves spent more time with other young calves. Allomother care increased with increase in age of calves.

The captive elephants, both adults and sub-adults, were mostly used for patrolling the sanctuary and for tourism. The work period was restricted to 2-3 hours/day, with alternate shifts in the morning and evening on consecutive days. Adult females in advanced stage of pregnancy or with calves, and adult males in musth were not used for these activities. The elephants were allowed to forage in the forest during the day and were provided with cut fodder during the night, apart from supplementary diet (twice a day) of rice and pulses. We make some recommendations for the management of these captive elephants.

I. Introduction

Jaldapara Wildlife Sanctuary located in the northern region of the state of West Bengal, India, maintains nearly 50 captive elephants (*Elephas maximus*), or about half the state's captive population of this species. The captive elephants in this sanctuary have been sourced from the wild elephant populations of northeastern and central India. The Forest Department of West Bengal has maintained these elephants for more than 40 years, mainly for patrolling the forest areas and, to a lesser extent, for tourism. Jaldapara is known for the greater one-horned rhinoceros (*Rhinoceros unicornis*) that has been under severe poaching pressure in the past because of the perceived medicinal value of its horn (Menon, 1996). The presence of

rhinos in this tall grass habitat makes patrolling on foot a difficult task; hence, the use of captive elephants. Many of the elephants in the present stock are captive-born but others have been caught from the wild, probably more than 15 years ago, or have been orphaned and rescued from the wild.

Since an estimated 3500 elephants are being held in captivity in India – in temples, timber camps, nature reserves and zoos (Bist, 2002) - it is clear that proper welfare, management and breeding of captive elephants is important for conservation of the species (Sukumar *et al*., 1997). Although the northeastern states hold more than half of India's captive population (Anon, 2004), scientific information about these elephants is meagre as compared to the southern Indian captive elephant population. The present study thus aimed to document the status of population, reproduction and management of captive elephants of Jaldapara Wildlife Sanctuary in northern West Bengal and make recommendations for the effective management of this captive group in relation to the broader management goals of the captive population of the species.

II. Methods

2.1 Study area:

Jaldapara Wildlife Sanctuary (JWLS) is located in the northern region of West Bengal state. The sanctuary covers an area of 216 km^2 and lies between 25° 58" and 27° 45" North latitude and 89° 08" and 89° 55" East longitude (Figure 1). Situated at the foot of the Bhutan hills (Eastern Himalaya), the Jaldapara Wildlife Sanctuary has special significance in maintaining the remnant *terai* grassland that harbours endangered species such as Greater Indian one-horned rhinoceros (*Rhinoceros unicornis*) and hispid hare (*Caprolagus hispidus*) that are specialized to the floodplain habitats. The area receives an average annual rainfall of c.4000 mm, predominantly from the summer monsoon, while the temperature varies from a cool 14°-26°C (mean minimum and maximum temperature) during November-March to a warm and humid 23°-32° C (mean minimum and maximum temperature) during April-October.

The sanctuary is divided into several administrative units or "beats" for effective patrolling of the sanctuary. River Torsa, along with its numerous tributaries, provides water round the year for various wildlife and the captive elephants. Jaldapara has a multi-tier vegetation assemblage and is broadly classified as a moist tropical forest along with grassland and plantations (Sukumar *et al*., 2003). The mosaic of tall grassland and wooded forest provide the diverse fodder resources for wild and captive elephants.

2.2 Population size and structure:

Data on age/sex of all captive elephants, both wild caught and born in captivity, maintained in the year 2004 by the Forest Department at Jaldapara were collected from the Service Register records. These records go back to the year 1976 in the case of the oldest elephants alive during 2004. Additionally, for individuals caught or rescued from the wild, the age was verified using shoulder height as described by Sukumar *et al*. (1988). Elephants were broadly classified into calf (<1 yr), juvenile (1-5 yr), sub-adult (5-15 yr) and adult (>15 yr) for subsequent observations.

2.3 Reproduction and maternal investment in calf:

The dates of first calving and successive calving thereafter were recorded to estimate the age of sexual maturity and the average inter-calving periods, respectively. In the case of abortion during pregnancy, the data were not taken into account. The attainment of sexual maturity was also compared between wild- and captive-born mothers to discern differences, if any. Maternal investment in terms of the sex of calves in relation to mother's age was assessed to know whether investment is uniform or biased towards a particular sex.

2.4 Suckling behaviour:

Suckling behaviour was studied in seven calves aged between 14 and 28 months; calves above the age of 28 months are usually weaned from the mother. Using focal sampling method (Altmann, 1974) calves were observed between 06:00 hr and 18:00 hr as there was no clustering of suckling during the day or night (Lee and Lindsay, unpublished data). The observations were recorded in the grassland, the tethering site and while patrolling. A total of 497 hours of observation was made on the seven calves. During each observation, the starting and ending time of suckling was recorded following Lee (1987).

2.5 Nursing behaviour of mother and allomother:

Focal sampling method (Altmann, 1974) was employed on individually-recognized suckling calves to study the nursing behaviour of mother and interactions with other members of the group. Observations were carried out between 06:00 and 18:00 hrs. Each observation hour was divided into four sample blocks (15 min each) and in each sample block 10-min observation was made with a break of 5 min (Lee and Moss, 1986). In total, 208 hours of observation were made. For each observation, activity of calf, it's nearest neighbour and distance from the calf, and distance of calf to its mother and her activity were recorded**.** If the nearest neighbour to a given calf was not its mother, that individual was considered as the allomother (Nair, 1983). The data were used to compute the time spent by the mother and the allomother, separately for foraging and tethering sites. In total, 8320 records (scans) of nearest neighbour distance were recorded during the 208 hours of observation. Apart from these, *ad libitum* observations of rarely occurring events such as supplants between females, calf distress, and inter-family interactions were recorded.

III. Results and discussion

3.1 Population Size and Structure:

During the study period a total of 48 elephants was managed at the Jaldapara Wildlife Sanctuary and these elephants were placed in 13 "beats" or locations of the sanctuary (Appendix 1). Among the 13 locations, Hollong had the highest number of elephants, as this place is the main training center for captive elephants and also the main tourism hub of the sanctuary. Of the 48 elephants, 33 individuals (69%) were born in captivity while the rest were caught or rescued from the wild.

The age class distribution of the 48 individuals indicated an almost equal number of adults (38%) and sub-adults (35%). While the juveniles represented 27% of the overall number, there were no calves during the study period (Figure 2). Of the 48 elephants, nearly two-thirds (67%) were female with an overall male: female ratio of 1:2, indicating a moderate skew towards females. Although some skew is natural in a polygynous species such as the elephant, the age-class specific sex ratios showed a much higher skew towards females in the adult class (1:8) as compared to sub-adults (1:1.1) and juveniles (1:1.2). Such a skew could be due to the fact that 87% of the wild caught or rescued individuals that formed 31% of the population were females with majority being adults (10 out of 13) at the time of the study. However, such a biased sex ratio in adults need not be detrimental to reproduction because most of the cows in captivity breed with wild bulls present in the sanctuary. Among the males, juveniles, sub adults and adults comprised 37.5%, 50% and 12.5% of this segment, respectively. This shows that >80% of the males are either sub-adults or juveniles. Most of the sub-adults are used for patrolling. On the other hand when we consider the female segment, juveniles, sub adults, and adults constituted 22%, 28% and 50% of the population respectively. This shows that half of the females were adults, which are needed for patrolling, tourism and breeding purposes.

The results of age class distribution showed a higher proportion (63%) of younger age segments such as sub-adults and juveniles compared to adults (37%), which is a possible sign of a growing population. The absence of calves need not be a cause for concern as elephants are known to have a long intercalving period of 4-5 years (Daniel *et al*., 1987); a higher number of females calving in any given year results in very few females for calving in the subsequent years (Douglas-Hamilton, 1972; Sukumar, 1989; Baskaran and Desai, 2000). The high proportion (27%) of juveniles in the overall population suggests a recent boom

in births here. Similarly, the highly skewed sex ratio towards females among the adults also need not be viewed negatively from the point of genetic diversity as wild bulls have sired most of the calves born to captive cows in the sanctuary.

3.2 Reproduction and Maternal Investment:

Age of sexual maturity

The earliest age at which a female gave birth was 13 years 3 months by a cow named Muktirani (first calving on 13th January 1998). Muktirani herself was born in captivity on 5th October 1984 and thus her age is known accurately. This suggests that she was sexually mature by about 11.0–11.5 years. The data is not exceptional because Sukumar *et al.* (1997) also found a similar age (13 years 4 months) of earliest first calving in a captive-born elephant (Meenakshi) in Tamilnadu, southern India. The next earliest age of first calving was 14 years 11 months by Kuntalini (captured at the age of 9 months). All the other cows have either calved for the first time well beyond 15 years or, in some cases, beyond 25 years. The oldest age at which a cow gave birth to her first calf was by Madhumala at the age of 28 years (she was purchased at an estimated age of 8 years). Among captive-born elephants whose ages are accurately know, the highest age of first calving is 19.7 years in Sakuntala. At present JWLS has 16 adult females, of these four females are yet to calve. Among these four, one is a young adult (Srilochana –17.8 years) and remaining three adult females (Chambakali – 45 years, Urvasi - 48 years and Poornima - 49 years), though quite old, are yet to give birth. Significantly, all these three cows were wild caught ones purchased from the famous Sonepur Mela (an annual animal fair) in Bihar state.

From the available data (of 12 calving females with 50 calves), an elephant named Shree, presently aged 61 years had given birth to the maximum number of calves (11 calves). However, data on her first five calvings were not available, as she was a wild caught elephant purchased from another state. These observations are comparable to that reported for captive elephants of southern India (Sukumar *et al*., 1997). Two cases of abortion were recorded. There have been no instances of twin calves out of 50 successful parturitions in captivity, but this could be simply due to chance as the incidence of twinning in elephants in only about 1% (Sukumar *et al*., 1997).

Another interesting feature is that when age at first calving of captive-born elephants and wild-caught elephants is compared, captive-born elephants showed earlier calving (mean = 17.3 yr (n = 5), min = 13.3 and max = 19.6) as compared to wild caught (mean = 21.8 yr (n = 5), min = 14.9 and max = 28). This difference may be due to the fact that wild-caught elephants may have to spend considerable time to adapt to the new environment and, thus, take relatively longer time to start breeding. Another possibility is that this could be biased by the fact that some of the wild caught elephants could have become captive when they were already adults, and thus the age of first calving is overestimated.

Sex ratio of calves in relation to the age of the mother:

Out of 50 calving records, the sex was known for 48 calves, 30 males and 18 females or a male:female ratio of about 1.7:1. The sex of the calves in relation to the mother's age showed that middle-aged females, especially 25-35 years old, gave birth to more male calves than female calves as compared to cows of other age classes (Figure 3). From the above results we can conclude that middle-aged cows are biasing their investment towards males. Physical and physiological condition of the mothers in the 20-40 years age group could be expected to be relatively good. This may conform to the Trivers and Willard (1973) model of adoptive variation in offspring birth sex ratio. According to this model, in a polygynous species for which the male has higher variation in lifetime reproductive success than does the female, a mother in good condition should invest preferentially in sons because a high quality male is likely to enjoy high reproductive success. Such a pattern has been observed in captive Asian elephants in southern India (Sukumar *et al*., 1997), and in several other mammalian species, *e.g.* caribou *Rangifer tarandus* (Thomas e*t al*., 1989), mule deer *Odocoileus hemionus* (Kucera, 1991), although contradictory patterns are seen in certain species (Robinette *et al.*, 1973; Slagland, 1986).

Seasonality of Birth:
Seasonality or date of birth was available for 48 births. This shows (Table 1) a clear seasonality in births between September and March, with a peak in December (19% of all births). Between April and July the calving rate remained low (< 4%).

Peak calving occurs in December, at the beginning of the dry season. This indicates that conception period peaked during February and March assuming a mean gestation period of 20-22 months (Sukumar, 1989). Similar seasonality in calving has been reported for captive elephants elsewhere in India (Sukumar *et al*., 1997) and in Myanmar (Mar, 2002). In some wild elephant populations in Africa, a seasonal peak in birth has been observed at the beginning of the wet season, when nutritious forage would be ensured for the lactating mothers, a pattern that would be favored by natural selection (Laws *et al*., 1975; Hanks 1979).

Inter-calving interval:
Out of 12 breeding females, ten have given birth more than once. Analyses of 33 inter-calving intervals from these 10 cows showed a mean inter-calving interval of 4.8 years (SD = 2.95) with a minimum of 2.3 years and a maximum of 14.9 years. The calving interval (4.8 years) estimated in the present study is much lower than the calving interval of 6.5 years estimated over a longer period for "timber camp" elephants of southern India (Sukumar *et* al., 1997). Although the artificial weaning of calves is expected to alter the inter-calving interval among captive elephants, this is more comparable to the 4-5 year interval estimated for wild Asian populations (Daniel *et al*., 1987; Sukumar, 1989; 2003).

3.3 Suckling behaviour:
Suckling behaviour observed in eight calves for 255 hours showed that the calves suckled in total 216 times with an average frequency of 0.85/hr. In total, 6.5 hrs of suckling was observed with a mean suckling duration of 93.4 (± 5.56) sec/hr.

The influence of the age of calves on suckling frequency and duration is presented in Figure 4. Sucking frequency decreased with increase in age (Kendal's Tau = -0.619, n = 7, p = 0.05) while suckling duration did not change much (Kendal's Tau = -0.238, n = 7, p = 0.45). These results suggest that as calves grow older, they suckled less frequently with more or less the same suckling duration exhibited by the younger calves.

3.4 Nursing behaviour of mother & allomother:
Elephants live in social groups notable for its high degree of allomothering and allomaternal care (Lee and Moss 1986, Lee 1987, Nair, 1983; Gadgil and Nair, 1984). Captive elephants were allowed in mixed groups of various age classes to feed in the natural habitat. In the grassland all members are free and, thus, the mother or allomother regulates the distance of the calf, whereas at the tethering sites the calf determines the distance to the neighbour because the mother and the allomother are chained. Hence, data were analyzed separately for the time when all members remain free for interacting, and when only the calf is free but the movements of all other members are restrained by chains.
The result of time spent by various age groups of calves with mother and other members in the grassland is shown in Figure 5. The results show that the time spent by mother as the nearest neighbour to the calf declined as calf's age increased. Similarly, the time spent by calves with other calves also showed a similar trend with age. On the other hand, time spent by allomother as the nearest neighbour to the calf increased positively with increase in the age of calves. The decline in time spent by mother as nearest neighbour to calf with increase in age seems to be compensated by the allomothers. Among African elephants such care shown by animals other than mothers has been viewed as important in the maintenance of the matriarchal society (Douglas-Hamilton and Douglas-Hamilton, 1975; Moss, 1982). The decline with age in time spent by calves with other calves could be due to the increase in time spent on feeding by calves with increased age. Lee (1987) also found a similar pattern in the case of African elephants. On the other hand, at the tethering site (Figure 6), time spent by calves with allomothers decreased with age, while time spent with other calves increased. Time spent by calves with their mothers did not show any pattern.

3.5 Management of captive elephants:

Housing

The tethering sites of all the captive elephants are located near the houses of the mahouts or the grass-cutters and even the beat office. The chaining or tethering place is commonly known as *than* or *pilkhana*. It is generally located 5–50 m away from the mahout's residence or the beat office. At any given time, the elephants are in the vicinity of the concerned authorities. The floor of the *than* is generally made of concrete though until a few years ago all of the beat offices used earthen floors or allowed the elephant to stand on dry unused fodder. These days the elephants spend their nights on concrete flooring. There is no roof at the *than* for the adults that are forced to stay under the open sky, but the sub-adults and juveniles have roofs made of asbestos (a banned substance in many countries). During the night, elephants in most of the beat offices remain without light with the exception of Hollong beat. The distance between two elephants is maintained around 15-20 m. The tethering place is encircled by electrified-wire fence to protect them from wild elephant attacks at night. Tethering sites are cleaned every morning and left vacant from 7 am to 4 pm, when elephants are taken for work or grazing.

Food and Feeding

The captive elephants in the sanctuary are allowed to graze freely, as well as fed with natural fodder cut from the sanctuary and a supplementary diet of rice and pulses. They predominantly feed on grass throughout the year due to the presence of extensive grasslands. Apart from grazing of wild grasses and browse, the elephants are also provided at night with wild grass cultivated by the Forest Department as well as harvested from the wild. The natural fodder used is also mainly grasses from April to November, during the rainy season. During winter and dry season the availability of grass decreases and, hence, banana stems and leaves are collected from the nearby villages (2-6 km away). Apart from these, browse (leafy branches and twigs) from wild trees are also provided.

In the morning (07:00-08:00 hrs), each grass cutter or *patawala*, goes with the elephant to collect fodder (grass) from the nearby grassland. The elephant is given commands to uproot grass methodically and pile them with the help of the grass cutter and carry these bundles back to the tethering site. Old, pregnant and injured elephants are exempted from collecting fodder. After the fodder collection, the elephants are allowed to freely forage in the nearby grasslands for six to eight hours from 08:00 to 16:00 hrs. In the grasslands, elephants mostly feed on grass as well as a few herbs, shrubs and, occasionally, bark and leave of trees. During winter and the dry season, they feed on large quantities of leaves as the availability of palatable grass decreases as reported elsewhere in the natural habitat (Sukumar 1989). The increase in the consumption of browse during winter and dry season could also be ascribed to higher protein availability as reported for the free ranging elephants elsewhere in Asia (Sukumar, 1989; Sivaganesan and Johnsingh, 1995).

During the afternoon, after bathing they are provided with supplementary food known as *kher* according to the prescription of the veterinary doctor. Every elephant has a ration chart, which shows a fixed diet consisting of soaked rice and pulses. An adult is provided 3-4 kg rice and 2 kg of pulses per day. The grass-cutter makes the *kher* by putting the grains and pulses in packets of long grass and feeding the elephant slowly to avoid wastage. After consuming the supplementary food, elephants are chained at the tethering site and provided with cut fodder collected in morning.

A veterinary doctor based in the sanctuary performs monthly health checks. Pregnant mothers, injured elephants and calves are paid special attention. Juveniles, sub-adults and adults are provided 1.5 kg, 4 kg and 6 kg rations per day respectively. During winter and dry season, managing the elephants becomes difficult due to the scarcity of forage in the sanctuary.

Bathing

Elephants are bathed once every day in the river. The time of bathing is generally from 15:00 to 16:00 hrs and the duration varies from 15 to 80 minutes (average of 60 minutes). The grass cutter cleans the skin using a stone. Care is taken to clean the nails, legs, eyes and ears and genitalia. The calves are not cleaned

and they remain free all the time. Besides this, each elephant takes dust bath, mud bath and water bath as they wander freely in the grassland.

Work Load
The elephants here are used generally for patrolling the sanctuary and for tourism.

Patrolling: Adult males and females, sub-adult males (from 10 years onwards) and sub-adult females (12 years onwards) are generally used for patrolling for 2-3 hrs in the morning (from 06:00 to 09:00 hrs) or at evening (from 16:00 to 19:00 hrs). They are generally used alternatively in the mornings and evenings of consecutive days. Mothers in advanced stage of pregnancy, injured members, and juveniles are not used for patrolling.

Tourism: A few healthy adult and sub-adult elephants of the sanctuary are used for tourism especially at Hollong lodge and Kunjanagar beat. They carry up to 6 visitors and a mahout from 06:00 to 09:00 hrs and from 15:00 to 18:00 hrs. From June 15th to October 15th the sanctuary is generally closed for tourism because of heavy rains. During this period the elephants are rested.

Than cleaning**:** Every morning elephants clean their own tethering place. At first the grass cutter collects the dung and puts it into an open box with two wheels. The elephants pull the box to the dumping place with trunk. The unused fodder is gathered by the elephant at a single place and then they are commanded to push the waste using the foreleg to the nearest dumping place, which is 20 – 200 m apart. Un-weaned calves and juveniles are not used for cleaning.

Fodder collection: Another minor workload is fodder collection from the nearby grasslands. During the rainy season, the elephants collect grass within 1-2 km of the tethering yard, while during winter and the dry season they collect branches of trees with leaves and banana stems from a radius of about 6 km. Injured members and mothers are not used for fodder collection for 1-2 months prior to and after calving.

IV. Conclusions and recommendations
The captive elephant population at Jaldapara with >60% of sub-adults and juveniles, and 12 adult females with an average inter-calving period <5 years indicates a population that is breeding at a rate comparable to a wild population. Such a prolific breeding rate has not been recorded among captive elephant populations elsewhere. An analysis of the overall dynamics of this population, including survivorship rates, would help place its demography in perspective. All indications are that this is a healthy population under effective management. However, we make following observations for the welfare of these captive elephants.

Supplementary diets in cooked condition would enhance the assimilation rate of nutrients (Krishnamurthy and Wemmer, 1995) as elephants are known to have low digestive efficiency (Benedict, 1936). The Forest Department may thus consider introducing cooked rice and pulses, as practiced in Tamilnadu state, instead of feeding them with cereals soaked in water.

Elephants that are forced to stand or move for considerable periods of time on concrete flooring are known to develop various afflictions of the footpad (Club and Mason, 2002). In fact, this is recognized as one of the major problems faced by captive elephants in western zoos. The recent change at Jaldapara in the flooring of the tethering site or '*than'* to concrete is thus highly undesirable. Therefore, converting the flooring back to earthen ones would help avoid the appearance of foot problems in these elephants.

The Forest Department presently finds it difficult to manage the increasing numbers of juveniles and sub-adults because of inadequate resources. Thus, the department has plans to introduce contraception to reduce the number of births. Testing immuno-contraception (Fayrer-Hoskin *et al.* 2000) in a few individuals would certainly enhance our knowledge about the efficacy of this technique in controlling births, and even be useful for introducing in wild populations where necessary. However, it would be desirable to consider the management of the Jaldapara elephants within a broader framework of sustainable management of captive Asian elephants at the regional and national level (or even global level). In spite of

a history of taming that goes back 4500 years ago, the captive elephant populations are not self-sustainable because of poor breeding and high mortality (Kurt and Mar, 2003; Sukumar 2003), and inputs from the wild population are required to sustain the existing captive populations at most places. This has resulted in depletion of wild stocks of the Asian elephant in many countries. Any "surplus" numbers of elephants in captivity would thus be an enviable situation at a time when many western zoos are spending huge amounts of money to build facilities to breed elephants! We thus feel that a perspective plan for management of captive elephants at all geographical scales will have to be prepared and agreed upon such that we ensure the sustainable management of both captive and wild Asian elephant populations.

V. Acknowledgments

We are thankful to the West Bengal Forest Department for permitting us to carry out the study and to the Indian Academy of Sciences, Bangalore, for financial assistance (to Subhamoy Das). We also acknowledge the financial support given by International Elephant Foundation to present this paper in the International Elephant Symposium conducted in Denmark during October 2006.

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Recent findings about the macroscopic and microscopic morphology of the elephants' hooves (*Elephantidae*)

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Introduction:
As the elephant is the largest living terrestrial mammal, its feet are probably one of the most important parts of its body. They have to carry an enormous weight. Thus, it is very important that the hooves are of good horn quality that can withstand all the mechanical and environmental influences. Therefore, it is easy to appreciate that elephant husbandry demands a great deal from zoological institutions. However foot disorders in elephants are quite common. Although foot problems have been recorded frequently in case reports, basic anatomical investigations of elephant hooves have rarely been described (e.g. RAMSAY and HENRY, 2001). Therefore, this study sets out to analyse the normal macroscopic morphology and the normal microscopic structure of both African and Asian elephant species' hooves by means of different measurements, with a view to finding "loci of minor resistance" as possible causes of foot problems. The histological findings provide a basis for assessing histopathological changes and especially horn quality.

Definition of elephant's hoof:
The "hoof" in general means firstly the foot of an ungulate mammal and secondly the horny covering of the end of the foot of hoofed mammals. In this study, references to the hoof mean all structures that are surrounded by the horn capsule in an elephant's foot (nails included). It represents the digital organ consisting of central supporting structures and the surrounded modified skin with subcutis, corium and epidermis. The stratum cornuem of the epidermis, which also means horny covering or horn capsule of the hoof, is also often called hoof capsule.

Material and Methods:
By means of the macroscopic investigations of 61 feet of 24 captive and semi-wild Asian elephants (5 males/19 females) and 25 feet of 9 captive African elephants (1 male/8 females), which have been measured and compared (partly with pictures) with the feet of their wild, semi-wild and captive relatives still living in their countries of actual origin, the normal macroscopic anatomy of the foot could be documented. The growth rate of the horn wall was measured in 12 different animals of both species by cutting a small notch close to the coronary border in one of the centrally located nails of the front and rear feet.
For the histological description of the elephant's hoof, 24 feet (17 of the Asian and 7 of the African species) from 14 captive and wild animals (6 males / 1 female / 7 unknown sex and exact age) were studied at defined locations. Each foot was measured macroscopicly and then 18 blocks for the histological processing were cut out at defined locations of a 1 cm thick longitudinal slice through a centrally situated, macroscopicly sound looking nail of the respective foot for longitudinal and cross sections. All together 727 prepared specimens, including pathological and some special slides, were examined histologically, stained with HE, Alcianblue-PAS and Oil red, respectively. Finally, some nails were exungulated for the macroscopic examination of the horn structures by placing the samples for one hour in water heated to 65° C and then putting them in cold water for two hours. The horn capsule could then be removed with forceps.

Macroscopic anatomy of the elephant's hoof:
The basic macroscopic anatomy of the elephant's hoof does not diverge from other hoofed and cloven-hoofed animals, such as horse, cattle or swine. The foot (= digital organ) of the elephant is defined anatomically by the supporting structures in the foot and the surrounding, partly modified skin and horn capsule. The supporting structures include the phalanges I to III, the metacarpal/metatarsal bones, the distal sesamoid bones and the different articulations between the bones, the respective tendons/muscles/ligaments as well as bursae and the digital cushion.
The outmost layer of the cutis (horny layer of the epidermis or stratum corneum) is modified in the range of the nails and the weight bearing surface by building a horn covering layer and horn capsule or hoof capsule. This horn layer has a special construction with horn tubules and intertubular horn in general and additionally with horn leaflets in the wall of the nails. This finding contradicts statements of SEILKOPF (1959) and FOWLER (1993).
The hoof can then be divided into five segments: periople, coronary, wall, sole and pad segment. This approach is based on the anatomy of domesticated animals (BOLLIGER, 1991; FUERST, 1992). Even a white zone is detectable.
The horn of the epidermis in the range of the horn capsule of the nails is very hard and sometimes brittle, producing cracks. Beneath the epidermis of the hoof is located the corium, which nourishes the epidermis through its vessels. The corium is similar to the subjacent subcutis algesic so that irritations of these two layers, e.g. due to injuries of the epidermis, can cause pain. The horny layer is very thin in the pad horn so that irritations of the algesic tissues can very easily lead to pain (see below).
The feet of Asian and African elephants appear very similar at first sight, but have macroscopic differences between fore and hind foot and between Asian and African elephant. Apart from the already known distinction between the number of nails (generally 5 nails in the fore foot and 4 in the hind foot of the Asian elephant, in contrast to 4 nails in the fore foot and 3 in the hind foot of the African elephant), some obvious differences were found, which is showed in table 1. These distinctions might reflect the different distribution of weight on the feet, the different size and weight and/or the different origins and habitats of the two species with the different substrates on which they live. This might be considered for the husbandry. The fact that the front foot is larger in general than the rear foot shows that the greatest stress is on the front feet, especially with the Asian elephants, which have a more massive head and neck than African elephants. This could be an explanation for the greater amount of foot problems (especially cracks) occurring mainly in the front feet.

Microscopic anatomy with some measurements:
The microscopic morphology of the elephant's hoof is similar to other domesticated (BOLLIGER, 1991; FUERST, 1992) and wild (VON HOUWALD, 2001) ungulates. Only little differences could be found between fore and hind feet and between species histologically. Thus, there were no significant indications for the proposed differences in the occurrence of foot problems between the species (RAMSAY and HENRY, 2001). As already mentioned briefly, the hoof of an elephant consists of corial papillae and of horn tubules and intertubular horn in all segments (see definition), except in the wall segment of the nail wall where corial, epidermal and horn leaflets as well as distally terminal horn are built.

Special findings of the macroscopic morphology of the elephant's foot:
A statistically proven difference was observed in the growth rate of the horn wall between the front and hind feet, but also between Asian and African elephants (front feet: 7.6 mm/28 d – Asian, 5.9 mm/28 d – African, hind feet: 6.4 mm/28 d – Asian, 4.7 mm/ 28 d – African). This contradicts statements of SEILKOPF (1959) and FOWLER (1993). Consequently, the healing of nail wall defects depends on the length of the nail wall, the species and the foot that is affected; on this basis a more exact prognosis of the time that it will take to outgrow a pathological alteration in the horn wall can be made. This also means that attempts to improve the horn quality with a feeding supplementation, for example with biotin supplementation, have to be planned for this time span or even longer (the horn has to grow down to the weight bearing border). It also has to be taken into consideration that horn with already bad quality proximally will take longer to grow down than a normal, qualitatively good horn (Leu, 1987). But it also seems that the cause for the too fast horn growth lies in the bad horn quality as Leu (1987) confirmed, too.
A comparison to the weight-bearing surface of captive and wild elephants showed distinctive differences in the thickness and appearance of the horn layer. The wild African elephants have more furrows on the

undersurface of their pads. These trenches also give the impression that the pad horn is much thicker in comparison to those of the African zoo elephants, which show a thinner horn layer especially after foot care. This much thinner horn layer of the weight bearing surface of captive elephants could be proven histologically (see below). The same observations on horn thickness are valid for Asian elephant. In the wild, the pad horn has built up circle-shaped horn pieces about 5 cm in diameter, which provide much more resistance to the environment. On the contrary, the captive Asian elephants show furrows like the wild African elephants, but less pronounced. The macroscopically estimated horn quality of wild elephants looks good in all visible segments, which gives the impression that the horn is much more resistant, even if there are some fissures to be seen on the surface of the pad horn. But it does not look so smooth and thin.
As a result, questions might be posed regarding the quality and correctness of different aspects of husbandry. A floor that is too abrasive, especially for Asian elephants, and foot care that is too frequent could trigger or contribute to foot problems, as SCHANBERGER (1990) has already mentioned.

Special findings of the microscopic morphology of the elephant's foot:
Widely distributed signs of bad horn quality (e.g. vacuoles in the stratum spinosum, decayed marrows of the horn tubules, dispersed and disintegrated intertubular horn, micro cracks within the intertubular horn, increased numbers of pyknosis of the nuclei in the marrows and in other horn cells) were detected in the hooves of captive elephants, even in neonate and juvenile elephants. The different segments are differently affected by the various kinds of alterations indicating bad horn quality that can be found in the respective segment.
"Loci of minor resistance" in the horn construction were discovered, partly even in wild animals: micro cracks and vacuoles in the terminal horn were visible in both captive and wild animals; the sole appeared with a thin horn layer and with far distally reaching papillae in captive elephants; the pad horn also occurred with a very thin horn layer in relation to the weight of the elephants and compared with the wild animals examined, and with micro cracks reaching close to the papillae in captive and wild animals.
On the basis of histological measurements of the thickness of the horny layer in the sole and pad horn, the difference between captive and wild elephants could be assessed. The thin horn of the weight bearing surface of the captive elephants was considered as one of the most important findings. The thin horn layer of the epidermis of the pad horn causes the corium beneath, which covers the digital cushion, to become irritated. The corium and the digital cushion are algesic so that pain can be caused by irritations. The pad area and the tough nails are the most common problem areas for elephants' feet.
These above-named findings in connection with the great weight and the husbandry employed (e.g. hard floor, little moisture, hygiene, feeding, foot care) might promote foot problems (FOWLER, 1993; CLAUSS and KIEFER, 2003). A genetic factor cannot be excluded in connection with the existence of bad horn quality. Exercise and motion in captivity are essential to improve horn quality because they further a better blood supply (STERN, 2000). Possibly, foot disorders could be prevented by taking horn samples regularly to check horn quality. An examination form for hooves can be found in the appendix of the thesis (http://www.dissertationen.unizh.ch/index2006.html).
The digital cushion of the pad segment that has the largest extension of the inner part of the foot is constructed similarly to that in cattle (RAEBER et al., 2004) and serves as an effective shock absorber and protection for the underlying structures. Its extension, which is probably the largest one for any terrestrial mammal, varies according to sex and age. The digital cushion contains fat tissue that is encircled by connective tissue in different ways (see figure 6). The connective tissue can be imagined as a "meshwork of dense connective tissue", which "divides the cushions into compartments similar to the stitches of a mattress" (RAEBER et al., 2004). The digital cushion is divided into three different parts. The connective tissue has the task of maintaining the formation of the fat tissue by holding it together and padding the bones. The fat tissue is also enclosed in "connective tissue islands" and so may be responsible for absorbing the animal's weight. In this way, it is possible for the cushion not to collapse under the heavy load. However, the digital cushion can expand a little due to its construction from fat and connective tissue, so that it acts as a shock absorber each time the foot is placed on the floor, but only so far as is tolerated by the "connective tissue islands". Thus the foot adapts itself to the shape of the ground, in spite of the horny structure of the weight bearing surface. The Asian elephants seem to have more connective tissue than the African species, which could be explained by the different substrates on which the species live and should be considered when choosing the surface of zoo enclosures (BENZ, 2005).

Acknowledgment:
This study was only possible due to the intensive support and help of the following people and institutions: Prof. Dr. H. Geyer and the Institute of Veterinary-Anatomy, Vetsuisse-Faculty University of Zurich, Switzerland; J. Peter of the Institute of Veterinary-Anatomy, Vetsuisse-Faculty University of Zurich, Switzerland; Dr. W. Zenker and "Tiergarten Schoenbrunn", Vienna, Austria; Dr. T. B. Hildebrandt, Institute for Zoo and Wildlife Research, Berlin, Germany; Dr. G. Weissengruber, Anatomy Department of the University of Veterinary Medicine, Vienna, Austria; Dr. K. Eulenberger and Leipzig Zoo, Germany; Dr. R. Zingg and Zurich Zoo, Switzerland; Dr. R. Asher, "Naturkundemuseum" Berlin, Germany; Dr. W. Schaftenaar and Diergaarde Blijdorp, Rotterdam, The Netherlands; Dr. W. Rietschel and "Zoologisch-Botanischer Garten Wilhelma", Stuttgart, Germany; Dr. A. Ochs and Berlin Zoo, Germany; Dr. M. Hofmeyer and Dr. I. Whyte, Kruger National Park, South Africa; Dr. P. Martelli, Singapore Zoological Gardens, Singapore; Roche Vitamine GmbH, Grenzach-Wyhlen and DSM Nutritional Products/R&D Human Nutrition and Health – Analytics (VFHA), Kaiseraugst, Switzerland; all participating zoos.

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Beyond Kaziranga -- A vision towards Kaziranga - Karbi Anglong landscape

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Introduction:

The world famous Kaziranga National Park (KNP), one of India's best secured Protected Areas, is located in the central part of Assam in north eastern region of India, on the south bank of the mighty river Brahmaputra. It plays an important rule in the conservation of biodiversity and is home to many charismatic and endangered mega species like the Asian elephant (*Elephas maximus*), Tiger (*Panthera tigiris)*, Indian Rhino (*Rhinoceros unicornis*), Swamp Deer (*Cervus duvauceli*), Wild Buffalos (*Bubalus arnee*), etc and other important wildlife. The park also provides habitat for a number of other rare, endangered and threatened species. Seasonal floods, erosion, poaching, etc become the major threat to the Kaziranga NP and moreover the carrying capacity of the park seems to be limited for the gradually increasing population of wildlife. Therefore, there is an urgent need to identify a viable complex of contiguous habitat that can act as a support as well as buffer to the wildlife of the Kaziranga.

With this view WWF India has identified a contiguous PA complex called Kaziranga - Karbi-Anglong Landscape (KKL). This PA complex has rich biological and socio-economic significance. WWF has started some activities towards conservation of this complex since 2004. The Kaziranga National Park has contiguity with the forested areas of Karbi Anglong, Golaghat and Nagaon disctricts in the landscape through which wildlife of the park use to move southwards to other parts of the landscape during flood/rainy season and also harvesting period. Among the mega-species, the landscape has a good number of Asiatic elephant distribution with a population of about 51% of Assam's total elephant population (5246 nos 2002 census). The highest concentration of elephants is observed within the Kaziranga NP (1246 nos, census 2005) and adjoining areas (694 nos, census 2005) which are included in the Kaziranga-Karbi Anglong Elephant Reserve towards the north. This distribution of elephant is found to extend from Kaziranga National Park in the north of the landscape through the Karbi Plateau in the central portions to almost all parts of the landscape. The elephant conservation works including their distribution, movement and related issues were focused in the some of the published literature (Anonymous, 2002; Bist, 2002; Choudury, 1993a, 1993b, 1999; Gurung and Choudhury, 2000; Talukdar, 2003; Williams and Johnsing, 1996a, 1996b) in north eastern India.

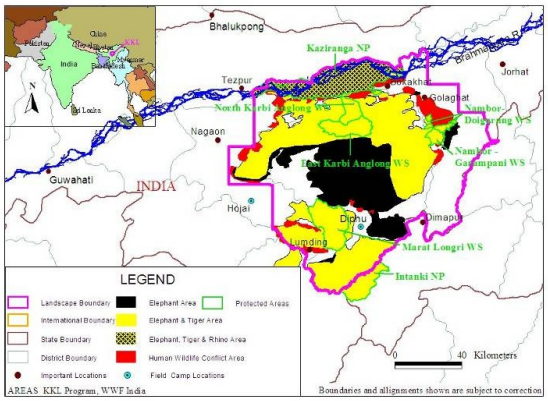
During the first phase of our studies the critical issues are identified in the landscape and a brief note especially on elephant distribution and movement, human elephant conflict and threats to the flagship species in the landscape is highlighted in the present paper. The data will assist the formulation an action plan and a perspective to manage Kaziranga- Karbi Anglong as a continuous unit.

Study Area:

The Kaziranga Karbi-Anglong Landscape (KKL) is located in the central part of Assam, on the south bank of the mighty river Brahmaputra (Fig 1) lies approximately between $92^0 15^/$ E - $93^0 53^/$ E longitudes and $25^0 18^/$ N- $26^0 42^/$ N latitudes and covers the hill district of Karbi Anglong and parts of Nagaon, Golaghat, and North Cachar Hills with an area of about 12000 sq km. The landscape is fairly rich in terms of biological as well as ethnic and cultural diversity. The population pressure has been comparatively less in

two hill districts of the landscape (NCHills: 30.8, Karbi Anglong: 63.5, Nagaon: 494.1, and Golaghat district: 236.4 per sq km as per 2001 census)

Fig. 1: Map showing KKL



Besides the Kaziranga National Park (KNP), the landscape covers six Wildlife Sanctuaries (WLS) and 42 Reserve Forests (RF), a number of Proposed Reserve Forests (PRF) and 17 District Council Reserve Forests (DCRF). Apart from other protected areas two Elephant Reserves namely Kaziranga – Karbi-Anglong (3,270 sq km) and Dhansiri - Lungding Elephant Reserves (2,740 sq km) also overlap the landscape.

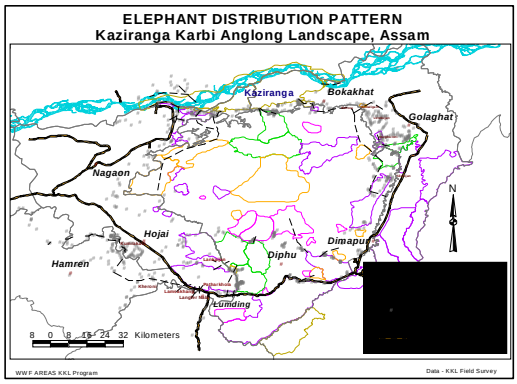
Methodology:

Data was collected from multiple sources and directly through field surveys. The study on elephants was done to find out their presence / absence in different parts of the landscape and also to find out areas / tracks popularly used by the elephants for moving from one forest patch to the other. The survey was conducted either through vehicular tracks or on foot depending on the possibilities and ground situations. During tracks, signs of presence or absence have been geo-recorded with global positioning system or records have been taken on a suitable time / distance interval. The presence and corridor study was established on the ground by direct sighting, tracks, dung, feeding signs and body rubbing marks on trees on an regular interval. Landuse & Landcover maps were generated using Satellite data. All of these have been analysed using state-of-the-art GIS technology.

Elephant distribution and movement:

The elephant in north eastern India had an almost continuous distribution together with those of Bhutan, Bangladesh, Nepal and Myanmar (Choudhury, 1999). As per historical records elephant travelled through long distances in this landscape to move into forested areas in Myanmar through Nagaland to the east; and also towards the west to Meghalaya. But these long very prominent movements are not being observed as of now. These historical ranges are disrupted and isolate the elephant population due to various anthropogenic pressures. The elephant population of the south bank of Brahmaputra can be divided into three distinct population (Choudhury, 1999). Tiwari *et al.* (2005) highlight some of the important elephant corridors of North-Eastern India.

Fig. 2



In the present landscape area, the movement patterns of elephants extend from the Brahmaputra flood plains (KNP) towards the space in Golaghat, Nagaon and Karbi Anglong district. The presence of elephant is seen all over these places (Fig 2) except from the heart of Karbi Anglong, where it is presumed that there may be a good population of elephant inside this space.

The movement even though seem to follow the same alignment and pattern have become curtailed to smaller portions / stretches connecting two popular habitats as observed and studied in the field till present.

It is observed that the elephants from the flood plains of Kaziranga National Park generally prefer to use five prominent linkages through which they move southwards to other parts of the landscape in the Kaziranga-Karbi Anglong Elephant Reserve during flood seasons and also during the crop harvesting period. For moving to the adjoining forests in the southern portions of Karbi Anglong and adjoining districts elephants usually prefer three sites to cross the national highway NH 37 for their temporal/seasonal movement. The elephants from the park also move along the banks of the river Brahmaputra to the adjoining areas or to inhabit the river islands as well; the elephants also cross the river to enter the north bank areas near Panpur.

In the present study fifteen elephant important tracts/corridors have been identified. This paper discusses only the following four important linkages. All of these four tracks are located along the southern boundary of the KNP. Collectively these are refrred to as Kanchanjuri-Amguri Corridor Complex.

Kanchanjuri-Amguri Corridor Complex:
The Kanchanjuri-Amguri corridor complex (Fig 3) is one of the important and active corridor for the Asiatic Elephants and also using by Indian Rhino and other animals for moving from the Kaziranga National Park to southwards into the adjoining forest of Karbi Anglong and Nagaon district during flood and also during the crop harvesting period. This important corridor is located between Kuthori and Jakhalabandha on NH 37.

There are four main linkages in this complex for animal movement:

a. ***Kanchanjuri*** (4th edition) connecting KNP with Ruthepahar forest in KarbiAnglong
b. ***Monkrakjuri*** connecting KNP with Bagser RF in Nagaon district
c. ***Ghorakhati*** connecting the KNP with Bagser RF in Nagaon district.
d. ***Amguri*** connecting KNP with Bagser RF in Nagaon district.

Fig. 3: Kanchanjuri Amguri Elephant Corridor Complex

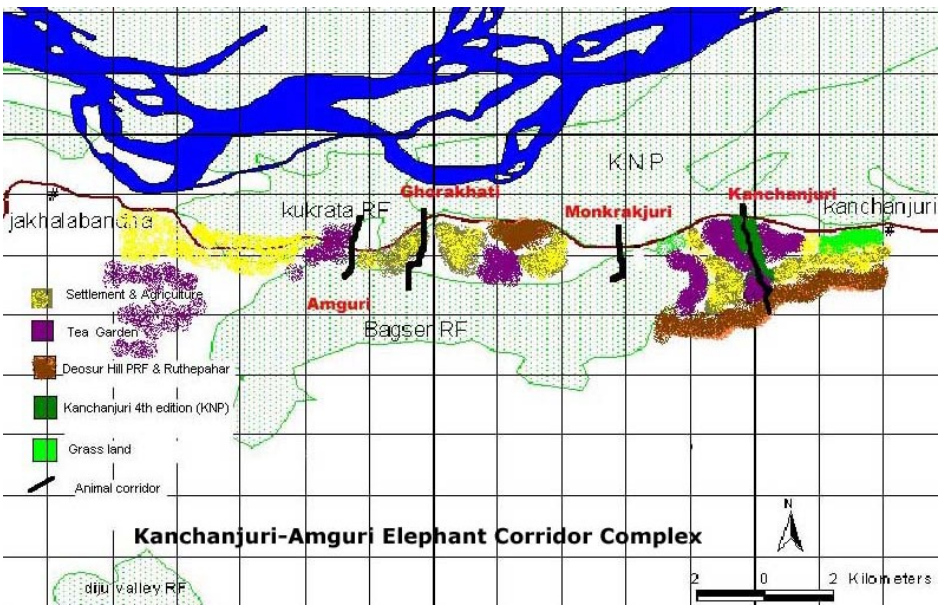
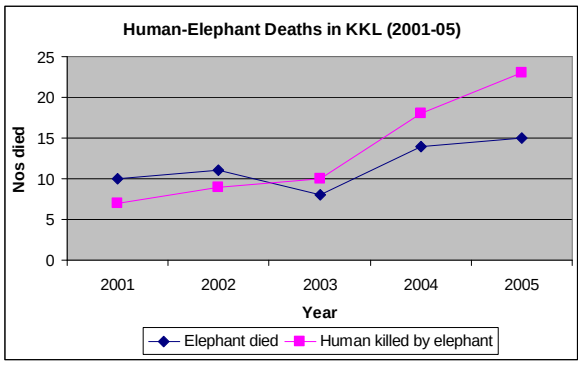


Table 1: Status of the Elephant corridors

	Kanchanjuri Elephant Corridor	Monkrakjuri Elephant Corridor	Ghorakhati Elephant Corridor	Amguri Elephant Corridor
Location	Kanchanjuri on National Highway 37	Deosur on National Highway 37	Ghorakhati on National Highway 37	Amguri on National Highway 37
Width of the corridor	about 100m	about 50m	about 200m	about 200m
Length of the corridor	about 1 km	about 50 m	about 50 m	about 1 km
Landuse pattern	Mostly Tea cultivation with patch of Topical Moist deciduous forest.	Grassland	Topical Moist deciduous forest and agriculture.	Tea cultivation and settlement
Average Herd size	8	15	10	8
Min no.of elephants	1	1	1	1
Max no. of elephants	20	30	30	20
Intensity of usage	High	High	High	High
Movement type	Regular (all season and very high during flood)	Seasonal (during flood)	Seasonal (during flood)	Seasonal (during crop harvesting period)
Primary Threat	High speed vehicles on National Highway 37	High speed vehicles on National Highway 37	High speed vehicles on National Highway 37	High speed vehicles on National Highway 37
Emerging Threat	Expansion of nearest settlement like Enzai gaon, Silimkhowa and Neherubasti.	Poaching	Expansion of nearest settlement like Phuloguri and Ingti gaon.	Expansion of Tea cultivation at the foothills of Bagser hill and expansion of Amguri settlement.

Conflict:

Fig. 4



The gradual fragmentation and shrinking of wildlife habitats due to the heavy anthropogenic pressure cause the gradual increase of human-wildlife conflict, mostly Human Elephant Conflict (HEC), in many areas of the landscape. About 40 % of the Reserve forest like Nambor, an important elephant habitat, is encroached (Talukdar and Burman). This increases the conflict intensity in its fringe areas. The cases of conflicts are getting intensified, and newer areas are experiencing this phenomenon.

It has been observed that in the last five years both human and elephants deaths in this landscape is showing an increasing trend (Fig 4). In many places crop raiding has increased drastically in areas surrounding protected elephant habitats. The fringe areas of Kaziranga NP have witnessed HEC since long. The incidence of HEC has been identified to be more prominent and become more critical in some areas.

Two conflict hot zones viz., Golaghat-Silonijan and Kheroni-Hojai (Fig 5) have been identified on the basis of the conflict intensity in the landscape. In case of nature of elephant death in the last fie years it has been observed that the pattern varies within the landscape. In the Golaghat-Silonijan area elephant dies more in tree garden due to felling in trances or retaliatory killing using gun shoot and spears. Whereas in the Hojai-Kheroni area elephants die more of electrocution and train accident (Fig 6)

Fig. 5

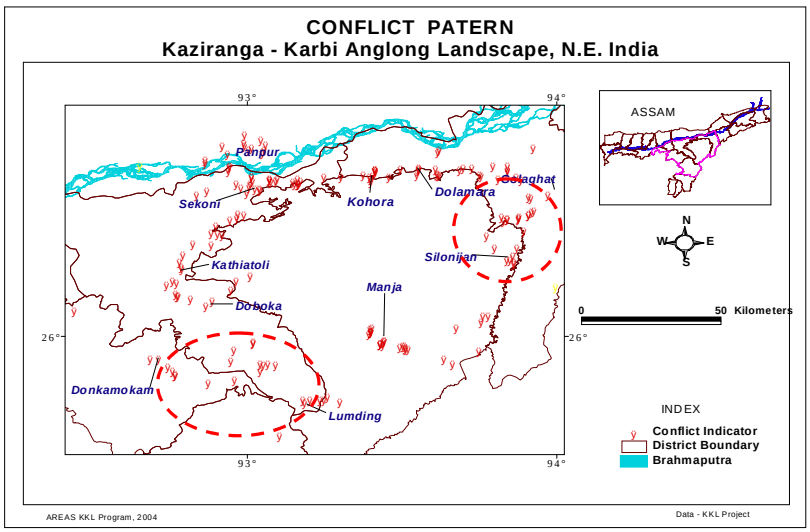
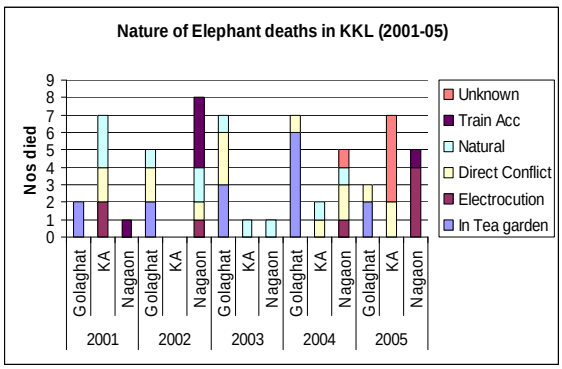


Fig. 6



Threats:

The gradual increase of various anthropogenic pressures is also posing major threats on the elephant habitat. The elephant population and habitat are getting fragmented due to rapid landcover changes mainly because of planned developmental activities like expansion of road, stone quarries, encroachment and logging, poaching, wildlife trade and secret killing of wildlife for meat by some locals is another major threat in the landscape in and around the PAs. The elephant herds gets disrupted due to the development of a numbers of stone quarries along the district boundary of Karbi Anglong, Golaghat and Nagaon towards the southern part of KNP. One of the other major threats is the railway tract passing through the Elephant

Reserve (Dhansiri-Lungding Elephant Reserve) in KKL. Moreover, there will be a severe pressure on the elephant movement by the expansion of NH 54a into four lanes that passing through Lumding RF. Regularly elephant gets killed by heavy traffic of speeding train in this tract between the section Lanka-Lumding and Lumding-Diphu. The gradual increasing of the Human Elephant Conflict intensity in some part of the landscape stands as a serious threat for the elephant conservation.

Conclusion:

It has been observed that the distribution of elephant is widespread throughout the landscape. The consequent fragmentation and loss of wildlife habitats due to expansion of anthropogenic pressures is the root cause of the gradual increase of human elephant conflict. The protected area network beyond Kaziranga NP towards the southern boundary play a significant role in the conservation of wildlife and also act as buffer zone for the park. We look at KKL as a single landscape for conservation of large mammals and are only beginning to understand the landscape. A lot more needs to be done to get a clearer picture of the situation, specially in central Kabi Anglong. Success of conservation in the landscape is possible through generation of scientific data and also through active participation of all stakeholders. The planning of long term strategy involving all the concerned stake holders is very much felt necessary rather than short term activities to mitigate this problem. Generate awareness among the local communities including student and women, Lobbying with the management of respective tea gardens, railway department, declaring of community reserve including parts of some fringe villages and formulation of strong policy plan are some the important and urgent need for protection and conservation of elephant in the landscape.

Limitations:

There are some limitations that affect on our field activities and due to which the achievement was not fully gained within a limited period. Accessibility, communication, social unrest, lack of awareness among both communities and field level forest staffs, lack of secondary information, etc are some of the constrains for generating field level information.

Acknowledgement:

Most of what we have done so far is really because of the active participation and support of the forest department of Govt. of Assam, Karbi Anglong Autonomous Council (KAAC), local communities and NGOs and all are greatly acknowledged. Our donors – WWF-Netherland, WWF-Germany and IRF have helped us to start this work. We hope to get their continuous support in the coming years.

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Update on the reproductive status of female Asian and African elephants in the SSP population of North America

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Abstract:
Asian and African elephant populations in western zoos are not self-sustaining and reproductive rates are low. One problem is that some female elephants do not exhibit normal ovarian cycles. To better understand the extent of this problem, we are conducting written reproductive surveys every 3 years to monitor the reproductive health of Asian and African elephants managed by the SSP in North America. To date, two surveys have been conducted, in 2002 and 2005. Facility response rates surveys were 98% for Asian and 97% for African elephants in 2002 and 100% for Asian and 80% for African elephants in 2005 managed by the SSP. For the 2002 survey, 58% of Asian and 69% of African elephant females were being monitored for ovarian cyclicity via serum or urinary (mostly serum) progestin analyses on a weekly basis. For 'reproductive aged females' (i.e., 11-35 years of age), hormone-monitoring rates within the SSP were 64% and 72% for Asian and African elephants, respectively. Results showed that for Asian elephants, 12% were not cycling, whereas 7% exhibited irregular cycles. For African elephants, 22% were acyclic and 7% exhibited irregular cycles. For Asian elephants ovarian inactivity was more prevalent in the older age categories (>30 years of age); however, for African elephants acyclicity was found in all age groups. For the 2005 survey, hormone-monitoring rates were 78% for Asian and 92% for African elephants. For reproductive aged females, monitoring rates were 86% for Asian and 95% for African elephant females. The percentages of ovarian acyclicity and irregular cycling were about the same for Asian elephants (9 and 8%, respectively), but were significantly higher ($P<0.05$) for African females (31 and 12%, respectively). Again, acyclicity was found in all age groups for African elephants, but was primarily an age related problem in Asians. These results are discouraging in that they show a significant increase in the overall rate of acyclicity/irregular cycling for African elephants in just 3 years (from 29 – 43%). There were eight African females that switched from exhibiting normal cycles to either irregular cycles or noncycling between the two surveys. An additional eight females not monitored in 2002 were added to the acyclic category in the 2005 survey. An obvious concern is that these numbers will continue to increase as more females are added to the database and as they age. The ultrasound data suggest that reproductive tract pathologies, such as uterine or ovarian cysts or leiomyomas, do not account for the majority of acyclicity problems in African elephants. These findings reinforce the need to conduct periodic reproductive surveys. Hopefully, with more data we will be able to determine what factors (e.g., social, husbandry or environmental) are related to changes in ovarian activity and how to reverse the trend towards acyclicity.

Introduction:

Despite the well-recognized need to establish self-sustaining populations of captive elephants (Weise and Willis, 2006), less than 20% of Asian and 10% of African elephants of reproductive age have produced offspring (Asian Elephant Studbook, 2005; African Elephant Studbook, 2006). The logistics and expense of transporting females to breeding facilities have hampered captive breeding efforts, but there also are reproductive problems of physiological origin. Through basic progestin monitoring encouraged by the Elephant Taxon Advisory Group/Species Survival Plan (TAG/SSP), many female elephants of reproductive age have been identified as 'flatliners', a term given to describe the observation of stable, baseline concentrations of serum progestins indicative of ovarian inactivity (Brown, 2000). The cause of this acyclicity is unknown, there is concern that if the number of acyclic females is high or growing, a significant population decline is inevitable. Transrectal ultrasound examinations also have shown that aging females develop reproductive tract pathologies, like uterine or ovarian cysts and tumors, that may prevent cyclicity or conception (Hildebrandt et al., 2000; Hermes et al., 2004).

In light of these findings, the Elephant TAG/SSP has endorsed studies to determine the extent of reproductive dysfunction in captive elephants, identify causes, and develop mitigating treatments. One of these efforts involved conducting periodic Reproductive Surveys in conjunction with SSP Studbook updates to determine: 1) how many females in the captive population are being hormonally evaluated for estrous cyclicity; 2) how many females are not cycling normally; 3) what types of reproductive tract pathologies exist; and 4) if any pathologies are related to acyclicity. The first survey was conducted in 2002 (Brown et al., 2004) and found that 49% of Asian and 62% of African elephant females in North America were being hormonally monitored for estrous cyclicity. Of those, 14% of Asian and 29% of African elephants either were not cycling at all or exhibited irregular cycles. For both species, ovarian inactivity was more prevalent in the older age categories (>30 years of age); however, for African elephants acyclicity was found in all age groups. Thus, survey results suggested that ovarian inactivity is a significant reproductive problem for elephants held in zoos, especially African elephants.

Until recently, it was believed that elephants exhibited only a cyclic or noncyclic progestin profile. However, as more elephants have been evaluated for longer periods of time, it appears that some alternate between cyclic and noncyclic periods (Schulte et al., 2000), or exhibit erratic progestin secretion. Therefore, evaluation of reproductive data collected through periodic TAG/SSP surveys could serve as a valuable management tool to help identify and understand the factors that impact reproductive health.

Methods:

Reproductive survey
Using the same format as in 2002, written reproductive surveys were sent to all facilities managing elephants in the Asian and African Elephant Studbooks; however, in contrast to the 2002 survey, emphasis was placed on receiving completed surveys from animals managed by the SSP. Survey questions included: 1) management system (free contact, protected contact, other); 2) collection of samples for progesterone monitoring (blood, urine, none); 3) if yes to #3, sample collection frequency (weekly, bi-weekly, monthly, in training, collected but not analyzed); 4) estrous cyclicity status (cycling, not cycling, irregular cycles, undetermined); and 5) transrectal ultrasound results (normal, ovarian cysts, uterine cysts/tumors, vaginal cysts, other pathologies, in training, not done). Hormone cyclicity status referred to results from the survey completed in 2002 (i.e., a 3-year period). Analyses of progestin cyclicity data were only conducted if a female had been assessed for at least a year. Animal age refers to the age in 2005. Pregnant cows were not included in the survey results or analyses.

Statistical analysis
All data are presented as means ± SEM. Mean survey data were compared using Student's t-tests. Differences in survey and ultrasound results between species or cyclicity status within species were determined using Z-tests (SigmaStat v. 2.03, Jandel Scientific, 1997). Percentage data for age categories within species were tested by Chi Square analysis. Comparisons of data between the two surveys were done using Student's t-tests and Chi Square analyses. Comparisons among animals and between species were done using ANOVA on individual means. Mean data are ± SEM.

Results and discussion:
Results from the 2005 survey were compared directly with those of the 2002 survey published by Brown et al. in 2004. Overall, there was a lower response rate ($P<0.05$) for the 2005 survey with 119 (52.89%) surveys returned for the captive Asian population and 110 (58.51%) surveys returned for the captive African population. Response rate was higher ($P<0.05$) for facilities participating in the Elephant SSP with 116 (100%) surveys returned for the Asian and 103 (80.47%) surveys returned for the African elephant populations. As in the 2002 survey, there was a higher response for Asian elephants compared to African elephants ($P<0.05$). Of the total 77 facilities that participated in the 2005 reproductive survey, 37 (36 SSP) facilities housed Asian elephants only, 32 (29 SSP) facilities housed African elephants only, and 4 (all SSP) housed both Asian and African elephants.

The range in age for captive Asian elephants was 1 – 65 years for both the studbook and SSP populations. The average age for the studbook population was 32.9 ± 1.2 years and 32.8 ± 1.3 years for the SSP population, which was not different from that in 2002 ($P>0.05$). Age of African elephants ranged from 1 – 48 year, with an increase ($P<0.05$) in the average age for both the studbook (25.0 ± 0.6 versus 28.5 ± 0.8 years) and SSP (26.6 ± 0.8 years versus 28.6 ± 0.8 years) populations between the 2002 and 2005 surveys, respectively. The average age did not differ between the studbook and SSP populations for either species. However between species, the captive African elephant population was younger on average ($P<0.05$) than the captive Asian population.

The 2005 survey showed a significant ($P < 0.05$) increase in the percent of reproductive monitoring for both the Asian and African populations. Reproductive monitoring for the captive Asian elephant studbook population increased from 49% in 2002 to 77% in 2005. For the Asian SSP population, monitoring increased from 58% to 79% in 2005. For the captive African population, monitoring increased from 62% to 92% for the studbook population and from 69% to 92% for the SSP population. As in 2002, both the studbook and SSP populations for the African elephants had overall higher monitoring rates as compared to the Asian elephant captive populations. A summary of the reproductive survey results for both the studbook and SSP populations is presented in Table 1.

Tables 2 and 3 summarize the 2005 survey results divided into 5-year age increments. The 2002 survey found that within the hormonally monitored individuals, Asian elephants exhibited a higher rate of normal cyclicity as compared to African females ($P < 0.05$). Similar results were observed in the 2005 survey, with the majority of acyclic Asian elephants (64%) falling in pre-pubertal (0 – 10 years) or post-reproductive (> 35 years) age categories. In the 2005 survey, African elephants continued to have the majority of non-cycling females falling in the reproductive age categories. Survey data showed that 77% of the acyclic African elephants for both the studbook and SSP populations fell between the ages of 11 and 35 years. Excluding individuals under 10 years of age, the age category 31 to 35 years contained the highest percentage (47%) of non-cycling females for both the studbook and SSP African elephant populations. As in the 2002 reproductive survey, the current survey did not show a significant ($P>0.05$) difference in the number of non-cycling females between free or protected contact management systems for either Asian or African elephant populations.

Figures 1 and 2 compare the percentages of non-cycling females between the 2002 and 2005 surveys for the Asian and African elephant populations, respectively. In 2005, the percent of non-cycling Asian elephant females decreased from 13% to 8%. The African elephant population had an increase ($P<0.05$) in the percentage of non-cycling females between the surveys from 22% in 2002 to 32% in 2005. In 2005, there was an increase in the percent of elephants with irregular cycles for both the Asian and African populations ($P < 0.05$). For the captive Asian population, 8% were found to have irregular cycles in 2005, an increase from the 2002 results of 2% for the studbook and 3% for the SSP populations ($P<0.05$). The captive African elephant population had an increase in irregular cycles from 6% of the studbook population in 2002 to 11% in 2005, and from 5% of the SSP population in 2002 to 12% in 2005. For individuals that were monitored in both the 2002 and 2005 surveys, a number of changes in cycling status were noted. For the Asian SSP population, 3 individual went from having irregular cycles to normal cycles, 2 switched from acyclic to cycling, 5 switched from cycling to irregular, and 2 became acyclic. A female that switched from noncycling to cycling. and one that went from irregular to cycling were both young; thus, these may have been pubertal changes. For the African SSP population, 3 individuals switched from acyclic to cycling (2 are animals we do not monitor here), 1 switched from acyclic to irregular, 4 switched from cycling to irregular, and 4 cycling individuals became acyclic. The 3 females noncycling females that began cycling all were post-pubertal (19-36 years of age).
As with hormone monitoring, there was an increase in the percentage of individuals monitored for urogenital pathologies via ultrasound ($P < 0.05$). The percent monitored for the captive Asian elephant population increased from 36% in 2002 to 58% in 2005. For the captive African elephant population, the percent increased from 32% in 2002 to 50% in 2005. Overall, the 2005 survey showed a decrease in the percentage of urogenital pathologies in the non-cycling individuals for both Asian and African elephant populations (see Figures 3 and 4). Of the Asian elephants monitored via ultrasound, 25 displayed

urogenital pathologies, 10 of which cycled normally and 2 that were acyclic. For the African elephants, 11 had urogenital pathologies, 2 of which were cycling normally while 6 were acyclic. The complete summary of ultrasound results is presented in Table 4.

In conclusion, again, acyclicity was primarily an age related problem in Asians, but was found in all age groups in African elephants. We were particularly dismayed by the significant increase in the overall rate of acyclicity/irregular cycling for African elephants in just 3 years (from 29 – 43%). Plus, there were a number of African females that switched from cycling to noncycling between the two surveys. An obvious concern is that these numbers will continue to increase as more females are added to the database and as they age. The ultrasound data suggest that reproductive tract pathologies, such as uterine or ovarian cysts or leiomyomas, do not account for the majority of acyclicity problems in African elephants. These findings reinforce the need to conduct periodic reproductive surveys. Additionally, pinpointing the precise time a female stops cycling would enable a better assessment of what factors (e.g., changes in social status, environment, behavior, disease, nutrition, etc.) are associated with the development of reproductive problems. Through cooperative efforts between zoo staff and researchers, we hope to gain a better understanding of what causes ovarian cyclicity problems so that effective treatments can be developed to allow captive breeding programs to succeed.

Acknowledgements:

The authors thank Nicole Abbondanza for excellent technical assistance. This project was funded in part by the Diagnostic Products Corporation, International Elephant Foundation, Morris Animal Foundation, Shared Earth Foundation and Friends of the National Zoo.

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Table 1.
Overall response rates and cyclicity status results of the 2005 SSP Reproductive Survey for captive female Asian and African elephants in North America. Data are evaluated for studbook and SSP populations for each species.

	African		Asian	
	Number	**Percent**	**Number**	**Percent**
SB Population	188		225	
SSP Population	128		116	
SB Surveys Returned	110	58.51	119	52.89
SSP Surveys Returned	103	80.47	116	100.00
SB Monitored (% SB responses)*	102	92.73	92	77.31
SSP Monitored (% SSP responses)*	95	92.23	91	78.45
SB Unkown + NM (% SB population)	109	57.98	133	59.11
SSP Unknown + NM (%SSP population)	35	27.34	25	21.55
SB In Training (% SB responses)	4	3.64	3	2.52
SSP In Training (% SSP responses)	4	3.88	3	2.59
SB Cycling (% SB monitored)**	53	51.96	69	75.00
SB Irregular (% SB monitored)**	11	10.78	7	7.61
SB Not Cycling (% SB monitored)**$	32	31.37	8	8.70
SB Immature (% SB monitored)**	2	1.96	3	3.26
SB Undetermined (% SB monitored)**	4	3.92	7	7.61
SSP Cycling (% SSP monitored)**	47	49.47	69	75.82
SSP Irregular (% SSP monitored)**	11	11.58	7	7.69
SSP Not Cycling (% SSP monitored)**$	31	32.63	8	8.79
SSP Immature (% SSP monitored)**	2	2.11	3	3.30
SSP Undetermined (% SSP monitored)**	4	4.21	6	6.59
Average Age SB (+/- SE)	28.50+/- 0.78		32.86 +/- 1.24	
Average Age SSP (+/- SE)	28.57 +/-0.79		32.77 +/- 1.25	

* does not include 1 female that is bled but not analyzed
** Percentages based on those monitored hormonally
Unknown = no surveys returned; NM = not monitored hormonally

Table 2.
Numbers and age distributions of Asian elephant females exhibiting normal estrous cycles, no ovarian activity, or irregular estrous cycles in both the studbook and SSP populations in North America based on the 2005 Reproductive Survey results.

	Age of Asian females in 2005 (years)							
	0 to 10	**11 to 15**	**16 to 20**	**21 to 25**	**26 to 30**	**31 to 35**	**36 to 40**	**>40**
Totals								
SB	17	9	6	11	19	41	48	74
SSP	9	7	6	9	11	24	21	29
Responses								
SB	8	9	6	9	10	25	21	31
SSP	9	7	6	9	11	24	21	29
No. Monitored								
SB	6	8	6	9	9	18	12	24
SSP	6	7	6	9	9	18	12	23
No. Cycling								
SB	5	8	6	8	5	15	10	12
SSP	5	7	6	8	5	15	10	12
No. Noncycling								
SB	1	0	0	0	2	2	1	5
SSP	1	0	0	0	2	2	1	5
No. Irregular								
SB	0	0	0	1	2	1	1	2
SSP	0	0	0	1	2	1	1	2
% Noncycling								
SB	16.67	0.00	0.00	0.00	22.22	11.11	8.33	20.83
SSP	16.67	0.00	0.00	0.00	22.22	11.11	8.33	21.74
No. Undetermined (and monitored)								
SB	0	0	0	0	0	0	0	4
SSP	0	0	0	0	0	0	0	3
No. Unknown & Not Monitored								
SB	11	1	0	2	10	23	36	50
SSP	3	0	0	0	2	6	9	6
% Unknown & Not Monitored								
SB	64.71	11.11	0.00	18.18	52.63	56.10	75.00	67.57
SSP	33.33	0.00	0.00	0.00	18.18	25.00	42.86	20.69

Table 3:
Numbers and age distributions of African elephant females exhibiting normal estrous cycles, no ovarian activity, or irregular estrous cycles in both the studbook and SSP populations in North America based on the 2005 Reproductive Survey results.

	Age of African females in 2005 (years)*							
	0 to 10	11 to 15	16 to 20	21 to 25	26 to 30	31 to 35	36 to 40	>40
Totals								
SB	3	8	16	73	43	28	22	13
SSP	2	8	8	30	31	16	20	10
Responses								
SB	2	2	9	32	25	15	14	6
SSP	2	2	8	27	24	15	14	6
No. Monitored								
SB	2	0	9	31	24	15	12	4
SSP	2	0	8	26	23	15	12	4
No. Cycling^								
SB	0	0	6	18	13	7	6	1
SSP	0	0	5	13	13	7	6	1
No. Noncycling^								
SB	2	0	2	6	9	7	4	1
SSP	2	0	2	6	8	7	4	1
No. Irregular^								
SB	0	0	1	5	1	1	2	1
SSP	0	0	1	5	1	1	2	1
% Noncycling^								
SB	100.00	0.00	22.22	19.35	37.50	46.67	33.33	25.00
SSP	100.00	0.00	25.00	23.08	34.78	46.67	33.33	25.00
No. Undetermined (and monitored)^								
SB	0	0	0	2	1	0	0	1
SSP	0	0	0	2	1	0	0	1
No. Unknown & Not Monitored**								
SB	1	8	7	42	19	13	10	9
SSP	0	8	0	4	8	1	8	6
% Unknown & Not Monitored**								
SB	33.33	100.00	43.75	57.53	44.19	46.43	45.45	69.23
SSP	0.00	100.00	0.00	13.33	25.81	6.25	40.00	60.00

Table 4.
Numbers of elephants with urogenital tract ultrasound data from the 2005 SSP Reproductive Survey for captive Asian and African elephants in North America.

	African*					Asian*				
Category	Cycling	Non-cycling	Un-determined	Irregular	Not Monitored	Cycling	Non-cycling	Un-determined	Irregular	Not Monitored
Normal Ovarian	26	10	3	3	2	42	1	0	1	0
Cysts	0	2	0	0	0	0	0	3	0	0
UT cysts/tumors	0	2	0	0	0	6	1	0	3	4
VA cysts/tumors	0	1	2	1	0	2	0	0	0	0
Ovarian Cysts/Other	0	1	0	0	0	0	0	0	0	0
OC, UT c/t, VA c/t	0	0	0	0	0	0	1	0	1	0
OC, UT c/t, OP	0	0	0	0	0	0	0	0	0	2
OC, UT c/t	0	0	0	0	0	1	0	0	0	0
UT c/t, VA c/t	0	0	0	0	0	1	0	0	0	0
Other Pathologies	2	0	0	0	0	0	0	0	0	0
Not Done	10	9	4	3	6	16	7	5	2	23

Figure 1:
Comparison of the percent non-cycling females across 10-year age categories between the 2002 and 2005 SSP Reproductive Surveys for captive Asian elephants.

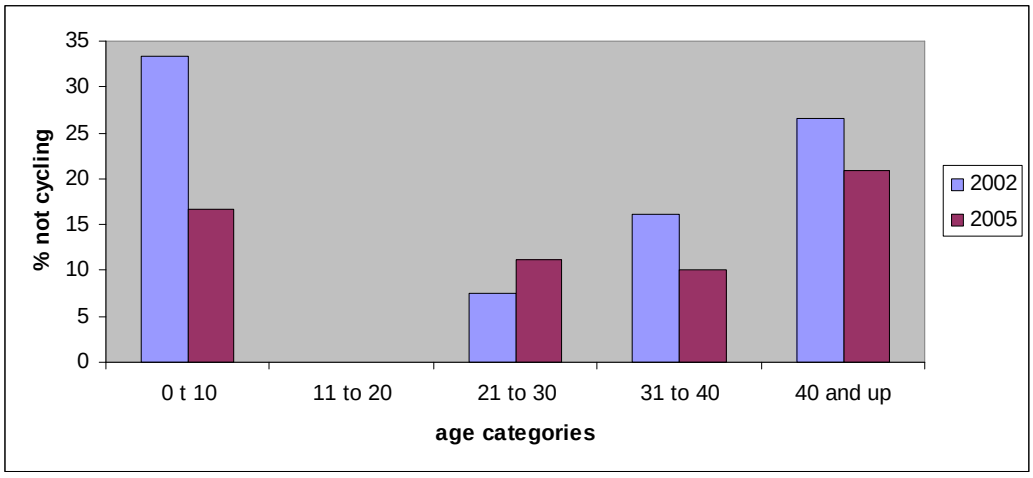


Figure 2:
Comparison of the percent non-cycling females across 10-year age categories between the 2002 and 2004 SSP Reproductive Surveys for captive African elephants.

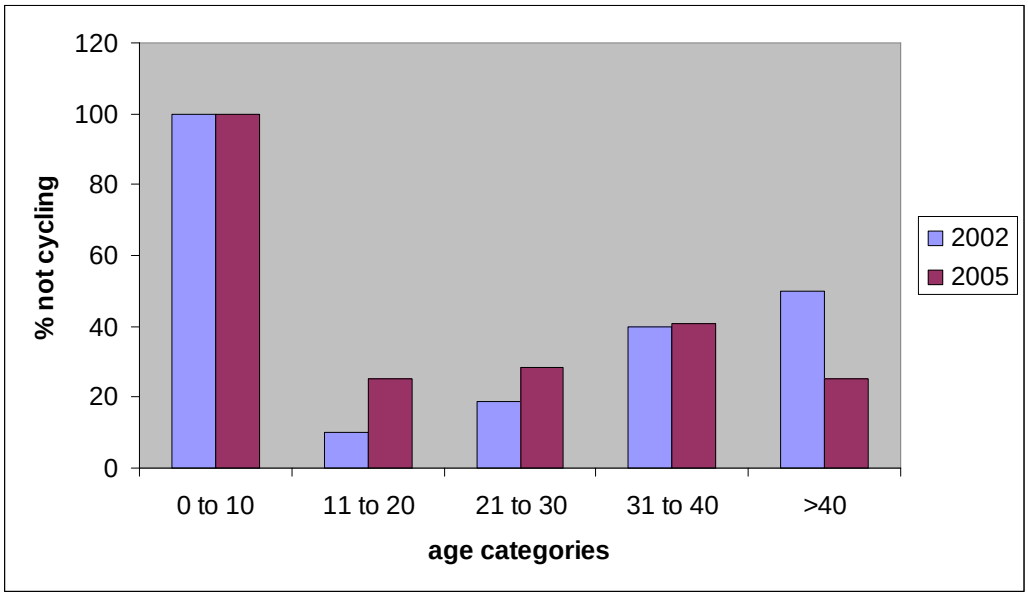


Figure 3:
Comparison of percent non-cyclers with urogenital pathologies between the 2002 and 2005 SSP Reproductive Surveys for the captive Asian elephant SSP population in North America.

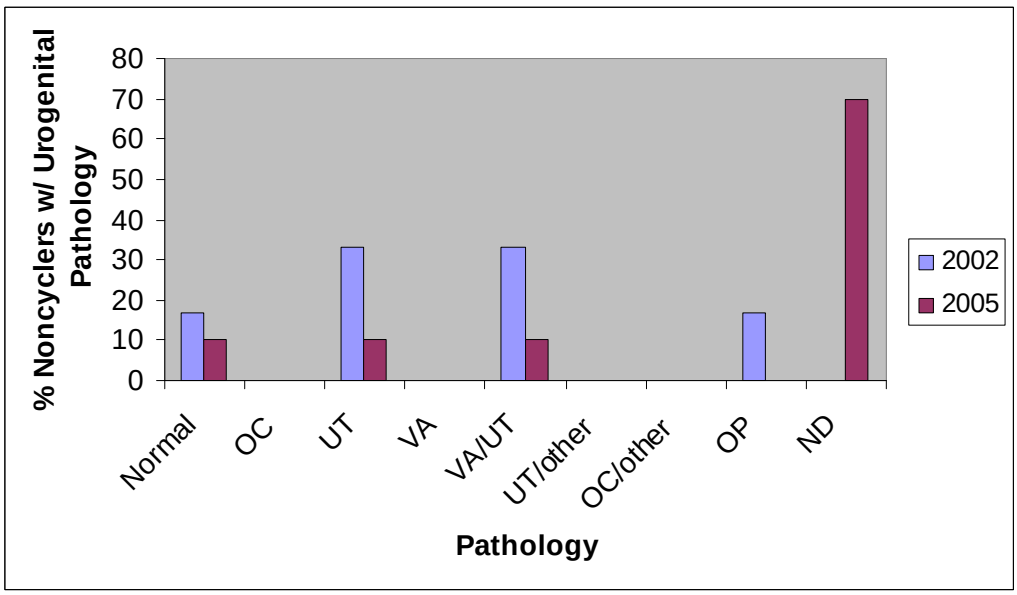
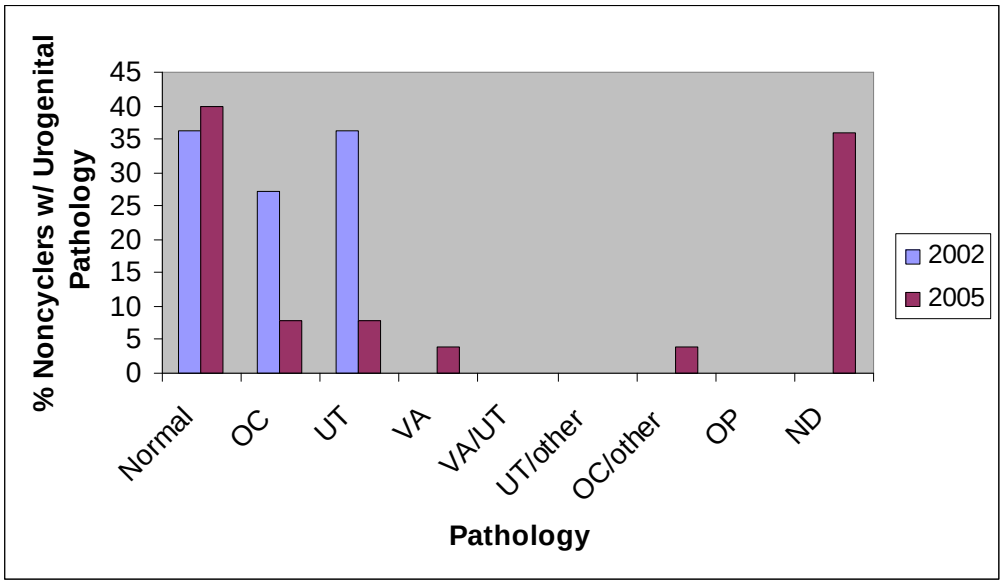


Figure 4:
Comparison of percent non-cyclers with urogenital pathologies between the 2002 and 2005 SSP Reproductive Surveys for the captive African elephant population in North America.



Comparative endocrinology of testicular and thyroid function in captive Asian and African elephant bulls

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Abstract:
Concentrations of serum testosterone, thyroxine (free and total T4) and triiodothyronine (free and total T3) were measured to determine if changes in thyroid function were related to testicular activity and musth in captive bull elephants. Blood samples were collected approximately weekly from Asian (n = 8) and African (n = 9 African) bulls at seven facilities for periods of 4 months to 9.5 years. Age ranges at study onset were 8 – 50 years for Asian and 10 – 21 years for African elephants. Seven Asian and three African bulls exhibited signs of musth, which lasted 2.8 ± 2.5 months in duration. Elevated serum testosterone, often exceeding 100 ng/ml, was observed during musth. There was no evidence of seasonality in patterns of testosterone secretion and musth for either species ($P>0.05$). Only three bulls at one facility exhibited classic yearly musth cycle. Others exhibited more irregular cycles, with musth occurring more than once a year. A number of bulls never exhibited significant temporal gland secretions (TGS) or urine dribbling (UD) (1 Asian, 6 African) and were characterized by testosterone concentrations generally <10 ng/ml. At facilities with multiple bulls (n=3), testosterone concentrations were highest in the oldest, most dominant male. Patterns of thyroid activity were irregular throughout the year in all nonmusth and most musth bulls, with the exception of three musth bulls where thyroid hormones (T3, T4) were negatively correlated (range, $r = -0.25$ to -0.47; $P<0.05$) to testosterone secretion. These were the bulls that exhibited clear, yearly musth cycles. Overall mean thyroid hormone activity declined with age for all bulls combined. In summary, a number of bulls did not exhibit musth despite being theoretically old enough. Some of these bulls may have been suppressed due to the presence of an older, dominant bull that did exhibit musth. Data were generally inconclusive as to a role for thyroid hormones in male reproduction, but the finding of discrete patterns in bulls showing clear testosterone cycles suggests they may facilitate the expression or control of musth in adult bull elephants.

Introduction:

Captive elephant populations in North American zoos are not self-sustaining because of low reproductive rates (Wiese and Willis, 2006). Factors limiting population fecundity are the small number of available bulls and breeding facilities. Proportionately, males make up <20% of the captive population in North America, and many of these are still sexually immature (Keele, 2005; Olson, 2006). Few zoos have the required space and reinforced enclosures necessary to hold one or more adult bull elephants, and many are reluctant to try because adult males can be dangerous, especially during musth. If we knew more about the biology of bull elephants and what controls musth, then perhaps better strategies could be developed to mitigate management problems.

In general, musth is described as a period of heightened aggressive and sexual behavior in association with increased temporal gland secretion (TGS) and urine dribbling (UD). Elevated androgens during musth, up to 50-fold higher than baseline, are believed to be at least partly responsible for these symptomatic changes (Jainudeen et al., 1972a; Rasmussen et al., 1984, 1990; Hall-Martin and Van der Walt, 1984; Hall-Martin, 1987; Cooper et al., 1990, Niemuller and Liptrap, 1991; Brown et al., 1993; Lincoln and Ratnasooriya, 1996). Physiologically, musth has been compared to the rut observed in some seasonally breeding ungulate species. Like musth, rut is characterized by high testosterone concentrations, increased intra-male

aggression and a heightened interest in females (Clutton-Brock et al., 1988). Unlike rut, musth is not seasonal, although the time of year it is exhibited often is consistent within an individual bull (Jainudeen et al., 1972b; Poole, 1987, 1989, 1994; Cooper et al., 1990; Lincoln and Ratnasooriya, 1996). Another difference is that rut is a prerequisite for breeding, whereas musth only increases mating opportunities. Wild bulls in musth do most of the breeding (Eisenberg et al., 1971; Poole, 1987, 1989), but non-musth males also can breed successfully (Hall-Martin, 1987; Hollister-Smith, 2005).

While the characteristics of musth have been well described, controlling mechanisms have yet to be identified. However, nutritional status is one factor linked to the occurrence and/or intensity of musth (Poole, 1989; Cooper et al., 1990). Both wild (Poole, 1989) and 'domesticated' (Jainudeen et al., 1972b) elephants drop out of musth as they lose body condition due to reduced foraging/eating. Consequently, one method of decreasing unwanted symptoms in captive elephants is to withhold food and water (Cooper et al., 1990; Schmidt, 1993; Lincoln and Ratnasooriya, 1996; Ganswindt et al., 2005a). By what means nutrition impacts musth has not been determined, but it may be related to changes in metabolic function affecting testicular steroidogenesis and downstream effects. During periods of fasting, thyroid hormone activity often decreases to lower metabolism and conserve energy (St. Aubin et al., 2001; Ortiz, 2001). Zoo personnel note it is not uncommon for feed intake to diminish voluntarily in bull elephants during musth, which can result in a loss of body condition. Regulation of metabolic activity in most species is driven by the hypothalamo-pituitary-thyroid axis, the control of which involves a classical negative feedback system (see review, Greenspan, 2004). Hypothalamic thyroid-releasing hormone (TRH) stimulates thyroid-stimulation hormone (TSH) secretion from the pituitary, which causes hormone release from the thyroid gland. These consist of thyroxine (T4), an inactive form that is converted to biologically active triiodothyronine (T3). Increased thyroid hormone concentrations negatively feedback to reduce the secretion of TSH, and thus homeostasis is maintained. Thyroid hormones increase tissue basal metabolic rate and exert ubiquitous effects on lipid, protein and carbohydrate metabolism.

Among ungulates, changes in thyroid activity also are associated with the reproductive cycle of seasonal breeders, including many that exhibit rut. In deer, duration of the breeding season is extended by thyroidectomy, whereas the transition from a reproductive to quiescent state is shortened by thyroid hormone administration (Parkinson and Follett, 1994, 1995; Zucker and Prendergast, 1999). Increased thyroid hormone concentrations are observed at the seasonal transition to a nonbreeding state in several other species as well (Ryg and Langvatn, 1982; Loudon et al., 1989; Shi and Barrell, 1992, 1994). These findings support the hypothesis that thyroid hormones play an integral role in regulating seasonal reproduction, although others caution that thyroid hormones may merely facilitate seasonal rhythmic expression (Shi and Barrell, 1992; Zucker and Prendergast, 1999). Although musth is not seasonal in the true sense, thyroid hormones may play a role in modulating the dramatic changes in gonadal steroidogenesis observed during musth through regulation of metabolic rate and partitioning of energy resources.

The majority of what is known about elephant reproduction is derived from studies of females (see reviews, Hodges, 1998; Brown, 2000, 2005). Comparatively few studies have been conducted on males, and none have directly compared the biology of Asian (*Elephas maximus*) and African (*Loxodonta africana*) elephant bulls using a large sample size. The objective of this study was to evaluate individual and species variability in musth characteristics and conduct longitudinal analyses of testosterone, free and total T4, and free and total T3 to determine if changes in thyroid activity are related to musth status.

Materials and methods:

Animals and Sample Collection

Serum samples were collected from eight Asian and nine African elephant bulls housed at seven facilities across the United States (Table 1). At the beginning of the study, ages ranged from 8 to 50 years for Asian (mean, 27.4 ± 0.4 years), and 10 to 21 years for African (18.1 ± 0.1 years) bulls. Maximal ages at the end of the study were 52 years for Asian and 24 years for African elephants. In general, bulls had olfactory and visual contact with females, and occasional physical contact. Several of the bulls were proven breeders (Table 1). Facilities provided bulls with standard diets and *ad libitum* water, which were not altered during musth. All elephants were conditioned to blood sampling procedures as part of the

management routine. Blood was collected weekly, biweekly or monthly for periods of 4 months to 9.5 years. In general, blood samples were collected from a vein on the caudal aspect of the ear or from the saphenous vein in the leg. Blood was centrifuged (~1500 x g) within 1-3 hours of collection and the serum stored at -20˚C or colder until analysis.

Musth logs were provided by each facility based on subjective observations of TGS and UD (Jainudeen, 1972a,b; Poole, 1982; 1987), accompanied to a greater or lesser degree by aggressive behavior (Hall-Martin, 1987; Poole, 1994; Kahl and Armstrong, 2002). At multi-bull facilities, dominance status among males was also subjectively determined based on bull-bull interactions during the study period. At Riddle's Elephant and Wildlife Sanctuary and the Oregon Zoo, where bulls had physical contact, interactions consisted mainly of deference by subordinates to the dominant bull, but at times also included intimidation, pushing or mild aggression by the dominant individual. At the Dickerson Park Zoo, where bulls were kept separate, hierarchy was established by observations of behavioral posturing (bull assuming a dominant, neutral or submissive posture) and when in visual contact, physical location within adjacent yards, and reactions to scents when one bull entered a stall recently occupied by the other. Although Miami Metrozoo had two bulls, they were kept in different areas of the zoo ~0.25 mi apart, and thus dominance status was not evaluated.

Concentrations of thyroid hormones (free and total T4, free and total T3) and testosterone were analyzed using radioimmunoassays validated for elephants (Brown et al., 1993, 1995, 2004). Assay sensitivities were: 20 ng/dl for total T3, 1 □g/dl for total T4, 0.25 pg/ml for free T3, 0.25 ng/dl for free T4, 0.10 ng/ml for testosterone. For all assays, intra- and interassay coefficients of variation were <10% and <15%, respectively.

Statistical Analysis

Analyses were carried out using Excel and Sigma Stat (v2.03, SPSS, Inc.). Data were tested for normality using a Shapiro-Wilk test for goodness-of-fit. Data that were not normal were log transformed. Time series analyses were used to determine if there were cyclical patterns in hormone secretion. Baseline hormonal values for each individual were determined using an iterative analysis (Brown et al., 1999) where the mean and standard deviation was calculated followed by removal of all values above the mean plus two times the standard deviation (SD). This process was repeated until only those values that no longer exceeded the mean plus 2 SD remained. Comparisons between species were done using ANOVA. For hormones where there were no significant differences ($P>0.05$) in concentrations between African and Asian elephants, data were pooled further and summarized using boxplots indicating the median, 1st and 3rd quartiles, 1.5 x inter-quartile ranges (IQR) and 5% and 95% confidence intervals to identify outliers. Changes in hormone secretory patterns throughout the year were evaluated based on seasonal means (Dec-Feb, Mar-May, Jun-Aug, Sep-Nov) by ANOVA, followed by pairwise comparisons using Tukey's tests. Average hormone concentrations were calculated for each bull at each year of age. Pearson Product Moment Correlation analyses between bull age and hormone concentrations were calculated on pooled data from both species using overall yearly mean values for ages where $n = \geq 2$ bulls. Pearson Product Moment Correlation analyses were used to determine relationships between hormone concentrations within each bull. Mean data are presented ± SEM.

Results:

Mean concentrations of all hormones varied within and among individual bulls (Tables 2 and 3). Seven of eight Asian and three of 12 African bulls exhibited physical and behavioral signs indicative of musth, which lasted 2.8 ± 2.5 months in duration on average (range, 1 to 10 months per episode). There were no differences ($P>0.05$) in hormone concentrations between species, with the excretion of higher overall mean testosterone concentrations in Asian bulls due to the higher incidence of musth ($P<0.05$). There was no species difference in baseline testosterone concentrations ($P>0.05$).

Musth was associated with elevated testosterone concentrations, which often exceeded 50 ng/ml (e.g., Figs. 1-4). By contrast, testosterone was generally <10 ng/ml in bulls not exhibiting musth or during inter-musth periods. Hugo, Packy, Dahlip, Khunchorn, Onyx, Hank, Machito and Chip all began exhibiting musth before study onset. In those bulls, there were no periods of increased testosterone that were not

associated with recorded musth episodes. In younger bulls (Rama, Hank, Willie, Artie, Solomon and Tuffy), there were occasional periods of elevated testosterone not related to musth signs, usually in association with age-related increases in androgen secretion (e.g., Fig. 3). Three bulls began exhibiting musth during the study period (Rama, Hank and Willie). The age of first recorded musth was 15 years for Rama, 12 years for Hank (Fig. 3) and 21 for Willie. Testosterone concentrations in Digger, Artie and Solomon went from near undetectable levels at the start of the study to values that occasionally exceeded 5 ng/ml, but none showed signs of musth even though they were nearly 20 years of age at study completion. One Asian and five African bulls had overall mean concentrations of testosterone that were consistently at or below the detection limit of the assay (Tables 2 and 3). Of these, Tommy was the oldest. Toby also had consistently low testosterone (Table 3), and based on transrectal ultrasound examinations was considered sexually immature with underdeveloped accessory sex organs and testes.

Yearly patterns of testosterone and musth varied among bulls with no evidence of seasonality ($P>0.05$). Only bulls at the Oregon Zoo exhibited regular yearly musth cycles (e.g., Fig. 1) that tended to alternate. Elevated testosterone concentrations and recorded musth periods occurred on average from about Oct-May in Hugo and Jul-Nov in Rama. Packy had testosterone cycles between those of Hugo and Rama, from May-Sept, but recorded 'musth-like' behaviors occurred at other times of the year when testosterone was low, often at the same time as Hugo. Other bulls exhibited less clear patterns, with increases in TGS, UD or aggressive behavior associated with elevated testosterone occurring more than once a year. For example, Onyx exhibited increases in testosterone for several month periods in both the spring and fall (Fig. 2). The other bull at that facility (Khunchorn) also exhibited more than one musth period per year, which often overlapped those of Onyx. Machito had the highest overall and baseline testosterone concentrations and was described in the keeper log as being in a nearly constant state of musth, at least in terms of increased aggression and occasional TGS and UD (Fig. 4; Table 3). In general, UD and/or TGS began as testosterone increased or within a few weeks thereafter, but rarely before.

Table 4 shows the correlation coefficients between testosterone and thyroid hormones only in those bulls that exhibited musth. In all three bulls at the Oregon Zoo, thyroid hormones were correlated negatively ($P<0.05$) to testosterone secretion. Figure 1 illustrates the inverse relationship between testosterone and Total T4 in one of these bulls. Total T4 reached peak concentrations just before or as testosterone began to increase, and declined to baseline about mid-musth. For all other bulls, patterns of thyroid activity were irregular throughout the year and did not correspond to changes in testosterone secretion (e.g., Figs. 2,3,4; Table 4). One bull (Hank) had significant negative correlations between testosterone and all markers of thyroid function (Table 4). There was a significant seasonal effect on T3 and T4 secretion, with lower concentrations during the summer months in African ($P<0.05$) but not in Asian ($P=0.08$) bulls. There also was a decrease ($P<0.05$) in thyroid hormone secretion as a function of age ($r = -0.74$ for Total T4, -0.86 for Free T4, -0.47 for Total T3 and -0.49 for Free T3). Positive correlations ($P<0.05$) between free and total thyroid hormone concentrations were observed for most bulls. Thus, although the free hormone concentrations were only a fraction of the total, they tended to track together.

Comparing same species bull groups within a facility ($n = 3$), the oldest, dominant male had the highest ($P<0.05$) concentrations of testosterone (Tables 2 and 3). For Asians at the Oregon Zoo, overall testosterone concentrations were in rank order to age and dominance status (Hugo>Packy>Rama). At Riddle's EWS, the dominant African bull (Willie) was the oldest and also had the highest overall and baseline testosterone concentrations. At the Dickerson Park Zoo, overall and baseline testosterone concentrations in the dominant bull, Onyx, were over 2- and 10-fold greater, respectively, than those observed in the younger subordinant Khunchorn. There were no clear relationships between age or dominance status for the other hormones evaluated ($P>0.05$).

Discussion:

By examining a large number of bulls over extended periods of time it was possible for the first time to assess the degree of individual and species variation in testicular activity and how it relates to thyroid function. This was similar to a previous effort to characterize the endocrinology of female Asian and African elephants in association with ovarian cyclicity problems (Brown et al., 2004). Species comparisons are necessary because although there are many similarities in the biology of Asian and

African elephants, there are enough differences to warrant caution in over-extrapolating data (Brown, 2000, in press). Results of this and the prior study (Brown et al., 2004) suggest there are no major species differences in overall mean concentrations of adrenal or thyroid (Brown et al., 2004, this study). Rather, differences are more individual-specific, and in some cases related to gonadal status, for both males and females. With respect to musth, interesting co-relationships between adrenal and testicular activity were observed, whereas findings related to thyroid function were variable and not altogether easy to interpret.

Not surprisingly, there were marked differences in the duration and intensity of musth activity among the bulls of this study, with only about half exhibiting physical (TGS and UD), physiological (serum testosterone) and/or behavioral (aggression) signs. Recently, Ganswindt et al. (2005a,b) attempted to more accurately define what constitutes true 'musth'. Using direct behavioral observations and fecal androgen monitoring, they concluded that at least for African elephants, TGS + UD is a better physical indicator than TGS alone. This was based on UD being more tightly linked to sexual activity and elevated testosterone, and the fact that TGS is not just associated with musth, but occurs during other excitement states and in females as well (Buss et al., 1976; Rasmussen et al., 1984). By contrast, abundant TGS occurs in Asian bulls only during musth, and is rarely observed in females or young males (Eisenberg et al., 1971; Jainudeen et al., 1972b). Taken together, although the two are often coupled, UD is considered the best physical sign for defining musth in African elephants (Ganswindt et al., 2005b), whereas TGS alone appears to be sufficient for Asian elephants (Eisenberg et al., 1971; Jainudeen et al., 1972b).

Taking into consideration the potential species differences and array of symptoms associated with musth, plus the subjectivity of most keeper logs, it is likely not all zoos defined it in the same way. Nevertheless, all recorded musth periods occurred in conjunction with significant increases in testosterone secretion, not unlike that described for captive (Jainudeen et al., 1972a; Rasmussen et al., 1984, 1990; Niemuller and Liptrap, 1991; Lincoln and Ratnasooriya, 1996; Ganswindt et al., 2005a) and wild (Hall Martin and Van der Walt, 1984; Poole et al., 1984; Hall-Martin, 1987; Ganswindt et al., 2005b) bulls. Temporally, TGS and/or UD occurred one to several weeks after testosterone began to rise, similar to that in Asian (Lincoln and Ratnasooriya, 1996) and African (Ganswindt et al., 2005a) elephants. It has been further shown in African elephants that TGS tends to begin before UD (Ganswindt et al., 2005b). One African bull in this study did show evidence of TGS before UD as musth progressed, but this was not as clear in the other bulls. These findings suggest quantitative changes in testosterone may be causal in stimulating the onset of physical musth symptoms, as well as aggressive behaviors. A similar situation has been described in Soay sheep, where the aggression index was maximal about a month after the peak in testosterone when androgens were decreasing (Lincoln and Davidson, 1977). Humans also exhibit increased aggression, anger and irritability after a temporary reduction in testosterone (Bagatell et al., 1994). Thus from a management standpoint, detection of elevated androgens (with or without TGS) may be useful as an early indicator of impending musth. However, as others and we have noted, not all increases in testosterone are associated with musth behaviors (Lincoln and Ratnasooriya, 1996; Ganswindt et al., 2005a,b; this study), so its predictive value may be limited.

Many of the bulls that exhibited musth in this study were <20 years old, which is young compared to wild bulls that do not exhibit musth before 24 years of age or much later (Poole, 1987, 1989). Four bulls aged 14, 15, 16 and 19 years already were exhibiting musth at study onset; thus, their first musth would have been even earlier. Two bulls began exhibiting musth during the study period, at approximately 12 and 15 years of age. This was not unexpected, however, given the number of studies showing bulls initiate musth activity much earlier in captivity than in the wild (Eisenberg et al., 1971, 1972; Cooper et al., 1990; Niemuller and Liptrap, 1991; Ganswindt et al., 2005a). Somewhat surprising was that most bulls did not exhibit clear temporal patterns associated with musth. Rather, musth episodes or elevated periods of testosterone occurred more than once a year and at least one was nearly continual. The exception was the Oregon Zoo where all three Asian bulls exhibited clearly defined yearly cycles. Competition, age, social status and nutrition all impact the expression of musth in wild bulls, and probably captive bulls as well. It has been reported that regular, yearly episodes of strong musth may not occur in captivity until bulls are 20 years of age or older (Eisenberg et al., 1971, 1972a; Jainudeen et al., 1972b; Niemuller and Liptrap, 1991; Ganswindt et al., 2005a). Similarly, in the wild bouts of musth tend to be short and sporadic until males reach their mid-thirties (Poole, 1987, 1989, 1994; Hall-Martin, 1987). Older, dominant bulls in the wild

exhibit musth at better times of the year when resources are abundant (Poole, 1987, 1989; Hall-Martin, 1987), which is an important reproductive strategy because musth imparts a higher dominance rank that facilitates breeding opportunities (Hall-Martin, 1987; Poole et al., 1984, 1989; Hall-Martin 1987). As such, it might explain why the musth cycles in bulls at the Oregon Zoo were clearer and temporally staggered. Two of the three bulls at that facility were older (42 and 44 at study onset), with musth in the younger one being more variable but still clearly cyclic. Another older bull (Onyx, age 34) did not show a clear yearly cycle, nor for that matter did the younger bull at that facility. Thus, age alone not the only factor dictating musth characteristics. The oldest Asian bull (Tommy) in the study did not exhibit musth at all, perhaps because of advanced age (50 years at study onset), although bulls have been known to exhibit musth into their 50's and 60's (Jainudeen et al., 1972b; de Oliveira et al., 2004; Hollister-Smith, 2005). In comparing testosterone data among the multi-bull groups at the Oregon Zoo, Dickerson Park Zoo and Riddle's EWS, there was a direct relationship between overall concentrations and social rank, which was age-related. Other studies have shown that age and dominance status are important sexual determinants among captive bulls (Jainudeen et al., 1972b; Niemuller and Liptrap, 1991), not unlike that observed in the wild. When data for all bulls were combined, average testosterone concentrations also increased with age. Mean testosterone concentrations peaked in the late twenties, early thirties, and then declined slightly thereafter. Similarly, Jainudeen et al (1972b) reported peak musth activity occurred between 21 and 30 years of age among working bulls in Sri Lanka.

The early sexual maturation of bulls in zoological settings is presumably due to overall better nutrition and a lack of environmental stressors (Cooper et al., 1990). In both captivity and the wild, poor body condition is associated with reductions in the duration and/or intensity of musth (Jainudeen et al., 1972b; Poole, 1987, 1989; Hall-Martin, 1987). It is perhaps because bulls in North America are so well conditioned that many showed signs of musth multiple times per year. In a nutritional experiment, Cooper et al. (1990) reported that food restriction delayed the timing and reduced the intensity of musth in a captive Asian bull. Zoos in this study reported that diets were not altered during musth, but did state that food intake of individual bulls often decreases voluntarily. Unfortunately, weight logs were not available to determine if significant changes in body weight accompanied any of the musth episodes. However, marked changes in body condition like those noted in wild (Poole, 1987; Hall-Martin, 1987) or domesticated, working (Jainudeen et al., 1972b) bulls are not likely to occur in North America given standard feeding regimens.

One finding that was somewhat surprising was how many bulls were not exhibiting musth despite being 20 years of age or older, especially among the African species (6 of 9 bulls). Interestingly, all of these bulls were housed at Riddle's EWS, which had an older, dominant bull that did exhibit musth. This suggests that although bulls may be physically capable, social factors may suppress or delay the onset of musth activity. This has been shown clearly in wild African elephants (Poole, 1987, 1989). Similarly, in a study of captive Asian bulls in Sri Lanka, only three of six bulls exhibited musth (Lincoln and Ratnasooriya, 1996). The oldest, most dominant bull in that group showed the strongest musth and had the highest testosterone concentrations. The other five bulls were about the same age (19-22 years), but only two of them exhibited musth. The higher proportion of Asian bulls exhibiting musth in the present study probably is due at least in part to the age differential. However, some evidence suggests there may be a species difference as well. In 1984, Rasmussen et al. speculated that African elephants might not exhibit musth in captivity as early as Asian elephants. This was supported by Cooper et al. (1990), who studied two bulls at the Columbus Zoo between the ages of 13-17 years. Yearly 5-month musth periods were observed in the Asian (who began showing musth signs at 7 years of age), whereas musth was not observed in the African bull until the last year of the study, at age 17 years. Alternatively, there may be a species difference in bulls' responses to social suppression. All Asians in multi-bull groups exhibited musth (n = 2 facilities), whereas at the one facility with multiple Africans, only the dominant bull went through musth. Ganswindt et al. (2002) also suggested social suppression by a dominant bull may have been responsible for lack of clear musth cycles in a captive 18-year-old African bull. It is tempting to speculate this might be similar to what is happening among captive female elephants. A high rate of ovarian acyclicity is observed in African, but not Asian elephants (Brown et al., 2004), and appears to be related to dominance status (Freeman et al., 2004). Proving such a hypothesis in bull elephants, however, will require a more balanced study with respect to animal numbers, age and social situations.

Taken together, these data suggest that a variety of factors impact when bulls begin to exhibit musth and the variability of subsequent cycles. We might expect singleton or dominant bulls to exhibit musth as early as 12, and at least by 20 years of age. Given the young age of the captive Asian (average, 20.7; median, 18.0, standard deviation, 13.9 years; n = 43) and African (average, 20.0; median, 23.0; standard deviation, 10.1 years; n = 31) bull populations in North America (Keele, 2005; Olson, 2006), a significant number will reach sexual maturity within the next decade, and many likely will exhibit musth. While this may prove challenging to managers, it also will provide a great opportunity to do more comparative research on the physiology of musth.

Endocrinologically, this study focused on how thyroid function related to testicular activity. Relatively clear patterns of hormone secretion were observed only in four of 10 bulls that exhibited musth. In those individuals, T3 and T4 were correlated negatively to testosterone secretion. Interestingly, three of these bulls resided at the same facility and were among the only ones that exhibited clear yearly musth cycles (i.e., Hugo, Packy and Rama at the Oregon Zoo). The other was Willie at Riddle's EWS, who exhibited two cycles per year (early spring and summer) that were fairly clearly demarcated. Inverse relationships between T3 and/or T4 secretion and testicular function have been reported in other species, as males transition from a breeding to a nonbreeding state (Boissin-Agasse et al., 1980; Maurel and Boissin, 1981; Shi and Berrell, 1992). Temporally this was not unlike that observed in the four bulls with significant correlations to testosterone; thyroid hormones decreased as bulls were coming out of musth. A direct impact of reduced thyroid hormones impairing Leydig cell steroidogenesis may be related to decreased levels of the steroidogenic acute regulatory (StAR) protein (Cooke et al., 2004). Such a relationship between thyroid hormones and testosterone in the remaining bulls, however, was not observed. There were no obvious differences in environment or management practices that could explain these apparent bull and/or facility effects on thyroid function. Bulls were of varying ages, so it was not an age effect. To our knowledge, body condition of these individuals was no different than that of the others in the study. They had occasional access to females for breeding, just as did the other bulls. One thing they did have in common was the occurrence of clearly demarcated hormonal and musth cycles. The intriguing findings in bulls at the Oregon Zoo and Riddle's EWS suggest further investigations are warranted to examine possible cause or effect relationships related to the hypothalamo-thyroid-testicular axis in elephants.

Mean thyroid hormone concentrations varied seasonally in captive elephants, significantly for Africans, but only tending towards significance in Asians. In both species, total and free T3 and T4 concentrations decreased slightly during the summer months (June – August), not unlike that in other reports where seasonal decreases in metabolism and thyroid function occur in response to increases in air and body temperature (Ingraham et al., 1979; Greenspan, 2004; Silva, 2006). Bulls have a relatively low surface to volume ratio and so do not need a high metabolic rate to maintain body temperature in the warmer summer months. Mean total and free thyroid hormone concentrations also decreased with age for all bulls combined, which is supported by findings in other mammals (St Aubin et al, 1996; Greenspan, 2004). Thyroid hormones work synergistically with growth hormone to promote protein synthesis during development (Greenspan, 2004); thus, it is not surprising that thyroid activity would decrease with age as growth rate slows. Finally, castration had little or no effect on thyroid function overall, similar to that observed in other species (Bagchi et al., 1984; Steger et al., 1989).

In summary, the variation in temporal hormone and musth patterns, coupled with inconclusive hormonal correlations among individuals makes it clear there is no one profile that fits all bull elephants. We were particularly flummoxed by why only the bulls at the Oregon Zoo showed clear yearly thyroid hormone and musth cycles. Compared to wild elephants in Africa and working domesticated elephants in Asia, bulls at this facility appear to be only ones exhibiting 'classic' musth cycles. Although this was among the largest captive study populations to date, it is clear that even larger, more controlled studies will be needed to determine the degree to which sexual and gonadal activity are related to species, age, social status, husbandry and nutrition. This will require more animals be blood sampled regularly, or participate in projects to noninvasively monitor endocrine activity. To our knowledge, no studies have directly compared testosterone production with semen quality, and there is no "cutoff" value for estimating the potential fertility of an individual. Research is needed to identify conditions for maximizing reproductive potential, especially given the limited number of available bulls and the urgent need to improve captive

breeding rates. In light of evidence that sexual activity and musth are not mutually exclusive, methods are needed to negate negative behaviors so that more zoos will be willing to hold breeding bulls. From the results of this study, there does not appear to be any benefit in trying to modulate musth symptoms through control of thyroid activity. Rather, suggested strategies could focus on treatments to suppress testosterone action either directly using antiandrogens (e.g., flutamide or cyproterone acetate) (Chandrasekharan and Cheeran, 1996) or indirectly through the inhibition of LH secretion (e.g., GnRH analogs) (Brown et al., 1993; de Oliveira et al., 2004). Studies along this line have been limited to date, and it still is not clear if any of these approaches would be feasible or effective. Because more bulls are expected to begin experiencing musth over the next decade, efforts should concentrate on finding ways to ensure fitness, while at the same time ensuring the safety and welfare of individual animals and their handlers.

Acknowledgments:
The authors are grateful to the staff at all participating institutions. We also thank Dr. Tom Tomasi, Dr. Melissa Carden, Susan Walker, Nicole Abbondanza, Abby Matthewson, and Jordana Meyer for excellent technical and logistical assistance. This project was funded in part by the Diagnostic Products Corporation, Carolyn Gabel and the Shared Earth Foundation, Friends of the Dickerson Park Zoo, Missouri State University, Friends of the National Zoo and Morris Animal Foundation. The authors would like to acknowledge a beloved colleague, Dr. Bets Rasmussen, who was a continual source of inspiration and a driving force behind our efforts to better understand the biology of bull elephants.

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Figure 1:
Individual profiles of serum testosterone concentrations (•) in the upper panel and Total T4 (Δ) concentrations in the lower panel for Hugo housed at the Oregon Zoo. Black bars represent recorded periods of musth.

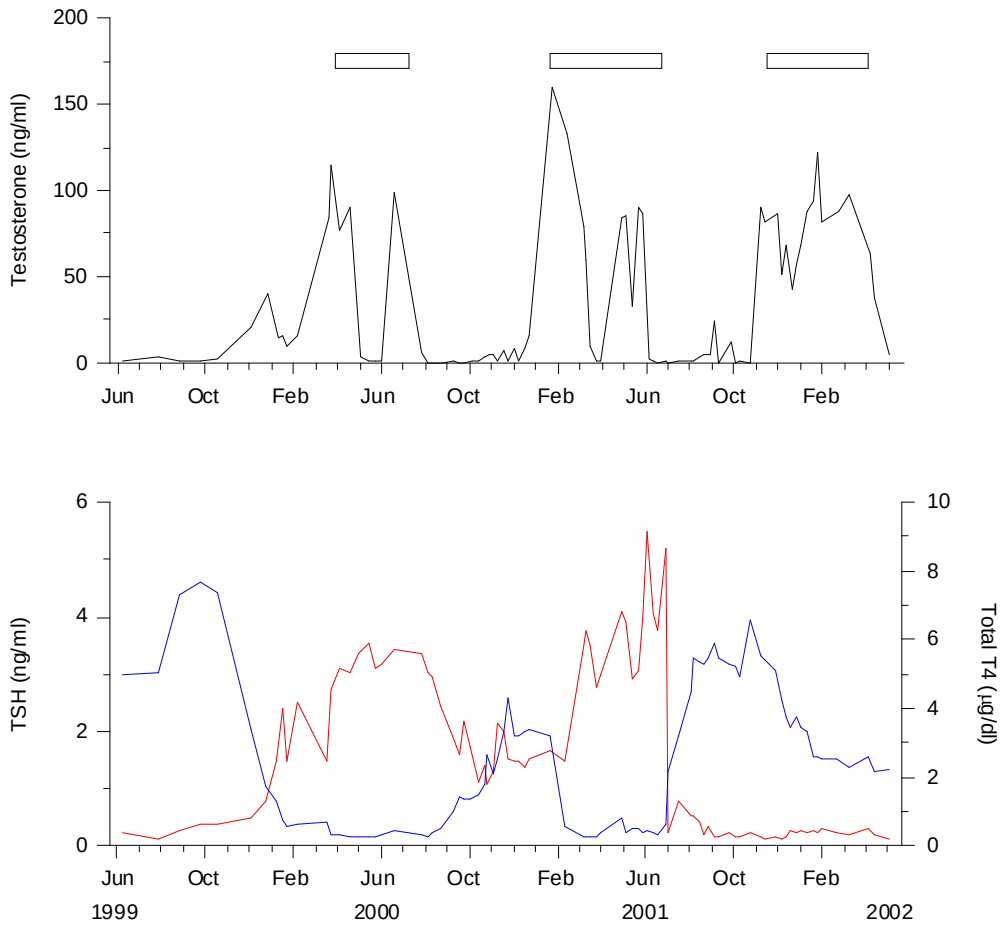

Figure 2:
Individual profiles of serum testosterone concentrations (•) in the upper panel and Total T4 (Δ) concentrations in the lower panel for Onyx housed at the Dickerson Park Zoo. Black bars represent recorded periods of musth.

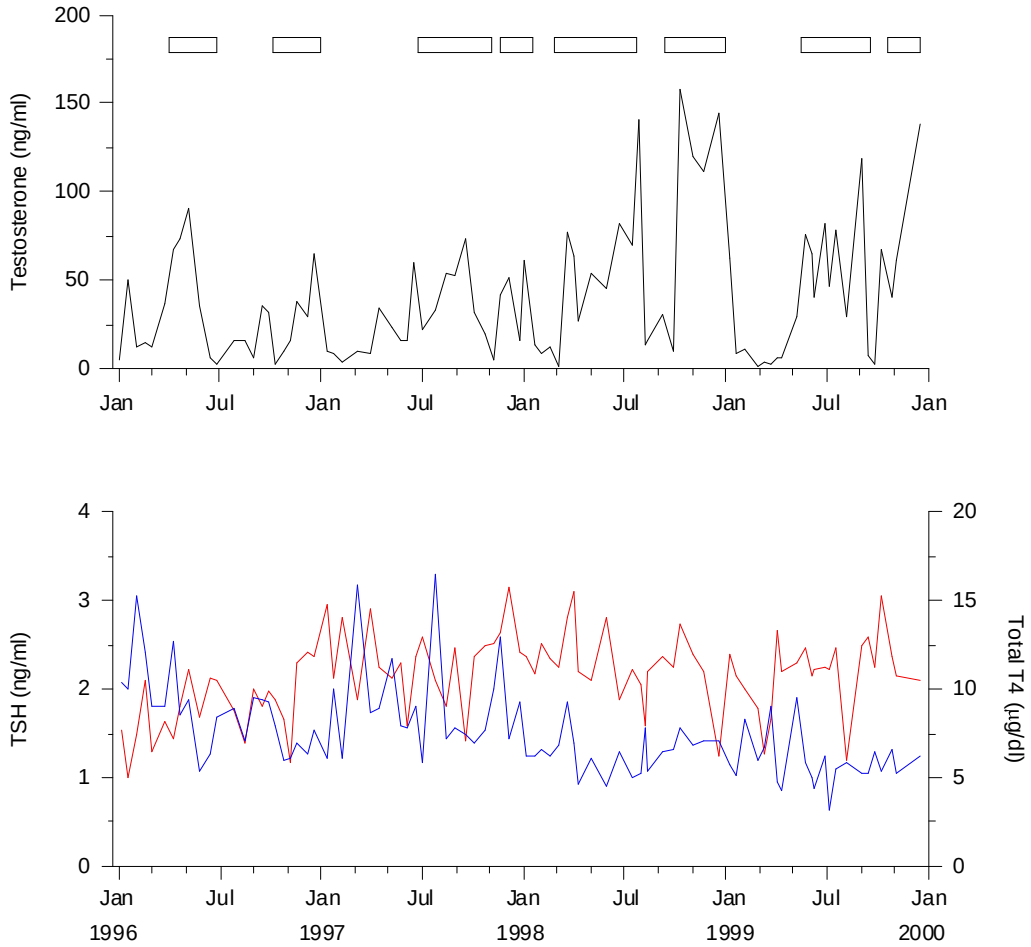

Figure 3:
Individual profiles of serum testosterone concentrations (•) in the upper panel and Total T4 (Δ) concentrations in the lower panel for Hank housed at the Riddle's Elephant and Wildlife Sanctuary. Black bars represent recorded periods of musth.

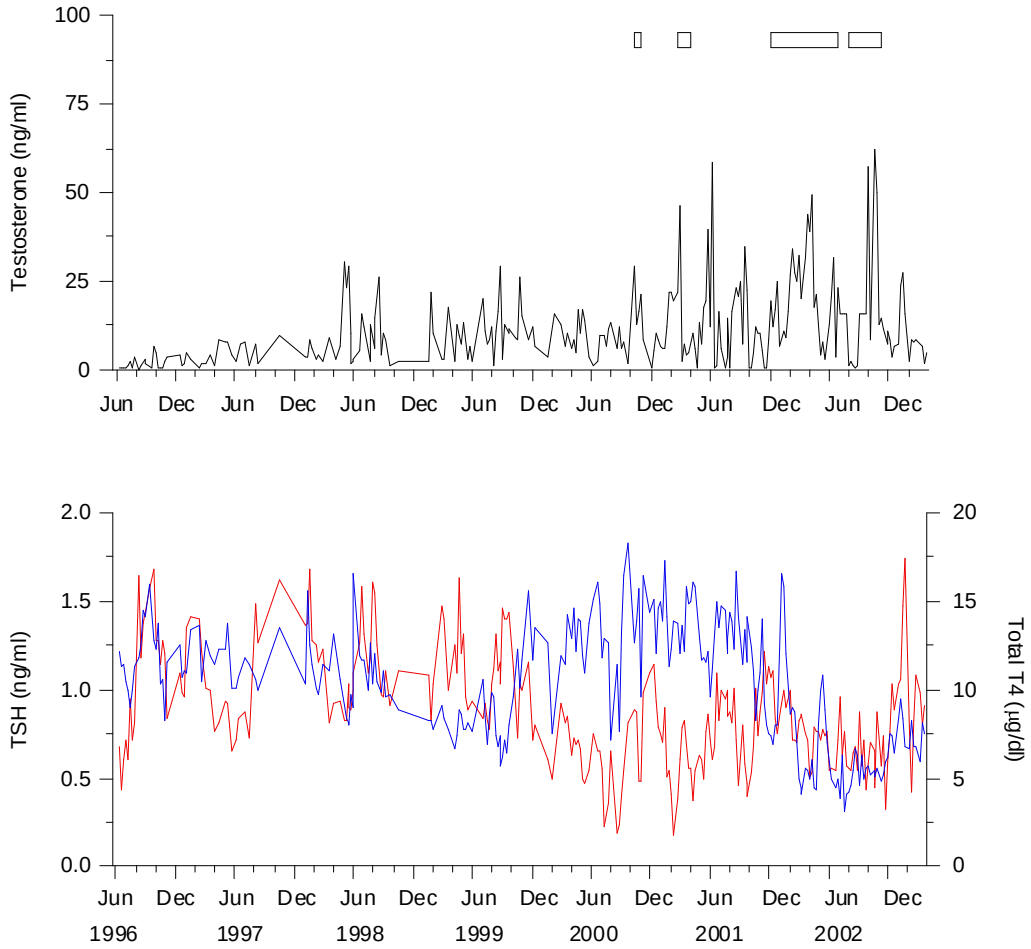

Figure 4:
Individual profiles of serum testosterone concentrations (.) in the upper panel and Total T4 (Δ) concentrations in the lower panel for Machito housed at the Miami Metrozoo. Black bars represent recorded periods of musth.

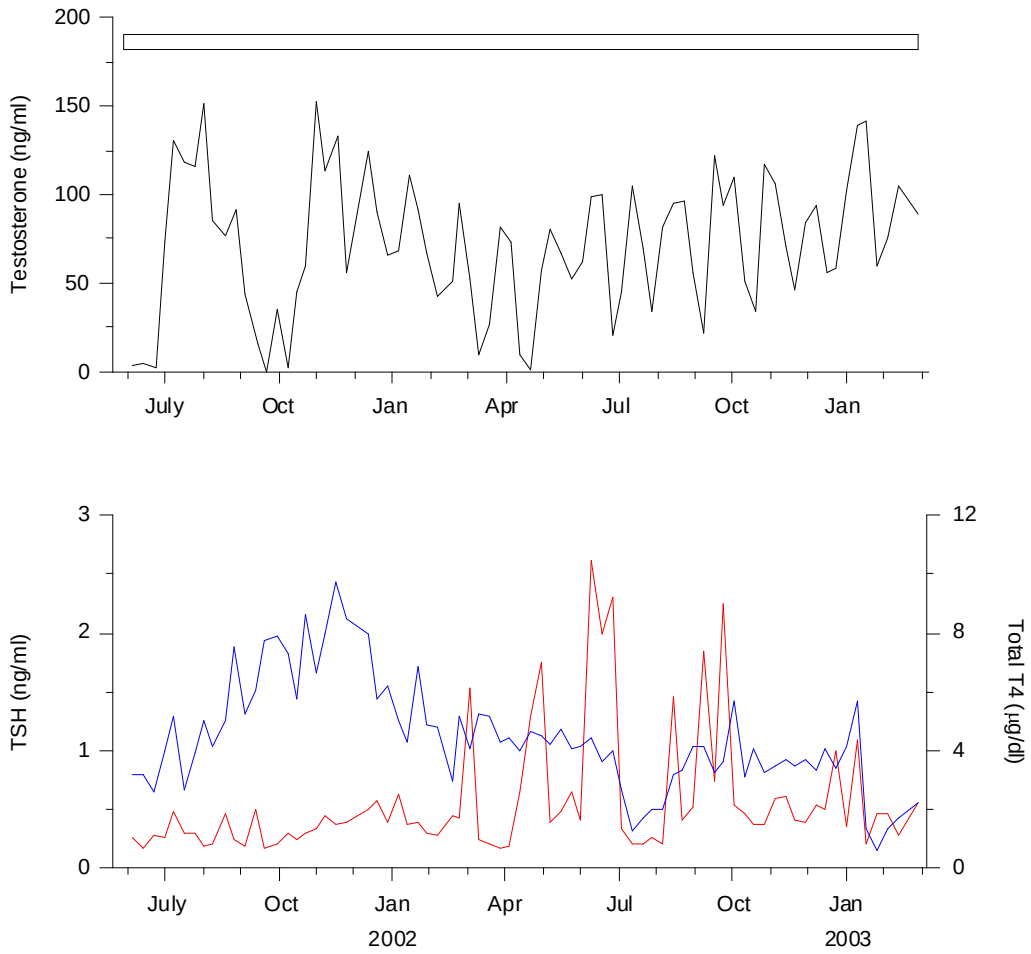

Table 1:
Summary of bulls, sampling dates and number of serum samples analyzed in this study.

Species	Facility	Animal Name	Birth Year	Exhibited Musth	Proven Breeder	Sample Dates	No. of Samples
Asian	Oregon Zoo	Hugo	1960	Yes	Yes	1/94-1/03	250
	Oregon Zoo	Packy	1962	Yes	Yes	5/94-1/03	232
	Oregon Zoo	Rama	1983	Yes	No	5/95-1/03	217
	Miami Zoo	Dahlip	1966	Yes	Yes	6/01-8/03	92
	Dickerson Park Zoo	Khunchorn	1978	Yes	No	1/94-2/96	54
	Dickerson Park Zoo	Onyx	1962	Yes	Yes	1/96-1/99	89
	REWS[1]	Hank	1988	Yes	Yes	6/96-4/03	258
	Venice Beach	Tommy	1944	No	Yes	7/94-2/96	62
African	Miami Metrozoo	Machito	1980	Yes	Yes	6/01-8/03	115
	REWS	Morgan	1979	No	No	8/94-12/94	12
	REWS	Willie	1979	Yes	Yes	11/93-4/03	240
	REWS	Toby	1980	No	No	10/93-4/03	383
	REWS	Digger	1983	No	No	4/00-7/02	107
	REWS	Artie	1983	No	No	6/96-4/03	259
	REWS	Solomon	1983	No	No	11/93-4/03	381
	REWS	Tuffy	1984	No	No	4/01-4/03	104
	Caldwell Zoo	Chip	1978	Yes	No	1/97-2/00	70

[1]Riddle's Elephant and Wildlife Sanctuary

Table 2:
Overall mean (±SEM) of testicular and thyroid hormones in individual Asian elephant bulls.

Elephant	Overall Testosterone (ng/ml)	Baseline Testosterone (ng/ml)	Total T4 (ug/dl)	Free T4 (ng/dl)	Total T3 (ng/dl)	Free T3 (pg/ml)
Hugo	33.40 ± 1.88	1.12 ± 0.39	7.78 ± 0.73	0.82 ± 0.03	105.65 ± 4.68	1.53 ± 0.12
Packy	29.36 ± 3.30	6.79 ± 1.36	7.51 ± 0.51	0.49 ± 0.02	109.19 ± 3.50	1.46 ± 0.11
Rama	15.82 ± 1.42	1.77 ± 0.69	9.97 ± 0.57	0.89 ± 0.04	139.40 ± 4.35	2.41 ± 0.09
Dahlip	17.80 ± 1.44	1.14 ± 0.45	5.85 ± 0.47	0.57 ± 0.03	64.81 ± 2.14	0.41 ± 0.03
Khunchorn	13.77 ± 2.41	0.75 ± 0.12	10.08 ± 0.60	0.58 ± 0.02	95.78 ± 2.10	2.17 ± 0.10
Onyx	35.63 ± 2.86	8.83 ± 1.32	7.06 ± 0.21	0.51 ± 0.01	113.13 ± 4.97	1.62 ± 0.08
Hank	11.32 ± 0.54	6.87 ± 1.25	11.01 ± 0.22	0.72 ± 0.01	113.71 ± 2.12	2.22 ± 0.04
Tommy	0.11 ± 0.01	0.10 ± 0.01	10.14 ± 0.59	1.21 ± 0.04	121.86 ± 3.11	1.43 ± 0.07
Overall	22.44 ± 3.35[1]	3.90 ± 1.38[1]	8.68 ± 0.65	0.72 ± 0.09	112.15 ± 4.85	1.72 ± 0.18

[1]Data excluded for Tommy

Table 3:
Overall mean (±SEM) of gonadal and thyroid hormones in African elephant bulls.

Elephant	Overall Testosterone (ng/ml)	Baseline Testosterone (ng/ml)	Total T4 (ug/dl)	Free T4 (ng/dl)	Total T3 (ng/dl)	Free T3 (pg/ml)
Machito	63.58 ± 3.86	8.68 ± 2.43	6.36 ± 0.71	0.32 ± 0.02	99.23 ± 4.05	1.35 ± 0.12
Morgan	0.15 ± 0.03	0.10 ± 0.01	12.72 ± 1.39	1.04 ± 0.06	127.93 ± 6.27	1.58 ± 0.14
Willie	9.71 ± 1.41	4.32 ± 0.64	8.07 ± 0.13	0.66 ± 0.01	110.93 ± 1.63	2.15± 0.05
Toby	0.16 ± 0.01	0.11 ± 0.01	10.44 ± 0.15	0.76 ± 0.01	109.00 ± 1.35	2.19 ± 0.03
Digger	1.00 ± 0.08	0.87 ± 0.06	8.34 ± 0.19	0.82 ± 0.02	108.18 ± 1.63	2.25 ± 0.05
Artie	1.78 ± 0.21	1.32 ± 0.20	11.97 ± 0.17	0.87 ± 0.01	122.62 ± 1.74	2.13 ± 0.04
Solomon	1.64 ± 0.08	1.21 ± 0.05	10.97 ± 0.15	0.82 ± 0.01	111.33 ± 1.03	2.10 ± 0.02
Tuffy	2.25 ± 0.15	1.97 ± 0.13	10.61 ± 0.32	0.71 ± 0.02	129.41 ± 3.51	6.11 ± 0.36
Chip	5.76 ± 0.31	3.13 ± 0.28	5.78 ± 0.16	0.48 ± 0.01	77.78 ± 1.25	0.96 ± 0.03
Overall	9.56 ± 6.83[1]	2.41 ± 0.91[1]	10.04 ± 0.68	0.76 ± 0.06	107.77 ± 5.23	2.22 ± 0.38

[1]Data excluded for Toby

Table 4:
Correlation coefficients and P-values of the relationships between testosterone and thyroid hormones in male Asian and African elephants that exhibited musth during the sampling period.

Correlation Coefficient (*P*-value)				
Testosterone	**Free T3**	**Total T3**	**Free T4**	**Total T4**
Asian				
Hugo	-0.265 0.010	-0.249 0.001	-0.306 0.034	-0.326 0.001
Packy	-0.312 0.001	-0.304 0.050	-0.344 0.002	-0.264 0.001
Rama	-0.312 0.001	-0.389 0.001	-0.380 0.001	-0.472 0.001
Dahlip	-0.134 0.098	-0.155 0.090	-0.103 0.087	-0.182 0.088
Khunchorn	-0.105 0.475	-0.123 0.396	-0.139 0.155	-0.254 0.130
Onyx	-0.086 0.435	-0.122 0.259	-0.094 0.388	-0.136 0.221
Hank[1]	0.113 0.317	0.127 0.325	0.218 0.159	0.109 0.321
African				
Machito	-0.139 0.193	0.064 0.558	-0.199 0.145	-0.160 0.116
Willie[1]	-0.196 0.114	-0.051 0.346	-0.095 0.321	-0.122 0.203
Chip	0.107 0.234	0.198 0.201	-0.192 0.111	-0.061 0.096

[1]Correlations were calculated only from the date when bulls began exhibiting musth.

Saving elephants by helping people – establishing a model for sustainable research, capacity building and community development for the protection of elephants in Sri Lanka and to resolve human elephant conflicts

Ravi Corea, Harsha Gammanpila, Zeenath Khalid, Nishantha Dharmasiri, Chandima Fernando and Chandeep Corea

The Asian elephant (*Elephas maximus*) is one of the world's most seriously endangered large mammals and it shares space with some of the most marginalized groups of people in the Asian elephants' range countries. In Sri Lanka the elephant shares space mostly with rural farmers. Adding to the considerable suffering of these people is human-elephant conflict (HEC). HEC is perhaps one of the biggest environmental issues Sri Lanka is facing today. The main constraints to developing and implementing a successful conservation and management plan in Sri Lanka has been:

1) the lack of baseline data on elephant ecology, behavior and human-elephant-conflict.
2) The sustainability of long term research and conservation efforts and
3) effective incentives for farmers to support elephant conservation efforts.

Management activities without giving consideration to these issues have failed to effectively address HEC and may in fact be detrimental to the survival of elephants. There is a need to develop an innovative approach to elephant conservation in Sri Lanka if elephants are to survive in significant numbers outside the system of protected areas. In the efforts to conserve the elephant some of the biggest and pressing issues are:

1) How can the need to conserve and protect the elephant be reconciled with issues such as human elephant conflicts and with the needs and aspirations of stakeholders who are most impacted by elephants.
2) How to develop economically and logistically feasible solutions that are sustainable as well as support the lifestyles and culture of the people of an area.
3) How to protect the last remaining habitat of elephants outside the protected areas.

The Sri Lanka Wildlife Conservation Society (SLWCS) has been addressing these issues since 1997 and developed the Saving Elephants by Helping People (SEHP) project to resolve HEC through a participatory approach. SEHP is in its 9th year of operations and is the first community based elephant conservation and research project in Sri Lanka that integrates ecological research, applied conservation, community participation, community development and sustainable economic development.

In 2003 a responsible travel initiative was integrated to make the SEHP project sustainable and to provide economic incentives for local people to support as well as benefit from elephant conservation efforts. As a part of these efforts a pilot project was initiated to introduce oranges as a cash crop to provide an economic buffer to farmers whose rice crops are frequently raided by elephants. Our field research shows that there are no records of Sri Lankan elephants raiding orange trees. The research component of SEHP investigates different areas of human elephant conflict using a range of activities conducted outside the Wasgamuwa National Park. Tank (Waterhole) monitoring and trail transects are conducted to study the habitat and resource use outside the park. Fence monitoring is conducted to identify the effectiveness of electric fences as a means to minimize HEC as well as to gauge community's capacity to maintain fences. Elephant Damage Survey (EDS) are carried out using semi-structured questions and Participatory Rural Appraisal techniques to understand the temporal and spatial scale of HEC as well as to estimate economic costs. The presence and absence of elephant dung is extensively used as an indicator for elephant presence. The results and lessons learned from the SEHP project is presented in this paper.

Variability in the gaits of African elephants (*Loxodonta africana*)

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Butler University

The species-typical patterns of limb-movement (gaits) during animal locomotion have been the subject of extensive investigation (e.g., Alexander, 2003). Most quadrupedal mammals walk with a lateral sequence gait (Hildebrand, 1976), so called because each forefoot movement immediately follows a movement of the ipsilateral hind foot. Starting with the left hind foot, by convention (Hildebrand, 1976), the lateral sequence footfall cycle is left hind foot (LH) → left forefoot (LF) → right hind foot (RH) → right forefoot (RF) → left hind foot (LH). Primates walk with a diagonal sequence gait, in which the contra-lateral forefoot moves first after any particular hind foot movement (Cartmill, Lemelin, & Schmitt, 2002).
Most quadrupedal mammals have a variety of gaits. For example, Waring (2003) describes at least eight gaits for horses: Walk, trot, pace, gallop, canter, rack, "slow gait", and the "running walk". Researchers have emphasized the adaptive significance of different gaits (Hildebrand, 1980) and the factors influencing gait choice (Alexander, 2002) and gait changes (Hoyt & Taylor, 1981). Static stability and dynamic stability are critical factors in gait choice (Alexander, 2002).
The few studies that have been conducted with elephants, however, suggest that elephants exhibit only one gait, although this gait has been called by several different names (see Hutchinson, Famini, Lair, & Kram, 2003; Hutchinson, Schwerda, Famini, Dale, Fischer, & Kram, 2006). It appears that African elephants move efficiently, at an unusually low energetic cost (Langman, Roberts, Black, Maloiy, Heglund, Weber, Kram, & Taylor, 1995), using lateral-sequence gaits over a wide range of speeds. Rapidly moving elephants are, in fact, walking quickly rather than running (Hutchinson et al, 2003). Only Hildebrand (1976, p. 266, Figure 15) has presented empirical data indicating that elephants sometimes use a walking trot, but he did not distinguish between Asian and African elephants or present data for individual animals.

This paper is an attempt to broaden the study of elephant gaits by examining several types of locomotion: walking forward, walking backward, walking uphill and walking downhill. Prior studies (e.g., Hutchinson et al., 2006) have observed only steady movement over horizontal surfaces (flat ground).

Methods:
One juvenile male and four adult female African elephants (*Loxodonta africana*) resident at the Indianapolis Zoo were observed over a period of four years during projects concerning calf development and the social structure of a captive group of elephants. The females ranged in age from 20-34 years when observation began in 2002. The male was two years old in 2002: However, all but one of the observations reported for the male were taken after he was five years old. Except for one Backwards walk sample, all observations were made in the main elephant exhibit (approximately 100m x 50m). This exhibit consists of upper and lower plateaus separated by a sloped section: The slope was estimated, by measurement, to be 5-6^{o} in the region where observations were taken. Several hundred hours of digital videotape were collected over the four years, with different elephants being the focal animal on different days. Several similar Sony Mini-DV cameras were used to collect the observations. The videotapes were analyzed with a Sony Mini-DV VCR (Model GV D100 NTSC). The video cameras taped at a speed of 30 frames/s. The videotape was analyzed frame-by-frame by the author.
The "stance" phase of a stride started with the first frame in which a particular foot touched the ground and was not moving horizontally, and ended with the last frame in which that foot touched the ground without moving horizontally (stance time). The stride duration (stride time) for a particular foot was the period between successive footfalls of that foot. The "swing" phase of a stride was the difference between the stride time and the stance time. The author rescored several tapes to assess the reliability of the timing. Almost all of the footfalls were placed in the same video-frame in both scoring sessions; Disagreements by more than 1 frame (1/30 s) were extremely rare.

The videotaped sessions were scanned for examples of walking uphill, downhill, backwards and forwards. In order for a sample of locomotion to be included in this study, the tape had to provide an unobstructed view of each footfall and foot-lift for all four feet over a two-stride period. When a movement sample consisted of more than two strides (some sequences involved more than 10 strides), the most consistent two-stride sequence was used. Consistency was defined in terms of the two successive strides having similar "duty factors" and "phase lags" (see Hildebrand, 1976). The *duty factor* for any stride is the left hind foot stance time divided by the left foot stride time – multiplied by 100. The *phase lag* is the delay between the left hind foot footfall and the next left forefoot footfall – multiplied by 100 (see Figure 1).

A total of 40 movement sequences were selected for display in Figure 2, from a total of 66 sequences that had been collected. This was done to equate the number of observations for each elephant because different numbers of movement sequences had been collected and scored for each elephant: 20, 13, 12, 12, and 9. Four types of movement were defined:
Flat walk – forward movement over horizontal ground: two samples per elephant. Ten out of a total of 17 sequences were used.
Uphill walk – moving directly up the slope between the bottom section and the top section of the exhibit: two samples per elephant. Ten out of 14 sequences were used.
Downhill walk – moving directly down the slope between the top and bottom sections of the exhibit: three samples per elephant. Only 15 out of 30 samples collected were used: The lowest, median and highest duty factor for each subject.
Backwards walk – moving backwards at a steady rate. Data collected only from two female elephants. All five sequences were used. For two of the five sequences, one for each elephant, an elephant handler led the elephant.

Results:
Each movement sequence was displayed on the standard Hildebrand (1976) gait graph, with each observation represented by a point on a diagram with Phase Lag as the ordinate and Duty Factor as the abscissa (See Figure 1).

It is clear from the overall results that the Flat walk and the Uphill walk data were very similar. All 20 observations indicated that elephants typically walk on level ground and uphill with the same gait: A lateral sequence gait with a Phase Lag of about 20. It is also clear that the Backwards walk data (n = 5) represent a diagonal-sequence gait with a Phase Lag of about 75, indicating that walking backwards ("backing": Waring, 2003) may be considered a stable gait for elephants. This gait has never been reported previously for elephants.

The Downhill walk results were less consistent. Of 15 observations, 9 represented a walking-trot gait, 5 represented the type of lateral-sequence gaits reported for elephants by other researchers, and 1 was an intermediate lateral-sequence gait. In the walking trot gait, the footfall sequence is LH & RF (simultaneous) --> RH & LF (simultaneous): The diagonally opposite feet strike the ground at about the same time.

The elephants rarely moved directly uphill or downhill, usually traversed the incline at an angle – walking sideways along the slope - as if to minimize the rate of ascent or descent. This is consistent with a suggestion that *in situ* elephants avoid hills because of the extremely high-energy cost of ascent (Wall, Douglas-Hamilton, & Vollrath, 2006).

Discussion:
The adult African elephants in this study used at least three, different walking gaits: the standard "single-foot" gait, a walking trot and - when walking backwards - a diagonal-sequence gait. The walking trot gait has been reported for elephants only once (Hildebrand, 1976). These data confirm his report.
The elephants used the walking trot gait while moving downhill, but not while moving uphill or on level ground. This is consistent with the idea that, for quadrupeds, trotting is a particularly stable gait – especially when traveling slowly (Alexander, 2002; Hildebrand, 1989). Slipping or falling might be more likely when traveling downhill rather than uphill or on level ground.

Finally, while walking backwards may a rare event for most mammals, elephants appear to shift back and forth frequently, often taking a step backwards rather than turning around (Note that, unfortunately, movements shorter than two complete strides were not recorded in the current study). When I replayed, *in reverse*, a tape of an elephant walking backwards, it looked just like an elephant walking forwards. For elephants, the kinematic and neurophysiological relationships between walking forwards and walking backwards may be unusually close.

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2. The author acknowledges the financial support provided by Butler University and by the Indianapolis Zoo.
3. This study could not have been completed without the cooperation and support of David Hagan and the elephant handlers at the Indianapolis Zoo.

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Figure 1:
The Hildebrand (1976) gait diagram (or gait graph) depicting the phase lag and the duty factor for each walking sample. The ovals summarize the gaits Hildebrand observed in 34 walking samples taken from Asian and African elephants. More detailed information was not provided. Note that the numerical scales on the ordinate and abscissa are inverted, *per* Hildebrand (1976).

Figure 1

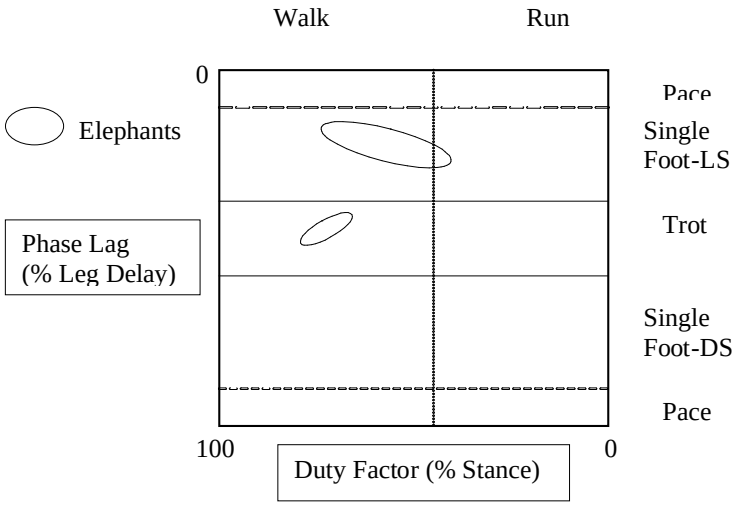
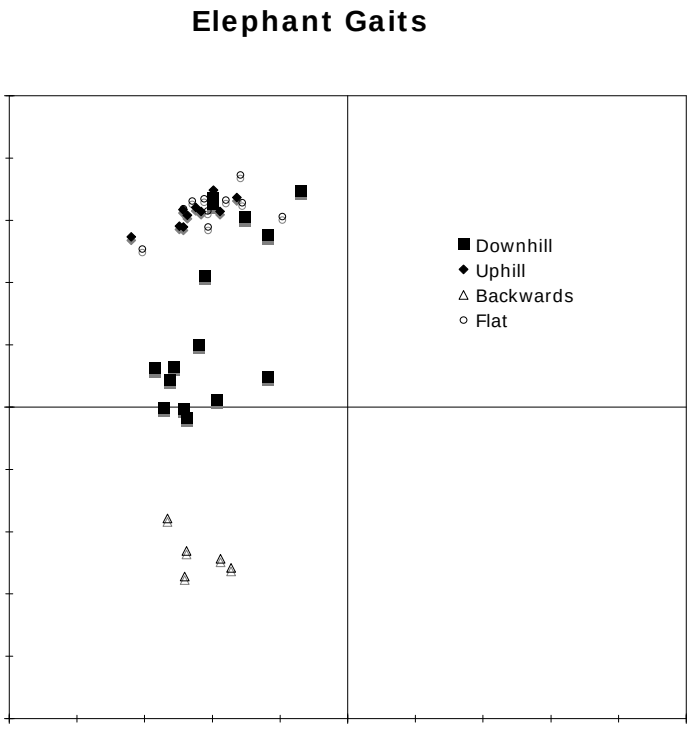


Figure 2:
The 33 observations collected from four adult female African elephants at the Indianapolis Zoo. Data are for walking forwards on horizontal ground (open circles), walking uphill on a slope with an incline of about 5° (filled diamonds), walking downhill on the same slope (squares) and walking backwards on a flat surface (triangles).



Morphological and ultrasonographic characterization of the embryonic development in elephants

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The lack of success with captive breeding and the paucity of long-term behavioural observations in the wild have made it extremely difficult to study fetal growth and development of the extant elephant species. Research in the past has to great parts been dependent on fetuses of unknown gestational age collected during culling operations which took place in Africa from 1967 - 1995. Due to decreasing public acceptance, however, culls are not planned in the future and the classical research material is no longer available.

The introduction of transrectal ultrasonography as an advanced means to monitor elephant pregnancies has opened up a new way to assess fetal development in utero (Hildebrandt et al., 1998). In this study, the first third of gestation of 0.10 Asian and 0.9 African elephants with known date of conception has been monitored by ultrasound.

On the basis of biometric measurements, new formulae have been developed to accurately determine fetal age. These formulae were applied to fetal elephant specimens and a different relationship between fetal age and fetal mass than the one assumed by Huggett & Widdas (1951) and Craig (1984) was found.

Embryonic and early fetal development was described by correlating developmental milestones characterised in the fetuses assessed by ultrasound with morphological observations made in the preserved specimens. Implantation was first seen by ultrasound on days 50 - 63 gestation, when a fluid filled vesicle could be seen within the uterine lumen. Embryonic tissue could not be detected until day 62 gestation. The embryo was attached to membranes, which were presumed to be the yolk sac and the allantois. Head and rump of the embryo could first be differentiated on day 83 gestation, shortly followed by the development of a beak like trunk on days 86 - 90 gestation.

The formation of the placenta started on days 80 to 85 gestation and resulted in a complete girdle placenta on days 105 - 110 gestation. The placental ring was not completely closed in all fetuses. By 92 - 97 days gestation, the head comprised almost half of the total body length and fore, mid and hind brains were prominent. Eyelids had not developed until day 103 gestation. A distinct dilatation of the umbilical cord close to the abdominal wall could be seen from days 95 - 120 gestation and was referred to as physiological midgut herniation, caused by rapid liver growth. With the proceeding pregnancy, internal organs such as lung, liver, gastric vesicle, kidneys and urinary bladder could be depicted. By day 169 the now elongated trunk displayed hairs at its base. On the tip of the trunk dorsal and ventral finger-like processes could be seen. Further fetal development was characterised by increasing growth and weight gain.

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Tuberculosis treatment protocols and complications for elephants

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Treatment for *Mycobacterium tuberculosis* (*M.tb*) infection in elephants has been ongoing in the United States for several years. Standardized therapeutic regimens have been established in human medicine. However, treatment regimens for elephants are still evolving. Between 1996 and 2005 twenty culture positive elephants have undergone treatment for Mycobacterial tuberculosis infection in the U.S.

The first step to effective treatment is an accurate culture with sensitivity results. Therapy for pansensitive infections, or while awaiting sensitivity results, includes the use of at least three first line drugs. The recommended starting combination includes isoniazid, pyrazinamide, rifampin and/or ethambutol. The key to effective drug therapy in people is to achieve adequate plasma levels. Plasma drug levels known to be effective in people are used as a guideline for determining effective treatment in elephants.

Direct oral administration is the preferred route of therapy. Administering medications over the food has proven ineffective. It is not likely that 100% drug delivery can be ensured by this method. Additionally some of these medications are very unpalatable. Rectal administration of drugs such as isoniazid and pyrazinamide have yielded adequate plasma levels. However, some medications, such as rifampin, are poorly absorbed from the rectum and must be given directly orally to achieve acceptable therapeutic levels.

Rectal administration involves direct administration of medications using large animal (400cc) dose syringes and flexible tubing. In at least one case a veterinary bilge pump was used for high volume administration. Medications can be suspended in water or carriers such as lecithin for delivery. In one instance medications were mixed with cocoa butter and lecithin to form solid suppositories. Lecithin may enhance rectal absorption. Elephants can be readily trained to accept rectal administration and this route overcomes issues of drug palatability and acceptance. Regardless of the route or carrier used, monitoring blood plasma drug levels is recommended.

Anti-tuberculosis medications may be associated with undesirable side effects. Certain adverse effects observed in elephants have been similar to side effects reported in humans. Common side effects in humans are listed in the table below. Human side effects are outlined below. Several of these have been observed by the author in an Asian elephant (*Elephas maximus*).

Table 1: Common side effects of anti-tuberculosis drugs in humans *

Isoniazid	PZA	Rifampin	Ethambutol	Quinolone
Peripheral neuropathy Nausea, vomiting, epigastric distress *Elevated liver enzymes*, hepatitis Agranulocytosis Skin eruptions, fever, vasculitis Pyridoxine deficiency Rheumatic syndrome Systemic lupus Erythematosis- like syndrome	Hyperuricemia -> gouty arthritis *Hepatocellular damage* Nausea, vomiting, *anorexia* *Arthralgia, myalgia* *Photosensitivity*, porphyria, fever	*Anorexia*, nausea, vomiting Thrombocytopenia *Muscle weakness*, limb pain, headaches, *ataxia* Visual disturbances Elevated BUN, serum uric acid Pruritis, urticaria, *rash, conjunctivitis*	Optic neuritis Acute renal ailure	Nervousness, agitation, insomnia, anxiety, dizziness, convulsions *Photosensitivity* Dermal rash or allergic reaction Crystalluria (with alkaline urine)

* Note: Side effects noted in elephants are in italics

A group of Asian elephants was also observed to experience excessive epiphora and blepharitis during a brief period on oral pyrazinamide and enrofloxacin. Some elephants also exhibited stiffness/ soreness of one or more limbs during therapy.

In cases of multidrug resistant tuberculosis, second line drugs are indicated. These medications also carry a risk of side effects. Certain second line agents may be more toxic than the first line drugs. For instance, aminoglycosides are known to cause ototoxicity and nephrotoxicity. Ethionamide has reported side effects in people such as digestive problems, psychotic disturbance, dizziness, liver problems, photosensitivity and thrombocytopenia.

Many elephants experience some side effects while on anti-tuberculosis therapy. Inappetance is probably the most common side effect noted. These effects can be diminished by withdrawing medication for 1-2 days then resuming therapy. Alternatively, drugs may be given every other day at double the recommended dose. This is referred to as pulse therapy and has been used successfully in at least one animal in the United States.

The treatment of an elephant with tuberculosis is labor intensive and expensive. Medication costs to treat an adult Asian elephant for one year can be $50,000 to $60,000 US. This only accounts for the cost of the medications. Blood work, serum drug level monitoring, employee time, extra materials and isolation adds additional costs. The entire animal care staff must work together to ensure effective treatment.

Successful therapy has been confirmed in some but not all treated elephants that have been examined post-mortem. Further research and surveillance are essential. Promising new diagnostic tests (ElephantTB StatPak™ and Multi Antigen Print Immunoassay, Chembio Diagnostics, Medford, NY, USA) have detected infection years in advance of a positive culture thus providing a tool for enhanced surveillance or early treatment.

While not every positive elephant has been treated successfully, several have been and will continue to be closely monitored. With the development of new testing methods the diagnosis and management of tuberculosis in elephants is destined to become more effective and timely. The earlier infection can be detected, the more effective therapy can be.

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Adolescent male African elephant behaviour

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Adolescence in male elephants is a very influential period during which they leave the herd and assert themselves in the male hierarchy. This in turn can affect their future mating success. Focal, satellite downloads and observational data were collected on male elephants in the Okavango Delta, Botswana, to assess how behaviour and social interactions differed between age groups (10-15 years, 16-20 years, 21-25 years, 26-36 years, >36 years), with particular reference to the period of adolescence and independence. Adolescent males (10-20 year olds) showed a preference for larger social groupings and being in closer proximity to other elephants, of which the majority were males older than 36 years. Males in the 16-20 year age group spent significantly more time socializing (greeting and sparring) than older or younger males. Males >36 years of age vocalised more frequently than males in younger age groups. Adolescent males did not have a set home-range, expanding the area they used continuously over the three years they were monitored. Which is indicative of a dispersal transfer phase. The tendency of adolescent males to associate with other elephants, in particular older males, may provide them with the opportunities to establish themselves within the social hierarchy, to learn appropriate patterns of social behaviour and gather information about potential dispersal sites from older individuals.

Reproductive success of elephants in Kruger National Park, South Africa (1976-1995)

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Ovarian inactivity is a serious and growing problem among African elephants in western zoos. Whether this phenomenon is captivity-mediated is not known because wild elephant populations have never been monitored in the context of individual ovarian activity. However, birth and conception rates suggest that not all free-ranging females cycle continuously when not pregnant. To increase our knowledge of reproduction in wild African elephants, we analyzed reproductive data collected from elephants culled in the Kruger National Park (KNP), South Africa over a 20-year period. In an effort to reduce elephant densities and preserve biological diversity, 4,740 elephants were culled or removed from Kruger National Park (KNP), South Africa between 1976 and 1995. Mammary, uterine and ovarian characteristics were cataloged for 1465 of the reproductively aged females (> 8 years of age). The objective of the current study was to evaluate this database for evidence that age and precipitation impact reproductive success and the ovarian cycles of free-ranging African elephants in South Africa. The youngest age of conception was 8 years (n=6) and by 12 years of age all females were sexually mature; i.e., they had either corpora lutea (CL) or albicantia (CA) present on the ovaries. From age 14 years onward, the percentage of reproductively active females (pregnant and/or lactating) was >90%; however, this percentage declined dramatically when females reached 50 years of age. Over the 20-year period, approximately one-fifth (20.8%) of females were nonreproductive (not pregnant or lactating); these were mostly in the youngest (<12 years) and oldest (>50 years) age classes. Of the 695 pregnant females, four (0.6%) had twins, six (0.9%) carried fetuses with abnormalities, and six (0.9%) had dead, resorbed or aborted calves. The seven largest recorded fetuses were all males (range: 128-181 kg). Of the 304 nonpregnant females, 13 had reproductive tract pathologies, including endometriosis, uterine or ovarian cysts. There was a seasonal distribution of mating activity; over two-thirds of conceptions took place between September and January, about two months prior to the rainy season (Nov-Mar). As has been demonstrated in other populations of free-ranging African elephants, analyses show that that age and climate affected reproductive success of elephants in South Africa even though most females were reproductively active. Determining if these trends are associated with ovarian inactivity is the next phase of this study. With hormone kits that will facilitate measuring steroid hormones in the field, it will be possible to determine if progestin concentrations remain at baseline during the dry season and after females reach 50 years of age. If it does, this could be functionally similar to the ovarian inactivity observed in *ex situ* elephants year round, albeit at an earlier age. Determining once and for all if ovarian inactivity is strictly limited to zoo elephants could aid in the development of long-term management strategies to help ensure survival of elephants in zoos and the wild.

Introduction:

The elephant estrous cycle lasts 12-16 weeks, with an 8-12 week luteal phase and a 4-6 week follicular phase based on weekly progestin analyses (Plotka et al., 1988; Hodges, 1998; Brown, 2000). However, more than one third of reproductive-aged African savannah elephants in North American facilities that are hormonally monitored exhibit irregular cycles or no ovarian activity (Brown et al., 2004; Brown et al., 2005). What causes this problem is not known, but it appears to be related to the age and social rank of the female (Freeman et al., 2004; Freeman et al., in review). Whether it is exclusively a captivity-mediated phenomenon is also not known because hormonal characterizations of ovarian cycles have only been conducted on captive animals. Although it is assumed that free-ranging elephants are always pregnant, lactating or cycling (Hall-Martin, 1987), wild elephant populations have never been monitored in the

context of individual ovarian activity. Birth and conceptions rates of elephants in many free-ranging populations suggest that age and precipitation affect reproductive success.

African elephants live in complex hierarchical groups of related females whereby each individual holds a status relevant to age, size and individual disposition (Dublin, 1983; Thouless, 1996; Archie et al., 2006a; Archie et al., 2006b) and the largest, eldest female in the family is the matriarch (Douglas-Hamilton, 1972; Poole and Moss, 1989; Archie et al., 2006a). A dominance hierarchy also is important for maintaining social harmony among *ex situ* elephants (Schulte, 2000), and a single female often acts behaviorally like a matriarch (Olson and Wiese, 2000; Schulte, 2000) even though the social structure of captive groups differ from those in the wild (Schulte, 2000). This older, dominant elephant typically does not cycle (Freeman et al., 2004; Freeman et al., in review). We hypothesize that acyclicity may be an adaptation of existing evolutionary mechanisms whereby dominant females dedicate more energy to their 'family' than towards their own future reproduction. Supporting this notion are demographic studies that show reproductive rates decline with age in free-ranging African elephants (Laws et al., 1970; Smuts, 1975; Moss, 2001) as they reach matriarchal status (B. Archie, Amboseli unpublished data). Environmental factors also impact reproductive success. Although elephants can breed year round, conception and birth rates show strong seasonality relative to precipitation (Laws and Parker, 1968; Hanks, 1969; Smuts, 1975; Dublin, 1983; Foley et al., 2001; Wittemyer, 2001). The mechanisms that control reproductive success with age, social rank and precipitation are not known because no one has evaluated the physiology associated with altered reproductive function. If these environmental and demographic factors cause reduced progestin concentrations in free-ranging cycling females, it could be functionally similar to the ovarian acyclicity observed in *ex situ* elephants year round.

To increase our knowledge of reproduction in wild African elephants, we analyzed the data collected from elephants culled in the Kruger National Park (KNP), South Africa over a 20-year period. The objective of the current study was to find evidence that age and precipitation impact reproductive success and the ovarian cycles of African elephants in South Africa. If they do, we plan to embark on a long-term study comparing progestin concentrations of individuals relative to age, social rank and precipitation to determine how these factors affect estrous cycle dynamics in free-ranging elephants and if ovarian acyclicity indeed is a phenomenon strictly limited to zoo elephants.

Methods & Materials:
In an effort to reduce elephant densities and preserve biological diversity, 14,629 elephants were culled in the KNP between 1967 and 1999 (Whyte, 2001). At each culling operation, elephants were selected at random regardless of sex or age class and comprised one or more family units (Whyte, 2001). Each August/September, aerial censuses of the elephant population were conducted and reduction quotas were set with the goal of maintaining the population near 7,000 elephants (0.32 elephants/km^2). The culls occurred between April and August, following the census values from the previous year (Whyte, 2001). Data pertaining to these reductions such as when and how the elephants were taken, individual age estimations based on molar dentition (Laws, 1966; Jachmann, 1988), shoulder height and tusk length were collected over 14 different years (1975, 1977, 1979, 1985 and 1987-1996). This information was compiled in a database that contains records on 4739 elephants. For a subsample of those elephants (2790 individuals from breeding herds and 503 bulls), reproductive organs were removed, examined and cataloged (Whyte, 2001). Thus, the database contains ovarian, uterine and mammary characteristics of 1465 reproductive-aged females (> 8 years of age). Ovaries were examined macroscopically and categorized according to existing structures (i.e., size of follicles, presence of corpora lutea/albicantia). Both horns of the uterus were dissected and developing fetuses or placental scars noted (Whyte, 1996). If the fetus was large enough (>138 days), it was weighed and the sex determined. Fetal age was determined using the method of Huggett and Widdas (1951) and based on an average birth mass of 120 kg (Perry, 1953) and a gestation length of 22 months (660 days) (Lang, 1967). Conception date was determined by subtracting fetal age from culling date and the projected birth date was calculated by adding 660 days to the conception date (Whyte, 1996).

Results:
The sex ratio of all culled elephants in the database was 1:2.10 (884♂:1857♀); however the ratio was much closer to one (1:1.08; 711♂:770♀) for the youngest elephants (≤ 14 years of age). The youngest age of conception was 8 years (n=6, 8.0%) and by 12 years of age nearly all females were sexually mature; they had either corpora lutea or albicantia present on the ovaries, or were pregnant and/or lactating (Table 1). From 14 years onward, the percentage of reproductively active females (pregnant and/or lactating) was >90%; however, this percentage declined dramatically when females reached 50 years of age (Fig. 1). Approximately one-fifth (20.8%) of culled females were nonreproductive (not pregnant or lactating); these individuals were mostly in the youngest (<15 years) and oldest (>45 years) age classes. Ninety-four (31.6%) of those females had active ovaries, but were not lactating or pregnant at the time of culling. Another third of those females were prepubertal (n = 89, 29.9%; with ovarian follicles <5 mm) or pubertal (n = 22; 7.4%; with ovarian follicles > 5mm but no corpora lutea or corpora albicantia present). The remaining nonreproductive females (n = 92, 31.0%) had no evidence ovarian activity listed in the database.

A total of 695 females were pregnant at the time of culling. Twenty carried fetuses that were at or near term (≥ 640 days; Table 2). The seven largest term fetuses were all males (range: 107-181 kg; Table 2). Four females (0.6%) carried twins, while six (0.9%) carried fetuses with abnormalities, and another 12 (1.7%) had dead or evidence of aborted calves. Of the 297 females that were not reproductively active, 18 (6.1%) had uterine abnormalities such as endometriosis and cysts, while three others (1.0%) had ovarian cysts.

There was a seasonal distribution of mating activity. The majority of conceptions (70.9%) took place between September and January (Fig. 2) and significantly more calves were conceived in November than April or July (Kruskal-Wallis One-Way ANOVA, $H_{11} = 34.1$, $P < 0.001$). The majority of births (71.3%) took place between July and November (Fig. 2) and significantly more calves were born in August and September than February or March (Kruskal-Wallis One-Way ANOVA, $H_{11} = 43.8$, $P < 0.001$). On average, KNP received 520.0 ± 26.1 mm of precipitation each year (1974-1995). Most of this precipitation (78.4%) fell over 5 months (Nov-Mar; Fig. 2). The percent of conceptions each month of the year was positively correlated with average monthly precipitation (Pearson Product Moment Correlation, r = 0.239, $P < 0.001$), while the percent of births was negatively correlated with precipitation (Pearson Product Moment Correlation, r = -0.258, $P < 0.001$). Neither conception month, nor birth month were related to the age of the female (Spearman Correlation, conception: r = 0.03, $P = 0.41$; birth: r = - 0.00, $P = 0.95$).

Discussion:
Most of the female elephants culled in Kruger National Park over this 20 year period were reproductively active (pregnant and/or lactating), thus cycling females were relatively rare. However, our analyses demonstrate that age and precipitation affected reproductive success. The percent of pregnant and/or lactating females declined as females reached an older age (> 45 years). Only half of these non-reproductive, older females showed signs of ovarian activity; they had corpora lutea or albicantia present on their ovaries. Similar age-related trends have been documented for elephant populations in Kenya and Uganda (Laws et al., 1970; Moss, 2001). Whether this phenomenon is evidence for reproductive senescence or the result of other factors has yet to be determined. Although elephants conceived throughout the year, reproductive activity was associated with changes in the annual precipitation. Most of the predicted births preceded peak rainfall; such timing ensures females are in optimal condition as lactational demands increase (Laws and Parker, 1968). Reproductive seasonality also has been documented for populations of elephants in Kenya, Tanzania, Uganda, Zambia (Laws and Parker, 1968; Hanks, 1969; Laws, 1969; Poole, 1989; Poole and Moss, 1989; Foley et al., 2001; Wittemyer, 2001). Poor nutritional quality during the dry season causes a decline in body condition which may negatively impact the success of implantations and early pregnancies (Laws and Parker, 1968; Foley et al., 2001). Yet, dry ecological conditions also cause lower progestin concentrations in pregnant elephants (Foley et al., 2001) and could hinder normal ovarian activity.
For the next phase of our research, we plan to investigate the physiological mechanisms associated with reduced reproductive success. Using hormone kits that are designed to facilitate measuring steroid hormones in the field, it will be possible to determine if progestin concentrations remain at baseline during

the dry season and once females reach advanced age. If it does, this could be functionally similar to the ovarian inactivity observed in *ex situ* elephants year round, albeit at an earlier age. Determining once and for all if ovarian inactivity is strictly limited to zoo elephants could aid in the development of long-term management strategies to help ensure survival of elephants in zoos and the wild.

Acknowledgments:
The authors wish to thank South Africa National Parks for granting (SanParks) us access to this data. We would also like to acknowledge all of the individuals within SanParks that were responsible for collecting and tabulating the data. We wish to thank the International Elephant Foundation for funding travel associated with acquiring the database. Additional research support was also acquired from the Smithsonian Undersecretary of Science's Endowment Fund and Friends of the National Zoo (FONZ).

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Dystocia - an increasing problem in captive breeding programs. Causes and treatment

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Elephants kept in zoos generally enter puberty at a much younger age than in the wild. This has negative consequences for the reproductive organs. The occurrence of endometrial or ovarian cysts (frequently found in African and Asian elephants), benign myometrium tumors, cystic malformations (leiomyomas, exclusively found in older Asian females) are the result of (normal) cyclic changes in the reproductive organs, without resulting in pregnancy. This phenomenon also is found in other nulliparous females of long-living species in captivity, and is termed 'asymmetric reproductive aging'. In the wild, most females are either pregnant or lactating. They experience comparatively few reproductive cycles in their lifetime and consequently fewer reproductive disorders. In addition to the direct pathologic impact of continuous non – fertile cycle activity, there is a tendency for older first-time mothers in captivity (age 25+ years) to experience severe dystocia. The main reasons for dystocia are the development of over conditioned calves (up to 180 kg) combined with malposition and the loss of flexibility in the pelvic region. The perinatal death rate for first-born calves in this age group is between 30% and 100%. Worldwide the percentage of affected females increased dramatically over the last decade due to enforced breeding programs in the captive populations including older nulliparous cows. Important for an efficient dystocia treatment is an early diagnosis of this problem. Therefore all near-term pregnant elephants should be monitored for blood progesterone levels on a daily basis starting before observing the first signs of labour activity or discomfort. They should be also conditioned for rectal palpations as well as transrectal and transcutaneous ultrasound examinations which allows the best option for monitoring the health of the baby. Primary focus of dystocia treatment should be the rescue of the life of the mother without surgical interventation. That would allow future breeding with this female. However, some situation such malposition or oversized calfs require surgical intervention. The first step would be the episiotomy which allows a limited correction of the calf position and a forced extraction of the dead calf through an incision in the perineal region. A fetotomy through the perineal approach is indicated if the malposition very complicated or the size of the calf to big for an entire extraction. So far all attempts to perform a Caesarean in elephants failed and caused the death of the cow.

Due to the dramatic increase of dystocia cases preventive methods such as new conditioning and exercise programs for pregnant elephants and optimized pregnancy diets with balanced calcium levels should be developed and applied.

Chronoethology of African elephants (*Loxodonta africana)* in Zoological Gardens

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Introduction:
The behavior and body functions of animals are controlled by internal clocks. This multioscillator system needs an external input called zeitgeber (German for time clues) to become synchronized with the environmental periodicity (e.g. day/night rhythm). If the external zeitgeber is not strong enough it can lead to a desynchronisation of the clock system, which can cause health problems and has consequences for the well-being of the animal.

In chronoethological studies the actual time at which a specific behavior is shown is recorded over an extended period of time. To show the time structure of this behavior a so-called "chronoethogram" is generated (Fig. 1).
A "norm-chronoethogram" shows the behavioral pattern in a "normal" situation and can be used as a reference for further chronoethological research, for they show the reaction of animals to different husbandry conditions and help to identify problems in management and health care. Also long lasting rhythms (e.g. seasonal processes and reproduction cycles), which influence animal behavior, can be considered. A substantial advantage of the chronoethological method is that it is non-invasive and enables us to discover rather early conspicuous behaviors, their reasons and the dynamic of the whole process.

To give a first insight into the PhD project on chronoethology of African elephants in captivity, a "norm-chronoethogram" has been created. Based on this, we show how the behavior of African elephants is influenced by seasonal aspects and husbandry conditions.

Method:
Ten African elephants (*Loxodonta africana*) have been observed by time lapse video recording during the night in their indoor enclosures (Tab. 1). At Opel-Zoo Kronberg (Germany) the animals have been observed for two years and at Vienna Zoo (Austria) for one year. Husbandry differs distinctly between these zoos. At Opel-Zoo the elephants are chained at night and stay side by side with the possibility to get in contact with each other. The elephants at the Vienna Zoo roam freely in their enclosure at night and stay together in the group. In summer they are able to use the outdoor as well as the indoor enclosure during night.
To obtain a chronoethogram the behavior was noted using "instantaneous (point) sampling method" (Altmann 1974; Martin 1993) in time intervals of five minutes.
Following behaviors have been recorded: resting in a lying and standing position, food intake, stereotypic and social behavior.

Results:
The chronoethogram shows that elephants are usually active until midnight followed by a resting period until 5:00h in the morning and start activity again in the early hours of the morning, around 6:00h (Fig.: 2). During the main resting period short activity bouts occur. The occurrence of several resting periods during the night is known as a polyphasic activity time pattern (Hassenberg 1965). Several studies about the nocturnal behavior of elephants (Tobler 1992, Wuestenhagen 2000, Brockett 1999, Kuehme 1962) confirm that the main resting period lies after midnight.

Comparing the activity time patterns of summer and winter, a difference is clearly visible (Fig. 3a,b; 4a,b). The animals show an additional resting period before midnight, between 18:00h and 20:00h. If the mean values for resting behavior at Opel-Zoo were compared, the animals rest 390 minutes in winter and 316 minutes in summer (Chi² test: 7,756 df=1; p=0,005). At Vienna Zoo the animals rest for 326 minutes in winter and for 247 minutes in summer (Chi² test: 10.892; df=1; p=0,017). In both zoos the elephants rest significantly more during winter. However, it is not clear yet if endogenous or exogenous influences are the reasons for these differences. Tobler (1992) mentioned that seasonal differences in sleep behavior of Asian elephants (*Elephas maximus*) are an effect of the earlier retiring hours of keepers in winter. This PhD project will help to find the reasons for these seasonal effects.
The comparison of the chronoethograms of both zoos shows that the general polyphasic structure is similar, but there are differences in the duration of resting behavior (Figures 3a,4a; 3b,4b). At Opel-Zoo, likewise in winter and summer, the elephants show more resting behavior than at Vienna Zoo. For a better comparison the average of total resting behavior of all animals per night was calculated for each Zoo. While at Opel-Zoo the animals rest in winter an average of 390 minutes per night, at Vienna Zoo the average resting time is 326 minutes per night. The times differ significantly (Chi² test: 5,721; df=1; p=0,017). In summer the average resting time at Opel-Zoo is 316 minutes and at Vienna 247 minutes (Chi² test: 8,456, df=1; p=0,004). This could be seen as an attribute to the possibility to move freely at night. Due to the chaining at Opel-Zoo the elephants are not able to move around. After the complete food is eaten they start to rest in a standing position, since there is nothing left to engage with. At Vienna Zoo they have the possibility to walk around and search for food. During the summer they are also able to use their outside enclosure where they mostly have some branches to engage with.
In addition to husbandry conditions there are other factors like age, physical fitness or social issues, which may influence resting behavior in elephants. To find out more about the reasons for these differences further studies need to be made.

Conclusion & Future Prospects:

The first results show, that African elephants in zoological gardens have a polyphasic behavioral time pattern with a main resting period after midnight. This time pattern differs between the seasons. In winter the animals rest longer than in summer, as they show an additional resting period before midnight.
As a consequence from different husbandry conditions it could be seen that animals, which do not have the possibility to roam freely at night, spend more time with resting behavior.
These results build the basis for further research within this study. One aim is to find out more about which and how endogenous and exogenous modify the behavioral time pattern of African elephants. It should also be investigated which factors act as —zeitgeber for these animals and how handling and different husbandry conditions influence the time pattern.
In general this PhD project should demonstrate that chronoethology can point out husbandry and health problems of an African elephant. Therefore it is necessary to search for behavioral parameters which can be indicators for indisposition. This will be the next topic addressed in this PhD project. In the field of well-being chronoethology is a very promising, non-invasive method to find out more.

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Table 1: Observed African elephants

Opel-Zoo			Vienna		
Name	Gender	Age	Name	Gender	Age
Aruba	female	26	Tonga	female	21
Zimba	female	24	Sabi	female	20
Wankie	female	24	Drumbo	female	30
			Jumbo	female	46
			Mongu	female	2
			Abu	male	4
			Pambo	male	13

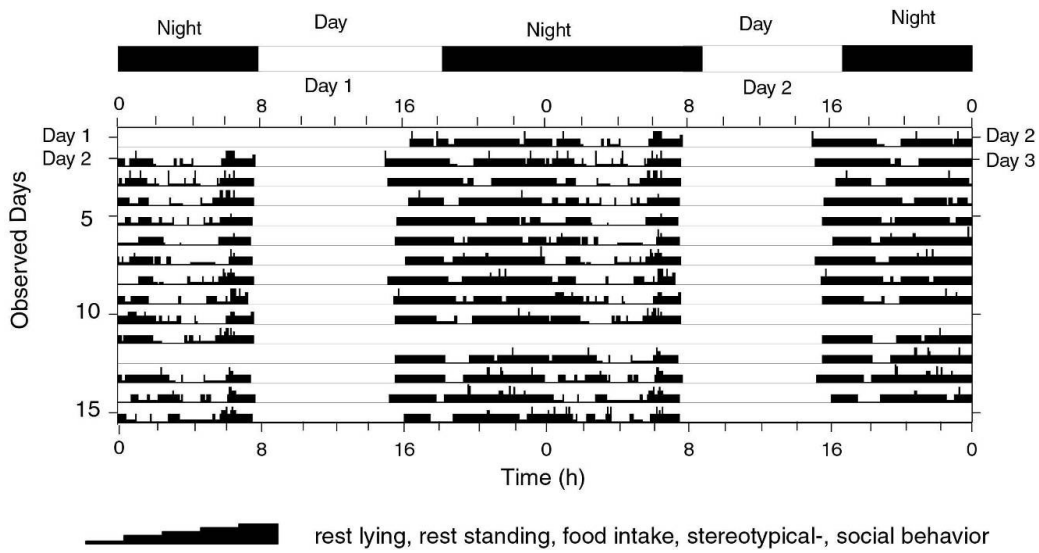
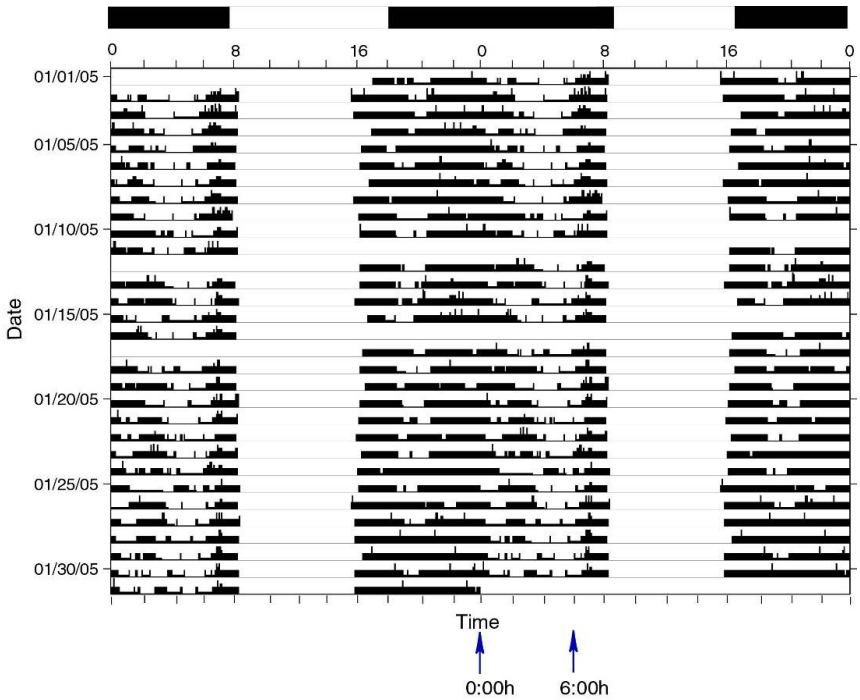


Fig 1: How to read a chronoethogram? - 48 consecutive hours (Day 1, Day 2) per line are plotted underneath repeating the last 24 hours (Day 2) of the first line as the first 24 hours (Day 2) in the second line and so on. Different levels of beams show different behavioral categories, with lowest level rest lying and highest level social behavior.

Figure 2: Norm-Chronoethogram Tonga, Vienna. Several resting periods occur during night. Main resting period from 0:00h until 6:00h (arrows).



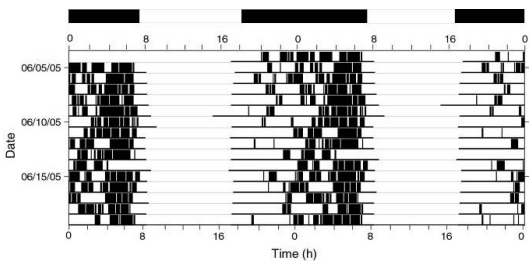


Figure 3a: Filtered chronoethogram of resting behavior; Zimba Opel-Zoo in June 2005

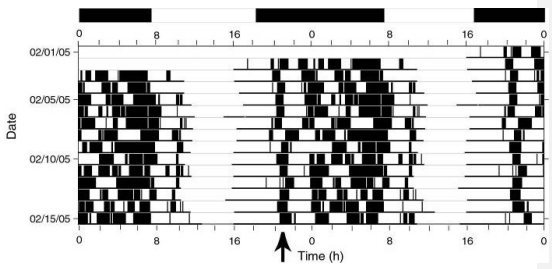


Figure 3b: Filtered chronoethogram of resting behavior; Zimba; Opel-Zoo in February 2005; Additional resting period before midnight (see arrow)

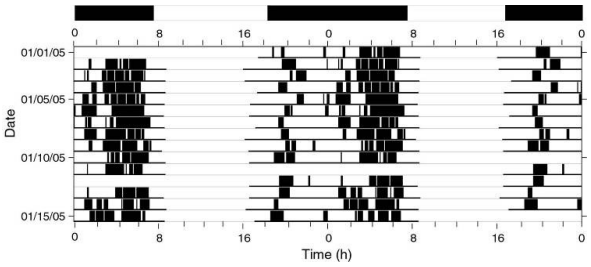


Figure 4a: Filtered chronoethogram of resting behavior; Sabi Vienna in July 2005.

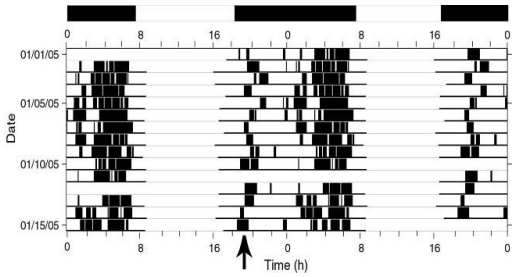


Figure 4b: Filtered chronoethogram of resting behavior; Sabi Vienna January 2005. Additional resting period before midnight (see arrow)

Habitat evaluation of Asian elephant (*Elephas maximus)* and spatial aspects of human elephant conflict in Manas National Park using Remote Sensing/GIS

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Introduction:

The Asian elephant *Elephas maximus*, once ranges across the Tigris Euphrates in west Asia eastward to the Yangtze Kiang and probably in northern China, but now its habitat has been shrunk drastically to few pockets in the biologically rich tropical forest of Asia (Sukumar, 2003). Although its overall range is still remains the same, but expansion of human habitation, destruction of habitat for agriculture, and poaching have resulted in a sharp decline of the wild population, besides fragmenting the habitat (Choudhury, 1999).

India is the only country, which has the largest surviving population of elephants. There are at least 21,000-25,000 wild elephants still left in the country. The distribution of wild elephants in India can be described under four regions-northern, northeastern, central and southern India (Sukumar, 1986).

The estimated population of elephants is about 11,000 in the northeastern region, the largest in the Indian subcontinent (Choudhury 1999). However, it is at high risk for its survival because of large scale ivory poaching, fragmentation and degradation of its habitat. One large population of 3800-5800 elephants ranges along the Himalayan foothills from northern West Bengal, eastward through Assam touching southern Bhutan and Arunachal Pradesh and Manas National Park is the key conservation area in this landscape (Sukumar & Santiapillai 1996; Santiapillai & Jackson 1990).

Much studies has been conducted on Asian elephant in the past (Daniel, 1980; Ishwaran, 1984; Jackson, 1985; Oliver, 1978; Santipillai& Suprahman, 1986; Storer, 1981; Sukumar, 1989), particularly in southern India. However, its status and ecology in north-eastern India remains poorly known (Choudhury, 1999). For proper management planning, ecology of Asian elephant should be studied including its habitat utilization pattern, seasonal movements and behavior in north-east India. Petite information on its status in north-east India can be found in Choudhury (1991, 1992a, b, 1993a,b, 1995) and Williams and Johnsingh (1996a,b). Recently the status of Asian elephant in North-East India and conservation priorities were discussed in detail by Choudhury (1999).

The Manas National Park is perhaps the only remaining safe home for elephants in entire Himalayan foothills in Assam. The Park plays a vital role in movement of elephants along the northern West Bengal, Bhutan and Arunachal Pradesh. The Park is home of more than 500 elephants (as per 2002 Forest Dept census). It is also part of the Chirang Ripu Elephant Reserve, declared in the year 2003 by Government of Assam, with an area of 2600 sq. km. Despite the importance of Manas landscape and its current elephant population, there is a huge gap on scientific data of elephants from Manas National Park. To understand the ecology of elephants in the foothills requires characterization of the natural habitats, land use patterns within and outside habitats and seasonal movement of elephants. We developed a vegetation map and a land use map of the study area using remote sensing and GIS to understand their seasonal movement and distribution.

This paper signifies a detailed account of habitat utilization patterns during different seasons and current status of human elephant conflict in Manas National Park based on our fieldwork from September 2005 to September 2006.

Study Area:
Manas National Park (Fig 1) (26°35'-26°50'N, 90°45'-91°15'E) is located in foothills of the Bhutan Himalayas in Baksa and Chirang districts of Assam. It was declared as a National Park in 1990 with an area of 500 sq. km, which is the core area of Manas Tiger Reserve. Altitude of the Park ranges from 50 m MSL to 200 m MSL. The Manas National Park is continuous with Royal Manas National Park of Bhutan on the northern side. The climate is moist tropical with annual rainfall between 3000 mm to 4000 mm. The climate can be divided in four distinct seasons viz. winter, pre-monsoon, monsoon and retreating monsoon on the basis of variation in rainfall, temperature and winds (Borthakur, 1986). Manas is noted for its spectacular scenery, with a variety of habitat types that support a diverse fauna, making it the richest of all Indian wildlife areas and probably for that reason Manas harbours by far the greatest number (21) of the Wildlife (Protection) Act, 1972 Schedule I mammals of any protected area in the country (UNEP WCMC 1997).

Methodology:
The study area was extensively surveyed to classify the land cover. Multiple GPS points were collected from the different landscape elements (LSE) types. For change detection we used four satellite imageries of 1977, 1991 (LANDSAT TM), 1998 (IRS 1D LISS III) and 2004 (IRS 1D LISS III).
For stratification of habitat, vegetation types were classified using quadrate method following line transects. This study was largely aimed to complement the study of elephant ecology, in particular the patterns of seasonal movement and habitat utilization. Plant species were identified with the help of standard field guide following Hajra and Jain (1978) and Kanjilal *et al*. (1934-1940).

Seasonal variation in habitat utilization pattern was studied following indirect-dung count method (Barnes and Jenson, 1987). A total of 15 transects of 1 to 2 km in length were laid covering different major vegetation types after Varma *et al*., (1995). The dung density was calculated using software DISTANCE 4.1 (Buckland *et al.* 2001).

For conflict study, the following aspects were studied - extent of conflict, patterns and economic impacts of crop raiding, expectation of local people and methods of prevention and mitigation commonly used. An overview of crop raiding data was collected from records maintained by Forest Department and exclusive field visits. Raided villages were visited and affected farmers were interviewed to obtain detailed information on raiding patterns. Methods used for reducing or driving away elephants, were noted carrying out inspections of the villagers, as well as assessing local people's reaction to the effectiveness.

Results and discussion:

Land Use changes:
Anthropogenic changes in land use and land cover are being increasingly recognized as critical factors influencing global change (Nagendra, *et al.* 2004). Remote sensing provides an effective tool for landscape pattern analysis, though it is only in recent years that its potential for landscape analysis has began to be fully utilized (Forman, 1995). Land use change due to human pressure has been identified as the major cause for biodiversity losses (Nagendra and Utkarsh, 2003). We classified the seven types of landscape elements (LSE) in Manas National Park. Overall landuse pattern changes from 1977 to 2004 are shown in Fig. 2.

These landscape elements are-
1. Semi Evergreen Forest: Currently semi evergreen forest covers an area of 177.02 km^2 in the Park. Most of the semi evergreen patches are well protected and intact, lies in the northern part of the Park touching Indo-Bhutan border. These patches have substantial value fascilitating elephant's trans-boundary movement.

2. Moist Mixed Deciduous Forest: Although our study suggested the area of mixed moist deciduous forest reduced to only 65.61 km^2 in 2004, its importance cannot be underestimated. Most of the elephant's food plants recorded in our study is of mixed moist type.

3. Grassland: The dry grassland of the Park has gone up from 120 sq. km (24 %) in 1977 to 202 sq. km (40%) in 2004, whereas the swampy grassland has drastically reduced from 94 sq. km (18%) in 1977 to 12 sq. km (2.45%) in 2004 (Fig. 3). The major causes for this severe reduction of swampy grassland are heavy siltation along the river edges, reduction in water holding capacity of soils because of unscientific grassland burning. Swampy grassland is a prime habitat for elephants in Manas; therefore its reduction signifies a major concern.

4. Flood Plains or River sand: The flood plain area has gone up from 23 sq. km (5%) in 1977 to 28 sq. km (6%) in 2004. Heavy silt deposition is prime cause of this increase.

5. Wetlands: The water body within the Park has gone dried from 9 sq. km (2%) in 1977 to 5 sq. km (1%) in 2004. Water source is a major requirement for elephants to survive; new tactics should be incorporated to stop further reduction in wetland size. Permanent waterholes should be developed inside the Park.

6. Human Settlement/ Cultivation: From 1977 to 2004 an area of 20.05 sq. km. (4.08%) has been deforested within the National Park boundary, out of which 15.33 sq. km. has been deforested in the southwestern part of the Park where rest 4.72 sq. km has been deforested in the eastern most part of the Park. Ethnic disturbances in the nineties are the major cause for this as timber smugglers and some opportunist villagers took the opportunity and destroyed the forest.

Population structure and Habitat utilization:
A reliable estimate of population size and assessment of the population structure as related to demography are important to planning for the conservation of a species, especially in a protected area that is under intensive management (Sukumar *et al.*, 2003).
Database information on its population status always helps in proper management practice. A total of 120 individuals of elephants were sighted during the study period at a ratio of 2:1 female: male.

The habitat utilization pattern in different habitats in different seasons was studied using indirect evidence such as dung piles, feeding signs and track signs. Dung density was recorded highest in grassland (1748 ± 178) and lowest in mixed moist deciduous (125 ± 41.38) (Fig. 4). Elephant's movement was more or less confined within an altitudinal range of 50 m to 100 m MSL (Fig 5).

During the study period, 18 species of flowering plants were recorded as a food plant of elephants. Food plants such as *Sterculia villosa, Careya arborea, Dillenia indica, Albizzia spp*. are favored by elephants during dry periods where as after first shower of rain elephant mostly favored species like *Narenga porphyrocoma, Saccharum spontanuem, Themeda arundinaceae* and *Imperata cylindrica.* Elephants feed bark of certain species such as *Careya arborea, Sterculia villosa, Michelia champaca, Bombax ceiba* etc.

Human-elephant Conflict:
The conflict problem is a cause for concern because it threatens to erode local support for conservation in areas where human life and property are at high risk of destruction by wild elephants (Williams and Johnsingh, 1997; Thouless, 1994; Lahm, 1996)

Raiding pattern and crop preference:
There are around 305 cases of crop raiding filed in the Forest Department records, which include raiding of both field crops as well as backyard garden crops. The intensity of crop raiding attains the highest level as the crops get full maturity. Generally the peak raiding moment arrives twice a year as the paddy harvesting time approaches, once in June-August (for *Ahu* paddy) and another in October-November (for *Sali* paddy) (Fig 6). Of the raided crops indubitably Paddy (69%, n=269) suffered highest proportion of damage, which is probably directly associated to its greatest availability due to huge extent of cultivation in the study area.

During the months of December up to April, intensity of crop raiding was very low. Because, December is the post-harvesting month, so it remains no longer attractive to the elephants as most of the crop fields are cleared up and it remains unplanted till January. In February, sowing of Ahu paddy starts and till the month

of May the paddy remains in the vegetative stage, which is although raided but preferred comparatively less by the elephants. With increasing maturity of paddy the intensity of raiding also increases. Paddy crops were much preferred followed by fruits (Fig. 7).

It has been found that the single animals tend to raid crops more times (59%, n=134) than the female led family herds (41%, n=93) (Fig. 8). Singles generally visit the villages and raid the crops on round the year basis, whereas the herds on seasonal basis. The average herd size recorded was 8 with raiding group sizes ranging from 1 to 16. Majority of the single crop raiders i.e., 88% were *Makhnas* (n=118) and only 11.9% (n=16) were Tuskers.

Human injury and man slaughter by elephant:
Human injury and death by the raiding (rogue or disturbed) elephants is one of the very crucial aspects of the human-elephant conflict. Since 1991 till 2006 there are only nine death cases (29%) and 22 human injury cases (71%) reported. In majority of the cases the *Makhna* appeared responsible for 61% death and injury cases, tusker was responsible for 33% cases and herd in only 6% cases. In the majority of the human death/injury cases most of the elephants responsible were either in the state of *musth*, injured or a rogue individual. However, there were some accidental encounters also where both humans and elephants were unaware about each other's presence due to obscurity at night and suddenly came across.

Conservation Measures:

1. Infrastructure enhancement & protection: Decade long civil unrest in had led severe infrastructure damaged in the Park. Although renovation works has started in the Park that is not adequate, all the destroyed camps, roads and bridges should be build to strengthen protection. To mitigate human-elephant conflict special protection squad should developed with better communication network facility.
2. Habitat improvement & management: Improvement of degraded habitats is utmost necessity to provide habitats and foraging sites to elephant. No new encroachment should be allowed to take place in the Park. Due to human pressure the habitats close to southern boundary has been degraded; proper management planning should be done to natural regeneration. The grassland management should address properly. Permanent water holes should develop inside the Park
3. Eco-development: The people living on the southern boundary of Park are highly depended for thatch, fuel wood, timbers, food and housing material etc. Moreover, economic status of local community is very poor. Eco-development initiative needs to be encouraged in fringe villages. The ecotourism should promote in villages, which will help to developed more cordial relationship between the villages and forest department. Initiative like Manas Maozigendri should encourage to community participation for long term conservation of Manas landscape.
4. Awareness and Education: Mass awareness programme in the fringe villages is a must to reduce anthropogenic pressure on the Park. Awareness will also help in minimize human-elephant conflicts around the Park. Alternative cropping pattern in conflict villages would be only possible through awareness.
5. Extension of Manas National Park: The Reserve Forests (Manas, Deodhara, Batabari) on western and eastern side should be included in the Manas National Park.
6. Monitoring of elephant population: Elephant demography in the Park should be recorded at regular interval at least once in a year.
7. Orientation of policy makers: The policy makers often make chilly decision, hence orientation programme should be developed to motivate them on legal as well as biodiversity aspect.
8. Compensation: Loss of life, property and crop damage are responsible for increased animosity between human and elephant. Compensation process should be expeditious for loss of life and property.

Acknowledgement:
We are grateful to Mr. M. C. Malakar, CCF (Wildlife), Assam for provide permission to work and for cooperation in conducting the studies. The study was generously funded by US Fish and Wildlife Service, special thanks are due to Dr. Meenakshi Nagendran. We thank Mr. Abhijit Rabha, Field Director and Mr. Ritesh Bhattacharjee, Deputy Field Director, Manas Tiger Reserve for their cooperation and valuable suggestion during the study. We are especially thankful to Prof. R. Sukumar, Prof. P.C. Bhattacharjee,

Surendra Varma, Dr. Arun Venkataraman, Dr. Anwaruddin Choudhury and Sonali Ghosh for their valuable inputs to this work at various stages. We would like to thank our colleague at Aaranyak Dr. Bibhab K. Talukdar, Ashok Dey, Dr Hillol Jyoti Singha and all others for their support and encouragement. We would like to thank all Forest Range officers (M.C. Brahma, L. Ramsiwary and A. Rajbongshi), Foresters, Forest Guards, Mahouts and Conservation volunteers their cooperation and assistance during fieldwork.

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Habitat evaluation of Asian elephant *Elephas maximus* and spatial aspects of human elephant conflict in Manas National Park using Remote Sensing/GIS

Fig. 1: Study Area

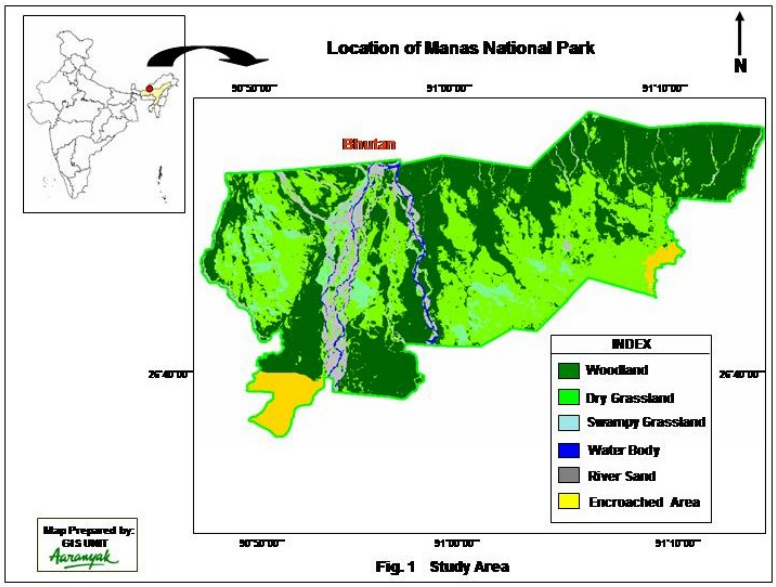


Fig. 2: Changes in land use pattern from 1977 to 2004

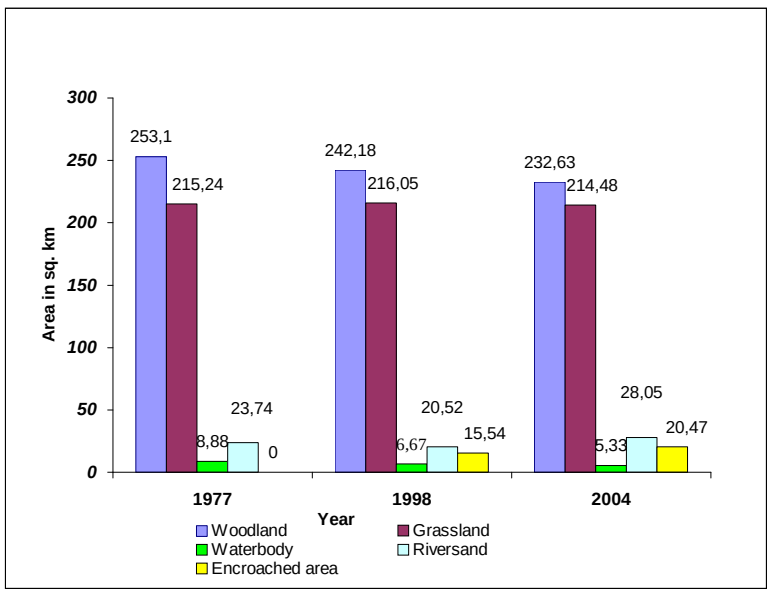


Fig. 3: Grassland pattern changes from 1977 to 2004

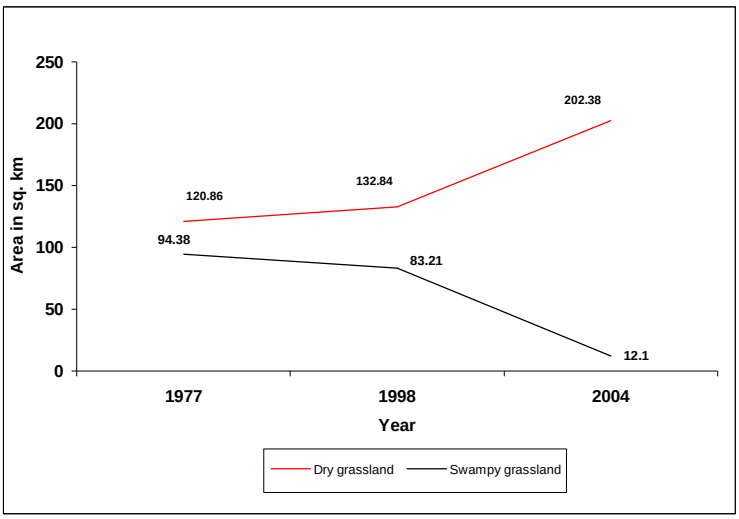


Fig. 4: Dung density recorded in different habitats

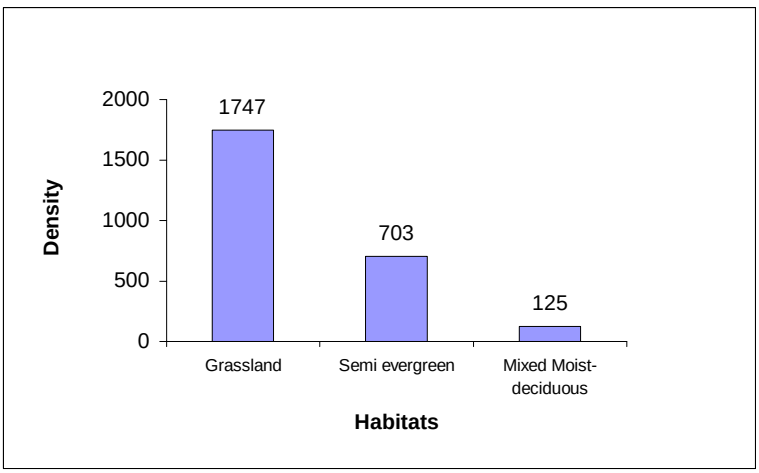


Fig. 5: Altitudinal distribution of elephants

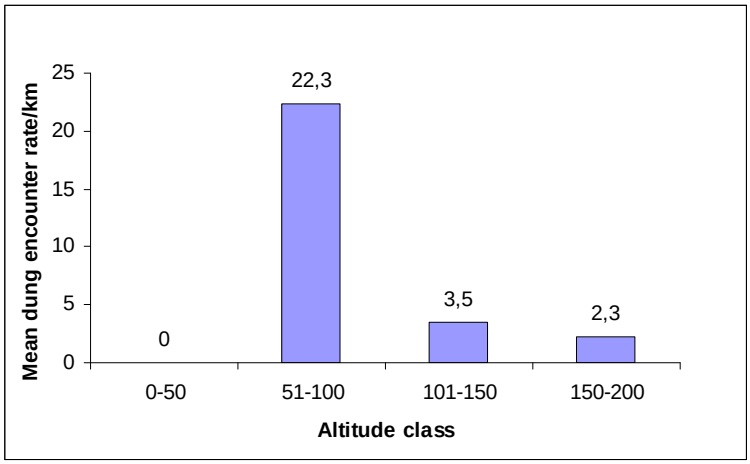


Fig. 6: Intensity of damage at different months

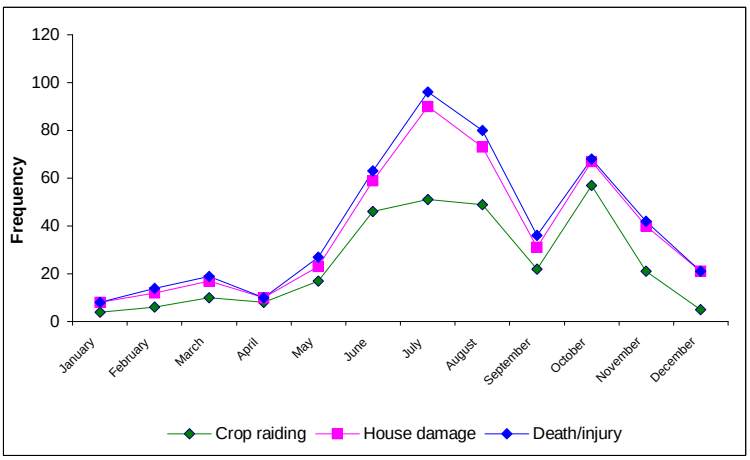


Fig. 7: Crop preference by raiding elephants raiding group size

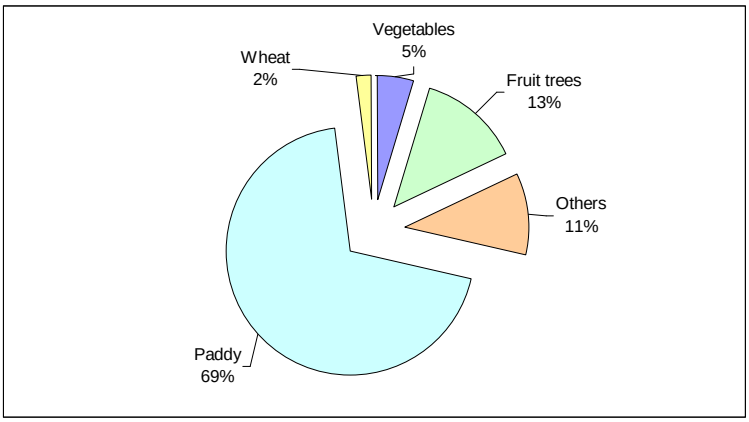
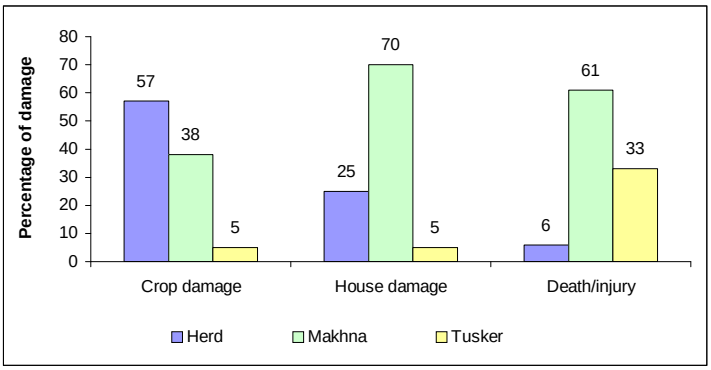


Fig. 8: Damage caused by Wild Elephants



Tuberculosis in elephants: An update on diagnosis and treatment; implications for control in range countries

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Introduction:
Tuberculosis (TB) is an ancient disease of animals and humans. Skeletal lesions characteristic of TB have been found in 52 % (59 of 113) of recently examined mastodon (*Mammut americanum*) skeletons and the investigators suggest that a TB pandemic may have played a role in the extinction of the mastodon at the end of the Pleistocene (Rothschild 2006).

TB (and its treatment) was described in extant elephant species by Ayurvedic physicians in Asia over 2000 years ago (Iyer 1937, McGaughey 1961). TB continues to plague modern elephants and the disease has been reported in captive elephants in the U.S. and Europe (Lewerin 2005; Mikota 2000, 2001; Moller 2005). Sporadic published reports of cases in Asia (Bopayya 1928, Chandrasekharan 1992, 1995, 2002, Chakraborty 2003, Iyer 1937, Narayanan 1925, Rahman 2003, Ratanakorn 2001) and observations by authors (Dr. Cheeran, Dr. Gairhe) suggest that TB is endemic among captive elephants in Asian range countries.

Etiology and Transmission of TB:
TB is caused by bacteria in the genus *Mycobacterium*. Over 100 species comprise this genus. Mycobacteria infect a broad range of species including humans; non-human primates; domestic and non-domestic ungulates and carnivores; marine mammals; psittacine birds; reptiles; and fish. Specie susceptibility to specific mycobacteria varies (Montali 2001).

In mammals, the term "tuberculosis" defines disease caused by *Mycobacterium tuberculosis* complex organisms. The *M. tuberculosis* complex includes *M. tuberculosis, M. bovis, M. africanum, M. microti, M. canetti, M. caprae, and. M. pinnipedii*. (Note that *M. bovis* BCG , a vaccine strain derived from M. bovis is sometimes listed as a separate member of this complex).

The term "mycobacteriosis" describes disease caused by non-tuberculous mycobacteria (NTM). The latter are also called atypical mycobacteria or mycobacteria other than TB (MOTT). Most NTM are saprophytes found in soil or water but they may occasionally cause disease in humans and animals. *M. elephantis*, a rapidly growing, newly described mycobacterium, was isolated from a lung abscess of an elephant that died of chronic respiratory disease (Shojaei 2000). This same organism was isolated from 10 human sputum samples and one human lymph node specimen in Canada, however there was no epidemiologic link between these reports (Turenne 2002).

Mycobacterium tuberculosis (*M. tb*) is the predominant disease-causing agent in elephants although cases due to *M. bovis* have occurred. *Mycobacterium szulgai*, an uncommon NTM species, has been associated with fatal disease in two African elephants (Lacasse 2007, Journal of Zoo and Wildlife Medicine, in press). *Mycobacterium avium* is commonly isolated from elephants (Payeur 2002) but has not been associated with clinical disease.

Both African and Asian elephants are susceptible to TB although the disease appears to be more common in Asian elephants. This may reflect a closer human association with Asian elephants related to work, festivals, tourism and other activities. Thirty-eight cases of TB affecting 33 Asian and 5 African elephants have been diagnosed in the U.S. between 1994 and 2006. This includes two African elephants infected with *M. szulgai*, an unusual mycobacterium that is not a member of the *M. tb* complex. See Table 1. Five cases were reported in Europe in 2002 (Lewerin 2005) and two subsequent cases were reported in 2005 (Moller 2005). Health surveys of captive elephants, including testing for TB have recently been conducted in India and Nepal (publications pending). There are no reports to date of TB in wild Asian or African elephants.

Table 1. Summary of TB Positive Elephants in the U.S. 1994 - August 2006

	Mycobacteria species			
Elephant species	***M. tb***	***M.bovis***	***M. szulgai***	**Total cases**
Asian	6.27	0.0	0.0	33
African	1.1	0.1	0.2	5
Total cases	35	1	2	38

1.0 = male, 0.1 = female

M . tb and *M. bovis* primarily infect humans and cattle respectively (Hirsch 2004). Transmission may occur via respiratory or alimentary routes. Feces, urine, genital discharges, milk, and feed or water may contain contaminated droplets. In elephants, *M. tb* has been isolated from respiratory secretions, trunk washes, feces, and vaginal discharges.

The pathogenesis of TB is complex and has not been adequately studied in elephants. In humans, exposure may result in various outcomes. See Table 2. Latent TB infection (LTB) is characterized by the absence of clinical disease and no evidence of active shedding of live organisms. In LTB, the bacteria are sequestered in granulomas in the lung, but may reactivate at a later date. Individuals with LTB are a reservoir for future active cases and while only 4-10% of latently infected humans with normal immune status will develop active TB during their lifetime, the identification and treatment of individuals with LTB and at high risk for activation remains an effective means of control (Nuermberger 2004). TB is a global epidemic for humans. Three million people die of TB every year and the World Health Organization estimates that 2 billion humans (one-third of the global population) are infected. Recent serological and culture studies suggest that elephants may also have LTB.

Table 2. Possible outcomes following exposure to TB

Scenario	Outcome	Tuberculin skin test status in humans (the skin test is not accurate in elephants)
1	All bacteria are killed and no disease results	negative
2	Bacteria multiply and clinical disease results (primary TB)	positive
3	Infection and eradication	positive
4	Bacteria become dormant and never cause disease (LTB)	positive
5	Dormant organisms reactivate and cause active disease (often associated with immune suppression or concurrent disease)	positive

Clinical Signs of TB in Elephants:
In elephants clinical signs are often absent until the disease is quite advanced. When present, signs may include weight loss, wasting, and weakness (Gutter 1981, McGaughey 1961, Mikota 2001, Saunders 1983) and coughing or difficulty breathing (Pinto 1973, Ryan 1997, Seneviratna 1966). Respiratory discharges from the trunk are occasionally noted. Exercise intolerance may be seen in working elephants. Ventral edema has been reported but other factors may have contributed (Pinto 1973, Seneviratna 1966). Elephants that show wasting antemortem may have disseminated disease on necropsy.

Diagnosis of TB in Elephants:
Guidelines for the Control of Tuberculosis in Elephants (USDA 2003) were first developed in the U.S. in 1998. These Guidelines are updated periodically to incorporate new diagnostic and treatment information and are under revision as of this writing. These Guidelines are availableonline and the reader is encouraged to consult the most current version.

Tests to diagnose TB can be broadly divided into direct and indirect tests. Direct tests detect the TB organism and include acid-fast staining, culture, and nucleic acid amplification techniques (i.e. polymerase chain reaction or PCR). Indirect tests detect antibody or measure cellular reactivity against mycobacterial antigen. Indirect tests include the intradermal tuberculin test (skin test), in vitro cellular assays, and serological assays.

The intradermal tuberculin test is widely used as a screening test in humans and cattle, but this test correlates poorly with culture in elephants (Mikota 2001, Lewerin 2005) and in one study demonstrated a sensitivity of only 16.7% (Mikota 2001). This test is not recommended for elephants. Currently, adequate in vitro cellular assays (e.g., interferon-ã-based test) are not available for use with samples from elephants.

Acid-fast stain (AFS): Mycobacteria may be detected by acid-fast stains such as Ziehl-Neelsen. A positive AFS is suggestive of TB but not definitive and further testing is needed. Nonpathogenic bacteria are detected with AFS, as well as several other organisms such as *Nocardia* spp. . Acid-fast staining has low sensitivity (50% in humans) and is non-specific, particularly in geographic areas where NTM are commonly isolated (Dalovisio 1996).

Culture: According to the 2003 Guidelines for the Control of Tuberculosis in Elephants, isolation of *M.tuberculosis* or *M. bovis* by culture is the current "gold standard" to diagnose TB in elephants. Samples are obtained by a trunk wash technique. Briefly, 60 cc of sterile saline is instilled into the elephant's trunk, after which the trunk is elevated for 20-30 seconds and then lowered into a zippered plastic bag or other clean collection device. Ideally the elephant is trained to forcibly exhale (the usual command is "blow") so that the sample is from the lower respiratory tract. The sample is transferred to a secure screw-top tube and should be submitted only to a laboratory that is certified to perform TB cultures. As the bacteria are shed intermittently, three samples are collected on separate days (within a 7-day period). The Guidelines include a detailed description of the procedure or see Isaza (1999). Elephants must be trained to accept the procedure.

Culture has inherent limitations as a primary diagnostic technique. Failure to isolate the organism does not rule out infection. Reporting time is slow (up to 8 weeks) because pathogenic mycobacteria may grow slowly.. Obtaining three samples may not be practical or affordable for screening large numbers of elephants in Asia where surveillance is urgently needed.

Culture is not likely to yield a false-positive result but sensitivity is low and infected elephants may fail to be identified (false-negative). If contamination or overgrowth is reported sample collection should be repeated. Cleaning the distal tip of the trunk with water prior to sample collection may minimize such contamination.

When a sample is positive for TB it is important to request speciation to differentiate between *M . tuberculosis* and *M.bovis.* Sensitivity testing is also critical to determine appropriate antibiotics if treatment is planned. Despite limitations, culture is an important diagnostic technique.

Nucleic acid amplification techniques: The Gen-Probe Amplified Mycobacterium tuberculosis Direct Test (MTD; Gen-Probe, San Diego, California, 92121,U.S.A.) detects RNA from live or dead TB organisms. In the U.S. the MTD is approved for the diagnosis of TB in humans but only in conjunction with culture. The MTD is quick (2.5 to 3.5 hours) and can detect low numbers of organisms. The MTD has been used in a limited number of elephant studies. In one study of 35 elephants, the MTD was positive in 14 and negative in 6 elephants from which *M. tuberculosis* or *M. bovis* was cultured; the MTD was positive in 15 cases from elephants from which there was no isolation (Payeur 2002). A positive MTD with a negative culture result may represent infection and low-level shedding of organisms (below the detection limits of culture) or non-viable (dead) organisms (detectable by MTD but not by culture). Failure of the MTD to detect the six culture positive elephants may have been due to improper specimen collection and transport, specimen sampling variability, laboratory procedural errors, the presence of amplification inhibitors, inadequate test sensitivity, or other causes.

A polymerase chain reaction (PCR) technique is under investigation to detect DNA form mycobacterial organisms in trunk wash samples. Experimentally, this PCR has detected very small numbers of mycobacteria using *M. bovis* spiked trunk washes, but further work is needed to better determine test sensitivity and specificity (personal communication, Dr. Scott Larsen, Davis, California, May 2005).

Additional diagnostic tests currently under investigation include an ELISA (Larsen, University of California, Davis, California, USA), the Elephant TB STAT-PAK™ and Multi-Antigen Print Immunoassay (Lyashchenko, Chembio Diagnostic Systems, Inc., Medford, New York, USA), and an immunoblot assay (Waters, National Animal Disease Center, Ames, Iowa, USA). These assays detect the presence of antibody in elephant serum to antigens of *M. tb*, and shared antigens of *M. bovis.* Current data suggest that serological tests may be accurate and early detectors ofmycobacterial infection.

Enzyme linked immunosorbent assay (ELISA): The ELISA measures antibodies against specific antigens. A study using a six-antigen ELISA demonstrated an estimated sensitivity of 100% and specificity of 100%, on a limited sample size of 47 Asian and African elephants (7 culture positive) (Larsen 2000). A modified version of this ELISA, with increased numbers of positive and negative Asian elephants, has so far had a similar specificity and sensitivity (personal communication, Dr. Scott Larsen, Davis California, May 2005). The ELISA continues to be evaluated but is not available commercially.

Elephant TB STAT-PAK™ and Multi-Antigen Print Immunoassay (MAPIA): The Elephant TB STAT-PAK™ (previously called the Rapid Test) is a lateral-flow assay that incorporates aunique cocktail of mycobacterial antigens impregnated on a nitrocellulose membrane and placed in a plastic cassette similar to a pregnancy test kit. Serum, plasma, or whole blood may be used and results are available in 20 minutes (Lyashchenko 2006).

The MAPIA is a laboratory procedure for antibody detection that uses a panel of multiple purified and recombinant antigens of *M. tuberculosis* and *M. bovis* that are separately applied to a nitrocellulose membrane using an automated printing device (Lyashchenko 2000). Elephant serum samples are incubated with a MAPIA strip and antigen-bound antibodies are visualized using a specific IgG-binding enzyme conjugate and corresponding substrate.

As of this writing, 99 Asian and 72 African elephants in Europe, Australia, South Africa, and the U.S. have been tested using the Elephant TB STAT-PAK™ and MAPIA including 22 elephants with culture-confirmed TB. Preliminary data has demonstrated 100% sensitivity and 97% specificity for the Elephant TB STAT-PAK™ and 100% sensitivity and 100% specificity for the MAPIA using culture as the reference standard. The Elephant TB STAT-PAK™ is undergoing licensing procedures in the U.S. and will likely be available commercially in early 2007.

If the Elephant TB STAT-PAK™ is used as a screening test and the MAPIA is sequentially applied as a confirmatory assay, the accuracy of this testing algorithm is 100%. Seroconversion on Elephant TB STAT-PAK™ and MAPIA has been noted in several elephants months to years prior to a positive culture (Lyashchenko 2006). In one elephant that was euthanized and determined to be TB positive, retrospective evaluation of serum indicated seroconversion eight years prior.

An important advantage of TB serodiagnosis compared to trunk wash culture is that, once established, the antibody response remains sustained throughout infection and disease while culture may be intermittently positive or negative in infected elephants. A decline in specific antibodies to certain antigens in MAPIA has been observed in seven culture positive elephants tested to date that had undergone treatment suggesting that this technology may also be a useful for monitoring response to therapy.

Immunoblot assay: Immunoblot detects antibodies to bacterial antigens that appear as discrete bands on a nitrocellulose membrane following electrophoresis. Experimentally, immunoblot detected antibody responses to a *M. bovis* whole cell sonicate in TB-infected elephants four years prior to culture of *M. tb* from trunk washes (personal communication, Dr. Ray Waters, Orlando Fl, May 2005). This assay is not commercially available.

Biosensor: A biosensor (a breathalyzer) that detects TB organisms is under investigation for application to elephants. If effective it could be used in conjunction with serological tests to identify actively shedding animals.

Miscellaneous tests:
Clinical pathology cannot provide a definitive diagnosis of TB, however, a comparative study has shown statistically significant differences in selected hematology and serum chemistry values in TB infected vs. non-infected elephants. Values for A:G ratio, mean hemoglobin concentration, and glucose were lower, and platelets, band neutrophils, eosinophils, calcium, and bicarbonate were higher in culture positive elephants that were shedding at the time of sampling compared to 20 clinically healthy, culture negative elephants (Harr 2001).

Restriction fragment length polymorphism (RFLP) commonly called DNA finger-printing can identify different mycobacterial strains. A variety of strains have been isolated from elephants. In one study of six herds in the U.S., six *M.tb* strains were identified (Mikota 2001). In the European report five elephants and one giraffe were infected by four different *M. tb* strains (Lewerin 2005).

Elephants that die or are euthanized should undergo a complete postmortem examination. A comprehensive necropsy protocol has been developed by the Elephant Species Survival Program of the American Zoo and Aquarium Association and is available online (Anon. 2005). Appropriate protective equipment should be used during elephant necropsies to protect personnel even if TB is not suspected.

Treatment:
The reader should consult the current on-line Guidelines for the Control of Tuberculosis in Elephants (USDA 2003) for the most recent recommendations.

Elephants in the U.S. have been treated for TB based on protocols developed for humans. Limited pharmacokinetic studies have been conducted in elephants for isoniazid (Maslow 2005), ethambutol (Maslow 2005), pyrazinamide (Zhu 2005), and rifampin (Maslow 2006, in press). The duration of treatment for elephants is 12 months compared to six months for humans. Current recommendations are to administer three drugs for two months followed by two drugs for 10 months. Isoniazid (INH), pyrazinamide (PZA), rifampin (RIF), ethambutol (ETH), and streptomycin are considered first-line drugs. It is important to note that pyrazinamide is not effective against *M. bovis.* The clinical pharmacology of anti-TB drugs has been reviewed by Peloquin (2003). Anti-TB drugs are expensive and the cost to treat one elephant for a year in the U.S. may exceed $50,000 exclusive of laboratory costs to monitor drug levels.

In the case of multi-drug resistant TB (MDR-TB), defined as resistance to both INH and RIF, second-line drugs such as amikacin, ciprofloxacin, levofloxacin and others may be needed. The increased risks to staff must be considered before initiating treatment for MDR-TB.

Anti-TB drugs may be given by direct oral or rectal administration. Adequate and reliable drug levels cannot be achieved if drugs are mixed with food offered free-choice. Some elephants can be trained to accept a bite block and medications delivered via a large animal dose syringe. Most elephants can also be readily trained to accept rectal administration and adequate blood levels can be achieved for isoniazid and pyrazinamide (but not rifampin) by this route. For a further discussion of general medication techniques for elephants see Isaza (2004).

Therapeutic drug monitoring (Peloquin 2002) is recommended for elephants receiving anti-TB drugs. Veterinarians seeking to treat elephants for TB should consult current Guidelines and experienced colleagues.

Euthanasia has been elected as a management strategy to control elephant TB in Sweden.

Nepal and India Projects:
In January 2006, 120 captive elephants in Nepal were evaluated in a research project to compare culture to results of the ELISA, Elephant TB STAT-PAK™, MAPIA, and Immunoblot tests for the diagnosis of TB in elephants. Results of this comprehensive study are currently being analyzed.

Health evaluations (with an emphasis on TB diagnosis) will begin in India late this year. Approximately 800 elephants will be evaluated under the leadership of Drs. Cheeran and Abraham and funded by Elephant Care International. This study will include many of the previously described tests and as well as two molecular techniques to identify TB in trunk wash samples, a technique for potential diagnosis of TB from dung samples, and a novel erythrocyte-based immunoassay.

Implications of TB for Management of Elephants in Range Countries:
The commercial availability of the Elephant TB STAT-PAK™ will open the door to testing in other range countries. Developing effective disease management strategies for elephants and their handlers in resource-poor countries presents great challenges where TB is endemic among the human population and where captive elephants are vital to tourism.

TB has not yet been reported in free-ranging elephants, but wild populations are at risk in countries where captive and wild elephants commingle. These new technologies offer the means to screen captive elephants in range countries to prevent further spread of this disease to humans or between captive and wild elephants.

Numerous issues confront the management of TB in Asia. Elephants are an integral part of the history and culture of most range countries. They are protected by national and international laws. They are essential to tourism – especially in India, Nepal, and Thailand but in other countries as well. Management and tracking of privately-owned elephants may be more difficult than government-owned elephants. Euthanasia may not be acceptable or legal.

Treatment is expensive. Hopefully, less expensive drug sources can be found in Asia – but even if this is possible it will still be costly. Can funds be found? Will people rally to help the elephants or will there be a negative perception given the scope of human TB problems in Asia? Is there a potential for MDR-TB in elephants in Asia? This has already occurred in elephants in the U.S.

There are two basic management groups to consider – elephants that are culture positive and actively infected and those that are culture negative but serologically positive. This latter group may represent latent disease or they may be active cases that we have failed to detect because of the limitations of our diagnostic toolbox.

Figure 1 is a simplistic flow chart of possible options for culture positive elephants. Segregation may be the most effective and efficient initial tool. A permanent quarantine situation with protective barriers to prevent the intermingling of wild elephants may be possible in some areas. Detailed protocols for the protection of human health will be essential. Treatment may be an option if there are only a few cases and funds can be found for the drugs. Euthanasia is undesirable but perhaps should be considered in cases of MDR-TB given the difficulty of treatment and increased risk to humans.

Figure 1. Options for culture positive elephants

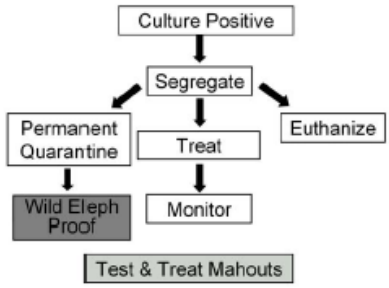

Figure 2. Options for culture negative / serologically positive elephants

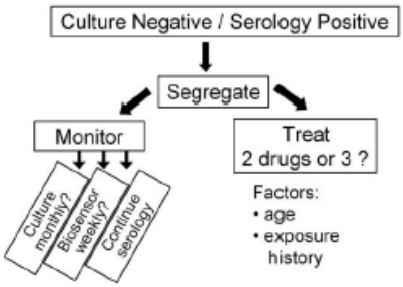

Figure 2 depicts the more challenging management of culture-negative / serologically positive elephants. Prophylactic treatment is an option - again depending on the number of cases and available funds. Age and exposure history are considerations. Monitoring for active disease is also another option. Protocols will need to be established to determine the frequency of culture and continued research on other ways to detect shedding is encouraged. The current lack of a fast and accurate method to determine shedding is a major drawback.

Figure 3. Options for exposed elephants that are culture and serologically negative.

Elephants that are serologically and culture negative but have had known exposure should be placed on an enhanced surveillance schedule because we do not yet know the time interval from infection to serological conversion (Figure 3).

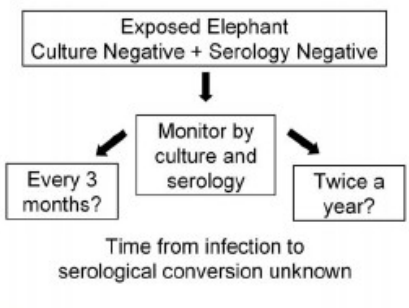

Figure 3. Care and treatment of staff members.

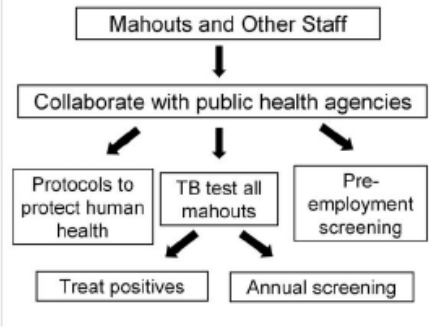

Figure 4 describes a protocol to address the TB health status of mahouts and other staff. This is a critical component of the overall strategy. Collaboration with public health agencies that already have TB screening programs will be helpful. All mahouts should be tested to initiate the program. Elephants cared for by infected mahouts should undergo increased monitoring.

Certainly infected elephants pose a risk to mahouts who live in close association. The extent of risk to humans (or elephants) in other situations like religious events or large festivals such as those in India and Sri Lanka is undefined. According to the U.S. Center for Diseases Control Travelers' Health Yellow Book (CDC 2006):

"To become infected, a person usually has to spend a relatively long time in a closed environment where the air was contaminated by a person with untreated tuberculosis who was coughing and who had numerous *M. tuberculosis* organisms (or tubercle bacilli) in secretions…"

Note however, that the World Health Organization Tuberculosis Fact sheet N°104 Revised March 2006 (WHO 2006) says:
"…When infectious people cough, sneeze, talk or spit, they propel TB germs, known as bacilli, into the air. A person needs only to inhale a small number of these to be infected…."

Many factors determine the final outcome including the environment in which the exposure occurs and the infectiousness of the diseased individual. Immune suppressed persons (especially those HIV positive) have a significantly heightened risk of contracting and developing active TB.

TB and Wild Elephants:
TB has not yet been diagnosed in wild elephants. What are the risks that it will cross into this population or that it may already be there? Could TB become as devastating a problem for elephants as it is for humans? The risks are greater in regions where captive and wild elephants intermingle during grazing or breeding, India, Nepal and Myanmar for example. Communal grazing areas shared by elephants and domestic cattle pose an additional risk. Further studies of both captive and wild elephants are needed.

In conclusion, there are management strategies under development in Nepal that may serve as a model for other countries. Based on present knowledge, it is likely that TB is at least as prevalent in captive elephants as it is in humans. Support from international agencies will be needed to help fund additional surveys and initiate treatment. Elephant Care International will continue to address the problem of elephant TB both from a research and a clinical standpoint in Nepal and India and we are planning a meeting in 2007 to address effective management strategies to control TB among elephants in range countries. Please visit the Elephant Care International website for more information concerning the elephant TB initiative (www.elephantcare.org/tbshort.htm).

Acknowledgements:
The authors thank the Department of National Parks and Wildlife Conservation, Government of Nepal and the Government of India for permission to conduct elephant health surveys. We acknowledge the support of Dr. Mo Salman and Joni Triantis at the Animal Population Health Institute, Colorado State Univerisity for ELISA studies. We are grateful for the financial support of the Alexander Abraham Foundation,

Mazuri Fund, American Veterinary Medical Foundation, Dodge Foundation, and Walter J. Ernst Memorial Foundation which facilitated work in Nepal.

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The elephant Rapid Test (RT) – the future diagnostic test for TB (*M. tuberculosis*) in elephants? Call for a validation study in Europe

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Abstract:
The prevalence of TB in the European elephant population is largely unknown and most probably underestimated due to unreliable test methods. In Sweden, as in other European countries, trunk wash culture is still the only officially recognized test for the diagnosis of TB in elephants. However, as shedding is believed to be intermittent and to occur in a late stage of infection, culture is of little use for detecting newly infected animals and taking effective measures to prevent spread of the infection.
The diagnostic, preventative and therapeutic limitations, relying on culture only, became very obvious in an outbreak of TB in a herd of five Asian elephants in Kolmården Zoo, Sweden, from 2001-2003.
A pilot study performed on sera from Swedish and French elephants showed an immunoassay test – the Elephant **R**apid **T**est (**RT**; Elephant TB STAT PAK) to be a promising new tool for an early diagnosis of *M. tuberculosis* infection. Concurrent RT test results were recently obtained in a major US investigation involving 15 elephants, also characterizing in depth the diverse serological response to TB by use of Multi Antigen Print Immuno Assay (MAPIA) – the technology from which RT was developed.
In order to further validate the RT in elephants, with special focus on specificity, a retrospective study is proposed. Existing information from autopsies of elephants in European zoos will be used and preserved serum samples from such animals analysed with the RT test.

Key Words:
Tuberculosis, Asian elephant, African elephant, diagnostics, culture, serology, MAPIA, RT.

Introduction:

During the last decade infection with *Mycobacterium tuberculosis* in elephants has evolved into a medical problem of growing concern (7, 8, 9, 10, 13). In the US alone, 30 captive elephants in 14 herds, all Asian (*Elaphas maximus)*, have been diagnosed with TB-infection from 1994 to 2004 (14) and in Sweden TB was recently detected in both Asian and African elephants (*Loxodonta africanun*) (4, 11)

The TB prevalence in the European elephant population is not known, one of many reasons being inadequate test methods, resulting in a low overall effort to test at all and an inherent underestimate. Therefore, there is no reason to suspect the prevalence of TB to be lower than the 3-6 % estimated in the US population (9, 14).

As described in the US guidelines (12), *M. tuberculosis* positive culture from trunk wash samples is the only recognized ante-mortem diagnostic for TB in elephants. This method is adopted by the National Veterinary Institute of Sweden (4). Diagnosis by culture has the advantage of high specificity, but suffers from low sensitivity. Excretion of *M. tuberculosis* is known to be intermittent and culture can only be obtained at the advanced stages of disease (6, 8, 11). Therefore, as a screening tool for surveillance and early intervention, trunk wash culture is inadequate (2).

TB infection is commonly believed to generate cell-mediated rather than humoral immune response. Nevertheless, serology as applied in Multi-Antigen ELISA or Immuno Print Assays (MAPIA) are examples of novel serological techniques, being able to cover the very diverse antibody repertoire induced by an intracellular pathogen like *M. tuberculosis* (1, 3, 5, 6). Furthermore the antigen panel detected by MAPIA forms the basis for a lateral flow membrane-based rapid test – the RT test. This method employs

selected antigens conjugated to colored latex particles printed onto a nitrocellulose membrane. The sample (30 µl of serum, plasma or whole blood) flows laterally through the membrane and in the presence of specific antibodies (IgG, IgM or IgA), immune complexes are formed and captured on the membrane in the **TEST** area, producing a blue line. Any intensity of colored line in this area is considered a positive reaction (Fig. 1), but a semi quantitative evaluation based on intensity of color can be obtained by use of optical readings (6). In the absence of specific antibodies, there is no visible line in the test area and the test is negative. Irrespective of the test result the sample continues to migrate along the membrane and produces a blue line in the **CONTROL** area, demonstrating that the test immunoreagents are functioning properly. The test reads in seconds to a minute, the final and definitive reading takes place 20 minutes after applying serum. As such, the RT test is simple, rapid, inexpensive and discrete (6).

Fig. 1: RT test plates showing a negative and a positive reading

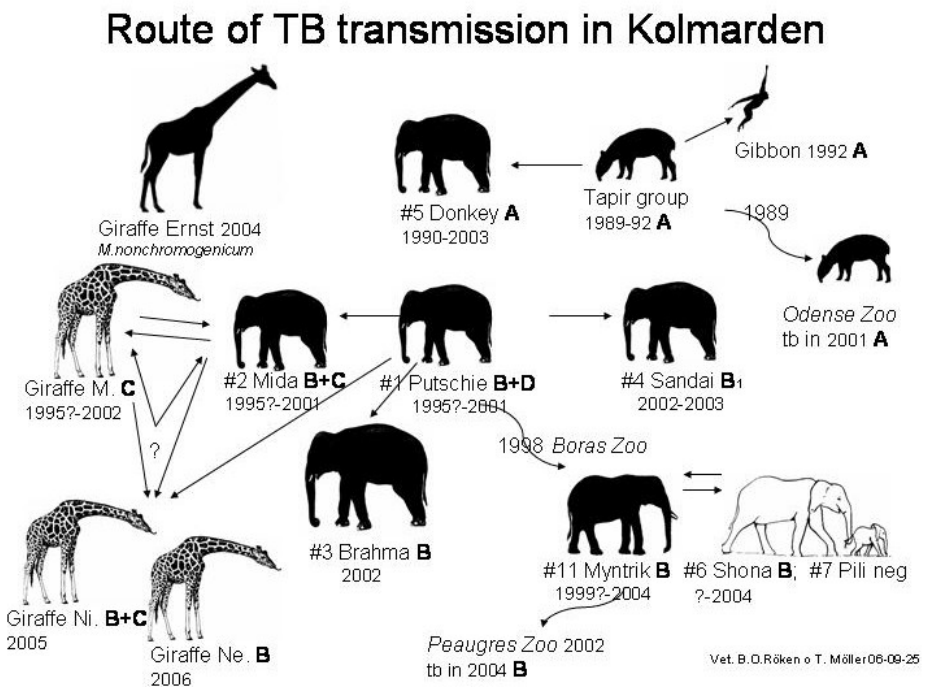
Background – the Swedish TB cases

In Kolmården Zoo an outbreak of TB in 1.4 Asian elephants took place between August 2001 and May 2003. Only the index case #1 was clinically affected, 4 of 5 animals were found *M. tuberculosis* positive by trunk wash culture and 4 different subtypes were detected (4).

The whole group was euthanized according to the Swedish Epizootic Act (SCF SFS 1999:657) and all specimens presented different stages of pulmonary TB on post mortem.

In November 2004 a new Swedish case of TB in a group of African elephants in Boras Zoo was reported leading to a new investigation (11). The epidemiology and route of transmission can be seen in Fig. 2. The subtype named **B** found in both African specimens elephant #6 and #11 points at Kolmarden Zoo as the center of infection.

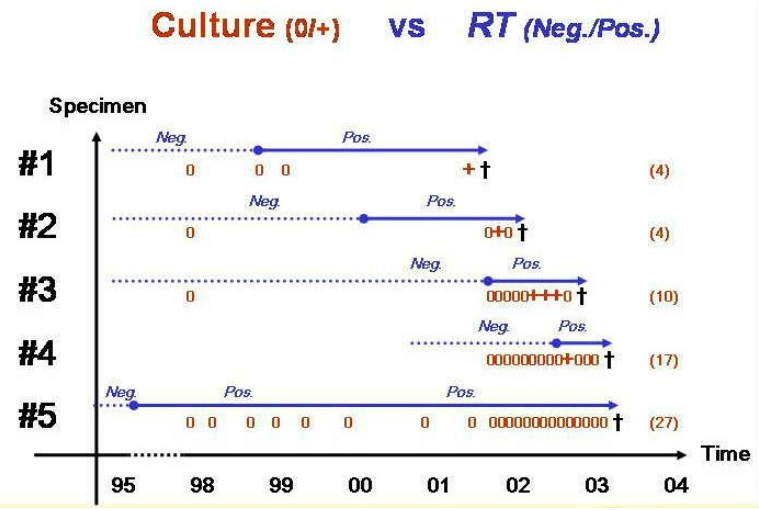
Fig. 2: Route of TB transmission in Swedish elephants.



indicate specimen
A, B, C and **D** denotes working names for *M. tuberculosis* subtypes
(year^{x}-year^{y}) indicate time of disease symptoms/positive culture/immunological reaction^{x} and time of euthanasia^{y}

RT results - Swedish cases:
The RT test was applied in both the retrospective investigation of Asian elephant sera as well as in the new outbreak in the African elephants. In 9 of 9 animals the true TB-infectious status, known by post mortems (7 positive and 2 negative), were accurately predicted by the RT test.
Furthermore, RT test positive results in the Kolmarden sera appeared up to 3 years prior to the time of the first positive trunk wash culture. In one individual (specimen case #5), who never became culture positive on trunk wash, the infection could be traced back 8 years in relation to the time of euthanasia (11).
Based on the *M. tuberculosis* subtyping, it was reasonable to assume, that at the time of euthanasia of the index case (specimen case #1, subtype **B**, November 2001), specimens case #2, #3 and #4 (subtype **B)** had all contracted TB. Subsequently only 6 out of 31 triple trunk washes performed on these three animals came out as positive on culture. If specimen case #5 is included – an individual which contracted TB (subtype **A)** in the beginning of the 90´s, which tested RT positive consistently from 1995 an onwards, but where 27 triple trunk washes failed to retrieve any TB positive culture – this estimate of culture sensitivity becomes negligible. The results illustrated as RT readings relative to time of positive culture can be seen in Fig. 3.

Fig. 3:



(x) indicate the number of triple trunk wash cultures; 0/+ negative/positive culture
..... indicate a negative /positive RT reading.
† indicate time of euthanasia

Conclusive Concluding remarks:

A more recent US study, including 5 culture positive and 10 culture negative elephants shows identical results (6). Seroreactivity and positive RT readings appear up to 4 years in advance of the first positive trunk wash culture.

This ability to detect infection at an earlier stage of disease is the single most important and advantageous feature of the RT test.

For the management for the European elephant population and for the clinician the positive implications are numerous (5, 6, 15):

- As an early primary or confirmatory pre acquisition test.
- As a cheap and fast tool for screening, tracing infection (as in African specimen #11 in the Swedish outbreak), in epidemiological investigations, etc.

In case of a test-positive result:

- For implementation of protective measures: isolation and euthanasia
- For early treatment and/or monitoring effect of treatment.

To what extent the RT test are is already in use in Europe is not clear to the authors, but to maintain trunk wash culture as the only officially recognized diagnostic test for TB in elephants (4, 6, 8, 9, 10, 12, 15), as in the case of Sweden, not only poses a serious zoonotic threat (7, 13), but also a threat to other herd members as well as other species. This was shown by the rapid transmission of *M.* tuberculosis, subtype **B,** within the herd of Asian elephants and to Giraffe in Kolmarden Zoo.

Progress has been made in USA towards official approval the last couple of years (14, 15), but the need of a European validation study of the RT test still exist. Especially concerning test specificity data are insufficient. In the Swedish material only two and in the recent US study only four animals with proven **non**-TB status were investigated (6, 11). None of these reacted as RT positives, but false positive reactors, amongst elephants suffering from other chronic infection (arthritis), have recently been reported from USA (Lyashchenko, pers. comm. September 2006). The extent of false positives is unknown, which is why a

retrospective European validation study should focus on investigating sera from elephants having died/or euthanized for other reasons than TB. Bearing the impressive RT sensitivity in mind, good clinical records and absolutely reliable post mortem data are imperative for this study, which we hope will be received with interest and participation by the European elephant community.

Proposal:
In order to validate the RT test for TB detection in elephants in European zoos, we propose to use the existing information from autopsies and banked serum samples from qualified animals. The project will be coordinated by Dr Susanna Sternberg Lewerin from the Section of Epizootiology at the National Veterinary Institute (SVA) of Sweden and Dr Torsten Moller at Kolmården Zoo in Sweden. The proposed retrospective study will be performed during 12 months starting January 1., 2007.

Study design:
All zoos willing to participate in the study submits a list of the number of elephant autopsies performed for the past three-four decades and the number of available serum samples from the autopsied animals.
Zoos with autopsy records on elephants and frozen serum samples taken from the same animals will be asked to fill out a questionnaire on autopsy results and clinical records (if available), and submit all available serum samples for testing. A minimum amount of 0.1 ml serum is required from each sample.
Elephants diagnosed with tuberculosis (i.e. positive cultures), but where autopsy was not performed, can still be included in the study, provided serum samples are available. In such cases, details of positive cultures and clinical records have to be submitted in the questionnaire. At least, 50 samples from elephants with confirmed disease status, which would meet inclusion criteria, will be selected.
All serum samples will be tested using the RT test, in one laboratory and the results will be read by the same 2 persons each time and/or by standardized optical readings. Photographic records of the results will be saved.
The results of the study will be made available to all participating zoos as soon as they have been compiled and analysed.

Commitments for the zoos:
The retrospective study involves the labour necessary to retrieve information on autopsies and clinical records, as well as the submission of serum samples, plus the cost of sending the serum samples.
It is foreseen that the only "unusual" cost (i.e. cost that would not have arisen had it not been for the studies) is the postage for submitting serum samples, as most participating zoos will routinely take serum samples and perform autopsies on dead animals.
In return, the zoos will be given first-hand information on the validation results, and serological analysis of serum samples free of charge.

Data and sample analysis:
Autopsy reports will be reviewed, serological testing will be performed, and data will be analyzed at the National Veterinary Institute (SVA) in Uppsala, Sweden.

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Duration of pregnancy and its relation to sex of calf and age of cow in the European population of Asian and African elephants

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Birth rates of elephants in Europe have increased considerably over the last years. Between 1996 and 2005 a total of 144 births (92 births in Asian + 52 births in African elephants) has been recorded, as compared to 55 births (40 Asian + 15 African) in the previous decade (**TABLE 1**). The reason for this successful development is most likely the combined effort to improve both keeping conditions and breeding management of elephants in captivity. Effective breeding management requires basic information on female reproductive status. In Europe it is possible to obtain this information by participating in a service based on hormone analysis via non-invasive methods, i.e. the measurement of hormones in weekly collected urine or fecal samples. The service has been offered since 1994 to all facilities keeping Asian elephants and since 1997 to those keeping African elephants. From the beginning it has been heavily used and by the end of 2005 a total of 37 facilities with 122 Asian elephants and 33 facilities with 119 African elephants has participated by sending samples for analysis. As a result, a hugh data base has accumulated from more than 241 elephant cows (including new animals in 2006). Based on this data set, the study presented here will focus on aspects of pregnancy, in order to examine species differences and provide information on duration and variability of gestation and possible factors related to this, such as sex of calf, and age and parity of cow.

TABLE 1: Number of births of elephants in Europe (including Israel)*

year	Asian elephants	African elephants	Total
1996	11	2	13
1997	7	4	11
1998	12	5	17
1999	4	4	8
2000	8	1	9
2001	7	8	15
2002	11	3	14
2003	8	10	18
2004	9	5	14
2005	15	10	25
10 years	**92**	**52**	**144**
1986-1995			
10 years	**40**	**15**	**55**

*data calculated from running birth lists of the European Elephant Group, including all elephant births (= EEP + non-EEP animals)

Data have been compiled from a total of 45 full-term pregnancies and only include those monitored via urinary hormone analysis. These comprise 27 pregnancies in 20 Asian elephants (12 facilities in 5 European countries) and 18 pregnancies in 14 African elephant cows (7 facilities in 4 European countries). For the Asian elephant, data included 10 first, 9 second, 5 third, 2 fourth and 1 fifth pregnancy. In contrast 13 first, 4 second and only 1 third pregnancy formed the data for the African elephants. An overview of all 45 pregnancies is given in **TABLE 2 a+b.**

TABLE 2a: Full-term pregnancies of Asian elephants monitored via urinary hormone analysis

TABLE 2a: Full-term pregnancies of Asian elephants monitored via urinary hormone analysis

Birth	Calf	Sex	Parents	Facility	Country	Pregnancy
25.12.1995	Tharun	Male	Thura x Hussein	Hamburg	D	2.
09.01.1996	†	Male	Benga x Hussein	Hamburg	D	2.
04.06.1996	Corny	Female	Yashoda x Hussein	Hamburg	D	2.
01.07.1996	Salvana	Female	Saida x Hussein	Hamburg	D	1.
11.01.1999	†	Male	Bernhardine x Alexander	Münster	D	1.
27.11.1999	Sandry	Female	Claudia x Hussein	Rapperswil	CH	3.
05.04.2000	Plai Kiri	Male	Kibo x Pang Pha	Berlin-Zoo	D	1
16.07.2001	Aung Bo	Male	KLH x Naing Thein	Emmen	NL	2.
09.11.2001	†	Male	Thura x Hussein	Hamburg	D	3.
02.12.2001	Punjab	Male	Ida x Chieng Mai	Copenhagen	DK	4.
20.01.2002	Senang	Male	Bernhardine x Alexander	Rotterdam	NL	2.
03.03.2002	Aung Si	Male	THP x Naing Thein	Emmen	NL	2.
05.04.2002	Voi Nam	Male	Trinh x Mekong	Leipzig	D	1.
13.05.2002	Chandra	Female	Indi x Maxi	Zuerich	CH	1.
27.05.2002	Kan Kaung	Male	YZ x Naing Thein	Emmen	NL	3.
05.09.2002	Than Myan	Male	HYA x Naing Thein	Emmen	NL	2.
02.02.2003	Califa	Female	Manari x Calvin	Hannover	D	1.
20.03.2003	Farina	Female	KNN x Calvin	Hannover	D	1.
14.05.2003	Kandy	Female	Yashoda x Hussein	Hamburg	D	3.
22.06.2003	†	Male	Lai Singh x Hussein	Hamburg	D	1.
07.03.2004	Sundara	Female	Sithami x Chang	Chester	GB	1.
10.10.2004	Tunga	Male	Jangoli x Chang	Chester	GB	3.
26.11.2004	Thai	Male	Thura x Hussein	Hamburg	D	4.
14.06.2005	Shaina Pali	Female	Victor x Pang Pha	Berlin-Zoo	D	2.
02.08.2005	Yindee	Female	Tong Thai x Alexander	Amsterdam	NL	1.
28.10.2005	Tarak	Male	KNN x Calvin	Hannover	D	2.
21.03.2006	Ghandi	Male	Ida x Chieng Mai	Copenhagen	DK	5.

TABLE 2b: Full-term pregnancies of African elephants monitored via urinary hormone analysis

Birth	Calf	Sex	Parents	Facility	Country	Pregnancy
25.03.1998	Pepe	Male	Celia x Chisco	Cabarceno	E	1.
22.04.1998	†	Female	Laura x Chisco	Cabarceno	E	1.
23.03.1999	Nachete	Male	Zambi x Chisco	Cabarceno	E	2.
14.06.2000	Coco	Male	Laura x Chisco	Cabarceno	E	2.
10.04.2001	Hilda	Female	Celia x Chisco	Cabarceno	E	2.
04.05.2001	Tana	Female	Pori x Tembo	Berlin-Tierpark	D	1.
13.08.2001	Kwanza	Female	Dudu x Kibo	Boras	S	1.
14.08.2001	Kenia	Female	Zambi x Chisco	Cabarceno	E	3.
06.12.2002	Kito	Male	Tanya x Tembo (AI)	Colchester	GB	1.
10.01.2003	Ashanti	Female	Shaba x Krueger	Knowsley	GB	1.
29.03.2003	Apili	Female	Shona x Kibo	Boras	S	1.
05.04.2003	Nala	Female	Tana x Krueger	Knowsley	GB	1.
15.03.2004	Jambo	Male	Rosa x Tembo	Colchester	GB	1.
08.05.2004	†	Male	Buta x Krueger	Knowsley	GB	1.
05.05.2005	Panzi	Female	Dudu x Kibo	Boras	S	2.
03.06.2005	Bongi	Female	Punda x Tusker	Wuppertal	D	1.
09.10.2005	Kibo	Male	Numbi x Tusker	Wuppertal	D	1.
23.03.2006	Bou-Bou	Male	Veri x Tonga	Hodenhagen	D	1.

Age at birth ranged from 7 to 36 years in Asian and from 11 to 21 years in African elephants. There were 24 pregnancies from Asian females of the founder generation (F0) and 3 from females that had already been born in Europe (F1). In contrast all of the 18 pregnancies in African elephants originated from founder females (F0).

Pregnancies were diagnosed and monitored via progestagen measurements in urine samples collected during 1995 and 2006. Since progesterone metabolism differs in the two species of elephants (see Hodges, 1998), pregnanetriol (P3) was measured in Asian elephants according to the method described by Niemuller et al. (1993) and 5á-pregnane-3á-ol-20-one (5-P-3OH) in African elephants as validated by Heistermann et al. (1997). All hormone values were indexed to the amount of creatinine in the sample.

Duration of pregnancy was calculated in days, ranging from date of conception to date of birth. The day of conception, if not given as a single mating date within the week of ovulation, was defined as the first date of matings occurring on consecutive days or, if no mating was seen or no date given by the facility, as the day following the last low hormone value before ovulation. The occurrence of ovulation is indicated by a sharp rise in progestagen levels which marks the shift from follicle to luteal phase of the ovarian cycle. Matings are usually observed within this week. As demonstrated in **TABLE 3**, not all pregnancies were diagnosed with a given mating date.

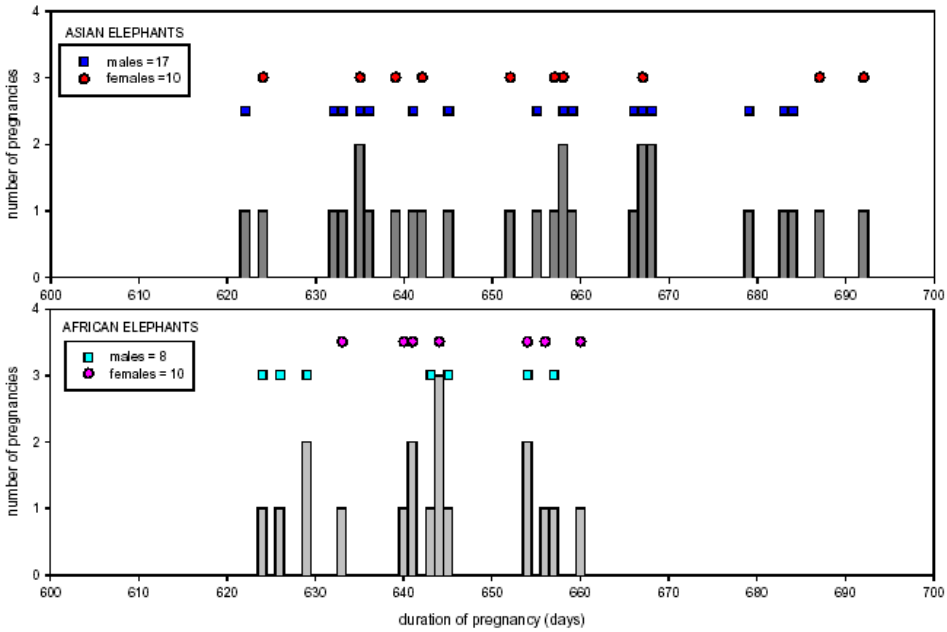
TABLE 3: Information on matings at diagnosis of pregnancy in elephants

	Asian elephants	African elephants	Total
Mating seen on one day only	6	3	9 (20%)
Mating seen on several days	17	10	27 (60%)
No mating seen at all	4	4	8 (18%)
Artificial insemination (AI)	0	1	1 (2%)
Pregnancies	27	18	45 (100%)

In 18% of the pregnancies (4 Asian and 4 African) no mating was seen at all. In the 4 cases of Asian elephants, facilities confirmed after diagnosis of pregnancy that female and male were kept together at the time of ovulation. In African elephants, bulls had access to cows every day in 3 cases, in 1 case the cow was associated with the bull at the time of predicted estrus. The high incidence of 60% of matings on several days indicates that males, if allowed, usually do not restrict sexual activity to one day only.

The 27 Asian pregnancies resulted in 17 male and 10 female calves (sex ratio 1.7 : 1), the 18 African pregnancies in 8 male and 10 in female calves (sex ratio 1 : 1.3). Whereas the sex ratio in African elephants appears balanced, a strong bias towards male calves characterizes the births in Asian elephants. 2 of the Asian calves (both males) were born dead, whereas all African calves were born alive. Mean gestation length in Asian elephants was 655 ± 19.9 days (range 622-692 days), in African elephants 642 ± 11.0 days (range 624-660 days). This difference in duration of pregnancy between Asian and African elephants was statistically significant ($p = 0.02$). The distribution of duration of pregnancy and sex of calf is shown in **GRAPH 1** for both species.

GRAPH 1: Distribution of duration of pregnancy and sex of calves in elephants



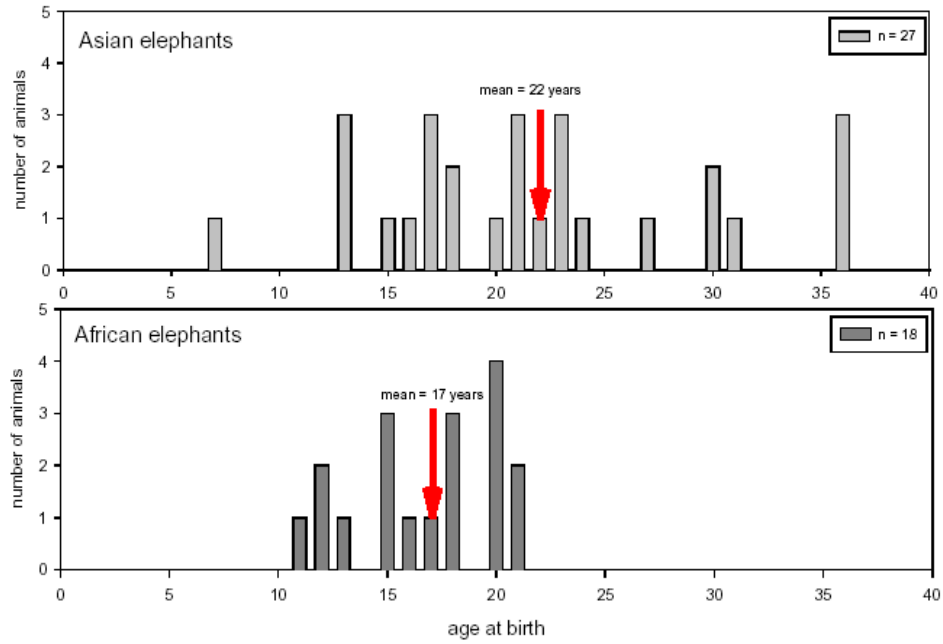
74% of births in Asian and 78% of birth in African elephants occurred between day 630 and 670 of pregnancy. No difference was found between duration of pregnancy according to sex of calf in either species. Mean duration of pregnancies with male and female calves, respectively are given in **TABLE 4**.

TABLE 4: Duration of pregnancy in elephants according to sex of calf

	Asian elephants	African elephants
Duration of pregnancy (mean ± STD)	655 ± 19.9 days (n = 27)	642 ± 11.0 days (n = 18)
Duration of pregnancy male calves	655 ± 19.3 days (n = 17)	638 ± 13.0 days (n = 8)
Duration of pregnancy female calves	655 ± 22.0 days (n = 10)	646 ± 8.3 days (n = 10)

The age distribution of females in both elephant species is shown in **GRAPH 2**. Mean age in Asian elephants was 22 ± 8 years (range 7 - 36 years), in African elephants 17 ± 3 years (range 11 – 21 years). This age difference was statistically significant (p = 0.01).

GRAPH 2: Age of elephant cows at birth

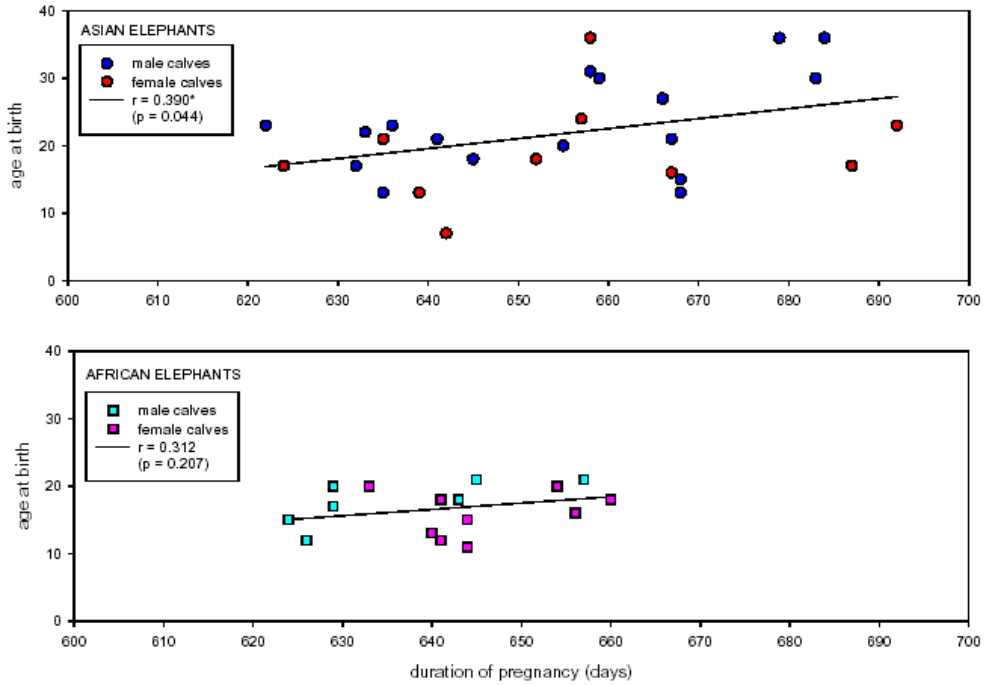


Gestation length slightly increased with age of cow at birth in both species (see **GRAPH 3**), however, the correlation was only significant ($p = 0.044$) for the Asian species. Since the Asian elephant females in this study were significantly older that their African counterparts, this finding must be attributed to the data set including a lower number of African elephants which was also of younger age. Since in captivity older cows are not necessarily of higher parity, data were also tested for the relation of gestation length and number of birth. No difference, however, was found between gestation length in primiparous females compared to multiparous females (see **GRAPH 4**).

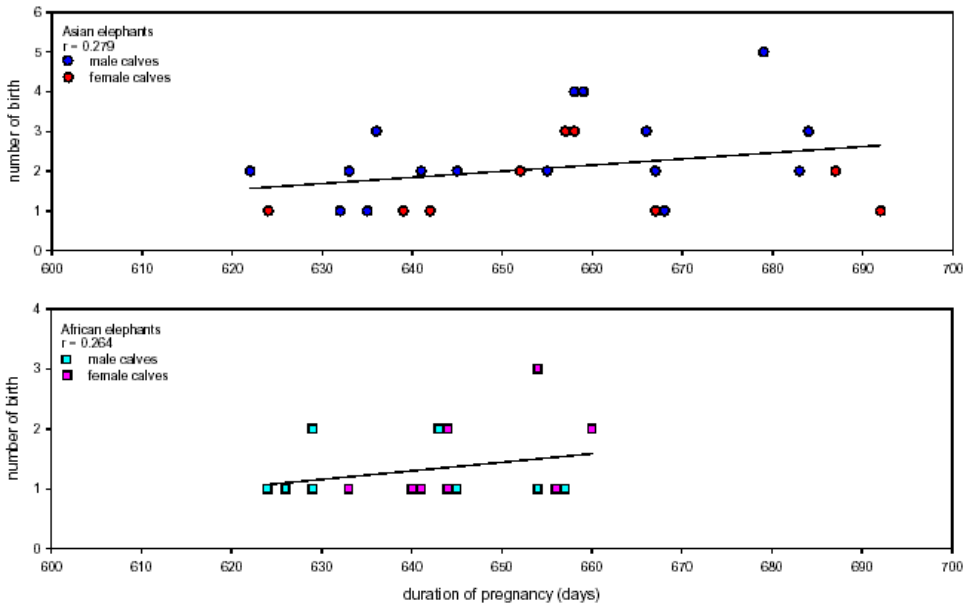
The surplus of male calves born to Asian but not to African elephants in this study complies with the current studbook data (see Belterman & Terkel,). It is therefore possible that due to older age and higher parity Asian females are more likely to give birth to male calves. However, there was no significant relation between age of cow and sex of calf in either species. Furthermore, no relation was found between sex of calf and parity of cow. Therefore the reason for the higher number of birth of males in Asian elephants remains unknown.

The age difference between Asian and African elephants in this study appears to reflect the situation in the active breeding population of elephants in Europe (for comparison see Belterman & Terkel) and is the result of the prohibition of imports of the Asian species in 1976. Whereas it was still possible to obtain young African elephants during the following years, birth rates were still unsufficient to replace the young age class in Asian elephants. Successful long-term breeding in both species will hopefully lead to an age structure resembling that in the wild.

GRAPH 3: Duration of pregnancy and age of cow in relation to sex of calf



GRAPH 4: Duration of pregnancy and parity of cow in relation to sex of calf



Measurement of progestagen concentrations in weekly urine samples is a valuable method to detect and monitor pregnancy and accurately calculate gestation length in elephants. Calculations of duration of pregnancy based on observed matings must be regarded with caution because it is known that bulls also mate after conception. According to reports of keepers in the routine exchange of information in the service, bulls are not able to discriminate between the time of the first and second LH-peak in cows, thus matings 3 weeks before ovulation also occur. Finally, as noted in 18% of pregnancies reported here, matings leading to conception are not even seen. Regular collection of samples from the time of ovulation is therefore highly recommended in order to confirm the time of conception and predict the time of birth.

Another aspect of practical importance is the fact that the majority of calves is born between days 630 and 670 in both elephant species. Preparations for birth can therefore be restricted to the period of a month, if the time of conception is known. However, there appears to be a species difference in duration of pregnancy. The data available so far indicate that Asian elephants generally have a slightly longer gestation period than African elephants.

Of the factors that might affect gestation length, sex of calf and age and parity of cow were investigated in this study. However, male and female calf do not differ in the length of gestation. Duration of pregnancy is also not different in old and young cows and there is no difference between pregnancy duration in primiparous and multiparous females. In conclusion the data show that neither sex of calf, nor age or parity of the cow have an influence on gestation length in elephants.

Acknowledgements:
The authors want to thank all facilities listed in **TABLE 2 a+b** for participating in the service and by sending samples provide the data base for this study. Jutta Hagedorn and Andrea Heistermann are greatfully acknowledged for professional laboratory skills.

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Comparative knowledge of elephant diseases to the first and second mahouts and its relative effect on the health management of captive elephants in Kerala, India

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Introduction:

The elephant forms an integral part of the cultural life of Kerala state (INDIA).There are approximately 750 captive elephants as known from the records kept by the elephant welfare association of Thrissur (EWA). Captive elephants are controlled and managed by two mahouts whom are designated as first and second mahouts (elephant keepers). It is absolutely imperative that mahouts especially the first, have an awareness of the disease management of elephants, symptom identification and first aid management. Lack of this scientific knowledge of elephants might have led to the present day conflict between mahouts and elephants which may lead to an unhealthy elephant (Joy 1990). The poor mahoutship was identified as the most frightening problem faced by the domesticated elephants (Lair 1997). The elephant keepers low knowledge of scientific elephant disease management led to over exploitation of elephants and consequent problems to them. (Panicker 1998, Nibha 1998) This study was conducted in order to assess the comparative knowledge level of first and second elephant mahouts about scientific disease management practices of elephants Identifying their level of knowledge, comparing the difference if occurs between second and first mahout, imparting of proper training to them based on this data in elephant disease management and timely refreshing of their knowledge can lead to decreased cruelty and discomfort to elephants.

Methodology:

The study was conducted among fifty each of first and second mahouts, from Thrissur and Palakkad Districts of Kerala State. They were selected from the 50 elephants units (each elephant with first and second mahout as a unit) out of which, 10 were devaswom owned, and 40 private owned including Government agencies. Proportionate random sampling techniques were used for selecting the samples. Pre-tested and expert validated structured interview knowledge schedules were used for collecting the data. The data were analyzed statistically using appropriate techniques.

Results and Discussion:

Table 1: Distribution of first and second mahouts according to their knowledge of elephant management as a whole.

n = 50

Level of knowledge	FIRST MAHOUT		SECOND MAHOUT	
	SCORE	%	SCORE	%
High	98 & above	32	95 & above	32
Medium	87 to 97	44	77-94	38
Low	64 to 86	24	<76	30
Total		100		100

Table 1 showed that 44 per cent of the first mahouts were having medium knowledge, 32 per cent were having high knowledge and 24 per cent were having low knowledge of elephant management. Compared to the first mahouts, 38 per cent of the second mahouts were having medium knowledge, 32 per cent were having high knowledge and 30 per cent were having low knowledge of elephant management.

The first mahouts are more informative than the second according to this result. Here the need for awareness among the second mahout is more important than the first. The matter of fact and relief in this regard is that in both groups a major portion is having medium knowledge of scientific elephant management.

Table 2: Domain wise knowledge of elephant management to first mahouts

Sl. No.	Domain	FIRST MAHOUT			SECOND MAHOUT		
		Mean score	% mean score	Rnk	Mean score	% mean score	Rank
1	**Disease management**	**18.62 ± 2.92***	**74.48**	**2**	**16.46 ± 3.671**	**65.84**	**2**
2	Harness	26.84 ± 3.70*	74.55	1	25.13 ± 4.24	69.72	1
3	General management	47.36 ± 6.30*	64.02	3	43.02 ± 8.09	58.13	3

* Standard deviation

According to Table 2 the first mahout's knowledge of harness practices was the highest followed by disease management and general management as indicated by the respective knowledge score viz., 74.48, 74.55 and 64.02. Where as, the second mahouts were having more knowledge of harness practices followed by disease management and general management with respective percentage means scores of 69.72, 65.84 and 58.13. Here in both groups the knowledge of disease management practices are at second level which could not be considered as favorable as far as the health management of captive elephants are concerned. The mahouts should be given prime importance to the knowledge acquirement in health aspects of elephants than any other domains.

Table 3: Ten least known elephant management practices to first mahouts

Sl.No.	***Practices***	Percentage mean score
1	***Methods to be adopted while taking elephant in hot weather***	***43.00***
2.	Water requirements (normal) for an adult elephant per day	40.00
3	Precautions to be taken by mahouts while experts make use of the capture gun to immobilise the elephant	33.75
4	***Signs of heat in female elephant***	***32***
5	***Symptoms of water deficiency in elephants***	***26.65***
6	Method of knowing aged elephants from external appearance	23
7	***Techniques of first aid for wound in elephants***	***20***
8	Various methods of sitting on the elephant	17.33
9	Different methods of mounting on elephants	15.53
10	***Method of detecting age of an elephant***	***9.8***

Table 3, suggests the ten least known management practices to first mahouts. Out of these practices in the descending order of percentage mean score, signs of heat in female elephants (32.00), signs of inadequate drinking water intake (26.65), methods of knowing aged elephants from external appearance (23.00),

techniques of first aid for wounds in elephants (20.00), and method of detecting the age of an elephant (9.8) were least known to first mahouts and need immediate attention of scientists and veterinarians in this regard to create awareness.

Table 4: Ten least known elephant management practices to second mahouts

Sl.No.	Practices	Percent mean
1	Precautions to be taken by mahouts while experts use capture gun to immobilise the elephant	37.5
2.	Precaution by mahouts at the time of performance in temple	37.5
3.	***Water requirement (approx.) for an adult elephant per day***	***37.0***
4	***Methods of determining age of elephants***	***37.0***
5	***Methods of knowing aged elephants from external appearance***	***36.2***
6	***Approximate age of the elephant when it start showing musth***	***31.0***
7	***Symptoms of heat in female elephants***	***30.25***
8	All different methods of sitting on elephants	27.0
9	Different methods of mounting on elephants	25.0
10	***Signs of drinking water deficiency***	***17.15***

Table 4 shows that in the the ten least known practices to second mahouts in the descending order of percentage mean score were approximate water requirement for an adult elephant per day (37.00), methods of determining age of elephants (37.00), knowing an aged elephant from external appearance (36.20), approximate age of elephant when it generally starts showing musth (31.00), symptoms of heat in female elephants (30.25), and signs of drinking water deficiency (17.15). Regarding the least known things there does not exist much difference from the first mahouts. Any way rigorous training should be imparted to the second mahouts, since they are the immediate caretakers of the respective elephants.

In short, its the time to act, to make this two groups well informed equipped in knowledge regarding the diseases of elephants. Since they are the primary caretakers, live and die with elephants, they should be more aware of this diseases, symptoms, first aids. They can help the elephant experts or veterinarians in prevention and control of elephant diseases and save the life of the pachyderms to a great extent.

Conclusion:

Kerala has a cultural integrity with the elephants and has a high population of captive in the state. They are usually managed by two mahouts, with hierarchy as first and second and occasionally a third one. Unlike other livestock species, owners have a limited control on this animal. The present study conducted among the selected sample of first and second mahouts from two districts of Kerala state compared the level of knowledge of disease management practices of their captive elephants. The results revealed that there exist a marked difference among the two group in knowledge and highlights the enhanced need for creating awareness among them about diseases, especially for the second mahouts. This study also identified the areas where knowledge lacks for the first and second mahouts and to help we the veterinarians to achieve our goal of a healthy elephant through healthy, informative and aware mahouts.

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Effectiveness of mitigating measures against human-elephant conflict in and around the Coimbatore Forest Division, Tamil Nadu, South India

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Abstract:
During the past few decades the vast elephant ranges have been either fragmented or connected only by narrow corridors due to agricultural expansion, developmental activities and various anthropogenic pressures. This resulted in increasing incidences of human-elephant conflicts such as crop depredation and human deaths by elephants, and elephant deaths by ineffective mitigating measures. Effectiveness of various mitigating measures against the human-elephant conflict has been studied from January to May, 2005 in the Coimbatore Forest Division, South India. Most of the farmers used AC charged DC pulsed fences (local made), while some of them still depending on conventional methods (fire, crackers, sound, guarding), and few others have used superior quality of the solar power fencing systems. The effectiveness of the physical barriers depends on the maintenance, the height of the fence, the thickness of wire, post mounting type and post protection. The manufacturers fabricated the physical barriers depending on the crop in side, except for solar power fencing system. The visibility and thickness of wire, the post protection techniques on the fence line, and other technological improvements in solar fences have fine tuned the reduction of crop damages caused by elephants. The inverse relationship between the extent of elephant's visit to the crop fields and the availability of ecological resources was noticed despite cropping pattern and type of the physical barriers. The attacks of crops by elephants were more in the forest ranges of the Sirumugai and Mettupalayam. The conventional method or mechanical/electrical method alone was not effecting in protecting the crops, but the combination of the both could yield better result in minimizing the crop damages caused by elephants. AC charged battery fences were more prone to the electrocution of elephants. Male elephants in the age group between 15 and 25 died more frequently than other sex category by electrocution. Electrocution incidences of elephants were more in revenue villages than in the tribal settlements despite high economic loss faced by them.

Introduction:

The competition between human and animal species and the resulting conflicts show increasing trend mainly for space and resources in the recent years (Pimm *et al.* 1995; Balmford *et al.* 2001). Long ranging animals such as elephants, rhinos and large carnivores are particularly more prone to conflicts with human. The movement pattern of elephants is severely hampered by both biotic and abiotic activities, and thereby elephants are forced to extend their traditional range and raid crops. During such forays, destruction of properties, killing of humans by elephants and death of elephants inflicted by human beings are serious conservation issues in many parts of Africa (Bell and McShane-Caluzi, 1986; Hough, 1988; Mackie, 1992; Njoroge, 1992; Lindeque, 1993a, 1993b; Thouless, 1994; Thouless and Sakwa, 1995; Barnes *et al.* 1995; Tchamba, 1996; Rodwell *et al.* 2000; Sitati *et al.* 2003) and Asia (Sukumar and Gadgil, 1988; Santiapillai and Widodo, 1993; Ramesh, 1994; Balasubramanian *et al.* 1995, De Silva, 1998; Williams *et al.* 2001; Kumar *et al.* 2004).

Crop depredation by elephants in Asian countries has been reported to be on the increase. Increase in human population and the shrinkage of habitat, coupled with over–exploitation of natural resources have been mentioned as the major factors responsible for the increased crop raiding incidences by elephants in Sri Lanka (McKay, 1973 and Santiapillai, 1987). In India, human deaths and crop raiding by elephants have been well documented (Sukumar, 1985; Desai and Krishnamoorthy, 1992; Ramesh and Desai, 1992; Balasubramanian, *et al.* 1995; Saravanakumar, 2004). Increased probability of crop raiding incidents led to

an anti-conservation attitude in the minds of people. Therefore, use of various mitigating measures to protect their crops and properties are considered as viable alternatives. Many different approaches have been used to mitigate conflict between the elephants and people, at different levels. In spite of being an endangered species, the options available to reduce human-elephant conflict are few.

Datye and Bhagwat (1995) mentioned that elephants were chased by using long burning torches during the night hours in Bihar in 1989. Balasubramanian *et al.* (1995) found that there were four protection methods used by the farmers of the Nilgiri Biosphere Reserve as measures of mitigating human-elephant conflict. Farmers in this area guarded the fields with low fencing, coupled with a minimum effort to protect their crops. Ordinary fencing and guarding methods were adopted by using various materials such as bamboo, thorns, barbed wire, hedgerows, etc. Night guarding also was done by keeping watch on proper on tree tops or ground based guard sheds. Sound making devices such as tins and drums were also used to drive away the elephants (Hoare, 1995; 2001) in Africa.

Conventional methods such as fire crackers, trip wires that set off explosive crackers and fire bands were used as elephant scaring devices in various parts of the Nilgiri Biosphere Reserve. Use of fences fitted with energizers that generated very short pulses of high voltage electricity was also recorded by the Balasubramanian *et al.* (1995) in South India. Apart from the physical deterrents chemical repellents (Osborn and Rasmussen, 1995) were also attempted in various elephant ranges. Bell (1984) and Sukumar (1989) suggested that the community approach of bringing 'front line' of farmers closest to elephant refuges to drive away.

Crop raiding strategies by elephants, and the success or failure of various crop protection methods have been studied to some extent. But the factors influencing the contact of elephants with barriers and the technical aspects responsible for the damage of electric fence, which is an effective physical barrier against elephants across the elephant ranges, have not been quantified. Besides describing the various techniques or subjectively evaluating them, there is no quantitative work on this important aspect. Therefore, the present study was attempted to find out both ecological and technical aspects with the following objectives,

i) To identify various mitigating measures being adopted by the local people,
ii) To evaluate the effectiveness of the mitigating measures in relation to technical features and
iii) To find out the ecological factors, which determine the effectiveness of the mitigating measures.

Study area:

The Coimbatore Forest Division falls under the Project Elephant Reserve No. 8, (Project Elephant Perspective Plan, 2003-2013, Govt. of India) in which Nilambur-Silent Valley National Park of Kerala forms the major portion of the tract. The study area lies between 11° 27' N and 10° 52 N latitude and 77° 3' E and 76° 39' E longitude (Map 1). This forest division has six forest ranges namely Sirumugai, Mettupalayam, Periyanayakkanpalayam (PN Palayam), Coimbatore and Booluvampatty. This forest division is bounded north by Nilgiris, south by Palghat Gap and west by Mannarkad Forest Division and the Silent Valley National Park of Kerala and east by Coimbatore City.

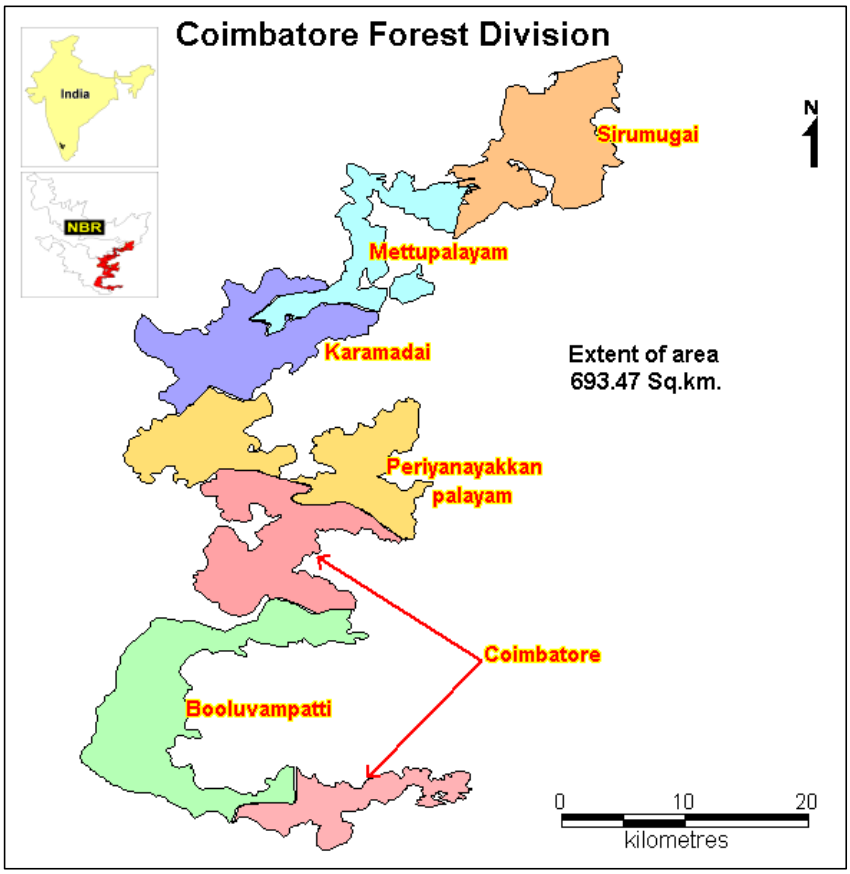
This forest division has a wide ranging altitude from 279m (Bhavanisagar water spread area) to 1801m (Velliangiri Peak). The Coimbatore forest division is drained by two major perennial rivers *viz*., Bhavani and Siruvani. The terrain is gently undulating in the foothills leading to steep escarpment areas in the slopes. The study area has a rainfall gradient (annual) from 750 mm at the foothills to 2000 mm on the hills from both south west and north east monsoons.

Correspondingly, the major vegetation types vary from tropical thorn forests in the north to mixed dry deciduous forests in the south. Besides, moist deciduous, semi evergreen and small patches of shola and grasslands are also found corresponding to terrain, altitude and rainfall on the west. Agricultural lands are surrounded in the east along the forest division. The physiognomy of the vegetation is determined by tree, species such as *Albizzia amara, Acacia leucopholea, Dicrostachyes cenerea* and *Tectona grandis* comprise in the study area.

The elephant population in the study area is estimated to be about 200-250 individuals (Ramakrishnan, Pers. comm. 2005). In dry season congregation of elephants can be seen more around the perennial water sources. Apart from elephants, this forest division also harbours many endangered mammalian species such as Indian gaur *(Bos gaurus)*, sambar *(Cervus unicolor)*, spotted deer *(Axis axis*), four horned antelope *(Tetracerus quadricornis)*, nilgiri langur *(Presbytis johni)*, tiger *(Panthera tigris)*, leopard *(Panthera pardus)*, wild dog *(Cuon alpinus)* and hyaena *(Hyaena hyaena)*.

Currently main threats to the elephant population in the study area include fire, weed invasion, development activities and crop patterns in the peripheral areas. Over the past decade, more electrocution incidences of elephants due to non-professional mitigating measures present an alarming and serious threat in this forest division. Elephants in this area also range seasonally to various protected areas and other reserve forests. Protection of this forest division would thus benefit the conservation of elephants in the Nilgiri Biosphere Reserve as a whole.

Map.1 Map showing the location of the Coimbatore Forest Division with six forest ranges



Methodology:

Identification of mitigating measures:
A questionnaire based survey method (Balakrishnan and Ndhlovu 1992; Ramakrishnan *et al*.1997) was used to identify various human-elephant conflict mitigating measures adopted by the local people, living adjacent to fringes of the study area. The survey was conducted for five months from January to May 2005. 529 people were interviewed along the fringes of the study site. The questionnaire was designed to evaluate factors such as frequency of elephant visits and types of mitigating measures adopted by the farmers. 222 farmers who had installed electric fences (both solar power fence and AC charged battery fences) and 78 farmers without fencing were interviewed, to identify various human-elephant conflict mitigating measures.

Evaluation of the effectiveness of mitigating measures:
The questionnaire brought out the advantages of using three differently powered fences, *viz*., AC powered electric fences, solar-powered electric fences and AC charged battery fences. Factors such as maintenance, height of the fence, thickness of wire, post mounting type, post protection and manufacturers etc. were collected in the questionnaire. Balasubramanian *et al.* (1995) documented the various types of mitigating measures and their effectiveness in the Nilgiri Biosphere Reserve. Totally 300 farmers were interviewed in six forest ranges of the study area, of which, 206 farmers used AC charged fences, 16 used solar power fences. Apart from the physical barriers, 78 farmers were using conventional deterrents to keep away the elephants from their agricultural lands.

Assessment of ecological factors to determine the effectiveness of mitigating measures:
The questionnaire method was used to assess the reasons for elephant visits to agricultural fields. The variables such as distance between the ecological requirements to elephants (perennial water sources and natural saltlicks) and forest boundary, water utilization for irrigation and cropping patterns were also collected.

Results:

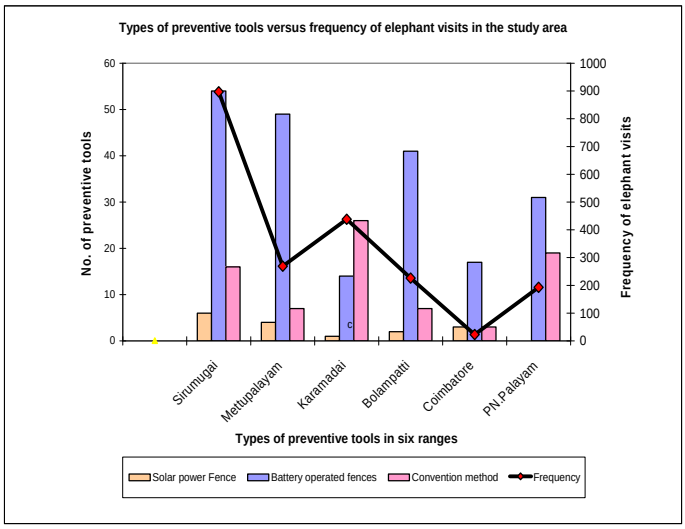
Types of physical barriers:
Crop damages by elephants were prevented with eight mitigating measures in all the forest ranges (Table.1) in the Coimbatore Forest Division. The findings showed that there was not much variation in the types of mitigating measures deployed by the locals. On the contrary, frequency of elephants' visits to crop fields varied, across the study sites, with more visits by elephants in Sirumugai (n=897) and Mettupalayam (n=438). The Coimbatore had less sighting of elephants, closer to the crop fields. It is interesting to note that the AC mains run fence, AC eliminator with live battery and serial numberless energizers were frequently used in all forest ranges (Table.1). On the other hand Elephant Proof Trench (EPT) was noticed only in one location of the Mettupalayam range.

Table.1: Various types of mitigating measures adopted by the local communities

Name of the Ranges	A	B	C	D	Fire	Fire Crackers	Spot light	Elephant Proof trench	Elephant visits
Sirumugai	6	48	6	0	1	11	0	0	897
Mettupalayam	4	47	2	0	3	2	1	1	438
Karamadai	1	10	0	3	6	8	0	0	269
PN Palayam	0	25	2	4	4	10	5	0	193
Coimbatore	3	17	0	0	0	3	0	0	23
Booluvampatty	2	40	0	0	0	3	4	0	226

(A - DC fence, solar panel, live battery with serially numbered energizers)
(B - DC fence, AC eliminator, live battery with no energizer serial number)
(C - DC fence, AC eliminator, dead battery/by-passed, with no energizer serial number)
(D - No energizer, no battery/dead battery, Probably AC driven, at night)

Fig.1: Types of preventive methods versus frequency of elephants' visits in the study area



Fields equipped with AC charged battery operated fences were frequently visited by elephants in all forest ranges except Karamadai (Fig.1). In Karamadai the conventional method seemed to be more effective during elephant visits than other methods. Inspite of the fact that Sirumugai range had a larger number of battery operated as well as solar power fences, the frequency of elephant visits was more. On the other hand, the low number of solar power fences provided showed an inverse trend with elephants avoiding the crop fields too.

Effectiveness of the mitigating measures in realtion to technical features:

Maintainance:
Different levels of maintenance of electric fences are also an important factor to prevent the elephants getting into crop fields. Out of sixty fences in the Sirumugai range, ten of them were in poor condition. Most of the fences were maintained in good condition in the forest ranges of Mettupalayam, Booluvampatty and PN Palayam (Table.2).

Frequency of attempts by elephant was more towards fences of good quality, in all the six ranges. On the other hand, fewer visits were made by elephants towards poorly managed fences (Table.2). The availability of crop inside the fences could be the determining factor for tempting elephants, getting into fenced areas. The crops such as plantain, sugarcane, and coconut were well maintained inside the quality fences, because of its economical value.

Table.2: Frequency of elephant visits versus maintenance of fencing in Coimbatore Forest Division

Frequency of elephant visits	Sirumugai n=60 (fences)		Mettupalayam n=53 (fences)		Karamadai n=15 (fences)		Booluvampatty n=43 (fences)		Coimbatore n=20 (fences)		PN Palayam n=31 (fences)	
	Poor n=10	Good n=50	Poor n=12	Good n=41	Poor n=2	Good n=13	Poor n=12	Good n=31	Poor n=7	Good n=13	Poor n=9	Good N=22
0 – 5	8	32	11	41	7	12	7	32	3	15	4	8
6 – 10	21	97	17	78	10	25	14	83	5	14	5	13
11 -15	54	156	33	62	8	21	11	18	9	19	8	16
16 – 20	0	151	28	46	0	28	16	22	0	21	9	15
21 – 25	0	109	2	30	0	0	2	6	8	22	11	23
26 – 30	0	0	1	15	0	0	0	0	0	0	0	21
31 -35	31	69	16	21	0	0	0	0	0	0	0	13

(Crops in poorly maintained fences: Cowpea, Tomato, Horse gram and Ragi)
(Crops in well maintained fences: Plantain, Sugarcane, Coconut, Paddy, Jack and Mango)

Height:
Most fences were 6.5 feet (2m) high. this did not influence the frequency of elephant visits (Table.3). The high cash vale and elephant preferable crops growing through out the year were protected by the fences with standard height of 6.5 feet. Nevertheless these crops were frequently visited by elephants.

On the other hand the seasonal crops were protected by fences of low height ranging from two to four feet. Even then the incidence of elephants raiding such crops was very low (Table.3).

Table 3: Height of fences versus percent frequency of crop raiding by elephants in various ranges

Fence heights (ft.,)	Sirumugai n=60 (fences)		Mettupalayam n=53 (fences)		Karamadai n=15 (fences)		Booluvampatty n=43 (fences)		Coimbatore n=20 (fences)		PN Palayam n=31 (fences)		Crops grown
	n	%	n	%	n	%	n	%	n	%	n	%	
2	4	10.1	*	*	2	11.7	3	9.0	2	10.3	3	11.0	Turmeric, Onion, Tomato, Ragi, Cowpea, Horse gram
4	13	21.0	5	9.2	3	11.7	7	14.2	5	20.7	9	25.3	Red gram, Paddy, Maize, Brinjal
6.5	43	68.8	48	90.7	10	76.5	33	76.7	13	68.9	19	63.6	Plantain, Coconut, Sugarcane, Jack, Mango

Turmeric *(Curcuma longa)*, Onion *(Allium cepa)*, Tomato *(Lycopersicon esculentum)*, Ragi *(Eleusine coracana)*, Horse gram *(Dolichos biflorus)*, Red gram *(Cajanus cajan)*, Paddy *(Oryza sativa)*, Maize *(Zea mays)*, Brinjal *(Solanum melongena)*, Plantain *(Musa paradisiaca)*, Coconut *(Cocos nucifera)*, Sugarcane *(Saccharum officinarum)*, Jack *(Artocarpus heterophyllus)*, Mango *(Mangifera indica)*.

Wire thickness:
Three different gauges thicknesses of wires were selected for the fence line by the local community in the Coimbatore Forest Division (Table.4). Elephants often visited fence lines made of 16 gauge, followed by 14 gauge and 12 gauge wires, in all forest ranges. Visibility of 12 gauge wires is prominent to elephants during night hours rather than the other two gauges. This could be the reason for more frequency of elephant visits towards 14 and 16 gauge wire fence lines.

Table 4: Frequency of elephant's visits versus wire gauges used for fence line in various Forest Ranges of the Coimbatore Forest Division

Types of wire gauge	Frequency of elephants visits					
	Sirumugai n=60 (fences)	Mettupalayam n=53 (fences)	Karamadai n=15 (fences)	Booluvampatty n=43 (fences)	Coimbatore n=20 (fences)	PN Palayam n=31 (fences)
12 G	138	98	27	43	12	26
14 G	185	111	34	63	27	42
16 G	405	192	50	105	77	78

Type of mounting:
Five different types of fence mounting were observed in the 222 electric fences (Table.5). In most of the cases, wooden poles were used (n=148), followed by flexible metal posts (n=36) and stone posts (19). The frequency of elephant visits were recorded more on wooden posts, followed by metal post fences. The use of stone posts in fence lines was not observed in Mettupalayam, Karamadai, Coimbatore and PN Palayam ranges. Metal offset was also not used in the fence lines at Mettupalayam, Karamadai and Coimbatore. The use of concrete posts was not found in Karamadai and Coimbatore ranges.

Table 5: Frequency of visits by elephants versus types of mounting of fences used in various ranges of the Coimbatore Forest Division

Types of mounting fence	Frequency of visit by elephants ranges					
	Sirumugai n=60 (fences)	Mettupalayam n =53 (fences)	Karamadai n=15 (fences)	Booluvampatty n=43 (fences)	Coimbatore n=20 (fences)	PN Palayam n=31 (fences)
Stone (n=19)	80	0	0	26	0	0
Metal post (n=36)	152	73	20	40	16	23
Metal offset (n=4)	4	0	0	15	0	2
Dry Wood (n=148)	387	282	91	111	100	108
Concrete (n=15)	17	46	0	19	0	3

Post protection:
The fences were protected with three types of electrical post protection, in all six forest ranges (Table.6). Among the three types, unprotected posts were more prone to elephant depredation than the other two types. It is interesting to note that four line Vertical post protection (capping) system was attacked by elephants more often than double line protection of the posts.

Table 6: Frequency of elephant visits with types of post protection used in the fences

Type of post protection	Frequency of visit by elephants ranges					
	Sirumugai (n=60)	Mettu palayam n=53	Karamadai n=15	Booluvam patty n=43	Coimbatore n=20	PN Palayam n=31
Double line capping (n=7)	0	7	3	19	0	10
Four line capping (n=28)	56	53	22	51	11	18
No capping (n=187)	672	341	86	141	105	128

Manufacturers:
Mean frequency of elephant visits versus power fencing companies have showed that fences provided by M/s. Intech Defence (13.7) received higher visits by elephants, which was followed by M/s. Crown (13) and M/s. Stinger (12) irrespective of the forest ranges of the Coimbatore Forest Division. On the other hand, the elephant's mean attack of fences was lowest for M/s. Ibex Gallagher (2.7), M/s. Star (6) and M/s. Laxtron (6.3) (Table.7). However, the sample sizes were too small to conclude on the relationship between the company and elephant visits. This needs a further detailed study, with relatively large sample size.

Table 7: Frequency of elephant visits and encounter rate with different energizers manufactured by various companies

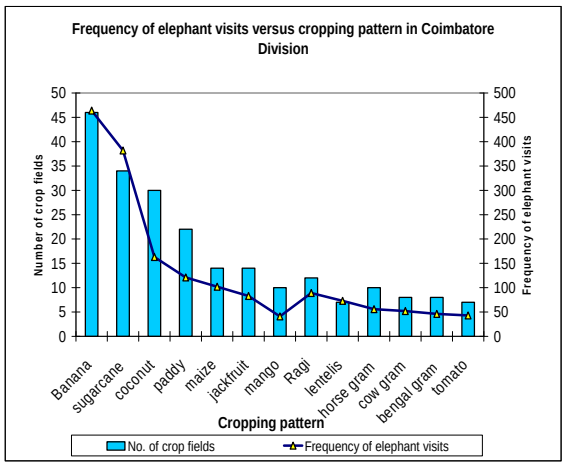
Type of energizers	Mean frequency of visits by elephants					
	Sirumugai	Mettupalayam	Karamadai	Booluvam patty	Coimbatore	PN Palayam
Ibex Gallagher (n= 10)	*	4.5	5	3.4	2.7	*
Star (n=10)	*	*	*	*	6	8
Stinger (n=9)	*	*	*	12	*	*
Crown (n=188)	13	7.8	7.4	7.5	7.9	9
Jai Solar (n=1)	*	*	*	9	*	*
Laxtron (n=1)	*	*	*	6.3	*	*
Intech defence (n=9)	13.7	*	*	*	8	*

(- No single fence of the company in the particular range)*

Availability of ecological factors in realtion to the effectiveness of the mitigating measures:

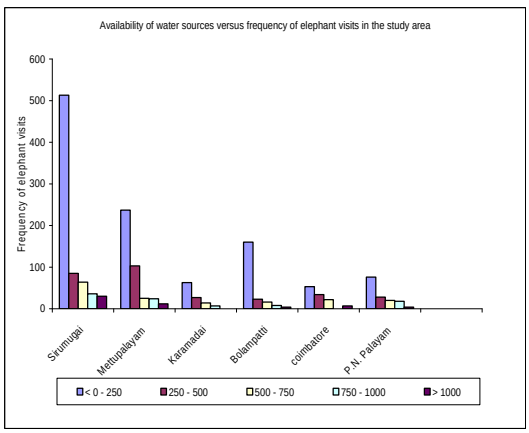
Cropping pattern:
There were thirteen major agriculture crops grown in the study area. Among them plantain (*Musa paradisiaca*), coconut (*Cocos nucifera*), sugarcane (*Saccharum officinarum*), paddy (*Oryza sativa*) and maize (*Zea mays*) attracted the elephants with more frequency of visits irrespective of the study sites (Fig.2).

Fig. 2: Frequency of elephant visits versus cropping pattern



Water source (natural):
Crop raiding by elephants was more common in Sirumugai (n=513), followed by Mettupalayam (n=237) and Booluvampatty (n=160) (Fig.3). The incidences of raiding of crops were low in other forest ranges. There was inverse relationships which show that there were greater distances between the perennial water sources and the crop fields. This was proved with the low visits of elephants to crop fields in all the ranges (Fig. 3). Interestingly, the number of sightings of elephants was greater when the proximity to water sources (< 250m) was close to the agricultural land, which resulted in more damages to human properties.

Fig. 3: The relationship between the frequency of elephants' visits and the distance to water sources from the location of physical barriers



Water source (artificial):
The mean distance between the crop field and forest boundary ranges from 96.75m to 360.19m in the study sites (Table.8). Both bore wells and open wells were available for irrigation purpose in the crop fields. Except the Coimbatore range, the pumping hours seemed to be similar in all ranges. The number of storage tanks in Booluvampatty, Karamadai and PN Palayam were 21, 19 and 2 respectively. No water tank was available in the other three ranges. Although no storage tanks were observed in the Sirumugai range, the frequency of elephant visits (N=728) was higher than in other ranges. Elephants visited the crop fields adjoining Karamadai infrequently despite the presence of more water tanks (n=19).

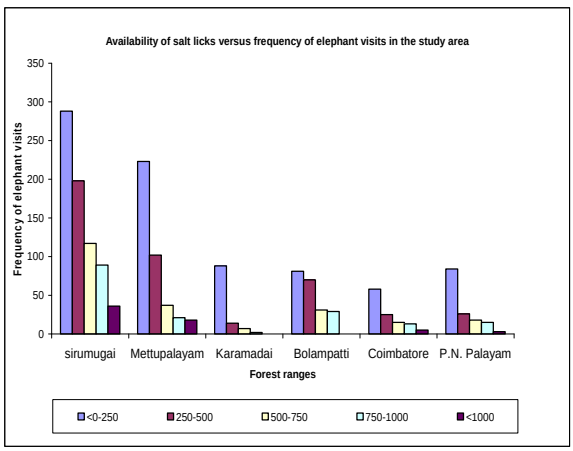
Table 8: Use pattern of under ground water versus elephant's visits

Name of the Ranges	Mean distance between crop fields and RF (m)	Total number of Bore wells and open wells	Number of storage tanks	Major cropping pattern					Total number of frequency of visits by elephants
				P	S	Pa	M	C	
Sirumugai	108.33	44	0	√	√		√		728
Mettupalayam	254.71	48	0	√	√	√	√	√	401
Karamadai	360.19	37	19	√	√	√		√	111
PN Palayam	322.58	42	2	√	√	√		√	146
Booluvampatty	313.95	55	21	√	√		√	√	211
Coimbatore	96.75	11	0	√	√	√		√	116

(P-Plantain, S-Sugarcane, Pa-Paddy, M-Maize, C-Coconut)

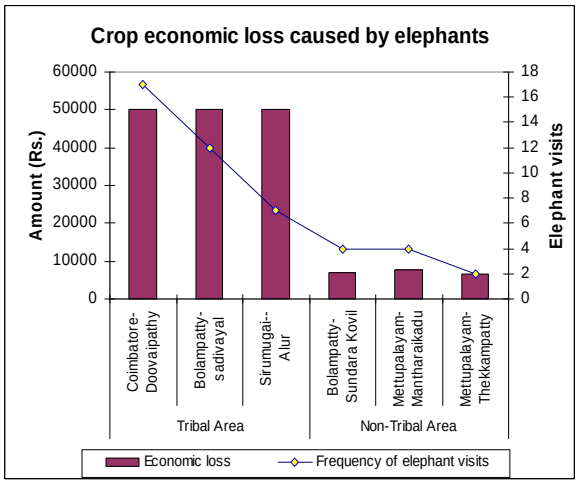
Saltlicks:
Frequency of elephant visits varied in relation to the distance between available natural saltlicks and crop fields. (Fig.4). There was a negative trend of elephant sightings, when saltlicks were placed at a greater distance from crop fields. Such a trend was seen for all the forest ranges. The frequency of elephant sightings increased, in relation to availability of natural saltlicks, in closer proximity to the crop fields. The sightings of elephants were inversely proportionate to the distance of natural saltlicks away from the fence line.

Fig. 4: The relationship between frequencies of elephants' visits and distance to natural saltlicks from the location of fence line



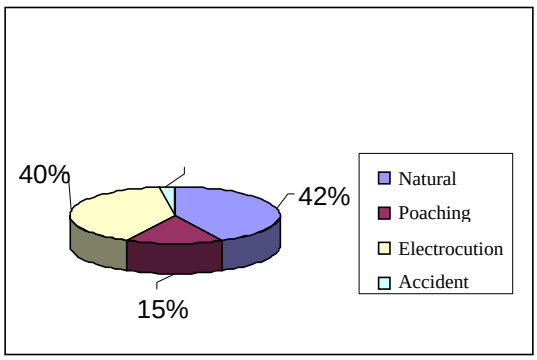
Crop economic loss versus frequency of elephant visits:
More crop economic loss was recorded in the tribal settlement areas than non-tribal areas, irrespective of the forest ranges (Fig.5). The revenue villages of Mantharaikadu (Rs.7,800), Sundarakovil (Rs.7,000) and Thekkampatti (Rs.6,500) have recorded a relatively low crop economic loss caused by elephants. On the other hand, tribal settlements such as Alur (Rs.50,000), Doovaipathy (Rs.50,000) and Sadivayal (Rs.50,000) were severely affected with the crop depredation by elephants. Although high economic loss is attributed in the tribal settlements no incidence of electrocution of elephants was noticed.

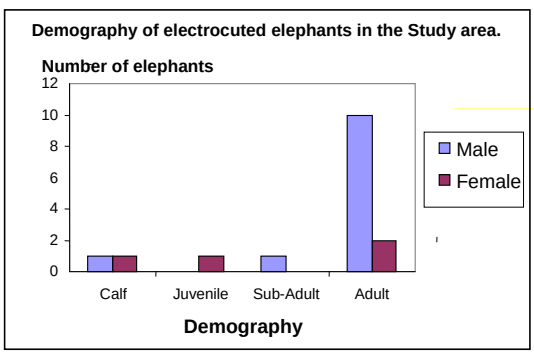
Fig. 5: Occurrence of crop damage incidences in tribal and non-tribal areas of the Coimbatore Forest Division



Stauts of elephant deaths:
The perusal of records of elephant death over a decade (1995-2004) revealed that there was no much variation between natural (42%) and electrocution incidences (40%) of death of elephants. Totally 22 elephant deaths were recorded by man made activities comprising poaching (6) and electrocution (16). It is important to note that out of sixteen electrocution incidences fourteen were males. Of which, 10 were adult males in the age of category between 15 and 25 years old viable breeding bulls. Death rate of 2 males per year is an alarming situation for the conservation of elephants in the long run, in this region (Fig.6).

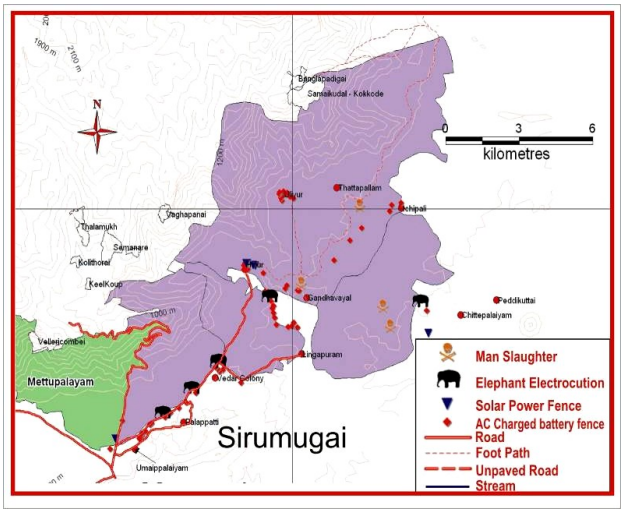
Fig. 6: Records of elephant deaths over a ten year period in the Coimbatore Forest Division (1995 - 2004)



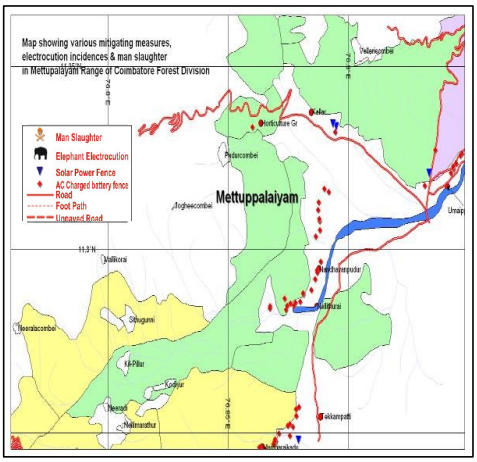


Map 2-7 showed all incidences of elephant electrocutions in relation to various mitigating measure in the six forest ranges of the study area, were occurred in the AC charged non professional fences irrespective of the forest ranges to the study area.

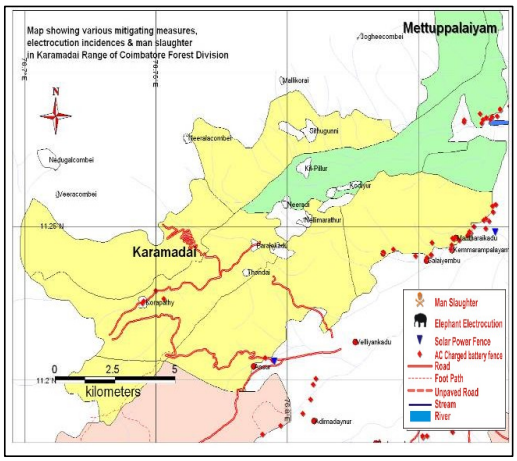
Map 2: Types of physical barriers, the location of elephant's electrocution and human death by elephants in Sirumugai Forest Range



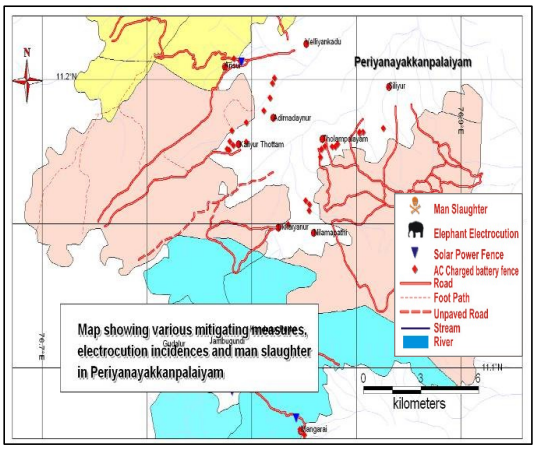
Map 3: Study site and location of fences along the elephant migratory route in Mettupalayam Forest Range



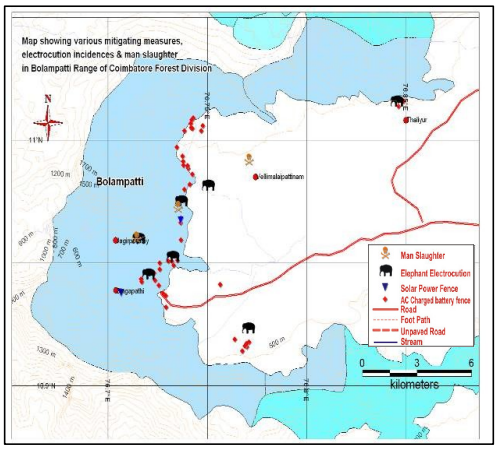
Map 4: Study site and location of fences, along the elephant migratory route in Karamadai range



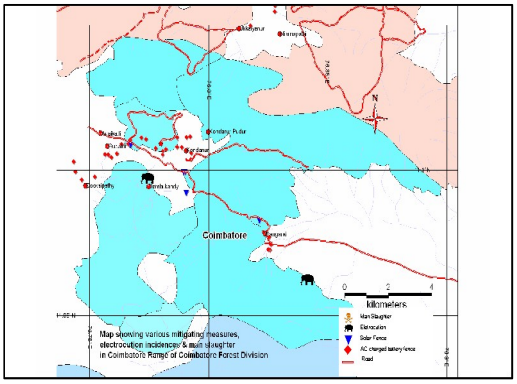
Map 5: Map showing the study site and location of electrocution cases and the elephant migratory route in the PN Palayam range

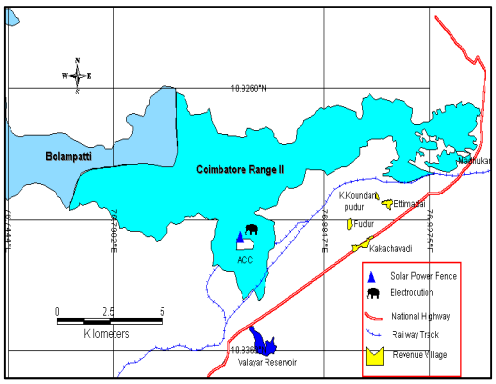


Map 6: Map showing the study site and location of fences along the elephant migratory route in Booluvampatty Range



Map 7: Map showing the study site with incidences of electrocution cases including the elephant migratoryroute in the Coimbatore Range





Discussion:

Human-elephant conflict is a challenging scenario for the forest managers because of more incidences of crop damages and electrocution of elephants in the crop fields adjoining the fringes of elephant forests and those that serve as habitat corridors. The situation further worsened with the invasion of elephant herds into isolated pockets and invasion of new sub-optimal habitats. This created a negative approach in the minds of the local community which depends on the jungle, along with elephants and other animals, for its sustenance. The exponential growth of developmental activities coupled with human induced activities such as wood gathering for commercial purposes, grazing of livestock and collection of non-timber forest produce by the locals are fast degrading the elephant reserve. This leads to an unfriendly situation between people and elephants in most of the elephant reserves in South India.

Of late, forest managers in South India with their own funding resources and international support help the local community to protect their agricultural fields with superior quality fences. In some villages, these

fences are erected with the combined efforts of the entire community. In addition, other physical barriers are installed by local authorities, based on local site specific factors, such as terrain and financial resources. It is noteworthy that various traditional practices are being deployed by the locals to scare away wild animals, especially elephants, without causing any physical harm.

The major tools used by locals are shouting in groups, guarding the fields from a tree top (machan), bursting crackers, throwing burning fire torches and stones and shooting in rare cases. In the Dharmapuri District of Tamil Nadu, a new concept of scaring away the crop raiders has been initiated. With the help of powerful search lights the locals guide the elephants to move towards their original track through habitat corridors; which has been successfully demonstrated on many occasions (Dr. Sukhdev, The Chief Wildlife Warden, Tamil Nadu State, Pers. comm.). It is also learnt from this study that regular crop raiders, mostly bulls and makhnas (tuskless males) were experienced with bullets. Of late, the concept of solar power fencing has attracted many farm owners and in many instances they have found new simplified technologies for protecting the crops using the concept of battery operated fencing technology, with low cost. This is the basic reason for the electrocution of animals in electric fences. Very little awareness on the value of the species and the rigidity of the forest laws vis-à-vis offenders also attribute to the death of elephants by electrocution.

Realizing the importance of the value of conservation, the issues of human-elephant conflicts and seeking to develop a suitable mitigating measure for the reduction of conflict issues, the Project Elephant, Government of India, came up with research programmes in order to understand the reality of the situation in some selected forest divisions in Tamil Nadu, India.

Ramakrishnan *et al.* (1997) have observed and documented the fact that elephant corridors are highly threatened by the impact of human activities in the Coimbatore Forest Division of Tamil Nadu. The synchronized Elephant Census-2005 revealed that this division holds 200-250 elephants. The findings have showed that a major part of the tract of elephant corridors has its connectivity with the Nilgiri Eastern Slope RF and the Eastern Ghats landscape. Many studies (Baskaran *et al.* 1995; Sivaganesan *et al.* 2000 and 2005) have reported that the elephants migrate from Mudumalai Wildlife Sanctuary to the Coimbatore Forest Division through the Greater Moyar Valley Corridor. It is possible to conclude that the tract of elephant corridors is highly significant not only to this division but also for regional conservation in South India. The evidence of elephant dung piles and feeding signs in all the corridor sites during the dry season coincide with the migrating season of elephants in the adjoining forest division of Sathyamangalam. Thus, conservation of this small number of elephants is absolutely vital considering the importance and usage of elephant corridors.

It was found that the elephant populations, by and large, used the low land forests bordering cultivation of small to big agriculture gardens. Although various mitigating measures (Solar power fencing system, AC charged battery fencing system and other conventional methods) were deployed by the local population, battery operated fences were noticed commonly. The expenditure involved for these fences is less and the farmers are generally able to meet the expenditure. Surveys and interaction with the farmers revealed that the cost factor greatly influenced the decision to erect battery operated fences. Further, it was found that this facility was easily accessible to them, because some companies located in Coimbatore city manufactured these batteries.

The study also revealed the fact that elephants visited the crop sites, which were mostly protected with AC charged battery fence lines rather than any other physical barriers. Therefore it can be obviously concluded that AC charged battery fences are often used by the villagers to guard their crops; it is also true that this low standard technology could be the possible reason for more electrocution of elephants in this division. These battery operated fences and solar power fences in the Sirumugai Range were recorded more incidences of electrocution of elephants. The most acceptable reason could be the locals' preference for sugarcane and plantain all along the fringes of the traditional home range of elephants in this range, which are guarded by both systems of fencing.

On the other hand, it was also found that the low occurrence of solar power fence had an inverse tendency of elephants visiting the crop field in the entire forest division. It is because of the fact that the concept of professionally erected solar power fence in the range is just emerging as a tool to protect the crops. Animals migrating through this tract of corridor have hitherto never experienced the effect of a solar power fence; which could be the factor that prevents animals from raiding crops guarded with solar power fences. It can be conclusively stated, on the basis of the findings, that not all the animals were crop raiders in this division and this could be the reason for variation in elephant visits. Evidences are also available in previous reports which states that all herds are not crop raiders in the elephant population in the Mudumalai Wildlife Sanctuary of the Nilgiri Biosphere Reserve, South India (Balasubramanian *et al.* 1995). Thus this present study supports the view of Balasubramaniam and concludes as such.

The inverse relationship between the extent of elephant visits to crop fields and the availability of natural saltlicks in the forest region shows that the occurrence of natural saltlicks could be the influencing factor for the elephant population to get attracted to crops fields adjoining the jungle corridors. Thus, it is possible to indicate that the natural saltlicks in the forests could be a proximate factor for the extent of elephant visits to the crop fields during their annual migration and seasonal movements between habitats. It is suggested that in addition to the relationship between the availability of natural saltlicks and elephant visits to crop fields, the distribution of dry soil texture of the Coimbatore Forest Division in the foothill forests could be investigated so as to assess the relationship between sodium content in the soil and the distribution of elephants. This might address certain factors responsible for human-elephant conflict in this division.

The frequent crops raids by elephants in the forest ranges of Sirumugai and Mettupalayam during the study period could be related to the annual movement of elephants between the Nilgiri Eastern Slope Reserve Forest and the Coimbatore Forest Division. Sivaganesan *et al.* (2000) recorded that the elephant populations largely move between the tracts of Nilgiris and Coimbatore during the North East Monsoon (October to December). Both the forest ranges of Sirumugai, Mettupalayam and Coimbatore are located in the migratory tract of elephants in the Coimbatore Forest Division and hence, the locations of these reserves could play a vital role to their susceptibility to crop damages by elephants despite the available physical barriers. The intensity of crop damages in these reserves could increase with the impact of various developmental activities and also the poor land use pattern adjoining the forest fringes. Thus, the present study on the human-elephant conflict warranted policies for the management of human-elephant conflict in the Coimbatore Forest Division in future. The forest ranges of PN Palayam and Karamadai ranges were not surely affected due to crop damages by elephants, as these areas are not located in the traditionally migratory routes.

The study clearly showed that the availability of crops within the fenced area could be the deciding factor for the extent of elephants visiting the crop fields. The competition and risk involvement factors of animals getting into crop fields were observed in this study. Although high percent frequency of elephant visits were made in the cash crops such as sugarcane and plantain due to its good quality for long periods of time did not suffer from elephant attacks. In contrast, short term crops such as grams and vegetables, protected with low quality fences ranging from 2 to 4m, were often attacked by elephants because the investments made by the villagers to protect their low value cash crops. The study also revealed that there is no uniformity in terms of adopting a standard technique to protect farm lands irrespective of long duration crops. There has been a phenomenal change in the capability of elephants in attacking the fences of different standards and technology to achieve the target of crop raiding. Therefore it is necessary for farmers to install fences of varying heights for protecting different crops. It would help if the forest authorities could develop uniform regulations that govern the erection of solar power fences with different height categories based on the findings of the present study.

The visibility and thickness of wire are factors that need to be considered while erecting 'elephant-proof' fences. Fences made of 12 gauge wires are more visible to elephants than those made with 14 and 16 gauge wires. It might be concluded that the thickness of wire gauge in fence lines could be a fundamental factor in withstanding elephant attacks. Fences with 14 and 16 gauges wires were subjected to intense damages. Similarly fence lines without post protection were more prone to elephant attack because they could be

easily accessed. Fences without post protection (capping) on the fence lines are largely prone to regular crop raids in the Coimbatore and Nilgiri Forest Divisions (Sivaganesan, Pers. comm.). The post protection technique for the fence line (Sachidanandha Niketan Premises: 1995) is an advanced technique first adopted by M/s. Ibex Gallagher dealer, M/s Perimeter Protection System, Coimbatore to deal with crop raiders in some areas of the Nilgiris and they are found to be successful in mitigating the damage to the fence. The development of methods such as capping and its associated protrusion of a few tentacles at 2m height was a further advancement in the fence system (Kallar Private Farms) to protect the solar power fence in its totality from crop damage by elephants. It is also possible that the capping system could no longer serve as a tool to "say no" to crop damages. This perhaps could be related to the behavioural changes exhibited in elephants by exposing themselves towards various revisions of the technological improvement in power fences.

There was a relationship between the type of energizer used in the fence and its influence on the number of attacks by elephants. Nevertheless, the sample size is too small to conclude the rate of success of the energizer company as part of fence efficiency to control the system as a whole to prevent crop damage by wild animals. However, the low contact of elephants with the fences of M/s. Ibex Gallagher Company is largely due to the professional development in fence technology, keeping in mind the behaviour of animals towards fences (Sivaganesan, Pers. comm.). Many types of energizers were used for solar power fences by the locals depending on their resource availability. It is clearly viewed from this study that superior quality of the fence contributes significantly against crop damage by elephants.

The result clearly showed that either conventional method or mechanical/electrical method alone did not protect the crops and the combination of both could yield better results in minimizing crop damages by elephants. The study also concluded that superior quality power fences with all safety standards including alarm systems are always better than the time consuming traditional methods deployed by locals to protect the agriculture crops from wild animals, especially elephants. The conclusive proof of the effectiveness of superior quality power fences as controlling tools was seen in many revenue and forest settlement areas of the Greater Moyar Valley Elephant Corridor (Sivaganesan *et al.* 2005).

The factors such as crop distance from reserve forests, availability of bore wells and number of water storage tanks in the village vicinity did not show any influence over the sightings of elephants in the village vicinity of all the forest ranges during the present investigation. The numerous sightings of elephants in Sirumugai and Mettupalayam Ranges could be related to the availability of water spread areas of Bhavanisagar dam and perennial river Bhavani, and not because of other water resources.

More cash crops were damaged by elephants than other crops in all the ranges. Maize was heavily damaged followed by sugarcane and paddy. The damage to crops varied from place to place depending on cropping pattern but the selection of a spectrum of crops by elephants is evidently seen in the study areas. Sukumar (1989) found that elephants show a strong preference to crops in various parts of its ranges in Tamil Nadu.

Elephants selectively attacked only some villages across the forest ranges. The area of the crop (acres) and the location of the village, its proximity to the forest area and their importance to elephants in terms of corridors were vital factors. This was reflected in the selection of one or two villages for frequent visits by elephants, perhaps related to the availability of preferred crops. The more damage to crops in tribal areas was associated with lack of proper physical barriers in many villages. The revenue settlement areas are protected well with good physical barriers of varied types depending on their financial resources.

The loss of elephants by electrocution in the revenue villages perhaps related to the promotion of cash crop cultivation in their field using inferior quality solar power fences and also due to AC charged battery fences of low standards. Although a high magnitude of crop loss was witnessed in the tribal settlement areas, no cases of electrocution of elephants occurred in the same area, probably because of the cultivation of seasonal crops to meet their sustenance.

Acknowledgement:
We gratefully acknowledge the funding received for this project from the Project Elephant, Government of India. We are particularly grateful to Dr. T. Sekar, IFS, Conservator of Forests, Coimbatore Circle, for overseeing the project. This study would not have been possible but for the wholehearted support of the all forest staff of the Coimbatore Forest Division. We thank Mr. K. Ramkumar in digitizing map and GIS work for this paper. At the organisation, we thank all the office bearers especially Mrs. A. Ulagammal and Miss. S. Anitha for layout of this manuscript and also rendering all administrative help.

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Foraging ecology of the Asian elephant (*Elephas maximus*) in northern west Bengal, north eastern India

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Abstract:
The elephant habitat in northern West Bengal, India is part of the Eastern Himalayas biodiversity hotspot. The habitat is characterized by a high degree of fragmentation and severe human-elephant conflict. Foraging by Asian elephants was studied in this landscape during 2002-2004 as part of a larger study of elephant-human conflict. The study was carried out in the eastern parts of the landscape comprising the Buxa Tiger Reserve and Jaldapara Wildlife Sanctuary that together constitute a 1074 sq km area and harbour ~300 elephants. Systematic observations along feeding trails were made on a monthly basis following radio-collared elephant herds. Additionally, stable carbon isotope analysis of collagen from bone samples collected from dead elephants was also carried out.

In total, from 18,308 feeding scores, 108 plant species (that include 52 trees species, 20 shrubs, 8 herbs, 21 climbers, 6 grasses and 1 orchid) were recorded. Of the 108 plant species eaten by elephants, the top 15 species contributed to more than 85% of the annual diet. Elephants consumed more plant species in the dry season (91 *spp*.) compared to the wet season (59 *spp*.). *Acacia pennata*, a climber, was eaten more frequently (11%) in the dry season while in the wet season *Saccharum spontaneum*, a grass species, dominated (66%) the diet of the elephants.
In deciduous forest, the bulk of the elephant diet came from *Saccharum spontaneum* (55%), while in semi-evergreen forest and mixed vegetation, *Acacia pennata* (10%) and *Cephalostachym pergracile* (48%) contributed the highest proportions, respectively.
The feeding trail observation revealed that the annual diet of elephants is dominated by browse (58%). This is in keeping with the habitats in the study area being predominantly forested habitat. On a seasonal basis, browse constituted 93% of the elephant diet in dry season, while in the wet season, grass species formed the bulk (78%) of elephant diet. Results of bone collagen analysis revealed most of the samples to have $\delta^{13}C$ values more negative than –20 per mil, which correspond to contribution predominantly by C3 plants (browse species) to organic synthesis.

Introduction:

Foraging, the search for food is a major influencing factor in animal movement and habitat selection. For a mega-herbivore food, water and shelter are the principal factors that dictate the choice of areas used and their long and short-term movement patterns (Owen-Smith, 1988, Sukumar, 1989). Elephant is a megaherbivore requiring large amount of food (estimated variously at 1.5-2.5% of its body weight at dry fodder daily) for their maintenance (see Sukumar 2003 for a review). Though the elephant is a non-ruminant, it is still capable of utilizing microbial action for the digestion of cellulose in its ceacum and colon (Clemens and Maloiy, 1982). Due to this enormous food requirement, the elephant cannot afford to be a selective feeder like smaller herbivores and thus they consume large quantities of available forage, without spending much time and energy on selection. The trunk acts as an efficient screening and scooping instrument for distinguishing between palatable and non-palatable forage. The fast rate of passage enables consumption of large quantity of forage.
Most of the studies on elephant feeding habits have been in savanna habitats in Africa or tropical dry forest in Asia. The northern West Bengal landscape in northeastern India is primarily a tropical moist forest habitat with grasslands along the floodplains of rivers. Although there have been some studies on elephant habitats, and its population and human-elephant conflict (Lahiri Choudhury, 1975. Dey, 1991, Barua and

Bist, 1995, Choudhury *et a*l, 1997) in northern West Bengal, no detailed study on the foraging ecology of wild elephant has been done. The present study was carried out to document the plant species composition and its seasonal variation in the diet of elephants in this tropical moist forest and grassland habitat.

Study area:
The moist tropical and sub-tropical forests along the foothills of the Eastern Himalayan Region have six designated National Parks and Wildlife Sanctuaries. The study area comprised the Buxa Tiger Reserve and the adjoining Jaldapara Wildlife Sanctuary. The Buxa Tiger Reserve is the only reserve in the Dooars region designated as a Project Tiger Reserve in 1983. Subsequently in 1997, an area of 117 km^2 of the reserve was notified as a National Park. The Reserve is located between 89°25′ - 89°55′ N latitude and 26°30′ - 26°50′ E longitude encompassing an area of 761 km^2 that includes a core area of 385 km^2 and a buffer area of 376 km^2. The Jaldapara Wildlife Sanctuary lies to the west of Buxa Tiger Reserve, between 89° 15' - 89° 35' N latitude and 26° 30' – 26° 48' E longitude covering an area of 217 km^2. The entire forest range along the foothills of northern Bengal, from the Mechi River in the west along the Indo-Nepal border to Sankosh River in the east along the border with Assam, is also believed to be a contiguous elephant range. The population is the western most extension of the North East population (~11000), particularly North bank of Brahmaputra landscape (~3250) contiguous with Myanmar in the east, Bhutan in the North and Nepal in the west. From an ecological point of view, this population is a Trans-boundary elephant population and the conservation of the entire landscape is essential to conserve the biodiversity of the region.

Buxa Tiger Reserve and Jaldapara Wildlife Sanctuary together constitute a 1074 sq km area and harbour ~300 elephants (Sukumar *et al*, 2003). The forest types are Sub Himalayan semi-evergreen, Moist mixed deciduous, Eastern Himalayan upper and lower bhabar sal, Sub Himalayan terai, moist temperate, grassland and savannah (Champion, et al., 1968). Rainfall varies from 360 cm to 600 cm and temperature varies from 11^0C to 31^0C. Dry season is from November to April and wet season is from May to October.

Methodology:

Feeding trail observation:
Data on feeding behavior of elephants were collected mostly by following fresh feeding trails, as direct observation (scan and focal sampling) was not possible due to extremely poor visibility in the forested habitat. Feeding trails of elephant herds fitted with radio-collars were used for recording food species eaten, by following the trails left by the collared elephants from the preceding day location. From each feeding trail, information such as plant species eaten, plant parts consumed and discarded were recorded. Unidentified food plant were collected, preserved and identified later. One feeding trail per month per animal was targeted to do the feeding trail and three radio-collared herds were followed from 2002 to 2004. Additionally, fresh elephant dung piles were examined in order to know the fruit species consumed.

Bone Collagen analysis:
Stable carbon isotope analysis was carried out to determine the relative proportions of C3 plants (browse or most trees, shrubs and herbs) and C4 plants (tropical grasses) (Sukumar and Ramesh, 1992). Bone samples were collected from 12 elephants, which died during the study period in the study area. The collected bone samples were cleaned and air-dried and powdered using a screw holder. About 50-150 mg of bone powder was mixed with 50ml of 1M HCl. After 15-20 minutes the supernatant was filtered through glass fiber filter. Residues were transferred to a beaker containing 50ml of 10^{-3} HCl and the beaker was heated for 10 hours at 95^0 C and again filtered using glass micro filter. Residues were discarded and filtrate was lyophilized to extract bone collagen (DeNiro and Epstein, 1978; Sukumar and Ramesh 1992).

Observations and Results:

Food plants eaten by elephants (Overall and seasonal):
In total 18,308 feeding signs of elephants were recorded from 68 feeding trail (Dry season 39, Wet season 29) observations between 2002 and 2004; from these 108 plant species consumed by elephants were

identified (Appendix-I). Additionally, five more species eaten by elephants were identified from 529 elephant dung piles examined. Overall, the 111 plant species eaten by elephants belonged to 54 families and the common families eaten are *Moraceae* (8%), *Mimosaceae (7%), Euphorbiaceae* (7%), *Fagaceae* (7%), *Poaceae (6%), Palmaceae (5%) and Zingiberaceae (4%).* Seasonal analysis carried out using feeding trail data revealed that more number of plant species (91 *spp*.) were eaten by elephants in dry season compared to wet season (59 *spp*.)

Important food plants:
Fifteen species comprised 87% of the overall diet of elephants in the study area. The higher contributions of *S. spontaenium* (48%) to the overall diet of elephants indicated the importance of this species as food for elephants. On the seasonal basis, the top 15 species formed a less proportion (79%) of the dry season diet of elephants as compared to the wet season diet (97%). *A. pennata* (11%) and *L. crenulata* 10% were the most commonly eaten food plants in dry season while in wet season *S. spontaneum* alone contributed to 66% of the elephant's diet (Table 1)

Table 1: List of top 15 species eaten in dry and wet season observed from feeding trails of wild elephants from 2002 to 2004

S. No.	Scientific Name	%Dry n =4819	%Wet n =13489	% Overall n =18308
1	*Acacia catechu*	~	1.06	0.98
2	*Acacia pennata*	10.77	3.79	5.63
3	*Acacia sp.*	~	2.37	1.75
4	*Albizzia lucidor*	7.57	2.14	3.57
5	*Atrocarpus lakoocha*	2.80	~	~
6	*Butea parviflora*	2.84	~	~
7	*Cephalostachyum pergracile*	~	11.65	8.58
8	*Commelina benghlensis*	7.47	~	1.97
9	*Cucurma sp.*	~	3.10	2.28
10	*Dendrobium sp.*	~	0.42	~
11	*Ficus hispida*	~	0.37	~
12	*Icynocarpus frutescens*	~	0.67	~
13	*Laportia crenulata*	9.55	0.91	3.18
14	*Lasia spinosa*	3.82	~	1.01
15	*Leea indica*	7.91	~	2.28
16	*Litsea monopetala*	~	0.47	~
17	*Mallotus philippinensis*	3.71	0.59	1.41
18	*Mallotus sp.*	2.26	~	~
19	*Phonix acaulis*	1.99	~	~
20	*Phyrinum pubinerve*	7.20	~	1.90
21	*Saccharum spontaneum*	~	65.67	48.38
22	*Saccharum arundinaceum*	6.00	~	1.63
23	*Shorea robusta*	2.26	~	~
24	*Sterblus asper*	~	0.84	~
25	*Tectona grandis*	~	2.60	2.09
26	*Zingiber rubens*	3.34	~	~
	Top 15 species	**79.49**	**96.65**	**86.64**
27	***Others species***	**76 *sp*=20.51**	**44*sp*=3.35**	**93*sp* =13.36**

Food plants in different habitats:
Feeding trail data were analyzed separately for each habitat to document the important food plants in different vegetation types. Food plant composition varied considerably between habitats. For example, *S. spontaneum* a tall grass found in the deciduous forests (55%) and flood plains (99%) habitats was being eaten by the elephants more often than any other species (Table 2). But in the case of mixed vegetation, elephants depended on 47 Species and C. *pergracile*, a bamboo found on the hill slopes formed 48% of the elephant's diet. In mixed plantations, *Acacia sp.* a shrub (30%) was the major diet of the elephants followed by *A. lucidor* 20%, *A. pennata* 17%, *Cucurma sp*, 11%, *and T. grandis*, 11%. In semi evergreen habitat, it depended on 89 species, in which *A. pennata* (9.7%) was followed by *L. crenulata (*9.15%), *C. benghalensis (9%), L. indic*a (8.8%) and *P. pubinerve* (8.5%). In teak plantation, *A. pennata* was most commonly used species (56%), followed by *T. grandis* 38%. (Table 2)

Table 2: List of top 5 species eaten by elephants in various habitats in the study area during 2002-2004

Sl.no.	Plant species	Deciduous	Mixed plantation	Mixed vegetation	Semi evergreen	Teak plantation	Flood plain
		n=2520	n=1052	n=2948	n=3998	n=295	n=7495
1	*Acacia catechu*	~	~	~	~	~	0.25
2	*Acacia pennata*	~	17.02	6.51	9.68	55.59	~
3	*Acacia sp.*	~	30.42	~	~	~	~
4	*Albizzia lucidor*	4.88	19.49	~	~	~	~
5	*Atrocarpus lakoocha*	4.80	~	~	~	~	~
6	*Butea parviflora*	5.44	~	~	~	~	~
7	*Cephalostachyum pergracile*	~	~	47.86	~	~	~
8	*Clerodendron sp.*	~	~	~	~	0.68	~
9	*Commelina benghalensis*	~	~	~	9.00	~	~
10	*Cucurma sp.*	~	11.12	7.43	~	~	~
11	*Dalbergia sissoo*	~	~	`	~	~	0.01
12	*Ficus hispida*	~	~	`	~	5.42	~
13	*Garuga pinnata*	~	~	~	~	0.34	~
14	*Ichynocarpus fruttescens*	~	~	~	~	~	0.09
15	*Laportia crenulata*	4.29	~	~	9.15	~	~
16	*Leea indica*	~	`	~	8.83	~	~
17	*Phrynium pubinerve*	~	~	~	8.50	~	~
18	*Saccharum arundinaceum*	~	~	8.24	~	~	~
19	*Saccharum spontaneum*	55.16	~	~	~	~	99.64
20	*Shorea robusta*	~	~	3.93	~	~	~
21	*Tectona grandis*	~	10.93	~	~	37.97	~
	Top 5 species	**74.57**	**88.98**	**73.97**	**45.16**	**100.00**	**99.99**
22	**Others species**	**25.43**	**11.02**	**26.03**	**54.84**	**0.00**	
	Number of other species	**28 sp**	**11sp**	**42sp**	**84sp**		

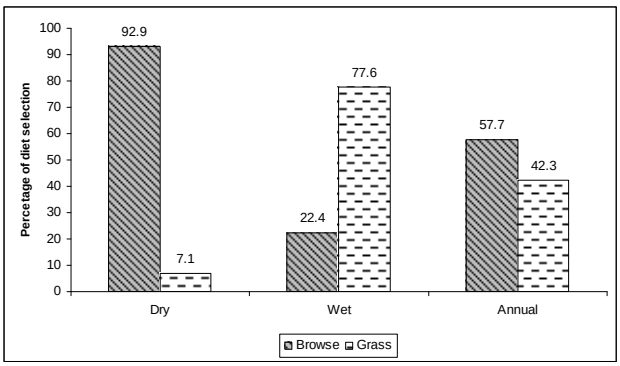
When the elephant feeds on trees and shrubs, both twigs and leaves are taken. In species like *Acacia sp, Ficus sp, etc.*, only twigs with leaves are selected. In case of *Mallotus and Albizia*, they discard the leaves and eat only twigs, and in case of *Laportea* it discards the leaves and eats only roots. In case of *Dillenia indica*, fruits are taken and in *Tectona* only bark is eaten. In dry season, after the grass has withered, the elephants turn to eat browse species like *Laportea* root, *Leea* twigs, *Acacia* twigs, *Dillenia* fruit, *Cayratia* stem, *Zingiber* stem frequently and in wet season *S. spontaenium* stem, *C. pergracile* twigs, *Cucurma sp.* stem and *Tectona* bark are frequently eaten. *Cepahlostachym, Bambosa*, *Musa* and *Acacia* are eaten frequently in the hills slope (Titi and Raimatang, Adma, Bhtanghat, Jayanti).

Elephants feed on bark of certain species in the study area like *Albizzia lucidor, Tectona grandis, Shorea robusta, Lagestromea speciosa, Artocarpus lakuoocha, Ficus sp, Ficus hispida, Dalberzia sissoo, Bombax ceiba, Sterculia villosa, Acacia catechu, Grewia sp, Mallotus philippinensis,* and *Litsea monopetala. Bridelia retusa, Terminalia crenulata, Dillenia pentagyna.*

Fruit is commonly consumed by the elephants here. Among the five fruit species (*Dillenia indica, Dillenia pentagyna, Ficus sp., Mangifera indica, Careya arborea*) recorded from (n=529) dung pile examination about 50% dung pile had *D. indica* remains in the dung pile of elephant during dry season (n=396, November to April). *D. indica* is one of the important food plants found mainly in semi evergreen undisturbed forest. *D. pentagyna* fruit is eaten in wet season.

Browse and graze ratio in the diet of elephants:
Evaluation of grass and browse consumption by elephants based on the feeding sign (n = 18,308) revealed that browse (58%) formed a marginally higher ratio of the elephant's diet compared to grass (42%). However, on seasonal basis, significant differences in browse and grass ratio was observed with the major part of the diet being browse (93%) during dry season and grass (78%) in wet season (Figure 1).

Figure 1: Browse and graze ratio found from feeding trail of elephant in the study area during study period



Stable carbon isotopic composition of Asian elephant bone collagen:
The $\delta^{13}C$ value of bone collagen of an animal is representative of the diet composition. Generally, $\delta^{13}C$ of C3 plants (browse) varies between –20 and -35 per mil and C4 plants (grass) -7 and -15 per mil. During metabolism the values are enriched by about +4.5 per mil in collagen relative to the diet (see Sukumar and Ramesh 1992). The collagen analysis of 12 bone samples showed the $\delta^{13}C$ value (Table 3) of all the samples closer to C3 plants as their values fall between –21 to –32 per mil indicating browse-dominated diet. Although, the bone collagen results show that all elephants have browse-dominated diet, difference in the ratio of browse and grass could still be very marginal as $\delta^{13}C$ values of 11 (out of 12) samples (–21 to –27) fall on the lower side of mid value (-27.5) of C3 plants (Table 3).

Table 3: Stable carbon isotopic composition of Asian elephant bone collagen

Sl.no.	Sex	Age	$\delta^{13}C$
1	Adult Male	15-20	-32.83
2	Juvenile	2-3	-27.38
3	Sub adult Male	5-10	-26.36
4	Adult Male	15-20	-25.69
5	Sub Adult Male	12-15'	-25.25
6	Juvenile	5	-24.87
7	Adult Male	30-35	-24.31
8	Sub adult female	10-15'	-24.12
9	Adult Female	45-50	-24.10
10	Adult Female	20-25	-23.67
11	Adult Male	40-45	-22.01
12	Adult Male	40-45	-21.00

Discussion:

Analysis of forage selection by elephants shows exploitation of large variety of species in the study area. Overall 150 species (including 39 additional species by captive elephants in the same) are being eaten by elephants in the region. Moreover it is likely that some herbs, shrubs and grasses could have been overlooked in the feeding trail observation due to the size of some plant species coupled with indirect method used by the study. The reason for elephants feeding on diverse food plants in the region as compared to elsewhere in India (Sukumar, 1985 recorded 112 plants in southern India in deciduous and thorn forest; Baskaran, 1998 recorded 83 plant species in Nilgiri Biosphere Reserve, Daniel *et al*, 1995 recorded central India 54 species) could be due to predomination of habitat by browse species (64% by Sukumar *et al*., 2003). Studies on foraging by elephants from primary forest of Asia (Olivier, 1978) and Africa (Ruggiero, 1992 recorded 45 species; White *et al*, 1993 recorded, 307 species) reported higher number of food plants being eaten than in the secondary forest (Tchamba *et al*, 1993 recorded 35 species, Kabigumela, 1993 recorded 36 species). From the present result and published literature it appears that elephants in the primary forest depend on diverse food plants. Sukumar *et al*, 2003, reported 307 plant species >1 cm dbh in the study area, of which elephants have eaten 34% of the species, which mean remaining 66 % of the species are not palatable to elephants. Therefore availability of palatable species could also be another reason for diverse food plants being eaten by elephants in the browse dominated habitats. In the study area, elephants consumed more species in dry season (91 *spp*.) compare to wet season (59 *spp.*) due to the abundance of grass species.

A few studies have mentioned that toxic plant secondary compounds influence elephant to take diversity of food plant species (Olivier, 1978; McNaughton, 1981; Jackman and Bell, 1985).

Analysis of grass and browse ratio in the annual diet of elephants from observations along feeding trails showed browse (58%) marginally higher compared to grass (42%). But on the seasonal basis, grass formed the major bulk of diet (77%) during wet season, a trend similar to earlier findings (Barnes, 1982; Sukumar, 1989; Buss, 1961). As discussed by Olivier (1978) the elephant's body size and dental structure have specialized towards grass feeding, but because of the seasonal variation in grass availability in wet and dry season he believed that they must be able to switch to alternative foods of browse during dry season. However, the carbon isotope analysis clearly indicates that browse (C3 plants) contributes over 90% of the carbon for protein synthesis. This could be due to the higher nitrogen (protein) content of the browse plants as compared to the tall, perennial grasses that provide bulk but not much protein. These results are consistent with the expectation that elephants move from a diet of an equal mixture of grass and browse in tropical savannas and dry forest to a pure browse diet as one proceeds along an increasing rainfall gradient to tropical moist forest (Merwe *et a,*. 1988, Sukumar 2003).

Acknowledgements:
We thank the West Bengal Forest Department for their funding support during the first phase of this study as well as logistical help to carry out the field work. Additional funding and support was provided by the Liz Claiborne/Art Ortenberg Foundation through the Wildlife Trust, U.S.A.

Appendix I: Food plant eaten by elephants during dry season, wet season and overall identified from feeding trail observation between 2002 and 2004 in the study area

Sl. No.	Scientific Name	%Dry	Rank Dry	%Wet	Rank wet	%Overall	Rank overall
1	*Saccharum spontaneum*	0.00	106	65.67	1	48.38	1
2	*Cephalostachym pergracile*	0.00	96	11.65	2	8.58	2
3	*Acacia pennata*	10.77	1	3.79	3	5.63	3
4	*Albizia lucidor*	7.57	4	2.14	7	3.57	4
5	*Laportia crenulata*	9.55	2	0.91	9	3.18	5
6	*Cucurma sp.*	0.00	98	3.10	4	2.28	6
7	*Leea indica*	7.91	3	0.27	17	2.28	7
8	*Tectona grandis*	0.64	30	2.60	5	2.09	8
9	*Commelaena benghlensis*	7.47	5	0.00	60	1.97	9
10	*Phyrinum pubinerve*	7.20	6	0.00	61	1.90	10
11	*Acacia sp.*	0.00	91	2.37	6	1.75	11
12	*Saccarum arundanicium*	6.00	7	0.07	32	1.63	12
13	*Mallotus philippinensis*	3.71	9	0.59	12	1.41	13
14	*Lasia spinosa*	3.82	8	0.00	62	1.01	14
15	*Acacia catechu*	0.77	22	1.06	8	0.98	15
16	*Zinziber sp.*	3.34	10	0.01	51	0.88	16
17	*Butea parviflora*	2.84	11	0.07	33	0.80	17
18	*Sterblus asper*	0.66	26	0.84	10	0.79	18
19	*Atrocarpus lakoocha*	2.80	12	0.00	63	0.74	19
20	*Mallotus sp.*	2.26	13	0.19	19	0.73	20
21	*Shorea robusta*	2.26	14	0.18	21	0.73	21
22	*Phonix sp.*	1.99	15	0.00	64	0.52	22
23	*Icynocarpus frutescens*	0.04	69	0.67	11	0.50	23
24	*Meliosma simplicifolia*	1.89	16	0.00	65	0.50	24
25	*Ficus glomeruta*	1.33	17	0.17	23	0.48	25
26	*Litsea monopetala*	0.42	34	0.47	13	0.46	26
27	*Cayratia japonica*	0.91	20	0.20	18	0.39	27
28	*Daemonorps jenkinensis*	0.73	24	0.19	20	0.33	28
29	*Ficus cunia*	0.93	19	0.10	30	0.32	29

30	*Dendrobium sp.*	0.00	99	0.42	14	0.31	30
31	*Ficus hispida*	0.04	68	0.37	15	0.28	31
32	*Tinospora cordifolia*	0.06	64	0.36	16	0.28	32
33	*Seteria palmifolia*	1.08	18	0.00	66	0.28	33
34	*Sterculia villosa*	0.85	21	0.00	67	0.22	34
35	*Castonopsis tribuloides*	0.66	25	0.04	35	0.20	35
36	*Ficus sp.*	0.75	23	0.00	68	0.20	36
37	*Smilax perfoliata*	0.64	29	0.01	52	0.17	37
38	*Pentapenax lesohenaultii*	0.44	33	0.07	31	0.17	38
39	*Leea sp (Bhui Galeni)*	0.64	27	0.00	69	0.17	39
40	*Pandanus sp.*	0.64	28	0.00	70	0.17	40
41	*Mucunia microcarpa*	0.25	42	0.11	29	0.15	41
42	*Atrocarpus chaplasa*	0.56	31	0.00	71	0.15	42
43	*Bombax ceiba*	0.06	59	0.16	24	0.14	43
44	*Thysolaena maxima*	0.00	108	0.18	22	0.13	44
45	*Oroxylum indicum*	0.15	47	0.13	27	0.13	45
46	*Bridelia scandens*	0.44	32	0.01	53	0.12	46
47	*Microstegium sp.*	0.06	63	0.13	25	0.11	47
48	*Bridelia stipularis*	0.08	55	0.13	28	0.11	48
49	*Lagostromia speciosa*	0.02	80	0.13	26	0.10	49
50	*Boehmeria macrophylla*	0.39	35	0.00	72	0.10	50
51	*Rhus sp.*	0.39	36	0.00	73	0.10	51
52	*Cissus repanda*	0.29	40	0.01	44	0.09	52
53	*Caesalpinea cuculata*	0.29	38	0.01	54	0.08	53
54	*Albizzia sp.*	0.15	46	0.05	34	0.08	55
55	*Calamus flaggelum*	0.29	39	0.00	75	0.08	56
56	*Herdycium gracile*	0.27	41	0.00	76	0.07	57
57	*Clematis sp.*	0.19	45	0.02	43	0.07	58
58	*Dalbargia sissoo*	0.10	51	0.03	38	0.05	60
59	*Castonopsis sp.*	0.19	44	0.00	78	0.05	61
60	*Piper sp.*	0.08	58	0.03	39	0.04	62
61	*Morinda citrifolia*	0.08	57	0.01	45	0.03	64
62	*Alpania sp.*	0.12	49	0.00	80	0.03	65
63	*Castonopsis indica*	0.00	95	0.04	36	0.03	66
64	*Grewia sp.*	0.00	101	0.04	37	0.03	67
65	*Syzygium cumini*	0.02	85	0.03	40	0.03	68
66	*Bahunia purpurea*	0.10	50	0.00	81	0.03	69

67	*Dillenia indica*	0.10	52	0.00	82	0.03	70
68	*Ficus sp (Timilo)*	0.10	53	0.00	83	0.03	71
69	*Crataeva unilcularia*	0.00	97	0.03	41	0.02	72
70	*Garuga pinnata*	0.00	100	0.03	42	0.02	73
71	*Clerodendron viscosum*	0.04	66	0.01	46	0.02	74
72	*Dillenia penta gyna*	0.06	60	0.01	55	0.02	75
73	*Bouhinia anguina*	0.08	54	0.00	84	0.02	76
74	*Lasia sp.*	0.08	56	0.00	85	0.02	77
75	*Entada scandens*	0.02	78	0.01	47	0.02	78
76	*Phylocanthus thyrsiflorus*	0.02	82	0.01	48	0.02	79
77	*Erythrina sp.*	0.06	61	0.00	86	0.02	80
78	*Macaranaga denticulata*	0.06	62	0.00	87	0.02	81
79	*Milletia auriculata*	0.00	103	0.01	49	0.01	82
80	*Wrighitia tomentosa*	0.00	109	0.01	50	0.01	83
81	*Citrus decumana*	0.04	65	0.00	88	0.01	84
82	*Elaeocarpus lanceefolius*	0.04	67	0.00	89	0.01	85
83	*Premana sp.*	0.04	70	0.00	90	0.01	86
84	*Bridelia retusa*	0.00	93	0.01	56	0.01	88
85	*Paedaria foetida*	0.00	104	0.01	57	0.01	89
86	*Polyalthia cimiarium*	0.00	105	0.01	58	0.01	90
87	*Teerminilia chebula*	0.00	107	0.01	59	0.01	91
88	*Amoora wallchi*	0.02	72	0.00	92	0.01	92
89	*Amora rohitika*	0.02	73	0.00	93	0.01	93
90	*Baccurea sp.*	0.02	74	0.00	94	0.01	94
91	*Castonopsis sp (katus)*	0.02	75	0.00	95	0.01	95
92	*Cinnamonum sp.*	0.02	76	0.00	96	0.01	96
93	*Comretum decandrum*	0.02	77	0.00	97	0.01	97
94	*Ficus sp 4*	0.02	79	0.00	98	0.01	98
95	*Machilus sp.*	0.02	81	0.00	99	0.01	99
96	*Smilax sp*	0.02	83	0.00	100	0.01	100
97	*Spondias pinnata*	0.02	84	0.00	101	0.01	101
98	*Viburnum erubescens*	0.02	86	0.00	102	0.01	102
99	*Albizzia procera*	0.00	92	0.00	107	0.00	107
100	*Calamus tennuis*	0.00	94	0.00	108	0.00	108
	Unidentified (8species together)	0.79		0.00		0.21	
	Total	100.00		100.00		100.00	

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Osmotic stress on motility and membrane integrity of Asian elephant spermatozoa analyzed by computer-assisted semen analysis

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Artificial insemination (AI) has been purposed as a powerful tool for conservation and genetic management in elephant. However, the optimal freezing procedure for Asian elephant spermatozoa is not well established, this may be due to the knowledge on osmotic properties of spermatozoa in this specie is limited. The objective of this study was to evaluate osmotic sensitivity of elephant spermatozoa. Two experiments were conducted (1) spermatozoa collected by manual rectal stimulation were exposed to sperm-TALP ranging from 290 to 2400 mOsm; and (2) spermatozoa were exposed to sperm-TALP containing 5% glycerol ranging from 800 to 2400 mOsm. In both experiments, spermatozoa were returned to isotonic sperm-TALP (290 mOsm) at 37 ^{o}C, stained with Hoechst 33358 and assessed for motility and membrane integrity using computer-assisted semen analysis (CASA). The percentage of motile sperm and sperm movement parameters were declined following exposure to sperm-TALP at osmolality 400 mOsm and greatly reduction in the $\geq$ 800 mOsm medium. In contrast, spermatozoa exposed to sperm-TALP containing 5% glycerol were more resistant to osmotic stress than those exposed to sperm-TALP without glycerol. High percentage of motile sperm and sperm movement parameters were maintained in sperm-TALP containing 5% glycerol at osmolalities 800 and 1200 mOsm but significantly reduction at osmolalities $\geq$ 1600 mOsm. In both experiments, membrane integrity of spermatozoa was slightly affected by osmolality changes. It was concluded that elephant sperm motility is more sensitive to changes in osmolality than membrane integrity and motility of spermatozoa was maintained in high osmotic stress by addition of glycerol.

Occupational injuries and work related diseases in the working elephants in India´s north east

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Introduction:
India's North East had been for centuries an ideal habitat for the Asian elephant. Even though massive deforestation has severely degraded and fragmented this habitat over the past century, it still remains a stronghold to the last remaining herds of this magnificent species. Abundance of natural foliage providing succulent fodder, a temperate climate with moderate temperature and high humidity, high average annual rainfall ensuring numerous perennial water sources are all critical components of a complex ecosystem which have made India's North East perhaps the best surviving habitat for these vanishing giants. Naturally, an estimated 6,000 Asian elephants still roam the region's forests and grasslands, an immensely significant population considering the fact that there are only about 50,000 Asian elephants left on this planet.

Another significant factor which had contributed to the survival of the Asian elephant in India's North East is the region's centuries old elephant keeping culture (Sarma.2003). A legacy of these traditions, an estimated 2000 Asian elephants still survive in captivity in this region, of which an estimated 1,200-1,300 are in the state of Assam alone. This constitutes a significant 4% of a population of this critically endangered species. Apart from being of significance because of its very size, this captive elephant population is also unique because the indigenous elephant keeping cultures have enabled these captive animals to frequently intermingle with wild herds in the vicinity allowing opportunities for interbreeding between the captive and wild populations, thus ensuring significant exchange of genetic material and sustaining the only captive population in the world to be breeding naturally in numbers which can be termed heartening (Sarma,2004). But even this population today is in the throes of crises in a rapidly changing world where their utility on the one hand is being rendered obsolete by rapid mechanization and on the other being slowly upstaged by newer icons of nobility or privilege.

Owing to the immense strength, intelligence and dexterity, an overwhelming number of captive elephants in India's North East have been most often been engaged in extremely strenuous and hazardous tasks such as hauling timber or in clearing forests in difficult terrain inaccessible at most times to mechanized modes of extraction and transportation It is therefore natural that the captive elephants engaged in such tasks have been prone to accidents, occupational injuries and work related diseases due to the very nature of the stressful and hazardous work they had generally been engaged in. Even though a focused systematic survey of occupational status of the region's working elephants is yet to be carried out to show clear patterns of occupation or engagement, an overview of records the author has gathered during the course of his clinical practice over the last two decades reveal that an overwhelming 50% of the region's captive elephants are still engaged in logging, about 5% in tourism and amusement, 5% in religious/ceremonial activities, 7% in wildlife protection and management duties while the rest remain without any significant engagement. This paper discusses some of the most common occupational injuries and work related diseases that the author had the opportunity to study and treat in the course of his clinical practice with the elephants in the last two decades in India's North East, particularly in the state of Assam.

Occupational injuries and diseases in loggin elephants:

For more than a century, the captive elephants in India's North East have remained indispensable to the region's hitherto burgeoning timber industry. So profitable did the enterprise became and in such high demand were trained captive elephants in the industry that the elephants themselves became commodities to be caught, trained and sold for profit in the relentless colonial exploitation of the region's forest wealth. Elephants were the most effective and viable means of hauling and extraction of timber in logging sites in difficult inaccessible terrain. The industry continued to grow and prosper during the postcolonial decades and fortunes continued to be made from engaging elephants in the trade. Such indiscriminate logging for over a century however severely depleted the region's forest cover and alarmed at the environmental disaster such deforestation may trigger, the Supreme Court of India, the nation's apex judicial authority, clamped a blanket ban on logging activities in the entire region in 1997. At one stroke, the most visible and economically viable engagement of the captive elephants was rendered illegal and scores of elephants, along with their handlers became unemployed. Even though the timber industry has been legally banned, illegal logging continues as reflected by the Forest Survey conducted by the Union Ministry of Environment and Forests which documented a continued loss of actual forest cover at an alarming rate. Hence, elephants too continue to be employed in this illegal but widespread enterprise.

As the largest numbers of captive elephants were engaged in logging, it is only natural that the logging related injuries and diseases most often afflicting elephants engaged in logging activities were the most numerous clinical cases the author had to attend to (Sarma,2005).

Farra gall: One of the commonest occupational injuries seen in logging elephants is *farra* gall or sore on its back due to constant chaffing from ill fitting harnesses the elephants are made to wear for hauling logs. In fact incidence of *farra* gall is so high that it can be safely stated that every logging elephant must have suffered from *farra* gall at least once during their working life.

In Assam, two types of logging harnesses are generally used. In Upper Assam, the logging harness constitutes of two long pieces of wooden bars which are placed longitudinally on either side of the thoracic spine with thick padding of gunny bags stuffed with coarse hay (*geddela*), underneath horizontally across the back. The middle portion of the padding is hollowed out so as to avoid pressure over the spine and lessen friction. Hand woven flat braided jute ropes are tied over these across the chest as a chest band (*farra*) which are reinforced with strong iron chains. The hauling chains are placed on either sides of the *farra*. In Central and Lower Assam, the *farra* is reinforced with a jute neck brace to distribute to distribute the pressure evenly while hauling logs but the wooden bars are not used as part of the harness.

Farra gall or injuries from logging harnesses, locally termed as *marak*, most often result from constant chaffing over a prolonged period of time from ill fitting logging harnesses and a loss of condition of the animal. Initially, the gall appears as a hot, painful swelling over the back or the anterior aspect of the shoulder area depending on the type of harness which has caused the injury. At first the swelling may not be too prominent and thus may remain unnoticed or ignored by the *mahouts*.
The elephant may however occasionally moan due to the pain or indulge in erratic sideways movement of the back or even refuse to sit on command. If the afflicted area is further chaffed, the swelling generally aggravates and results in enormous swelling on removal of the compressing harness. This often then results in suppuration or pus formation underneath the skin. As the skin of elephants is thick, the swelling may not usually rupture (Evans, 1910) and if as a result, the suppuration is not drained, it often migrates downwards due to proteolytic action of the pus (Fig-1).

Clinical treatment of *farra* gall involves drainage of the abscess under general anesthesia, scooping of the cavity with volksmann bone curette and destruction of the pyogenic membrane with 2.5 per cent tincture of iodine. The wound may take between 15 days to 6 months to heal, depending on the size of the cavity, effectiveness of drainage and quality of the wound dressing applied. When the size of the gall is enormous, dressing with lukewarm saline solution and application of acriflavin, placentrex gel or un-pasteurized honey helps in rapid epithelialization or new skin formation. The elephant should be laid off from work to avoid further trauma to the affected area during the healing period.

Farra gall, if not treated can be fatal to the afflicted elephant. The author has treated more than a couple of hundred cases during the course of his clinical practice and has encountered complications such as development of shirt-stud abscess, traumatic myiasis and spread of suppuration over the entire back. There have been also cases when incision of immature galls by mahouts had lead to severe hemorrhaging and septicemia. In one instance of severe neglect, the portion of the spine underlying the gall was necrosed and in yet another, the fistulous tract entered the thoracic cavity leading to fatal septicemia. Bacterial cultures of pus collected from mature galls in afflicted animals usually exhibited *Streptococcus*, *Staphylococcus*, *Corynebacterium* and *Pseudomonas* species.

Fractures of limb bones: Fractures in elephants as a result of logging accidents are relatively rare. The author has encountered only three such cases in a clinical practice spanning more than two decades. In two of the cases the fractures involved the distal end of the femur while in the remaining case, it was a compound digital fracture in the fore leg.

The first cases of femoral fracture the author witnessed occurred when a massive log the elephant was dragging up a steep incline by pulling on the chain the log was tied to, slipped from the grip of its trunk. The log hurtled down the slope, pulling along the chain it was tied too and as the chain reeled away its other end entangled and abducted the hind legs with a sudden massive jerk, fracturing the distal end of the femur. The injured elephant was treated with only analgesics to relieve the pain and took about a year to heal (delayed union). A severe deformity of the leg, however, remained (malunion).

The second case of femoral fracture involved the lower third of the bone and happened under similar circumstances. The treatment and rehabilitation of the elephant in this second case provided newer insights into fracture therapy of elephants. As the elephant was kept loose in a fenced area to recover, it was noticed that he preferred to spend most of his time in the large pond within the barricade which was filled with rain water and gradually slopped to a depth of about 7-8 feet in the middle. The middle aged bull took to spending about 18 hours a day in the middle of the pull with only its back visible above the water. At first it was believed that he preferred the water cool off but a more insightful explanation seems to be that the natural buoyancy of the water helped the elephant to take off the enormous weight of his body from his injured limb providing him immense relief from fatigue and pain, thus encouraging him instinctively to spend the greater part of the day in the middle of the pool. The fracture in this case had a remarkable clinical union in a one month period. A mild deformity, however, still existed due to a slight malunion. The elephant was back in work hauling timber within three months of the fracture.

The compound digital fracture in the forelimb was caused when a massive log rolled down and hit the foreleg of the elephant with considerable force. The trauma resulted in infection and chronic fistulation in the injured area rendering the elephant unable to bear weight on that leg. Inability to bear the weight on the heel made the elephant to put its weight on its toes which also resulted in the shortening of the anterior phase of the stride. Dragging the leg along the ground in sort of a limp also caused lowering of the middle toe. When normal dressing and antibiotic therapy failed to heal the wound, the area was X-rayed which revealed avulsion fracture of a first phalanx. The bone splinter was then surgically removed and the wound healed by granulation of tissues.

Tusk injuries: Tuskers engaged in logging are often made to use their tusks to push aside or even lift smaller logs. Tusk injuries too are therefore quite common in logging tuskers. Longitudinal cracks or imperceptible fissures often appear which becomes the entry point for agents of infection causing decay of dental pulp. The afflicted bulls loose appetite and condition and become irritable and disobedient due to constant pain. A remarkable rise in white cell count is noticed along with anemia. Diagnosis is often at first difficult until there is perceptible foul smell emitted through the fissures or traces of purulent materials ooze out. There is generally, however, no appreciable change in the colour of the affected tusk. Once diagnosis is made, the affected tusk is transected to drain out the liquefied pulp which gives almost ready relief to the pain. The loosened tusk is ultimately extracted from the alveoli and even though the hollow heals through granulation of tissues, a small fistula may remain, occasionally oozing out small amounts of pus till it is completely healed (Sarma, 2004a). In one particular case the author had to attend to, the tusk

developed a transverse crack inside the alveoli while no fissure or injury was visible in the exposed portion. Even though the pulp liquefied due to infections, no evidence of pulp decay was visible except for a mild drop and a slight slackness of the tusk. Only a little pus could be seen under one side of the tusk sulcus and that too on minute examination. When the slackness of the tusk increased and the tusker became visibly ill with signs of inappetance and leucocytosis, the tusk had to be uprooted under general anesthesia and the cavity later healed similarly.

Implications were much more serious in the case of a middle aged cow which injured her molar when she was made to pull a log with the hauling chain held between her molars. The exertion loosened one of her molars and she bled profusely from the injury. The attending veterinarian administered antibiotics and NSAID for about six days. She was unable to take food following the injury and in frenzy a few days later, ingested a huge amount of loose earth. Defecation and even urination stopped thereafter and the elephant could only be saved by clearing her bowel manually after administering her lukewarm soap-glycerine-water enema and then giving her a large amount of balanced electrolyte, dextrose and calcium borogluconate intravenously. Gradual oral feeding with soft chopped grass and *khichidi* (boiled rice, pulses and ghee) supplanted by vitamin B-complex slowly nursed her back to health.

Injuries of the trunk: Even though cuts and injuries in the trunks of working elephants are common enough, such injuries are relatively few in logging, except in a few peculiar cases. In one particular case the trunk of a cow was crashed between a fallen log and a huge rock. The trunk was severely lacerated and ruptured on the axial side in the lower third connecting the nares outside. The muscle thickness in the injured area was about 3 cm and was completely ruptured. The cow could suck in only a little water with the tip of her trunk due to the air portal on the body of the trunk due to the rupture and she had to hand fed. Retaining sutures on the trunk was extremely difficult and the rupture was sutured with primary vertical mattress sutures with no.2 black braided silk which were then reinforced with relaxation sutures. Healing was best achieved in mixed intention. The elephant was completely restrained from using her trunk till the sutures healed completely. Several cases of accidental cuts on the trunk by the mahouts were encountered by the author and these too were similarly treated.

Occupational injuries and diseases in elephants engaged in wildlife management duties:

Captive elephants in India's North East are also deployed in wildlife management duties in the region's Sanctuaries and National Parks which involves varied duties from anti-poaching patrolling duties to taking tourists on safaris. With the significant increase of man-elephant conflicts in several districts in Assam, the age old practice of using captive elephants to chase away crop raiding wild herds have been institutionally revived and an increasing number of captive elephants are being deployed for the task. Wildlife management duties do have their own hazards for the elephants such as being attacked by large carnivores or other wild animals. Attending to such emergencies has become a familiar part of the author's practice.

Injuries sustained due to attack by wild animals: In the famed Kaziranga National Park in Assam, the author has come across several cases of attacks by rhinos. Most of these attacks have not occurred while on patrolling duties or in safaris with tourists on the elephants' back as elephants and rhinos in the park generally maintain a mutually respectful distance. But rhinos often stray out of the National Park into surrounding areas of human habitation and have to be herded back into the Park with the help of herding elephants. Most of the attacks on elephants have occurred during such herding operations. Similar incidents have occurred in other protected rhino habitats in the region. Contrary to popular belief rhinos do not attack with their horns but inflict cut injuries with their lower incisors with a violent upward thrust of the jaw. In one particular incident, a large tusker named Kartik in Kaziranga National Park was severely wounded on the thigh of his hind leg when a stray rhino from the Park attacked him from behind (Fig-2). The deep wound took nearly a year to heal.

Full grown elephants are rarely attacked by tigers but adolescent elephants and calves of Park elephants are occasionally attacked. In Manas National Park one adolescent bull was bitten in the heel of one of its hind feet by a huge tiger. Another female calf in the same Park was injured in her knee by a tiger which even

though it healed caused an ancylosis. The same calf was later attacked again while grazing at night, this time fatally, and devoured. She was about 5 years old at that time. In Orang National Park, a 6 months old calf was attacked by a tiger and miraculously saved by a bull which chased the tiger away. The tiger maul inflicted with its claws on the elbow of the calf took several months to heal.

Captive elephants in sanctuaries and parks are at times also attacked by their own wild brethren. There had been numerous instances of captive elephants sharing grazing fields with wild herds being attacked by wild bulls and even at times fatally wounded. There have also been instances of libidinous wild bulls venturing into *pilkhanas* in search of receptive cows and attacking and killing defenseless captive bulls left tethered or hobbled in the *pilkhanas.*

Another injury that have been observed to be peculiar to elephants is the biting off of the tail of a bull by another dominant bull or even that of a cow if she had not been receptive to or had not succumbed to the overtures of a libidinous bull because she was not in oestrous. Some of the elephants with their tails bitten off suffered from gangrene and the portion had to be surgically amputated.

There had also been instances of goring sub-ordinate bulls or non-compliant cows by dominant tuskers within captive herds. In a widely reported incident, Gadapani, the master bull of Kohora Range of Kaziranga National Park attacked and completely disemboweled another unsuspecting makhna named Bhajan in frenzy at the onset of musth. In the mêlée, an American tourist, Mary Brunder who was astride Gadapani at that time, fell off from his back and got trampled to death.

Saddle gall: Even though at most times elephants deployed in wildlife management duties are ridden without a howdah, with just two or three riders sitting on the geddela straddling the elephant, and the jute rope or *kas* used to fix the gear as hand holds for tourists or officials not familiar with riding elephants the more elaborate *howdah* or *gaddi* with proper hand holds has to be invariably used. Even though the *gaddi* has undergone a lot of improvement in terms of making it ergonomically comfortable to the elephant to whose back it is tied to, large payload in terms of several riders at a time and carrying them around for a long period of time results in saddle gall under the bony prominences on the back of the elephant which are similar in nature to farra gall in logging elephants discussed earlier in this paper. The *gaddi* (specially curved Nickols's *gaddi*) which is supposed to vary for each elephant depending on the location of the external angle of its ileum and scapular spines, repeated use of even a slightly ill fitting gaddi could seriously injure the elephant and spell disaster.

In one particularly severe case of saddle gall which had developed over the wither due to an ill fitting howdah, the pus migrated underneath the skin over and behind the scapular spine to the level of the elbow and then further down to the level of fetlock. The triceps were detached from the olecranon and entire skin sloughed off due to the damaging effect of the virulent pus (Fig-3). Culture of the pus exhibited pseudomonas.

Foot infections: Elephants engaged in wildlife management duties are also afflicted with various foot diseases due to exposure to the muddy substrate conditions prevalent in most of the parks and sanctuaries of the region. Injuries caused to the pad of the foot by foreign objects like broken glass, discarded cans or shed antlers are also quite commonly seen. Trauma caused to the elbows and stifle joint surfaces as a result of being made to sit on hard surfaces like concrete or black topped roads or pebbled surfaces often cause haematomas and hygromas (Sarma *et al* 2001).

As working elephants have to often use the same motorable roads used by vehicles there are also numerous instances of traffic accidents. There have even been instances of accidents with trains while moving along railway tracks (Sarma *et al.*2001a).

Occupational injuries and diseases in working elephants is an extensive subject and this paper dwells on only some of the commonest problems elephant owners, handlers and veterinarians usually are faced with, drawing largely on the author's own experiences accumulated during the course of his clinical practice with elephants for more than a couple of decades. What is of significance, however, is that in spite of a

long and glorious history of elephant keeping, scientific knowledge critical for prevention and treatment of injuries and diseases of the captive elephants is still woefully lacking among a majority of the elephant owners and handlers of the region. Sensitization of the owners and handlers to modern and scientific management practices of captive elephants will go a long way in minimizing injuries and diseases among these elephants, thus ensuring the well being of this critically endangered population. Another significant issue is the near absence of institutional support towards creating adequate infrastructural and human resources to continuously extend and improve emergency and health care support to this very significant captive elephant population. It is the need of the hour that effective policies are evolved and adopted expeditiously for developing such institutional support without which it would perhaps be impossible to ensure the survival of this dwindling captive elephant population.

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Acknowledgement:

The author wishes to place on record the help received from the fellow faculties and the authority of Assam Agricultural University, Khanapara, Guwahati, Project Elephant Directorate, Ministry of Environment and Forests, Government of India, New Delhi, Carol Buckley and A. C. Williams in the studies and documentations of the observations for the present communication.

Critical care of an elephant calf suffering from femur fracture

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A female elephant calf of 3 years of age, weighing 600kgs has fall down from a hillock of 30 feet height and was unable to get up. Examination revealed right femur fracture in distal extremity and was confirmed with the help of radiograph .The calf was lying in lateral recumbency for long time, prior to treatment and developed bedsore. Prolonged recumbency lead to congestion of lungs with mucopurulent nasal discharge and off fed with extreme dehydration resulted wrinkleness of the skin. Application of plaster in femur fracture was impractical. Therefore, the fractured leg was immobilized with continuous knitting bamboo splints, after thick cotton padding, which was changed at alternative days, as the cotton soaked urine. Antibiotic and steroid was used to rduce congestion. Following reduction of congestion Dextrose with normal saline (DNS) and fructodex were injected intravenously, 4 bottles (500ml/bottle) twice daily for 45 days and mineral supplements was provided for a month. Bedsore were dressed daily with povid one iodine To provide uniform blood circulation and to avoid pressure atrophy, the calf was kept in standing for an hour twice daily by using a specially devised sling. The pulley operated sling hanged from a iron stand and fitted to the abdomen of the calf, which helped her for weight bearing. Moreover, massage was applied on the legs to avoid muscular atrophy. Ultimately the calf was able to stand and walked after 3 months.

Status of elephant movement in a historical corridor of North Bank Landscape, North East India

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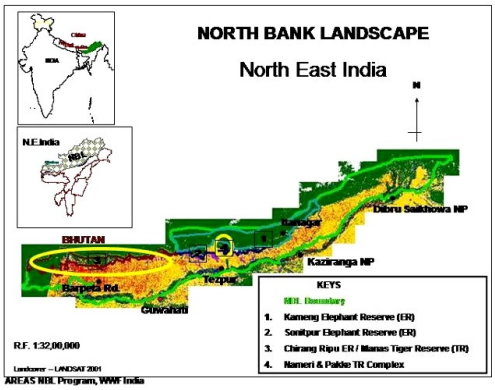
Abstract:
Forest corridors play a very pivotal role in maintaining connectivity for elephants in a situation where the forest landscapes are getting fragmented. *Kameng Sonitpur* Elephant Reserves (ER), in North East India, is one of the few Asian elephant populations estimated to number over a 1000 individuals. These two largely contiguous reserves constitute a core area for elephant conservation in the area north of river Brahmaputra in Assam and Arunachal Pradesh also known as North Bank Landscape (NBL). Tipi in the West Kameng district of Arunachal Pradesh has long been known as an elephant corridor in the Kameng Elephant Reserve. Due to the hilly nature of the terrain in this ER, elephants use a small relatively flat strip along the river to cross from Pakke Tiger Reserve to Doimara Reserved Forests across the Kameng river. The corridor has also been assigned high ecological priority in a nationwide study of elephant corridors by the Wildlife Trust of India. Tipi corridor is under threat for the several years due to expansion of human settlement. To understand the importance of this corridor for the elephant population, the WWF elephant program in NBL set up a monitoring system to look at the status of elephant movement in the Tipi corridor and adjoining areas.

Fig. 1

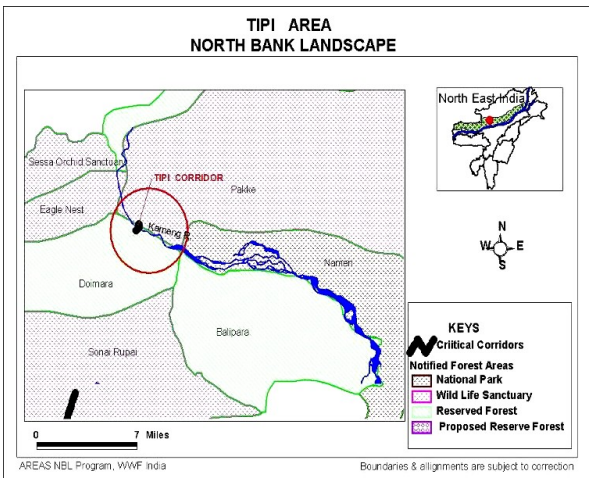


The initial works started since 2000 and intense monitoring work began in March'05 and has continued till date. Seventeen locations nearby Tipi were monitored throughout the year to understand the pattern of elephant movement in the area as well as the use of the habitat. Regular recce along the above locations helped us record the presence or visits of elephants along this strategic area. Secondary data on elephant movement in Tipi were also collected from the local informants for the different locations near Tipi.

Elephant visits were highly seasonal with the elephant movement, across the river, recorded only between the months of December to April. There was a distinct peak of usage of the corridor between the months of December to February. There is a high frequency of elephant visits (10-30 times) in several monitoring stations. Some of the monitoring stations, despite being in more elephant friendly terrain, recorded very few visits. Based on the monitoring outcomes, we have put forward key recommendations to the Arunachal Forest Department. These include removal of a few permanent and temporary structures, check further growth of settlement at certain locations, developing a restoration plan for the area and, also reduce the direct dependence of the local people on the forest.

Introduction:
The North Bank Landscape (NBL) in north east India is one of the last strongholds for Asian Elephants in the country which
harbors a more or less contiguous population of approximately 2,500 elephants. *Kameng Sonitpur* Elephant Reserves (ER) in NBL is one of the few Asian elephant populations estimated to number over a 1000 individuals. These two largely contiguous reserves constitute a core area for elephant conservation in the area north of river Brahmaputra in Assam and Arunachal Pradesh also known as North Bank Landscape (NBL). There are several critical linkages (*corridor*) in this vast landscape which help to maintain the contiguity of the landscape for elephants and other wildlife. Tipi in the West Kameng district of Arunachal Pradesh has long been known as an elephant corridor in the Kameng Elephant Reserve. Tipi forms a linkage between Pakke Tiger Reserve (TR) and Doimara Reserved Forest (RF) in Arunachal Pradesh, the part of the forest which has been found to be world's second richest in terms of Plant diversity (WWF, 2004). The corridor has also been assigned high ecological priority in a nationwide study of elephant corridors (WTI, 2005). Due to the hilly nature of the terrain in the Kameng ER, elephants use a small relatively flat strip along the river to cross from Pakke Tiger Reserve to Doimara Reserved Forests across the Kameng river. Tipi corridor is under threat for the several years due to expansion of human settlement. Tipi becomes more indispensable for elephants in view of the fact that free east-west movement of elephants down south in Balipara RF of Assam has reduced considerably due to human impact. To understand better the importance and usage of this corridor by the elephant population a regular monitoring system was set-up to look at the status of elephant movement in the Tipi corridor and adjoining areas.

Fig. 2



Methodology:
Elephant movement pattern was studied in Tipi by setting up a daily monitoring system in the area. One (1) person was engaged to monitor elephant movement in the area on a day to day basis. From the Tipi point an area within a radius of 3 km on the western bank of the river Kameng was monitored for elephant movement on daily basis. Daily field visits were made to different locations within the said area and new elephant movement signs were recorded. Data on elephant movement were collected on a field data sheet. Places to be visited on a particular day were decided subjectively by the person engaged on the basis of the highest possibility of encountering new elephant signs.

Moreover, secondary data on elephant movement in Tipi were also collected from the local informants during field visit to the respective areas. GPS information was recorded in each of these areas and all the information were recorded in a data format. These data were then incorporated into a Microsoft Excel

spreadsheet for comparison and analysis. Data were also integrated into the NBL GIS platform for output generation and analysis.

Results and Analyses:

The monitoring of elephant movement in Tipi started in mid March'05 and is presently ongoing. This report is prepared on the basis of data generated till April'06. One year of monitoring showed (see Fig: 3) that during this period, for 40% of the days elephants were found to be using the areas in and around Tipi and for 60% of the days elephants were absent from these areas which indicates a movement to other adjoining areas at a distance. This means that elephants spend a considerable time in and around Tipi and the findings re-establishes the importance of the forests in Tipi area for elephants.

Seventeen (17) locations (Fig : 4) in and around Tipi were monitored throughout the year to understand the pattern of elephant movement and habitat use in the area. The highest elephant presence / visit was recorded in *elephant flat* (see Fig: 5) and elephants visited this location 29 times during the monitoring period. Out of these seventeen locations, three (3) locations were visited by
elephants less than five times during the year. Places like *dedziling, tipi top, koilabhati, nair bridge, tipi and pinjuli* were also visited by elephants ranging from 10 to 20 times during this period. Moreover, more than ten (10) instances were recorded where elephants were seen moving towards Assam into the Balipara viz.- a north south movement (from the hills to the plains). It has also come to light that places like *kamla I, lower b'pong, b'png forest* and *duang nulla* are visited very infrequently . Different factors may be attributed to this fact, e.g. *lower b'pong* and *b'pong forest* are used less because of the expansion of the human settlement but, *kamla I* is used less because of the steep terrain in the location and this is not a man made deterrent for elephants. *Duang nulla* is another location which was found to be used very less frequently, maybe the increasing human presence can be a causative factor (more study will make the factors clearer).

Fig. 3

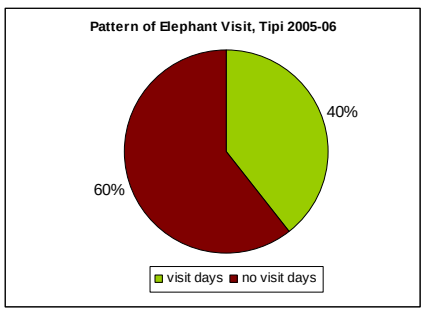


Fig. 4

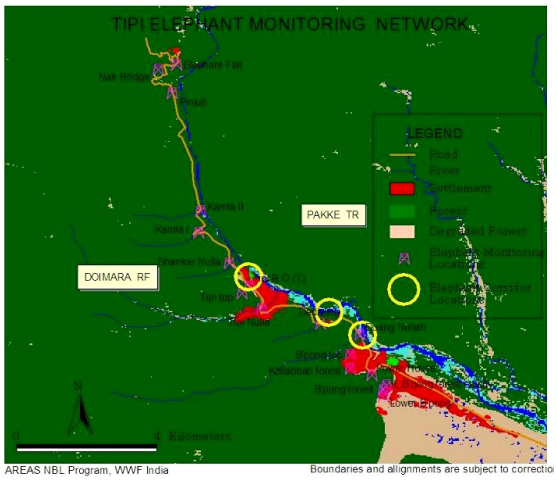


Fig. 5

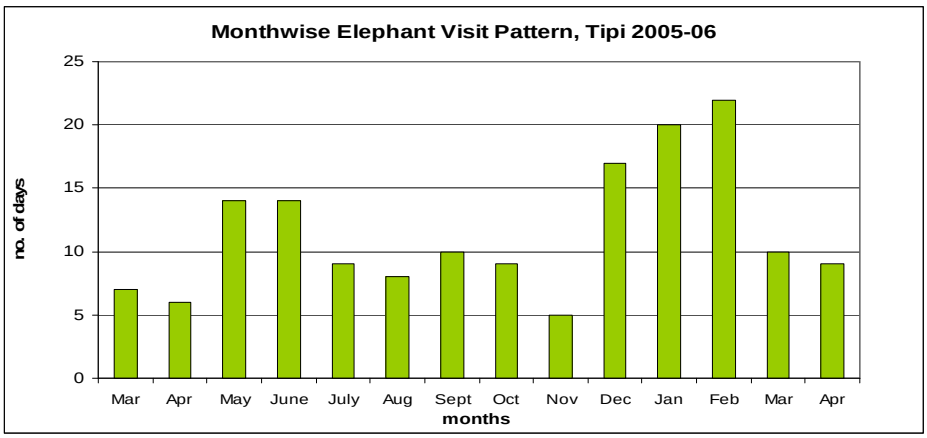
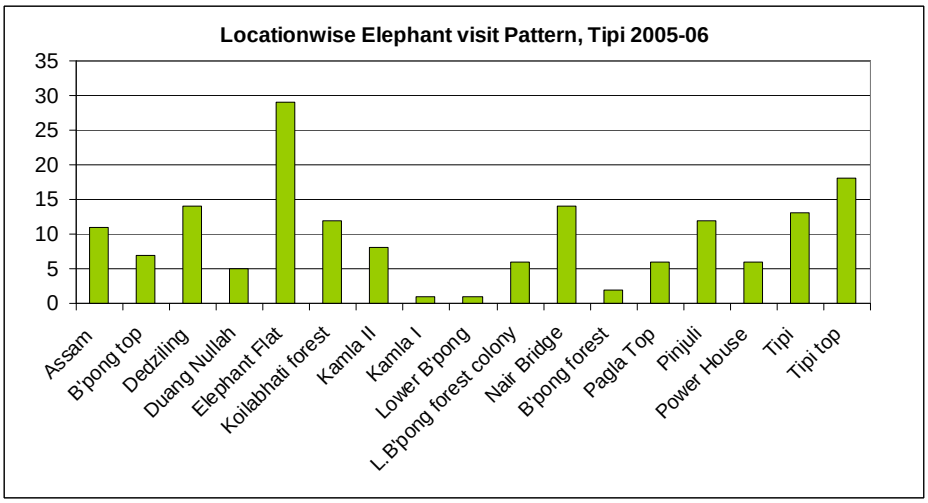


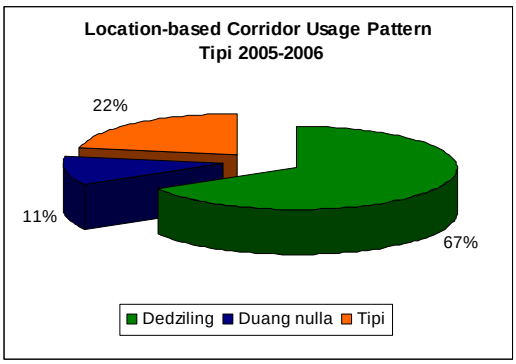
Fig. 6



If we look at the month wise elephant visit pattern (Fig: 6) in Tipi, the whole year of monitoring has shown a fluctuating trend. There is a distinct peak during the months of December, January and February in the elephant visit pattern and from December to February it has shown a rising trend in terms of elephant visits in the area. After February'06, to April a decline in the elephant visit pattern has been recorded which is similar to the lean phases of March, April, July, August, September, October and November'05. Another high elephant visit period was recorded during May and June. This elephant visit pattern may have some relation with the seasonal elephant migration pattern in the Kameng Sonitpur area where elephants come down during the crop season (December-January) from the foothill and lower foothill areas to the crop fields in the flat areas of adjoining Assam. Again, elephants ascend along the low hills during the monsoon (may-june) when the food sources in the plain become very limited and water remains available in the hilly

areas. During the other months of monitoring a comparatively low elephant visit pattern has been recorded in Tipi. It has also been established with the available data that, elephants use the Tipi area throughout the year although with varying levels of frequency and intensity. This also seems likely with the available data on elephant group size recorded in the Tipi area that the area under investigation in Tipi is also a part of home ranges for one or two resident herds of the area (data on elephant group size available till now is not sufficient to draw conclusion and hence not analyzed in this paper).

Fig. 7



Interestingly, from mid March to December'05 there was no record of elephants moving from Doimara RF to the Pakke TR across the river Kameng. During the reporting period elephants have only crossed the river during January, February, March and April. Three (3) days each during January and February'06 have seen elephants moving from Doimara to the Pakke side across the river Kameng. During March'06 and April'06 elephants have crossed twice and once respectively while moving from Pakke to Doimara or vice versa. Out of the nine (9) days of movement across the river, elephant have moved through *Dedziling* on six (6) occasions, twice (2) through Tipi Orchid centre area and once (1) through *Duang nulla*. On two (2) occasions elephant have moved from the Pakke side to the Doimara side through the *Dedziling* area. During March and April'06 elephants have been found to move from Pakke side to the Doimara side and not in reverse direction. These information reveal the undoubted importance of *Dedziling* as a corridor in the Tipi area. *Duang nulla* although came out to be a less frequented area (Fig 7) but it becomes important due to the fact that elephants have used this area to move from Doimara side to the Pakke side. Lastly, in spite of the increasing human pressure at Tipi (Orchid Centre and R.O (ter) area), elephants have been found to use the area as corridor while moving from Pakke to Doimara side. All these information help us to understand the importance of *Dedziling*, *Tipi* and *Duang nulla* in maintaining the forest connectivity for elephants between Pakke and Doimara forests and essentially in providing the elephants a bigger forest area in Kameng ER.

Historically, from secondary sources it is learnt that the Tipi area (from *ORDC* to *Tipi Nalla*) was extensively used by the elephants to cross over from the Pakke to the Doimara side. But even though at present, this movement exists it has gone down at present which can be attributed to the rapid growth of settlements / population in that stretch which tries to prevent any attempts of the elephants to move about into the area.

Recommendation:

It may be established with the available data that the area in and around Tipi is a very vital (or habitat) for the elephants since their presence / visit have been reported in the whole area throughout the year. Besides, the Kameng Sonitpur area has been found to be one of the world's richest biodiversity areas (*NBL Biodiversity Assessment Report'2004*). Therefore, it is recommended to have a sound development and landuse plan for the area as any unwanted development may prove to be a disaster for the rich biodiversity

of the area. Pride of Tipi rests on saving the rich biodiversity and not on promoting projects for short-term gains.

Places like *elephant flat, dedziling, tipi top, koilabhati, nair bridge, tipi, pinjuli* and *duang nulla* are of utmost priority for elephants and need to be kept free from any human interference. *Dedziling, tipi* and *duang nulla* have been recorded as cross over points for elephants (see Fig: 4) and needs special attention during elephant movement period to ensure free and safe passage for elephants. Elephant flat has been recorded as the highest frequented area which is already a settlement area and agriculture is expanding around it which needs to be restricted for securing the area for elephants. Agricultural activities need to be restricted in areas like *koilabhati, tipi top* and *nair bridge* as well to keep these areas accessible for elephants.

There is sufficient primary and secondary information in regard to the importance of Tipi (Orchid Centre and R.O.(ter) area) as an important cross over points for elephants. There is also report of elephant herds visiting areas very near to this. Probably elephants could not pass through this area frequently due to increased human activities like settlement, vehicular traffic since elephants have been recorded only twice (2) during the monitoring period (during March'06) to cross over through this area while moving from Pakke to Doimara. Therefore there is still sufficient justification to go ahead and restore this stretch of land for free movement of elephants. The obstructions at Tipi in the form of the ORDC complex, R.O.(ter) and the new temporary structures coming up on the other side of the road need to be removed to secure elephant movement inbetween Doimara and Pakke on either side of the river Kameng and the road to Tawang.

People dependant on local agriculture and forest produce in Tipi may be studied in terms of their livelihood requirements and necessary alternative livelihood support may be provided through concerned agencies. Moreover, the scope of generating employment through ecotourism may also be explored for the local youths of Tipi.

Conclusion:

The current work is an effort to assess the elephant visit and forest use pattern in and around Tipi besides looking at the elephant movement across the Kameng river unlike the earlier efforts which basically only tried to identify the elephant movement across the river Kameng. This is because the settlement and agriculture are expanding around Tipi at a brisk pace and if these are not checked at strategic locations, these might render Tipi completely unfavorable for the elephant population and also fragment the same. The findings mentioned here are not conclusive since these have been drawn from only one year of observation and more conclusive findings will come out in the coming years.

Acknowledgement:

We are thankful to all the officials and staff of the Forest Departments of Assam and Arunachal Pradesh. Thanks are also due to our active civil society partners in the field, the Dept. of Geography, Gauhati University and the Civil Administration, Govt. of Arunachal Pradesh.

Special thanks go to Boken Riba, Feysham Shekom, Sushila Basumatary, Sanjay Gogoi, Bulen Das and Jamir Ali for their untiring help and assistance in the field level.

The team is thankful to the donors namely WWF Netherlands, WWF US, US Fish and Wildlife Service, MacArthur Foundation and Smithsonian Institute.

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Laparoscopic vasectomy as a potential population control method in free ranging African elephants (*Loxodonta africana*)

Mark Stetter, Dean Hendrickson, Jeff Zuba, Kelly Stetter, Douw Grobler, JJ Van Altena, and Li-Ann Small

Elephant population control is one of the most critical conservation issues facing many areas in Africa. Wildlife managers are currently struggling with growing elephant populations and limited population control options. Our team has been working with conservationists and wildlife officials with the goal of providing a population management tool which might be of value in certain elephant populations.

Surgical sterilization is a permanent contraceptive technique which is used around the world and is one of the most common methods of birth control in both animals and humans. A vasectomy has the advantage of maintaining normal hormone levels and thus breeding and social behaviors remain unchanged. Elephants which have been vasectomized will continue to go into musth, breed (without being fertile) and maintain their social status among other elephants. Unlike most mammal species, elephant testes are internal and can be found adjacent to the kidneys. Recent advances in medical technology allow surgical access to the elephant's reproductive organs with laparoscopic instruments. This technique means that a small incision will allow a rigid endoscope to pass deep inside the elephant and be viewed by the surgeon on a television monitor. With this small incision, there is less chance for infection, the surgery time is decreased and there is less post-surgical discomfort. With all of our study animals, local wildlife officials use biotelemetry collars to find and closely monitor the animals following the surgery. Our goal is to document and ensure that there are no post-operative complications and to prove that the animals' behaviors are unchanged by the surgical procedure.

In July 2006, at the Welgevonden Game Reserve, four adult bull elephants had complete laparoscopic vasectomies performed on four consecutive days as part of a pilot study into the feasibility of this technique as a population control tool in elephants. Traditional translocation equipment was used including a helicopter and crane truck while local wildlife and veterinary experts supervised the procedure. The duration of the surgical procedures averaged just over two hours and the total time from dart induction of anesthesia to complete recovery averaged 3.5 hours. The local ranger staff have been monitoring the movement and health of these animals since the surgery and all are doing well.

This is an international collaborative project which brings together conservation groups, universities and private industry to address this complex problem. It is our hope that this team of dedicated professionals can provide a new tool and a legitimate option for elephant population management. We recognize that surgical contraception will not be the solution for large elephant populations, although it may be considered by small game reserves. Additionally, further research is essential and encouraged to fully understand any negative impact this procedure may have on the individual elephant, its herd or the ecosystem.

Infant talk - first insights into the vocal ontogeny of elephants (*Loxodonta africana*)

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Recent studies on African savannah elephant vocalisations indicate that their vocal repertoire is extensive and highly variable. However, all main studies on the vocal repertoire of elephants focused on adult individuals and next to nothing is known about the vocal ontogeny of elephants. Today, even very little is known about ontogenesis in elephants in general. However, social development and social learning appear to have a tiered structure among elephants. Therefore, elephant behavioural development is a process involving an interaction of individual attributes, gender and the social and physical world to which the individual is exposed (Lee & Moss 1999). An interesting question is the extent to which learning influences vocal development. Learning can effect the generation of sounds, referred to as vocal production learning, and their usage and comprehension, which is referred to as contextual learning (Janic & Slater 1997). Contextual learning in vocal development is relatively common among mammals. However, there are only few mammalian species that can modify their vocalisations in response to auditory experience-, for example dolphins, whales and bats (Janic & Slater 1997; Tyack 2003). Poole et al. (2005) demonstrated for the first time, that elephants belong to the disjoint group of vocal learners. They demonstrated that two elephants coin unexpected sounds as a form of social communication. Considering that elephants are social and vocal learners (Poole et al. 2005) all types of learning probably influence their vocal development, too. To date, only few studies have dealt with the vocal behaviour of calves or juveniles. In her thesis about the development of social behaviour in translocated juvenile African elephants, Gerai (1997) presented some behavioural and acoustic aspects of vocalisations by 2- to 7-year-old individuals. We documented certain aspects of calls by a new-born African elephant in captivity a few years ago (Horwath et al. 2001; Horwath 2002), but next to nothing is known about the call repertoire of different age classes and when elephants acquire the full adult vocal repertoire.

In our talk we provide a first insight into the early vocal ontogeny of elephants from neonatal to 18 months of age. As an important first step in our ontogenetic study, we defined structural and functional characteristics of the infant calls. We are further going to show that acoustic parameters in infant calls differ from the corresponding adult vocalisation, and are discussing the relevance of the study to conservation.

We analysed calls of 11 infant elephants from neonatal to 18 months of age (Table 1), recorded at the Vienna Zoo (from 2001 to 2004) and at the Daphne Sheldricks orphange in Nairobi, Kenya (January and February 2004). We defined 6 structurally distinct call types, the low frequency rumble, and several higher frequency calls, the grunt, the bark, the scream, the snort and the trumpet. The infant elephants further combined low-frequency rumbles with high-frequency calls in changing order including screams and barks. Combinations of up to three calls were documented. Calls of one type were immediately followed by another call type without an inhalation period. However, future studies will be needed to demonstrate whether the calls are combined according to certain rules. The fact that call combinations were recorded so frequently requires further study on this phenomenon in infants as well as other age groups. The results clearly demonstrate that infant elephants are capable to combine structurally distinct calls to more complex vocalisations, demonstrating the extraordinary vocal flexibility already in infant elephants.

Table 1: Study animals

Location	Name	Gender	Age at recording
Vienna zoo	**Abu**	**male**	**0-18 months**
Vienna zoo	**Mongu**	**female**	**0-18 months**
D.Sheldricks orph.	**Madiba**	**male**	**3 months**
D.Sheldricks orph	**Napasha**	**male**	**15 months**
D.Sheldricks orph	**Ndomot**	**male**	**3 month**
D.Sheldricks orph	**Olmalo**	**female**	**9 months**
D.Sheldricks orph	**Selengai**	**female**	**10 months**
D.Sheldricks orph	**Suneiy**	**female**	**6 months**
D.Sheldricks orph	**Taita**	**male**	**11 months**
D.Sheldricks orph	**Tomboi**	**male**	**13 months**
D.Sheldricks orph	**Wendy**	**female**	**14 months**

Similar to adults, the rumble was the most commonly heared call type. They can be very soft and hardly audible, as well as very loud with extreme bandwidth values of up to 20 kHz (Fig. 1), intermediate stages are also present. Discriminant function analyses showed that rumbles can be assigned to adult females or infants based on acoustic parameters, which differ significantly among these two age groups (Table 2).

Table 2: Structure matrix, results from univariate analyses and group statistics (N_{adult} = 80, N_{infant} = 80) from discriminant function analyses for adult and infant rumbles.

Parameter	Structure matrix	$F_{1,158}$	P =	X_{adult}	SE_{adult}	X_{infant}	SE_{infant}
Duration (s)	0.795	745.98	0.000	5.03	1.57	1.59	0.54
F0 min (Hz)	-0.712	598.088	0.000	13.20	0.89	25.50	4.57
F0 mean (Hz)	-0.628	465.413	0.000	15.17	1.51	27.65	5.20
F0 max (Hz)	-0.574	389.845	0.000	16.59	2.00	29.21	5.72
Formant 1 (Hz)	-0.431	219.417	0.000	41.58	7.33	63.55	12.72

In the leave-one out classification, 100 % of infant and 100 % of adult rumbles were correctly classified. Multidimensional scaling (MDS) was used to demonstrate the spatial representations of distances between means of duration, minimum and maximum, mean fundamental frequency and mean frequency of the first formant, in adult female and infant rumbles (Fig. 2; Stress = 0.5126, RSQ = 0.9947). The present contribution shows that particularly rumbles are subject to ontogenetic changes, at least in duration, frequency and formant formation; this probably reflects maturational processes. Defining the role of vocal learning in vocal ontogenesis is challenging. Maturational processes lead to changes in vocal tract morphology that can influence the characteristics of a sound, thus maturational processes rather than copying from another individual could be responsible for changes in calls. Vocal learning may or may not be involved.

Payne et al. (2003) documented the relationship between elephant numbers and calling rates, providing the basis for an acoustic monitoring. We characterised call features in infant elephants, and showed that it is possible to distinguish infants and adults based on acoustic features like duration, fundamental frequency and formant frequencies.

Additional measurements and studies of age groups may yield a fine-tuned monitoring (Payne et al. 2003) and detection (Doluweera et al. 2003), providing information about the age pattern and thus the reproductive state of elephant groups. However, to put these plans into effect, a detailed analysis of elephant calls is urgently needed to identify acoustic parameters that characterize vocalisations associated with individual identity, age and behavioural context.

Acknowledgment:
We wish to express special thanks to elephant keeper Gerd Kohl, who died in February 2005, for supporting our scientific research in numerous ways. It was a honour to meet someone who knew and loved his elephants the way Gerd Kohl did. We are grateful to Dr. Daphne Sheldrick and her team, in particular the elephant keeper Edwin Luitschi, for providing us the opportunity to walk with the orphans in the bush for several weeks. We acknowledge AKG Acoustics for supporting the project with the AKG 480 B microphone and the condenser capsule CK 62. The research was financially supported by the Vienna Zoo and the FWF Austrian Science Fund.

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Figure 1: Spectrographic presentation of one soft and two very loud infant rumble, demonstrating extreme values of bandwidths. Harmonics in the second loud rumbles reach up to 19 kHz. Overlap: 75%, FFT length: 1024.

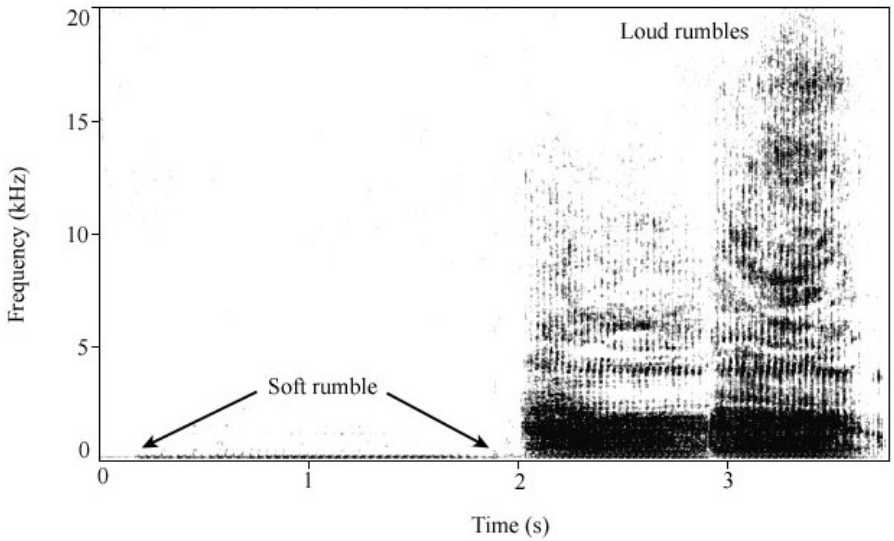
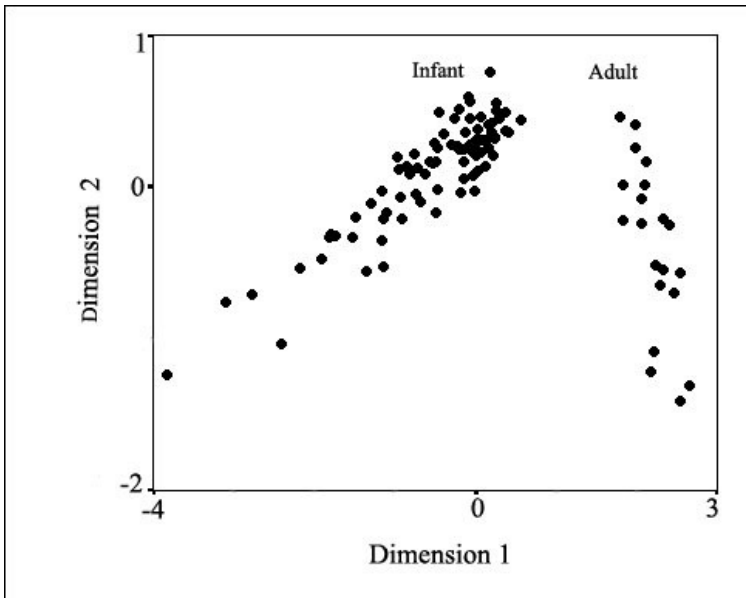


Figure 2: MDS-plot demonstrating spatial representations of distances between means of duration, fundamental frequency features and the first formant in adult female and infant rumbles.



Implementation of regular veterinary care for captive Sumatran elephants (*Elephas maximus sumatranus*) throughout north Sumatra and Aceh

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Abstract:
Today about 400 Sumatran elephants are living in captivity throughout Sumatra in elephant camps under governmental management. This elephants were captured from the wild during the past 20 years to reduce human elephant conflicts. It has appeared during the past 20 years that this captive elephant population is suffering from a serious lack of professional veterinary care and management caused by a lack of funds and veterinarians experienced and willing to focus on elephant healthcare in Sumatra. In 2004 the Veterinary Care Support program (VCS) was started aiming to implement regular healthcare for captive Sumatran elephants (*elephas maximus sumatranus*) and thus contribute to sustainable welfare and preservation of the genetic valuable population of captive Sumatran elephants. At the moment VCS is mainly active in the provinces of North Sumatra and Aceh. In this area regular veterinary care is provided to five camp locations with a total of 60 elephants. Beside regular health-checks of all elephants, treatments and implementation of preventative schemes, also training for Mahouts about handling and management, basic treatments and elephant behaviour and biology is conducted. On request of the forestry departments emergency respond is also provided to other areas of Sumatra. The most common veterinary cases during the pas two years were: Wound treatment, often complicated by generalized infections and myasis. Various species of nematodes and trematodes were identified as the most frequent endo-parasitic infections, elephant-lice was the most frequent ecto-parasites, and required implementation of regular anti-parasitic scheme. The frequently found Keratoconjunctivitis is often caused by dry hot and dusty surrounding, but also probably from bacterial infection because its susceptible to the antibiotic treatment. Cracked toe nails and podo-dermatitis are occurred frequently and it requires intensive and long lasting treatments. Increasing awareness and training mahouts for conduction of pedicure is also crucial for further prevention of foot diseases. Stereotype behaviour due to boredom and lack of social interaction is regularly found and it requires improved management and handling structures. Experience of this project so far show that necessary improvements for captive Sumatran elephants can be reached if support is provided on an ongoing and long term focused basis, and therefore gaining the necessary trust and willingness for co-operation amongst camp staff, governmental departments, local colleagues and institutions.

Keywords: *Sumatran elephant, captive elephant management, veterinary care, welfare*

Background:
As a result of capturing elephants from the wild in order to reduce human elephant conflicts during the period between 1985 – 2000, today there are about 400 captive elephant existing throughout Sumatra. This elephants are kept in governmental run so called Elephant Training Centres (about 350), in Zoos, recreation parks and timber companies. Due to a lack of funds, lack of dedicated and experienced camp managers and veterinarians and a lack of ideas how to integrate captive elephant in a conservation strategy, this captive population in most locations are lacking from sufficient maintenance, health and welfare management.

In order to approve keeping conditions for the captive Sumatran elephants, in the beginning of 2004 a small veterinary project called Veterinary Care Support program (VCS), funded by *elephant family* was started, aiming to implement regular healthcare for captive Sumatran elephants. Due to funding limitations at the moment the VCS program is active with regular veterinary care only in the provinces of North Sumatra and Aceh. In other areas the VCS program can at the moment only provide veterinary support on

special request of the responsible governmental departments in special cases. All activities are conducted in co-operation with the *Departments for Nature and Species Conservation* on provincial and national level (BKSDAs and PHKA).

Activities:

Area of activity
In the provinces of North Sumatra and Aceh the VCS program provides regular veterinary care to five location which all together keep a total of 60 elephants (see listed below).

Location	Provice /District	Male	Female	Distance from Medan / km
ETC Holiday Resort	North Sumatra/Labuhan Batu	6	13	380
Forest Park Brastagi	North Sumatra/Tongkoh	0	2	65
CRU Tangkahan	North Sumatra/Langkat	1	6	105
UPG Aras Napal	North Sumatra/Langkat	2	2	125
ETC Saree	Aceh/Aceh Besar	13	15	590
Total numbers		**22**	**38**	

1. Health-management
Above listed location are visited at least once per month to conduct regular health-checks and treatments. If special medical cases need more attention or emergency respond is requested additional visits are conducted.

A. Preventative schemes
Parasites - During every visit microscopic faeces investigations are conducted. Deworming are undertaken in 3 to 4 month intervals with different kinds of anti-parasitic drugs (see table below) according to intensity of infestation and parasite species.

Drug	Dosag	Rout of administration
Albendazol	10mg – 12mg/kg BW	oral
Triclabendazol	7,5mg – 10mg/kg BW	oral
Ivermectin	0,1mg/kg BW	subcutane or oral
Ivermectin	0,2mg/kg BW	rectal

Teatnus - Tetanus vaccinations for all elephants have been started in the beginning of this year using horse toxoid vaccines, following dosage recommendations for horses. First vaccination is repeated after 4 week and after this it is planed to re-vaccinate once a year.

Nutrition - In the ETC Holiday resort the availability of natural food is very poor due to encroachment of the ETC area and supplemented food is monotonous, therefore it seems obvious that the total diet in this location is lacking from energy minerals and vitamins. To improve the nutrition in this location a special high energy containing, mineral and vitamin enriched food supplement is cooked (composition listed in the table below).

Item	Amount per elephant
Rice	2kg
Sticky rice	1kg
Corn	1kg
Palm sugar	1kg
Vitamin-mineral powder	60g

This supplement is provided once weekly for all elephants and three times per week for nursing mothers. In addition to that during every visit in all locations about 50 bundles of bananas and 5 pineapples or papayas are provide per elephant.

Body-condition monitoring – Body measurements are taken twice a year and the body condition evaluated with standardised body condition formula, to record and document general health and nutritional condition of all elephants

Unfortunately regular blood samples of all elephants can not be realised yet due to budget limitations, therefore blood investigation are so far only used as a diagnostic tool in elephants showing some signs if illness.

A. Treatment of diseases and disorder

The most frequent disease and disorders that needed medical intervention during the past two years were, wounds, endo- and ecto-parasites, foot diseases, keratokonjunktivitis and stereotype behaviour.

Wounds – Fights between elephants left unattended or chained close to wild elephant habitat, sharp foreign bodies like old nails, sharp metal or glass debris thrown away in the surrounding and insufficient use of management and restrain tolls like ropes, chains hooks and unhygienic handling of darting equipment during capture of wild elephants, often cause serious wounds and abscess that need treatment. If treatment is administered immediately after occurrence, usually treatment of wounds is simple and easily heal. Besides washing the wound with clean water it gets flashed with antiseptic solutions, deep holes are also stuffed with antibiotic tablets and large superficial wounds are covered with antiseptic ointment. Which drugs ever used for wound cleaning and disinfections, the most important issue is to continue the treatment twice a day till the wound is healed which usually lasts 7days to 4weeks. If wounds are not immediately recognized or regarded as serious by the mahout to be reported to the veterinarian, delayed treatment can cause complications likes swellings, myasis and generalized infections, which than need more intensive and longer lasting treatment including systemic antibiosis and NSAPs (see used drugs listed below).

Drug	Dosage	Treatment intervals
Povidon Iodin 1% and 10%	Ad libitum / local	Twice a day
Peroxide 2,5%	Ad libitum / local	Twice a day
Povidon Iodin ointment	Ad libitum / local	Twice a day
Penicillin-Streptomycin 200.000 IU – 200mg/ml	10.000IU – 10mg/kg BW / i.m.	In 24h intervals for 7 days
Amoxicillin LA 150mg/ml	12mg/kg BW / i.m.	In 48h intervals for 7 days
Oxytetracyclin LA 200mg/ml	12mg/kg BW / i.m.	In 72h intervals for 7 days
Ibuprofen 400mg/tablet	5mg/kg BW / p.o.	Twice a day for 5-10days
Etamidon (NSAP drug combination)	5ml/100kg BW / i.m.	In 24h intervals for 3-7days
Dichlofention (Gusanex Spray)	Ad libitum / local	Twice a day

Handling and management advice to mahouts and camp managers about above mention reason that are causing wounds reduced its occurrence.

Parasites - Regular microscopic faeces investigations (flotation and sedimentation) detected, that different roundworms species (*Strongyloides spec., Strongyloides spec., Ascaridae*) and Trematods (Fasciola spec.) are the most frequent endo-parasites. And macroscopically Elephant-lice (*Haematomyces elephantis*) were detected to be the most frequent ecto-parasite. A permanent burden for most elephants are also different blood sucking flies. Whether this flies transmit other diseases (bacterial and/or protozoic) is not investigated and would need further research. (Find rugs used for anti-parasitic treatments listed above under “preventative schemes”.

Foot diseases – Most frequent foot diseases that needed treatment was Pododermatitis. Injuries of the footpad, lacking wear out of the footpad resulting in double layers and infections between this double layers, unhygienic and permanently wet keeping areas of the elephants were the causes of this diseases. Cracked toenails due to overgrown toenails were rarely found and rarely required treatments. For treatment the foot gets washed with water and effected areas with disinfecting solutions, overgrown toe-nails, foot-pad layer was cut down to an physiological extend. Overgrowing tissue of collagen fibre from the deeper layers was cut down to its physiological layers until blood vessels appeared. All infected and necrotic material was removed. Bordering areas of overgrowing collagen fibre and epidermis were cut out to the area where physiological connection between epidermis and corium appeared. This was repeated regular (about every 2-3 weeks) until recovery, because the connective tissue from corium and digital cushion is growing faster then the epidermis and hinders complete healing if not done so. Cut out areas were treated with antiseptic and adstringentive solutions, like Kaliumpermanganat 1% - 2% Coppersulfate 3% Formalin 5% . Treatments were done twice a day for some weeks until complete healing. Advise for regular checks of toenails and footpad, conduction of pedicure and awareness building amongst the camp staff about general hygienic management of the elephants keeping areas have reduced cases of pododermatitis.

Keratoconjunctivitis – This problems was often found and is characterized by increased tear dropping, inflammation of mucous membranes, slightly milky discolored cornea and performance of milky, opaque spots on the cornea. Dusty, dry and hot surrounding often can cause this disorder, but it seems that often bacterial infection, that are suspected to be transmitted by flies can be the main reason for this disorder or at least complicating climate inducted keratonconjunctivitis. Healing can sometimes happen without any treatment in some cases and first slight signs must not necessarily treated immediately but first the condition of the surrounding should be improved. If increased signs of this illness are not treated it can lead to corneal ulcers, total blindness and total loss of the eye. For local treatment with antibiotic eye-ointment chloramphenicol ointment was found to be most effective. Using eye-ointment it is crucial to repeat the treatment several times a day (at least 3 times day better more often) to reach an effect. If local treatment can not performed reliable (due to unreliability of mahouts, reduced acceptance of the elephant) systemic treatment can be given. Oxytetracyclin LA 12/kg i.m. repeated four times in 72 hours intervals were found to effect the disease.

Stereotype behaviour - In all locations that are visit some elephants were found that performed stereotype behaviour often also described as weaving, which can be described as permanent repetition of the same movements in the same rhythm without aiming to reach a specific result. This is usually caused by stress and boredom due to a lack of occupation and lacking social contacts and interaction. Although in all Camps sufficient numbers of elephants of both sex and different ages are kept, the animals are managed in a way that they are staying more than 90% of the day alone. During the day the elephants are brought to some places where they are chained for foraging and in the evening (sometimes also in the morning) taken for a bath and than chained with their supplemented food somewhere nearby the camp-site. Although often the elephants can hear and sometimes can see each other they can't have direct contact with each other, usually only during bathing the elephants have regular direct contact which each other and during this time the elephants still need to be under the command of their Mahouts and can not freely socialise with each other. In non of the camps regularly time is given to the elephants for free roaming and socialisation. In almost all camps visited the regular work loads and occupation for the elephants is very low if existing at all. This management structures leaves the elephants unoccupied and bored,after they have eaten their food as they are unable to perform social interactions due to their restriction. Unfortunately knowledge about elephant behaviour and mental well-being is very low amongst the camp staff therefore stereotype behaviour is not recognized as a problem that needs to be addressed. Education about elephant behaviour and different management systems are crucial to realise awareness building about the mental well-being of elephants amongst mahouts and camp-managers. Improvements are realised slowly and depend on the long-term continuation of regular education and advice about this subject.

Above described diseases represent not all but only most frequent diseases and disorders that needed medical intervention. Beside these also single cases of gastrointestinal diseases (colic, constipation,

diarrhea), tetanus infections, sunburns, navel infections, tail amputations, hyperkeratosis, e.coli infection, etc. needed treatment during the past two years.

2. Staff training

For the successful conduction of veterinary work good co-operation between camp staff (mahouts, veterinary technician and camp managers) and the VCS-program veterinarians is crucial. Therefore a good understanding amongst the camp staff about elephant biology, behaviour, its welfare needs and how a sufficient healthcare management contributes to this is important. The camp staff's willingness to co-operate with the VCS veterinarians depends also very much on the trust and believe in the veterinarians work and recommendations for improvements and changing's of established management structures and/or handling procedures. This trust was not automatically existing from the beginning of the VCS program work, but could be build due to reliable continuation of regular visits since more than two years. It was also possible because the VCS team does not only provide pure veterinary care but during every visit also conducts some kind of training and/or information sessions for the camp staff.

Mahouts – There is no structured education and training scheme existing for the mahouts, once people are recruited for the job as a mahout they just have to try to learn somehow from the more senior mahouts in the camps how to handle and train elephants. Although many mahouts develop after some time reasonable to good skills in handling the individual elephant they are in charge for, knowledge about elephant biology, behaviour, different management and handling systems, basic knowledge about health care and medical procedures and treatments is very limited. The VCS team tries to address this issue by training sessions using slide shows, video films and practical demonstrations about the following subjects:

- Elephant biology and behaviour
- Basic elephant anatomy and physiology
- Prevention and treatment of basic medical problems
- Different elephant handling, training and restrain techniques
- Training elephants for medical procedures (e.g. foot care, mouth inspection, blood sampling, rectal intervention, treatments

Veterinary technicians – the locally so called "paramedics" have undergone a basic education in a governmental or governmental licensed school about the basics of veterinary management, disease and treatments. But this education focuses on livestock and does not include any specially elephant related training. Often this is already a long time ago and as there is no continuing education and in the past there were often only a little if at all medical supplies available in the camps to really conduct treatments much of the once gained knowledge has been forgotten. The VCS team tries to address this issue by training sessions using slide shows, video films and practical demonstrations about the following subjects:

- Elephant anatomy and physiology
- Elephant diseases
- Sample gaining and investigation
- Treatment schemes and drug dosages
- Record keeping
- Elephant handling and management
- Waste management/Camp hygiene

Local veterinarians – Only a few governmental departments which are in charge for the elephants have their own veterinarians, but even if existing non of them is staying in the camp permanently and mostly they have more administrative than veterinary duties. Nevertheless the VCS veterinarians try to involve this colleagues and also sometimes interested local colleagues in the veterinary work as much as possible. Veterinarians from other areas in Sumatra have been invited and volunteered with the VCS program in the past. Beside this the VCS team has exposed its work for elephants in national veterinary meetings and workshops to raise more attention amongst colleagues about the veterinary needs and problems for elephants in Indonesia.

3. Mahout welfare
Salaries of the mahouts are very low, and living conditions in the camps are mostly very basic and monotonous, not providing many possibilities for recreation and information exchange. The possibility for the VCS program to interfere in these conditions due to budget limitations is very limited, but tries with some basic support also to reach some improvements for the camp staff with the following activities.

Mahout uniforms – Every year a basic uniform set for each of the 95 Mahouts in the 5 locations is provided, consisting of trousers, shirts, hat and Rubber-boots or raincoat (shifting from year to year).

Socialisations and information meetings – During this meetings newspapers are distributed, information about situations/problems in other elephants Camps (elephant and non elephant issues) and other actual news from Sumatra is exchanged and discussed. Snacks, drinks and Cigarettes are provided during this meetings, that have a very informal character and often not only attended by the mahouts but by their whole families.

Incentives – Small allowance are paid as a kind of reward to mahouts that have performed extraordinary care for their elephants that required increased work loads for the mahout, like continuing treatments advised by the veterinarians reliable and successfully, providing intensive care for mothers and new born babies during the first weeks after birth, successfully training the elephants for special medical procedures, etc.

Conclusion:
The captive population of the Sumatran elephant (*Elephas maximus sumtranus*) today represents probably about 20% of the overall population of this subspecies. This genetically valuable population can play an important role for the conservation of this unique subspecies if carefully managed focusing on conservation and self-sustainability. The experience of he VCS program show that implementation of sufficient veterinary care and changes in handling and management can be realised for this captive elephants, if support are long term focussed and conducted in close co-operation with the camp staff and governmental departments in charge.

For the future the VCS team hopes to be able to intensify its activities in the current areas of activity and enlarge such support to camps in other areas in Sumatra. The VCs team also hopes to realise more intensive knowledge exchange with other colleagues in Indonesia about veterinary care for elephants and to conduct courses for students about this subject in order to increase the number of colleagues able and willing to provide veterinary care for Sumatran elephants.

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Population, age and sex assessment of free ranging elephants in Periyar Tiger Reserve, Kerala, South India

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Introduction:

Elephants in southern India distributed along the Western and Eastern Ghats mountain ranges, covering an area of 39,500 km^2 with a population size of 12,500-14,500 accounts for 22 per cent of India's free-ranging elephant population (Sukumar, 2003). Periyar Tiger Reserve, one of the well known wildlife reserves in southern India, where once elephants roamed freely and in abundance is now cause for concern because of decline in population trends and disparity in sex ratios in different age groups, especially in adults. Several field researchers attributed the phenomenon primarily to severe poaching that took place in the Reserve since the 1970's. As a result of the selective removal of one sex from the population, severe detectable demographic changes in the population were observed such as skewed sex ratios, lengthy calving interval and poor fecundity rates.

There have been a number of studies on the ecology, population dynamics and habitat utilization as early as 1969 (Kurup, 1971) in Periyar Tiger Reserve. The recorded data from recent studies on the above parameters on elephants is so unbelievably different from earlier surveys and a sure case of conservation concern that warrants further investigations, especially with regards to population assessment and herd composition using reliable tools and modern techniques, to predict the prospects of Periyar elephants.

The present study combines conventional methods with more recent and developing molecular scatology (using dung extracted DNA to sex individuals) to study the population, age groups and sex ratio of free-ranging elephants in Periyar tiger reserve.

Materials and methods:

Study area

Periyar Tiger Reserve (PTR) in Kerala state, southern India, between latitudes 9^o 15' and 9^o 40' N and longitudes 76^o 55' and 77^o 25' E., one of the single largest compact forest blocks in the Western Ghats forms a significant part of the physical and cultural catchments of two major rivers of Kerala namely, Periyar and Pamba. The total area of 777 sq.km was declared as part of Project Elephant Reserve No.10 in 1991, a contiguous forest tract extending over an area of 3800 km^2 in Kerala and Tamil Nadu. The terrain is undulating in many areas and rugged with lofty peaks and precipitous slopes in other areas. The elevation ranges from 100 m to 2019 m above sea level with an average altitude of 800 m. The average rainfall is 2000 mm annually. The temperature varies between 15^{o}C and 31^{o}C. The average humidity varies between 60 % and 85 % round the year.

Major vegetation types in Periyar Tiger Reserve comprise of tropical evergreen and semi evergreen forests (579.64 km^2), moist deciduous forests (104.54 km^2), shoal/grasslands (11.66 km^2) and Eucalyptus plantations (55.17km^2). Periyar Lake forms an important aquatic ecosystem, which occupies about 26 km^2 of the area. The wealth of vertebrate diversity is very rich and of the 63 species of mammals recorded, Elephant, Gaur, Sambar deer, Wild boar and Barking deer are the common herbivorous species. Apart from these, Tiger, Leopard, Wild dog, Sloth bear, Nilgiri langur, Lion-tailed macaque, Nilgiri tahr, Small travancore flying squirrel, Nilgiri marten and Strip necked mongoose are frequently sighted.

Monitoring elephants in the reserve

The entire exercise of collecting information on free ranging elephants in the reserve was done primarily on foot, and at times in jeep, perambulating higher density areas more frequently and taking care to visit every forest section in the reserve at least once. The period of study was from March to July 2005, taking

advantage of the better visibility factor available during the summer months in the reserve. The main parameters observed for the study were herd composition, age estimation, and sex ratio in different age groups and population density based on direct sightings.

Observation of Herd Composition

The elephant herds were classified into type I, type II and type III depending on the nature and extend of age and sex assessment possible during observations. Type I indicates that all elephants in the group has been accurately classified; type II indicates that not all elephants were classified but, the presence or absence of adult males in the group has been confirmed, and type III indicates that not all elephants were classified and the presence or absence of adult males in the group is also not confirmed.

During observations, necessary steps were taken to identify each elephant herd/group separately to avoid duplication. This was achieved by recording moving visuals of every individual in the herd/group using camera. Herd identification was also achieved by noting conspicuous body features of the matriarch and other members if possible, such as torn ears, disproportionate ears, holes on ear flaps, cut tail, stumpy tail, other anatomical peculiarities and deformities. The visuals taken and peculiarities noted of every observed herd/group were compared regularly to differentiate herds. Using the herd composition data, the fecundity rate and calving interval was worked out from the number of calves and adult females in the observed population.

Estimation of Age

The elephants were broadly classified into four age categories described by Sukumar (1989).

1. Calf ---- less than one year (Height, 3-4 ft)
2. Juveniles ----1-5 years (Height, 4-5 ft)
3. Sub adults ----5-15 years (Height 5 ft for females; 5-8 ft for males)
4. Adults ----Above 15 years (Height above than 7 ft for females, above 8 ft for male)

Age assessment of elephants in the reserve was performed by observing a combination of criteria such as shoulder height, areas of depigmentation on body parts (blotches), size of ears and folds on upper margin of ears, hollows/depression on forehead, temples and buccal region, mammary development in case of females, size of tusks in males etc. The shoulder height of the matriarch ('target animal/oldest female') was first assessed by taking photographs (visuals in this study) of the elephant close to and against a natural object such as a tree, and measuring the height from the natural object after the elephant has moved away.

The shoulder height of other members of the herd was then compared with the matriarch's height from visuals taken. From the shoulder height, the age of all sex/age categories were calculated from the charts prepared by Sukumar (1989). Other physical characteristics mentioned above were also taken into consideration before the age of the members was recorded finally.

Sex Assessment of Free Ranging Elephants

Two methods were employed to assess the sex of elephants in the reserve (observed sex ratio).

Physical Verification

The elephants were physically verified by observing from a safe distance, preferably using a binocular primarily relying on observation of genital organs, supported by accessory sexual characters such as mammary development, presence of tusks etc to determine the sex. Any elephant, which cannot be readily categorized as bull or Cow, was recorded as Unsexed

Molecular Sexing

In rare instances it may not be possible to accurately identify the sex of certain elephants especially those belonging to sub adult, juvenile and calf categories by physical verification because of inconspicuous genitalia and other accessory sex characters. In such cases, the dung samples of those animals were taken for sexing using molecular technique.

The DNA extraction from dung and sexing procedure adopted by Vidya *et al.* (2003) was followed in this study. Extraction of DNA from dung sample was carried out using QIAGEN Gel Purification Kit. PCR conditions were standardized with cycles that comprised of an initial denaturation at 93°C for 3 minutes, followed by 39 cycles each of 1-minute denaturation at 93°C, annealing at 51°C for 1 minute, extension at 72°C for 1 minute to complete a total of 40 cycles, and final extension at 72°C for 5-7 minutes. The PCR

products were subjected to restriction digestion with 5 µl of *Bam* HI (MBI Fermentas 5U/ µl) and electrophoresed on a 2 per cent 1 agarose: 1 low melt agar gel to observe for bands that differentiate males and females.

Estimation of elephant numbers
Density of elephants was estimated using a direct sample count method (Block Count). The data for population number estimates was collected during the elephant census conducted by Project elephant, Ministry of Environment and Forests, GOI, in association with the respective state Forest Departments on the 6'th of May 2005.

The total park area of 777sq.km in the five ranges namely Thekkady, Periyar, Vallakkadavu, Azhutha and Pamba was divided into 61 blocks based on vegetation, geographic land marks, natural boundaries and elephant usage. Out of these, 23 blocks were selected for the sample count. Each block was perambulated on foot by a trained team from morning till evening and information collected regarding the number of elephants sighted, age and sex composition. The data thus collected was recorded on a data sheet supplied to every team.

The data obtained from sample blocks was pooled and analysed statistically using the calculations suggested by Sukumar *et al.* (1991) to compute the total number of elephants in Periyar Tiger Reserve.

Results:

A total of 239 elephants were observed during the study period. Fifteen animals in three herds were observed on more than one occasion, 17 animals observed were classified as type 11, and 14 animals sighted were classified into type 111. A total of 193 elephants were classified based on age and sex. During the period of study, high percentages of animals observed were in grasslands and adjoining sholas followed by the moist deciduous forests adjacent to the Periyar reservoir. The density was least in the evergreen patches.

Herd Size
Forty-three herds were observed in the reserve and the herd size varied from 1 to 16, with an average of 5.5. Six solitary elephants recorded were very old females. Two adult males aged between 15 –20 years only were recorded during the entire period of the study and at the time of observation, they were attached to groups.

Age structure
Adult females formed a major portion of the population (52.41%), followed by sub adult females (17.12%) and juvenile males (10.90%). Adult males formed 0.889 per cent and sub adult males, 3.63 per cent of the population. Among adult females, the frequently sighted elephants were in the age group 20-30 years (16.086%) and 30-40 year age category (14.53%). Surprisingly, no adult male above 20 years was recorded in the reserve during the period of study. A total of ten calves were recorded in nine different herds.

Sex Composition and sex ratio
It was observed that sex could be identified by physical verification alone in majority of the animals by observing the genitalia. Out of the ten calves recorded four were confirmed to be males based on physical verification and the others were unsexed. But considering the constraints in sexing calves, the proportion of male to female calves was taken as equal in the present study. Females formed 81.99 per cent and males formed only 18.01 percent of the population, but the proportion of males and females in the calf and juvenile category was almost same, with a shift biased towards the females from the sub adult category onwards. The sex ratio was calculated based on the observed proportion of males and females in the population. The adult female to male ratio was found to be 1: 58.95; in sub-adults 1: 4.71, and in the juvenile category 1: 0.9.

Molecular Sexing
Sixteen dung samples of animals of unidentified sex were collected from the reserve. They belonged mainly to juveniles, a group apparently difficult to sex by physical verification. After the DNA extraction, subsequent restriction digestion and analysis of the samples by electrophoresis, it was found that six samples produced three bands (males) and eight samples exhibited single band each (females). Two of the samples did not give any results.

Fecundity Rate and intercalving interval
The fecundity rate in the observed population was calculated by dividing the number of calves with the total number of adult females .The rate was worked out to be 0.099. The intercalving interval was calculated by dividing the number of adult females with the total number of calves observed in the population. The intercalving interval was worked out to be 10.1 years.

Population Number
Using the method of block count the total number of elephants counted by direct sighting on a single day in 23 selected blocks was 241 in different age groups. From the number of elephants recorded in the selected blocks, the total number of elephants in Periya Tiger Reserve was calculated to be 644 with an R value of 0.85. The calculations are presented in Table 1 and 2. In the calculations, Periyar, Vallakkadavu, Thekkady, Pamba and Azhutha ranges are designated as Stratum A, B, C, D and E respectively. The total effective area for calculating elephant population in Periyar Tiger Reserve was taken as760 km2, not taking into account the reservoir area during summer.

Discussion:

Periyar Tiger Reserve came into the limelight when research articles published on population study of elephants declared a progressively skewed adult sex ratio from about 1:6 (1969) to 1:19 (1977-'79) and then skewed substantially to 1:71 (1980-1982) reaching a peak of 1:122 in 1987-'89 (Uma Ramakrishnan, 1998). Most studies indicated a declining trend in the population and biased sex ratios towards females giving the elephants in Periyar Tiger reserve a high priority conservation status.

Herd composition
During the present study, among the different age groups adult females formed more than 50 per cent, adult males constituting only 0.889 per cent, juveniles between 1-5 years, 20.76 per cent, sub adults between 5-15 years, 20.76 per cent and calves below one year, 5.19 per cent of the total observed population. This indicates that there is a further decrease in the births in the Periyar population suggesting a deviation from the normal reproductive parameters in elephants observed elsewhere in Asian elephant populations. Only 10 calves were observed in the 43 herds that comprised of 101 adult females above 15 years of age suggesting an alteration in the reproductive pattern of adult females due to some stress, such as absence or limited presence of breeding males in the population. This is more evident by the mere presence of elephant groups comprising of only members from the sub adult category onwards and many adult females appear to be under productive without any mammary development suggesting that they have not reproduced or in any stage of lactation or late pregnancy. In the observed age-sex classes, adult females and sub adult females formed the major portion (69.53%) of the population, a shift towards the older age class.
The observed elephant population in Periyar Tiger Reserve constituted only 25.95 per cent young animals below five years, 20.56 per cent sub adults between 5-15 years and 53.3 per cent adults above 15 years. This suggests a population trend that is certainly declining indicated by a low proportion of young animals in the population. Lindeque (1991) opined that if the rapid changes in population size were mostly due to sudden changes in recruitment or mortality, the population age structure would show changes in the relative proportion of individuals in each age category. The only known mortality factor that could possibly affect all age categories is indiscriminate poaching.

Sex categories and sex ratios

A good number of juvenile tuskers (more than 15) were observed in PTR during the study period. This is a very good indication of the improving number of tuskers in the population, but a lot depends on how they fare in the coming years to become potential breeding bulls given the intense pressure Periyar Tiger Reserve is facing at present.

The observed sex ratio in different age groups in the present study was skewed from the sub adult category onwards with more disparate ratio in the adults (1:59). The skewed adult sex ratio in Periyar is the most disparate recorded for any major Asian elephant population or African population. This disparity has been mainly attributed to severe poaching of males from the sub adult category onwards for ivory until early 1990's resulting in selective removal of one sex from the population. This is one factor that has been agreed upon by researchers and forest authorities alike, although in earlier times skewed sex ratios were possibly prevalent due to capture of ideal tuskers by South Indian Kings for their army. But, at present the situation has worsened due to unscrupulous killing for ivory and weak protection measures.

While ivory poaching has been a problem in most southern Indian states, reports suggest that Periyar Tiger is the worst affected. The highly skewed or disparate sex ratio in age groups above sub adult stage has been attributed mainly to severe poaching during the period prior to 1987, when even juveniles have not been spared (Uma Ramakrishnan *et al.*, 1998). Easa (2001) also interpreted that another factor responsible for the disparate sex ratio was due to the official capture of elephants from the Reserve since 1810 that lasted till the 1970's.

The increasingly female biased sex ratios could affect populations seriously, by lowering the effective population size, lowering birth rates and decreasing genetic viability due to inbreeding. It is thus imperative to monitor sex ratios on a regular basis in addition to population sizes (Vidya, *et al*. 2003).

The calving interval and fecundity rate

Of all the parameters worked out during the present study, the calving interval of the elephants in Periyar is a matter of great concern, because the value calculated is above 10 years. Majority of the elephants observed were adult females and a great proportion of these animals were without calves and also did not apparently show signs of late pregnancy or signs of mammary development. The study reveals that only one in 10 adult females conceive every year, which again is suggestive of severe shortage of adult males in the population.

An important demographic effect of high rates of poaching and extreme skew in adult sex ratios is a decline in the birth rate of the population. The present study calculated the fecundity rate as 0.099, drastically low compared to other Asian elephant populations. With an extremely low number of adult males in the population, a substantial number of females coming into oestrus would not be detected and mated. Another possibility reason for the low number of calves and juveniles seen in Periyar is that females may have stopped reproducing under conditions of extreme stress (poaching), or infant mortality may have been very high, though accurate records on calf mortality is unavailable. Uma Ramakrishnan *et al*. (1998) reported that the average fecundity was only 0.075/adult female/year in Periyar Tiger Reserve as compared to between 0.20 and 0.025 for the more productive populations in southern India.

Population Density

As per reports on the census figures, the year 1978 recorded 588 elephants, 950 elephants in 1987, 980 in 1989, 615 in 1993, and 559 (0.72/km2) in 1997.The population numbers obtained by the block count method in this study indicate an elephant population that is not growing and a figure that is widely accepted by many research agencies. It must also be noted that for a large mammal like the elephant with very long generation interval, routine monitoring for an extended period of time is essential to identify trends in the population to avoid demographic catastrophe or accelerated loss of genetic variability. Removal of adult males from the population will result in reduced effective population size and increased rate of genetic drift. These two factors threaten the long-term survival of the Asian elephant as a species by gradually losing the ability to respond to environment changes by adaptation.

Uma Ramakrishnan *et al*. (1998) has stated that the elephant population in Periyar Tiger Reserve can possibly withstand the drastic reduction in the genetically effective population size (Ne), because this reduction has occurred over a single elephant generation (about 20 years). But, this may not be true unless we have sufficient reason to believe that poaching has been totally controlled in Periyar region. The recorded number of ivory poaching in Periyar in recent years is very low and attributing this to 'efficient

protection' may not be entirely true because of the simple logic that there are no more good sized ivory to be poached from Periyar at present. It must also be noted that tiger and leopard skin, and other valuable wildlife goods were recently seized from different parts of Kerala, especially Idukki district indicating that poachers are still very much active and waiting. So the population bottleneck is likely to continue affecting future elephant generations also.

This reserve and adjoining contiguous forests still remain a wonderful mosaic of ecosystems that can harbour and maintain good elephant population if degradation processes cease to continue and protection measures rise to the occasion to save the remaining population, especially the immature animals.

It is highly imperative that a clean, up-to-date mortality recording system for elephants are followed in the reserve, which at present is lacking. Adopting a regular population and health-monitoring programme at least on annual basis can provide important information on the status of elephants to help implement strategies in crisis situations. Identification of individual elephant herds/groups in the reserve area should be taken up as part of the monitoring programme to predict the trends in the population and changes in demographic parameters for an extended period of time. The extensive developmental projects initiated at Sabarimala pilgrim centre will in due course certainly affect the ecosystem drastically through progressive and rapid forest degradation.

There are many options and alternatives suggested to resolve the Periyar crisis. Many are aimed at improving the habitat conditions, stepping up protection activities, boosting eco-development programmes and educating the local mass. Some researchers have suggested translocation of adult male elephants from other populations with surpluses, in order to improve the genetically effective population size. This would also serve to stimulate the birth rate of the population. But it is a known fact that all other south Indian elephant populations are also facing the problem of skewed sex ratios and poaching.

It is also interesting to look at the situation prevailing in Kerala regarding the free ranging and captive elephant population. Studies have proved beyond doubt that the free ranging population has very low number of adult males, but the captive population of elephants (approximately 1000 numbers) in the State is comprised of more than 95 percent adult massive tuskers, many of which are ageing and under utilized for breeding purposes. This wide gene pool can be utilized in some feasible way to improve the status of wild populations.

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Table 1A: Block Census Data

Sample unit	Periyar (A)			Vallakkadavu (B)			Thekkady (C)			Pamba (D)			Azhutha (E)		
	Z	a	Za	Z	a	Za	Z	a	Za	Z	a	Za	Z	a	Za
1	8.73	0	0	9.35	23	215.05	11.38	4	45.52	11.27	5	56.35	10.16	32	325.12
2	9.62	0	0	13.09	9	117.81	7.98	7	55.86	10.75	8	86	8.56	5	42.8
3	14.72	0	0	7.74	6	46.44	14.59	22	320.98				13.45	26	349.7
4	13.65	12	163.8	13.9	29	403.1	7.92	17	134.64						
5	11.94	13	155.22												
6	11.56	12	138.72												
7	9.7	11	106.7												
8	12.71	0	0												
9	19.75	0	0												
10	15.35	0	0												
TOTAL	127.73	48	564.44	44.08	67	782.4	41.87	50	557	22.02	13	142.35	32.17	63	717.62
MEAN	12.77	4.8	56.44	11.02	16.75	195.6	10.47	12.5	139.25	11.01	6.5	71.18	10.723	21	239.21
Vz	9.78			6.53			7.63			0.067			4.144		
Va		34.76			91.19			53.25			2.25			134	

Z = Area of sampled unit
a = Number of animals in that unit
Vz = Variance in the area of units within each stratum
Va = Variance in the number of elephants recorded in each stratum

Table 1B: Computation of Block Census Data

STRATUM	N	n	N(N-n)/n	Mean a	Va	Vz	Na	Nz
A	362.26	10	12760.97	4.8	34.76	9.78	1738.85	4627.15
B	137.93	4	4618.24	16.75	91.19	6.53	2310.33	1519.99
C	94.97	4	2159.86	12.5	53.25	7.63	1187.13	994.05
D	78.16	2	2976.33	6.5	2.25	0.068	508.04	860.54
E	86.64	3	2415.52	21	134	4.14	1819.44	929.04
Total	759.96	23	24930.92	61.55	315.45	28.148	7563.79	8930.77

N = Total number of sampling units
n = Number of units sampled
V = Variance of numbers within units of a strata
Nz is computed by multiplying N and the mean z for each stratum

The total number of elephants $X = \frac{Na \times Z}{Nz}$

$X = \frac{7563.79 \times 760}{8930.77} = 644$

$R = X/Z = 644 / 760 = 0.85$

Therefore the total number of elephants in Periyar Tiger reserve with an effective area for calculating elephant population is 644 with an R value of 0.85

Multi-dimensional mitigation initiatives to human-elephant conflicts in Golaghat district and adjoining areas of Karbi Anglong, Assam, India

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Abstract:
The state of Assam is regarded as one of the stronghold of Asian elephant conservation with a population of about 5200 as assessed in the year 2005. The forest areas of Golaghat and Karbi Anglong districts are symbolized by Nambor-Doigrung Wildlife Sanctuary (97.15 km^2), Garampani Wildlife Sanctuary (6 km^2), Nambor Wildlife Sanctuary (37 km^2). These sanctuaries are also parts of Kaziranga-Karbi Anglong Elephant Reserve declared on 17-04-2003 with an area 3270 km^2 and crucial role in maintaining the seasonal requirements of elephants in the Kaziranga-Karbi Anglong landscape. However, massive shrinkage and fragmentation of habitat by the settlement of encroachers, opening up of tea industry and developmental works ancillary to it, retaliatory killing by people and also poaching for ivory and meat gradually reduced the key elephant habitat and elephant population in the area since 1980s. The animosity between man and elephant has also increased resulting into the severe *human elephant conflict* (HEC) in the area that has shattered the age old co-existence.

Keeping in mind the long term need of these key elephant habitat safe from further onslaught, this study has been envisaged increasing level of confidence among villagers for living in harmony with elephants by building their capacity to reduce the conflict and diversify their livelihood opportunities through cultivation of elephant repellent crops like *Patchouli* having significant market values. A multi-disciplinary approach is being used to mitigate the HEC based on practical and feasible option. Satellite images based on 1977, 1991, 1998 and 2004 were analysed along with intense ground assessment of the current forest cover and found that the forest cover in the area has declined by over 85% in between 1977 and 2004 which is the crucial cause of increased HEC. Based on the field work carried by our team the following measures were coined in Reducing Elephant Depredation and Mitigating HEC.

1. Identification and Mapping of elephant corridors.
2. Providing for adequate protection of elephant corridors and planting trees in them.
3. Evicting encroachers and settlers from the elephant corridors with the help of District Administration and Police.
4. Planting food trees in elephant habitats and elephant corridors.
5. Cleaning up and excavating existing water bodies in forests to provide for essential water source.

Introduction:

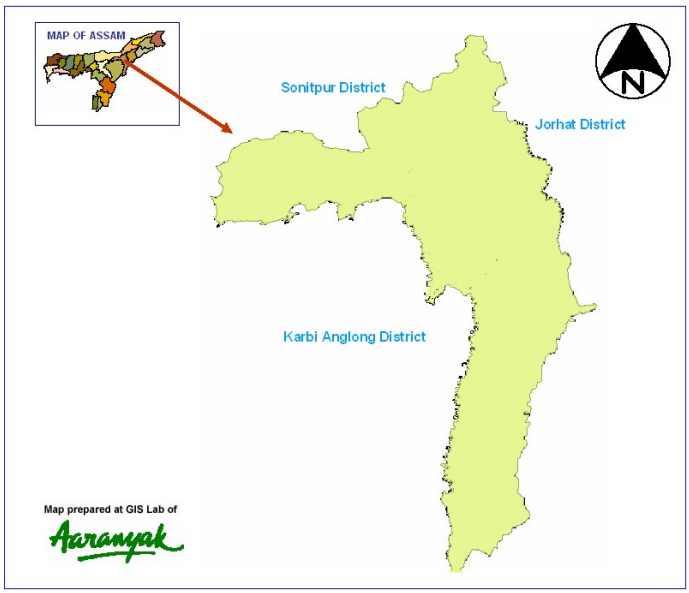
The state of Assam is known as the key conservation region of Asian elephant (Stracy, 1963; Gee, 1964; LahiriChoudhury, 1980; Santiapillai & Jackson, 1990; Choudhury, 1991, 1997 and 1999; Bist, 2002) with the elephant population of about 5200 as assessed in the year 2005. It had never occurred to Assamese people that few stray incidents of wild elephant menace in the past would assume the proportion of a severe conflict at present. The current state of human elephant conflict in Assam has been described by Talukdar and Barman (2003 and 2004) with some short and long term suggested solution. However in spite of the efforts initiated by various conservation agencies, both government and non-government, wild elephants have become a regular cause of concern, damaging standing crops, raiding villages for food, damaging houses and sometimes even taking human lives. The forests of Golaghat district and bordering Karbi Anglong District of Assam have been playing a major role in the conservation of elephants in the Kaziranga-Karbi Anglong Landscape where in a population of about 1940 wild elephant inhabits. Keeping the growing menace of human elephant conflict in view and the long term need of the remaining key elephant habitat protected from further alteration, this intense study was carried out in Golaghat and

adjoining Karbi Anglong district of Assam during October 2005 to September 2006 to find out workable strategies to mitigate the future human elephant conflict through multi dimensional and participatory approach. The strong community linkage has been encouraged in our work to increase level of confidence among villagers for living in harmony with elephants by building their capacity to reduce the conflict and diversify their livelihood opportunities.

Study Area:
The Nambor forests of Golaghat and Karbi-Anglong is one of the oldest elephant habitat that was declared as Reserve Forest in the year 1872. The Nambor forest lies within the two districts and is very famous for its number of hot water spring viz., Garampani (hot water spring), Borpung hot water spring and Fatasil water fall. The forests in Golaghat and adjacent Karbi Anglong Districts makes a key landscape for elephant conservation that is represented by 7 Reserve Forests (RF) in Golaghat districts viz. Diphu, Rengma, Doyang, Nambor North, Nambor South, Upper Doigrung, and Lower Doigrung covering 103792 hectares of land. The forest areas that are represented by adjacent Karbi Anglong district are - Kaliani RF, Nambor South RF, Borpung and Tarapung (both unclassified forest).

The forest areas of Golaghat and Karbi Anglong districts are also symbolized by Nambor-Doigrung Wildlife Sanctuary (97.15 km^2), Garampani Wildlife Sanctuary (6 km^2), Nambor Wildlife Sanctuary (37 km^2) besides reserved forests which falls within the geographical limits of 25°50'48'' to 26°58'35''N and 93°19'11'' to 94°14'24''E (***Fig-1***). These Wildlife Sanctuaries are also a part of Kaziranga-Karbi Anglong Elephant Reserve declared on 17-04-2003 with an area 3270 sq km.

Fig. 1: Map of Golaghat District, Assam



Purpose of the work:

- To explore the current status of the Asian elephant which include approximate numbers, movement, distribution and major threat in Golaghat and adjoining areas of Karbi Anglong districts.
- To identify and map the natural existing elephant corridors and threats.
- To motivate and demonstrate affected villagers to change the existing crop pattern with some high yielding elephant repellent crop on experiment basis besides exploring diversified livelihood options.
- To enhance capacity building among local people and local NGOs to protect elephants and their habitats through awareness and motivation.

Methodology:

The human elephant conflict data was gathered directly from the field sites and also from forest offices of the study areas during 2005-06. Satellite images of the areas based on 1980, 1991, 1998 and 2004 were analysed along with intense ground assessment to assess the current state of forest cover and loss of elephant habitat in Golaghat district. In this study we have extensively used the remote sensing and GIS technologies for analyzing and estimating habitat loss of Asian elephant due to deforestation and encroachment in the moist deciduous and semi evergreen forest of Golaghat district of Assam.

Results and Discussion:

The world famous Kaziranga National Park lies in Golaghat and Karbi Anglong districts and Reserve Forests like Upper Doigrung, Lower Doigrung, Kaliani serves as an alternative home for animals of the Kaziranga National Park during flood, as these Reserve Forests are adjacent to Kaziranga and act as back-up support forest in the event of high flood and key corridor linking the elephants to other habitats of the entire landscape. The forests in Golaghat district have been playing a crucial role in maintaining the seasonal requirements of elephants in the Kaziranga-Karbi-Anglong-Intanki Landscape. Due to increased in human population, this landscape has been facing severe biotic interference and as such the human-elephant conflict has been found increasing in the area within Golaghat district and adjoining areas of Karbi-Anglong. The human induced activities including encroachment and thoughtless destruction of forests has made the contiguous forests fragmented worsening further the already tenuous interface system.

The current problem of elephant depredation was not so severe a few years back when there was plenty of food and safety of the forest cover for the elephants within the forests. But unfortunately the status of these forests with regards to forest cover and food availability has deteriorated. Elephants migrate seasonally by nature and follow a definite route while moving from one place to another in search of food. These routes or Elephant Corridors were once free of human interference and pillaging, which is not the case now. Encroachment and increased anthropogenic activities within the forest areas have claimed most of the forestland. For instance, out of the seven Reserved Forests (RFs) under the Golaghat division, Doyang, Rengma, Nambor South and Diphu forests are now almost devoid of greenery. These once forested areas have now given way to settlements, cultivations, institutions, roads and other necessities of human life. In reality, out of the 103793.87 hectares of forestland under Golaghat Division only 9715.00 hectares have some trees and vegetations standing on it. The State Government had declared 9715.00 hectares as the Nambor Doigrung Wildlife Sanctuary (WLS) on 31st August 2003. In the past, apart from the RFs, large tracts of forestland in Karbi Anglong and Nagaland provided for elephant habitat. But unfortunately even these areas have gradually been stripped of their forests. The mushrooming of human settlements, small tea gardens, industries etc. on the long-established Elephant Corridors have led to the growing incidence of human-elephant conflict, putting a shadow on the age-old co-existence approach. The current state of encroachment in the Nambor Doigurung WLS and Nambor North RF has been shown in Figure-2. The current state of encroachment in forests in Goloaghat district has been summarized in Table-1.

Fig. 2: Current State of encroachment in existing forest of Nambor-Doigurung forests

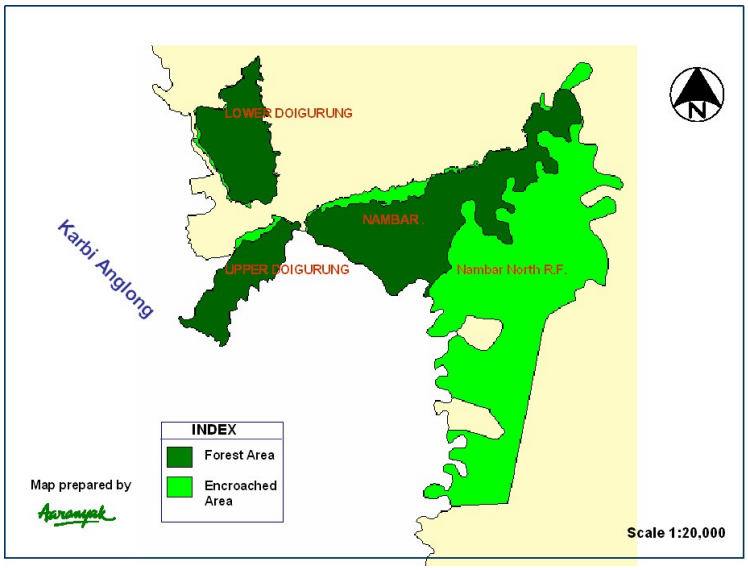


Table 1: Current state of encroachment in forest areas of Golaghat District

Name of the Reserve Forest	Original Forest area (in hectare)	Deforested area (in hectare)
1. Diphu	18,363	18,050
2. Rengma	13,921	11,050
3. Doyang	24,636	23,000
4. Nambor North	15,410	8,000
5. Nambor South	27,240	25,000
6. Upper and Lower Doigurung	4,223	1,900

In recent years, development activity like establishment of Numalighar Refinery in Telgaram area, widening of the National Highway and growing tea estates and encroachments has lead fragmentation of habitats as well as obstruction in traditional corridors. Besides extraction of stones from forests of Behora, Mikirchang, Bogidola and Lakowa area The present status of elephants in Golaghat is in complete contrast to its past. From the population of more than 500 (excluding Kaziranga National Park) in 1973 its current population has declined to only 160-190. The current elephant population has decreased due to loss of habitat and poaching.

Loss of Human and Elephant due to conflict:
Human death and injury at the hands of raiding, disturbed is another aspect of the human elephant conflict in the project site. The loss of human and elephant life due to animosity in Golaghat District since 1995 has been summarized in Table-2.

Table 2: Death of elephant and human in Golaghat district, Assam

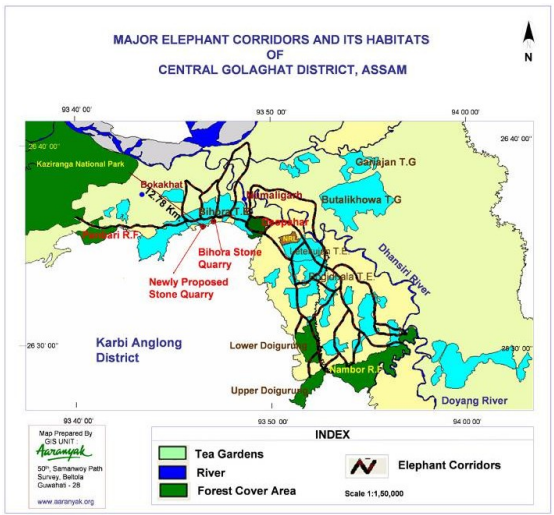
Year	Death of Elephant	Death of persons
1995	5	7
1996	5	11
1997	5	7
1998	4	7
1999	1	10
2000	4	11
2001	2	3
2002	4	2
2003	3	1
2004	9	7
2005	3	10
2006 (Till August)	4	3
Total	49	79

Movement of Elephant Herds in Golaghat District:
During the study period, we could identify at least two distinct herds in Golaghat district. One herd normally resides within the Nambor-Doigrung Wildlife Sanctuary, Garampani Wildlife Sanctuary, Bijuli reserve forest and its surroundings. This herd is consisting of nearly 50-55 elephants of which 20-27 are adult, 15-20 are sub-adult, 10-14 are juvenile and 3-7 are calf.

Another herd can be seen at the Numaligarh, Deopahar, Bihora, Lateku, Bokial, and Bogidola area. This herd comprises of 70-80 elephants in which nearly 40-45 are adults, 15-25 are sub- adults, 10-15 are juvenile and 6-10 are calf.

The movement of elephant in central Golaghat district of Assam has been mapped intensively during the study and the GPS points were plotted in GIS based map (Fig-3).

Fig. 3: Elephant corridors in central Golaghat District, Assam.



Diversified Livelihood Support:
Keeping the damages caused by wild elephants in view, experimental support was provided to form Self Help Groups (SHG) in some elephant depredated villages of Golaghat District. During the study period, three SHGs were formed for propagation of patchouli – a herb act as elephant deterrent and have encouraging market values involving 42 males from 42 affected families. Further Seven SHGs were formed on traditional handloom and textile involving about 81 females from as many affected families. This initiative has opened the path of greater community participation in mitigating human elephant conflict as the affected villagers got some options to compensate the loss suffered due to elephant depredation in crop fields. Although the SHGs formed are quite new and lacks professional approach, but continued guidance from the project team and other developmental institutions would further enhance the capacity of the formed SHGs and that would in turn encourage the other affected villagers to replicate the efforts with required modification in their respective areas.

Causes of Elephant Depredation
1. Rapid degeneration of elephant habitat.
2. Fragmentation of elephant habitat.
3. Encroachment and deforestation in elephant corridors.
4. Dearth of food for elephants in forests.

Measures to be Adopted for Reducing Elephant Depredation and Mitigating Human Elephant Conflict
6. Identification and Mapping of elephant corridors.
7. Providing for adequate protection of elephant corridors and planting trees in them.
8. Evicting encroachers and settlers from the elephant corridors with the help of District Administration and Police.
9. Planting food trees in elephant habitats and elephant corridors.
10. Cleaning up and excavating existing water bodies in forests to provide for essential water source.
11. Generating environmental awareness among the masses.
12. Prompt dispersal of adequate compensation to the affected people.
13. Grouping of Anti-Depredation Force in elephant menaced areas and arrange for their proper training. These groups also need to be regularly provided with the essential supply.

As mentioned earlier it is not solely upon the Forest Department to deal with the problem of human-elephant conflict but rather calls for a unified approach of all governmental, non-governmental agencies and departments.

Roles Identified for Different Groups of Stakeholders

Civil Administration
1. To provide vehicle and fuel for patrolling.
2. To arrange for regular supply of Kerosene Oil at subsidized rates in affected areas.

Police
1. Provide assistance to Forest Department staff as and when required.
2. Putting together a Task Force for the purpose.

District Rural Development Agency (DRDA)
1. Implement a few plantation schemes in the forests and elephant corridors around the affected villages and involve the community in it.
2. Implement schemes to provide immediate assistance for repairing and reconstructing legally established houses damaged by wild elephants.

Agriculture Department
Implement crop insurance schemes to cover for crop damages caused by wild elephants.

District Council and Village Panchayat
1. Village Panchayats to constitute Anti-Depredation Groups in affected villages and arrange for payment of wages to Group members.
2. Arrange for regular supply of Kerosene Oil, torchlights and crackers to the Anti-Depredation Groups, to enable them to discharge their duties efficiently.

Numaligarh Refinery Limited (NRL)
It is noteworthy that NRL has infringed into an area that was once the habitat of wild elephants. There are reasons to believe that the occupation of space and the disturbance created by the Refinery have caused elephants to move out into neighbouring villages and generate havoc. Therefore the Refinery authorities do have a responsibility towards mitigating this conflict and in this regard can do the following-
1. Provide for at least two vehicle and fuel at the Numaligarh and Bokiyal Forest beat office for patrolling purposes.
2. Arrange for payment of wages to at least 10 labourers at the above-mentioned Beats.
3. Provide for at least 10 wireless sets for ready transmission of information on elephant movement from the field to the Control Room.
4. Arrange for regular supply of Kerosene Oil, torchlights, crackers, searchlights etc to the Anti-Depredation Groups.
5. Arrange for engagement and payment of '*Kunkis*' (Domesticated Elephants) as and when required.
6. Provide for free medical aid at the Refinery Hospital to individuals injured by wild elephants.

Forest Department
1. Divisional Forest Officers (DFOs) to conduct programmes wherein the general public, Government and Non Government Organizations get together to discuss conflict mitigation measures.
2. Conduct programmes for awareness generation of the masses.
3. Forest Officials and staff to realize the gravity of the situation and carry out their responsibility with assistance from the public.
4. Set up a complaint cell and register all complaints related to elephant depredation on legally occupied lands.
5. Provide immediate ex-gratia to people in case of damages caused by wild elephants.

Non-Governmental Organizations (NGOs)
1. Organize environmental awareness generation camps in forest fringe areas.
2. Act as mediators between the aggrieved villagers and the Forest Department and make amends to develop a harmonious working relationship between the two parties.
3. Bring in projects and schemes for providing succor to the inhabitants of elephant ravaged areas.

It is only if all the stakeholders work collectively that tangible results can be achieved. Scattered efforts in small pockets will not do much to improve the situation. The general public on their part needs to extend their full support to such collective initiatives and be an active part of this entire working group.

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Molecular tool for genetic management and parentage test to control poaching in Asian elephants

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Abstract:
Numbers of the Asian elephants (*Elephas maximus*) population are declining due to poaching, human-elephant conflicts, capture of wild baby elephants for tourism and habitat destruction, which also may cause inbreeding in fragmented populations. In order to contribute to a reversal of this trend, we have developed molecular tools for parentage tests and genetic management of the elephant populations. Forty-three microsatellite loci generated from Asian and African elephant were tested on a panel of 19 Asian elephants. These yielded 26 polymorphic markers, 21 of which appear to be informative for an analysis of the molecular diversity. Twelve of the most polymorphic markers are proposed for a standard parentage test

Key words: Asian elephant, parentage test, genetic diversity test, microsatellite

Introduction:
The population size of Asian elephants (*Elephas maximus*) declines at an alarming rate. This is caused by habitat destruction, poaching for ivory and human-elephant conflicts (Sukumar, 2003). There was a report of the isolation of elephant small populations in habitat fragments in South and South-East Asia (Leimgruber et al., 2003) may very well lead to inbreeding and loss of genetic diversity (Amos and Harwood, 1998). In the past, wild elephants were captured to sustain a large domestic population. However, both the wild populations and the captive populations decrease now in size. Although is has been banned in 1995, capture of wild animals has continued (Lair, 1997), the captured calves being exported.

More recently, calves are also in great demand in Thailand as tourist attractions and for entertainment (Shepherd, 2002). This has caused prices for young animals to surpass that paid for an adult. Lair (1997) reported that each year approximately 50 calves, all approximately two years in age, enter Thailand from Myanmar and are sold at the border. While formerly both adults and young were captured, cow elephant may now be killed in order to capture the calf. In addition, the use of pitfall traps has increased the risk of injury to the animal. Another major threat to the survival of the Asian Elephant is the poaching for their ivory, skin, meat, and other various parts that are used in traditional medicines. Habitat fragmentation has also sharpened the human-elephant conflicts, which is apparent from the increased incidence of traffic accidents involving elephants.

Modern DNA technology now provides tools for the genetic management of endangered species. A most essential first step is the establishment of a standardized identification and parentage test in order to trace the origin of individual animals and to provide proof of illegal capture and poaching. Microsatellites have been widely used for population-genetic studies, linkage mapping, paternity test, forensic analysis (Ellegren, 2004) and as a tool for breeding strategies in various endangered species such as the black footed ferret (Wisely et al., 2002), Siamese crocodile (Fitzsimmons et al., 2002), Californian sea lion

(Acevedo-Whitehouse et al., 2003), Baird's tapir (Norton and Ashley, 2004), Korean goral (Kim et al. 2004), African elephants (Nyakaana and Arctander, 1998; Archie et al., 2003; Comstock et al., 2000; 2002; Eggert et al., 2000; 2002) and Asian elephant (Fernando et al., 2001; 2003a; 2003b). Several microsatellites have been developed from the African elephant (Nyakaana and Arctander, 1998; Comstock et al., 2000; Eggert et al., 2000. 2002). However, because of the divergence of African and Asian elephants about 5 million years, not all PCR primers developed for the African elephants will be useful in Asian elephants.

In this study, we tested 43 microsatellite markers developed for Asian (Fernando et al., 2001) and African (Nyakaana and Arctander, 1998; Eggert et al., 2000; Comstock et al., 2000; 2002; Archie et al., 2003) elephants, and selected the most polymorphic and best quality yielding markers to propose as standard laboratory tool for genetic management of Asian elephants.

Material and Methods:

DNA isolation from blood samples
Nineteen Asian (9 originated from Thailand, 2 from Myanmar, 3 from India, 1 from Vietnam and 4 with no regarding origin information) and 5 African (originated from Zimbabwe) elephant blood samples were extracted for DNA by using QIAamp DNA Blood Mini Kit (Gentra) for blood spots, the salt extraction method (Miller et al., 1988) for whole blood and the High Pure PCR Template Preparation Kit (Roche) for the frozen-thawed liver tissue preserved in DMSO buffered saline. Four mother-daughter pairs were included in the analysis.

Microsatellite loci amplification and genotyping
The elephant DNA samples were analyzed by 43 microsatellite markers (Nyakaana and Arctander, 1998; Eggert et al., 2000; Comstock et al., 2000; 2002; Fernando et al. 2001; Archie et al., 2003). PCR was carried out in 25 µL reaction volumes containing 50 ng DNA, 50 mM $MgCl_2$, 5 mM of each dNTP, 5 pmol of each primer and 2.5 units of Platinum Taq DNA polymerase (Invitrogen) and a thermal profile of 95°C for 10 min, followed by 35 cycles of 95°C for 30 s, annealing for 30 s at the various annealing temperature and 72°C for 30s. Only for LaT08 and LaT13, the thermal profile use touch-down PCR protocol with the first annealing 66°C, decreasing by 1°C per cycle for 10 cycles and followed by 30 cycles of annealing at 56°C annealing. All thermal profiles ended with a single extension of 72°C for 5 min. PCR products were separated on a 2% agarose gel, extracted from the gel (QIAquick gel extraction kit, Qiagen) and sequenced from both sides by cycle sequencing (BigDye, Applied Biosystems) and automatic gel electrophoresis (ABI Prism 3100). DNA sequences were analyzed by using LaserGene biocomputing software package

For the markers that could be amplified in Asian elephants, the annealing temperatures were adapted to 5' M13 extension of the forward primers (5'-GTT TTC CCA GTC ACG AC-forward primer) and the use of M13 primers labeled with a FAM fluorescent group. PCR products were run on ABI Prism 3100 machine together with TAMRA 500 (ABI) size standard. Results were analyzed by using GENESCAN (ABI) software version 3.7. Allele frequency, number of alleles per locus, allele size range, observed (H_o) and expected (H_e) heterozygosity from Hardy-Weinberg equilibrium were calculated with the Excel Microsatellite Toolkit (S.D. Park, Trinity College, Dubline) and the program GenePop (http://wbiomed.curtin.edu.au/genepop)

Results :
Testing the amplification directed by microsatellite primer pairs yielded PCR products for 33 markers. Marker EMX4, FH1, FH67, FH71, FH126, LA6, LaT05, LaT07, LaT17 and LaT18 did not yield any amplification product at any of the annealing temperatures tested. The sequences of the PCR products agreed to previous data (Nyakaana and Arctander, 1998; Eggert et al., 2000; Comstock et al., 2000; 2002; Fernando et al., 2001; Archie et al., 2003). Comparison of flanking sequences of Asian and African elephant, respectively, revealed a 91.2 % sequence similarity. Sequence of LafMS05 was different from a previous report (Nyakaana and Archtander, 1998), but contained a similar imperfect $(GA)_n$ tandem repeat.

In a panel of 19 Asian elephants, 26 of the 33 markers gave unambiguous polymorphic patterns. Markers EMX2, LaT24 and LaT26 failed to amplify with the M13 tail and the fluorescently labeled M13 primer, FH39 and FH129 were monomorphic, while LaT16, LaT25 and LafMS01 yielded more than 2 peaks or too many stutter peaks. With the presently available panel of animals we found a mean expected heterozygosity of 0.53 and an average of 5.1 alleles per marker.

For parentage test, we selected 12 of the most polymorphic markers (at least three alleles) with robust PCR and unambiguous patterns, EMX1, EMX3, EMX5, FH60, FH94, FH102, FH153, LA2, LafMS02, LafMS03, LafMS05 and LaT06. Testing of 4 parent-offspring pairs confirmed Mendelian inheritance of these markers. Moreover, these 12 markers may be combined with more 9 markers, FH19, FH48, FH65, FH103, FH127, LA3, LA4, LaT08 and LaT13 for a systematic study of genetic diversity within and among different elephant populations.

Discussion:
In this study, we have tested the practical use of published microsatellite markers, most of which were selected for the African elephants, for parentage and genetic diversity analysis of Asian elephants. In agreement with previous works (Nyakaana and Archtander, 1998; Eggert et al., 2000; Comstock et al., 2000; 2002), cross-species amplification was observed for most of the primer pairs. We found more than half of the tested markers yielded polymorphic and unambiguous patterns. We adjusted the various annealing temperature for the 5' M13 extension of the forward primers to one of three 3 temperatures (50, 57 and 60^{o}C) in order to allow a combination or multiplexing of PCR reactions.

Microsatellite repeat regions selected in one species are often shorter in related species (Ellegren et al., 1995; Kim et al., 2004). However, the Asian homologues of LaT08, LaT16, LaT24, LaT25 and LaT26 are longer than in the African elephant.

We propose our panel of 12 markers as standard tool in order to control illegal poaching by allowing a comparison of the genotypes of infant and alleged domestic parents. Eleven to twelve markers like used in commercial standard panels of microsatellites for domestic animal provide an adequate exclusion probability (Mommens et al., 1998). Furthermore, the larger panel of 21 markers can be used as molecular tool for the control of ivory poaching. Comstock et al. (2002) reported that allele frequencies in African elephants depend on the region and are informative for traceability of illicit ivory. This application would be even more relevant for the ivory poaching in Asia, where the demand is higher than in Africa (Menon, 2002).

Our results may also lay the foundation for studying patterns of genetic diversity for the detection of inbreeding, migration and genetic relationships between populations. An essential contribution of microsatellite genotyping to relevant insights in genetic diversity or breeding programs has already be demonstrated for other endangered species such as North American wolf-like canids (Roy et al., 1994), whooping crane (Jones et al., 2002), black footed ferret (Wisely et al., 2002) and Baird's tapir (Norton and Ashley, 2004). We intend to perform a strategy for genetic management of the Asian elephant by monitoring and maintaining genetic diversity. For instance, inbreeding can be reversed by avoiding the mating of close relatives, translocation of breeding bulls from other regions or international sperm transport for artificial insemination (Schmitt and Hildebrandt, 1998; Kitiyanant et al., 2000; Pukazhenthi and Wildt, 2004; Thongtip et al., 2004; Saragusty et al., 2005). This assisted reproductive technique has been recently successfully applied in this species (Brown et al., 2005). The genetic information from wild elephants can also serve as reference for genetic management of captive elephants in many captive elephant facilities and zoos.

Acknowledgements:
We would like to thank you for Dr. S. Mahasawankul, National Elephant Institute, Thailand, Dr. W. Schaftenaar, Rotterdam zoo, Dr. M. Hoyer, Amsterdam zoo, Dr. A. Klarenbeek, Emmen zoo, Dr. J. Kaandorp, Beekse Bergen safari park, Dr. B. Martina, Erasmus University, The Netherlands for providing blood and DNA samples. Ms. L. van Cann and Dr. I.J. Nijman, Utrecht university, The Netherlands for

technical assistance. This work is supported by the Center for Agricultural Biotechnology, Kasetsart University and the Royal Thai government scholarship

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Potential factors affecting Asian elephant semen quality in Thailand

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One of the major obstacles in using artificial insemination to managing genetic of elephant population is large variations in semen quality among ejaculates within the same bulls and among individuals (Thongtip *et al*., 2004). The objective of this study was to determine the influences of (1) zinc (a marker for prostate gland functions), testosterone and total protein in the seminal plasma (2) thyroid hormone and (3) seasonality on semen quality. Semen collections were performed twice monthly by manual rectal stimulation in 13 male elephants (one ejaculate/male) at the Thai Elephant Conservation Center, FIO from July 2004 to June 2005. Ejaculates were evaluated for volume, pH, % progressive motility, sperm concentration and % viable sperm. Blood samples were obtained monthly and serum samples were separated and assessed for Triiodothyronine (T3), Tetraiodothyronine (T4) and testosterone using chemiluminescence assay (CMIA). Seminal plasma were obtained by centrifuging semen samples obtained from individual bull at 2500 rpm for 10 min and evaluated for zinc, total protein and testosterone levels using atomic absorption, spectrophotometry and CMIA, respectively. Means $\pm$ standard deviation (SD) of volume, progressive motility, concentration/ml, pH and viable sperm, were 24.9 $\pm$ 21.5 ml, 24.4 $\pm$ 25.6%, 1.5 $\pm$ 1.1 x 10^7 sperms/ml, 7.8 $\pm$ 1.1, and 33.8 $\pm$ 27.8%, respectively. Means $\pm$ SD for T3, T4, and serum testosterone, as well as zinc, total protein and testosterone in the seminal plasma were 177.3 $\pm$ 57.6 ng/dl, 10.3 $\pm$ 1.8 ug/dl, 16.5 $\pm$ 33.9 ng/ml, 61.1 $\pm$ 25.5 mg/L, 1.1 $\pm$ 3.8 mg/dl, 51.0 $\pm$ 38.1 ng/ml, respectively. Correlation analysis revealed that progressive motility was correlated to T3 (r^2 = 0.193), volume (r^2 = 0.218), pH (r^2 = - 0.294) and % live sperm (r^2 = 0.329). pH was correlated to serum testosterone (r^2 = -0.296) and Zinc (r^2 = -0.361). Sperm concentration was correlated to pH (r^2 = - 0.358). In all bulls, seasonality significantly influenced serum testosterone and T4 and % viable sperm ($p<0.05$). Majority of elephants showed lowest viable sperm and serum testosterone in summer. Results obtained in this study indicate that seasonality influences gonadal and thyroid hormones, which in turn affects seminal quality of the Asian elephant in Thailand.

Key words: Semen, Asian elephant, seasonality

Elephant management in southern Africa: Dealing with causes, not symptoms

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The management of Africa's elephants is complex. This is especially the case across southern Africa where populations have increased notably since 1994. High elephant numbers have been blamed for degrading vegetation and habitat to the harm of other species. However, high numbers may often be induced by water supplementation, the erection of fences that limit dispersal, and the reduction and fragmentation of landscapes that provide for seasonal movements of elephants. Given present conservation paradigms these approaches to promote conservation seem dated and need to be reconsidered.

Past management practices focussed on dealing with numbers in an effort to reduce the impact that elephants may have on vegetation and habitat. Impact in general seems poorly defined and is often based on pre-conceived ideas that rely on the now dated asymptotic paradigm. Practices to manage elephants within this framework include culling and translocation, and have been extended more recently to include the potential application of contraception. All of these methods centre on reducing local populations through increased mortality or reduced fecundity – they clearly ignore the forces that gave rise to increasing numbers in the first place. In reality these approaches focus on the symptoms of management actions that enhanced population size by reducing dispersal and increasing survival and fecundity. Consequently, they may be considered symptomatic.

On the other hand, management that aims to recover the forces that underlie dispersal and seasonal movements, and that will enable populations to be driven by natural events is systemic. The systemic approach emphasises the population as a spatial entity and has the benefit of modulating impact through spatial and temporal shifts in land use. It relies on restoring spatial utilisation associated with season and the distribution of water, allows habitat selection to act as a key determinant of habitat occupation and nurtures sub-populations with distinct dynamics as discrete entities within a metapopulation. It permits for dispersal between sub-populations and favours the uneven occupation of habitat patches across the landscape.

The present discontinuous distribution of elephants across southern Africa, where most elephants live in differing numbers in discrete conservation clusters, is attractive for the systemic approach to management. Furthermore, a 'source-sink" model as a special case of the dynamics of a metapopulation, may add to the conservation sense of the systemic approach. In this model sources can be maintained through birth rates that exceed death rates, while sinks are sustained when immigration exceeds death rates, which in itself exceeds birth rates.

This scenario allows for the integration of economic development with conservation management by incorporating communal and private land into the source-sink model. It also calls for the heterogeneity of living conditions for elephants and for the development and maintenance of dispersal linkages within and between existing conservation areas. The harvesting of elephants in sinks may then maintain these populations with immediate economic benefits to people co-inhabiting these areas – sinks will continue to depend on "spill-overs" from source population.

The benefit for the source population is obvious since dispersal relaxes density related habitat degradation. In this model managers of source areas should focus on promoting linkages between their areas and sinks by removing fencing and unnatural water supplies. Source areas benefit through reduced expenditure and a moderation of impact, as the recovery of seasonal and long-term space utilisation patterns provide

vegetation and habitats the opportunity to recover. This systemic approach therefore addresses the most pressing concerns for managers of parks and regions.

The development of systemic conservation management further provides for reducing human-elephant conflict, as the inclusion of communal land into a conservation model could refocus people's attitudes towards the benefits of conservation-based resource extraction. What do these ideas mean in more practical terms? To address this we first have to evaluate the applicability of the systemic approach to present conservation development paradigms in southern Africa.

First, a management plan needs to be formalised that is acceptable to all stakeholders. Ideally this may include formalising linkages between existing conservation areas, the removal of artificial water sources, the identification of source and sink populations, the legitimization of sink zones and the development of capacity to maintain and continually refine the systemic management approach. In practical terms this calls for the acceptance of the megapark metaphor to maintain metapopulations. Its application goes beyond elephant management and is especially attractive for species that are unnaturally rare and where metapopulation dynamics are applied as an insurance policy to overcome the limitations imposed by earlier isolation. This is especially true for large carnivores and a variety of over-exploited plant species.

The application of the systemic approach in the development of a management policy for elephants as a whole has the benefit of providing a firm framework on which to integrate several theoretical and practical paradigms. More importantly it incorporates aspirations for economic development in a region where the livelihoods of millions of people are affected by the continued extraction of natural resources. To us this approach makes sense. At the same time, we are fully aware that many of the ideas proposed here need considerable development. Using the elephant as a flagship for such development seems sensible, especially in a part of the world where the elephant serves as an ambassador for conservation successes and failures.

Population demography and viability of Asian elephants in timber camps of Tamil Nadu, southern India

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Detailed demographic analysis on population size, structure, inter-calving interval, age specific mortality and fecundity of elephants kept for the past 10 years (from 1996-2005) in the timber camps of Tamil Nadu, were undertaken to understand the long term viability of this population with the current demographic parameters. There are 50 elephants kept under this captive regime at present, out of which about 70% are adults indicating an aged population. Males (66%) outweighed the females (34%) with a skewed male to female sex ratio of 1 : 0.5. Most of the female segment (26%) was adults (mostly > 40 years) with a very small portion of sub adults and juveniles (8%), which does not show a promise of revival even in the future. The fecundity rate (0.065) of females is considerably lower compared to the earlier report for the same population (0.155). A population projection model developed based on the current demographic values predicted that this population could not be a potentially stationary or increasing population without input from the wild. The population showed a negative growth rate, with the number of individuals poised to decrease to less than 10 individuals in about 100 years with the current demographic parameters. The unequal age structure and sex ratio could be largely attributed to selective disposal of juvenile and sub-adult females to temples from the forest camps in the past. The absence of captive born females in breeding condition, except the one last bred in 1943 in a 100 year old timber camp, supports the above reason. To ameliorate the population structure and sex ratio, and to retain the long history of timber camp elephants, inputs from the wild, especially females of adult and sub-adult classes should be given priority. Capturing and transferring of problem elephants especially herds ranging in isolated habitats to timber camps could be considered as a solution to restructure the captives as well as reduce human-elephant conflicts in the natural habitats.

Social organization of the Asian elephant (*Elephas maximus*) in southern India as inferred from microsatellite DNA

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Extended abstract:
Social organization of the endangered Asian elephant (*Elephas maximus*) is not well understood in the absence of long-term studies of identified individuals. In the African savannah elephant, a multi-tiered social organization exists among females (Wittemyer *et al*. 2005), comprising mother-offspring units, family groups, kinship or bond groups, and clans, in increasing order of complexity (Douglas-Hamilton 1972, Moss and Poole 1983). Unlike females, pubertal males leave their natal group and are thereafter largely solitary, only temporarily associating with female groups or other males (Poole and Moss 1981). Studies of the Asian elephant had confirmed that the basic social unit in this species also is the mother-offspring unit (McKay 1973, Sukumar 1989). Associations between two or more mother-offspring units were described as "family groups" (Fernando and Lande 2000) in southeastern Sri Lanka, and as "family groups", "joint family groups" and "clans" (larger associations of family groups) in southern India (Sukumar 1989, 1994, Baskaran *et al*. 1995). However, terminology apart, in the absence of any long-term study of identified individuals, it was not known if adult females of such groups were genetically related to one another or not. Genetic relatedness holds important implications for understanding the nature of social organization as a high degree of relatedness makes inclusive fitness benefits (Hamilton 1964) possible through improved survival of offspring. With regard to male social behaviour, while it was known that pubertal Asian elephant males disperse from their natal groups (Sukumar 1989, Desai and Johnsingh 1995), it was unclear whether they move away from their natal range (locational dispersal) (Desai and Johnsingh 1995) (locational dispersal) or remain in their natal range and move long distances only to mate (social dispersal). While locational dispersal is expected to bring about an absence of relatedness between adult females and adult males within locations, social dispersal is expected to result in adult females and adult males within locations being related to some degree.

We thus tested the following two hypotheses: 1. that adult female elephants within a group are random associations of adult females in the region (relatedness is zero), and 2. that male elephants disperse in a random fashion from their natal home range (that is, show random locational dispersal), resulting in no relatedness between adult males and adult females in a location as well as between adult males within a location. Rejection of the first hypothesis would imply that social groups of elephants are composed of related individuals, while rejection of the second hypothesis would indicate that either male elephants largely remain in their natal home range and show social dispersal outside for mating (when in musth) or alternatively that related males from a social group disperse to the same location (biased locational dispersal).

The study was carried out in the Nilgiris – Eastern Ghats region of southern India, which harbours the world's single largest contiguous population of Asian elephants. The focus of the study was Mudumalai Wildlife Sanctuary, situated centrally in the Nilgiri region, but samples were also collected from six other locations (BRT Wildlife Sanctuary, Hosur Forest Division, Nagarahole National Park, Madikeri Forest Division, Satyamangalam Forest Division, and Bandipur National Park) across the Nilgiris-Eastern Ghats region. Free-ranging elephants were tracked, individuals identified, and fresh dung samples collected upon observed defecation. Samples were collected into 95% ethanol. DNA was extracted from dung using previously standardized procedures (Fernando *et al*. 2003), six nuclear microsatellite loci (Nyakaana and Arctander 1998, Fernando *et al*. 2001) were amplified (see Vidya and Sukumar 2005), and alleles at these loci were used to calculate genetic relatedness (Queller and Goodnight 1989, Goodnight and Queller 1999) between individuals. A set of samples from 20 identified mother-offspring pairs from Mudumalai Wildlife Sanctuary was employed to confirm Mendelian inheritance of the microsatellite loci used, and the average

relatedness (± 95% confidence interval) between adult females and their offspring based on this set was 0.437 ± 0.051.

This study of relatedness is the first of its kind in elephants and gave rise to the following results and inferences (Vidya and Sukumar 2005). High genetic relatedness between adult females within elephant groups (R=0.37±0.159, n=13 groups) proved that the Asian elephant social group does represent a true family group. This relatedness was not different from that between known mother-offspring pairs, suggesting that most adult females were closely related as mother-daughters or full sisters, with the lower end of the relatedness spectrum probably corresponding to half-sisters. The average relatedness between adult females across groups but within locations was greater than zero (R=0.04±0.038, total $n_{adult\ females}$=98, 7 locations), indicating female philopatry, while the relatedness between adult females across groups and across locations was not different from zero. Adult females were not related to adult males within locations (R not different from zero, $n_{adult\ females}$=88, $n_{adult\ males}$=36), suggesting locational male dispersal. Surprisingly, adult males within locations were closely related to one another (R=0.20±0.102, n=36, 6 locations), implying biased dispersal of related males, which has not been previously reported in elephants.

Based on our results, we suggest a more detailed study involving associations of family groups and the relatedness between them in order to understand further hierarchical levels of female social organization that may exist in the Asian elephant. While our result of high genetic relatedness between adult males within locations is surprising, it corroborates our field observation of unusual tolerance between adult males in musth. However, this part of the study is still preliminary and a more detailed study of behaviour and relatedness, sampling in particular sub-adult males, which would be in the dispersing stage, is indicated for a better understanding of male dispersal in this species.

Acknowledgments:
Field work was funded by the Ministry of Environment and Forests, Government of India and samples were collected with research permissions from the state forest departments of Tamil Nadu and Karnataka. The molecular work was supported by a United States Fish and Wildlife Service - Asian Elephant Conservation Fund (USFWS-AECF) grant to Prithiviraj Fernando and Don Melnick, and the Columbia University Laboratory for Genetic Investigation and Conservation (LOGIC). We thank Prof. Don Melnick and Dr. Prithiviraj Fernando of Columbia University for their support and help. Dr. Uma Ramakrishnan collected the set of mother-offspring samples we used to test for Mendelian inheritance of microsatellite loci. Mr. K. Krishna, Mr. R. Mohan, and several forest department trackers provided field assistance.

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How do elephants deal with various climate conditions? Previous results, recent data and new hypotheses

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The physiological features of elephants, such as great mass, low surface/volume ratio, and nearly hairless condition, confer unusual problems related to heat balance and integument dehydration. In addition, elephants must deal with the highly variable climate conditions in their natural habitat. The thermoregulation mechanisms of elephants seem to be very effective. However, we lack information on how elephants handle the conditions they encounter.
This study examines the physiological and behavioural thermoregulatory mechanisms of African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants under temperate and hot climate conditions.
The African elephant group at Vienna Zoo (n=6) and the Asian elephant group at Hellabrunn Zoo, Munich (n=5) were observed during winter 2004/2005. The main research on thermoregulation under hot and humid conditions was carried out on a group of semi-wild elephants at the Pinnawala Orphanage in Sri Lanka (n=26) in February 2006. Thermoregulatory mechanisms were investigated using modern Infrared-thermography (Flir Inc.). Thermo-profiles of the surfaces were drawn up at various daily situations. The heat radiation of 8 Asian elephants in their natural habitat was calculated.
Low inter-individual differences were recorded among adult elephants. In contrast, juvenile elephants showed significantly different thermoregulatory patterns, which indicates, among other things, age-specific basal metabolism.
Thermoregulatory reactions due to exposure to various climate conditions primarily involved the pinnae. Adaptations might be facilitated by highly sensitive vasoconstriction and vasodilatation of the ear vessels. The results of this study emphasize the important thermoregulatory role of the elephants´ pinnae.
High correlations between body surface temperature and air temperature were found for both elephant species. A dependency on air humidity was demonstrated only for Asian elephants. This may reflect an adaptation to their natural habitat, which is mostly humid.
The present study provides a better understanding of the thermophysiological needs and constraints of elephants and helps to develop species-appropriate zoo management and suitable conservation.

Introduction:
With respect to heat dissipation, elephants have the most unfavourable surface/volume ratio of all living land mammals. On the other hand, elephants typically inhabit hot environments and gain heat throughout the day (Phillips and Heath, 1992). Because of high prevailing air temperatures and often high humidity, the opportunities to dissipate heat are low (Morgan *et al*. 1997). Furthermore, elephants lack sweat glands or sebaceous glands, and the stratum corneum of their integument is thick, limiting their capability of evaporative heat loss (Luck and Wright, 1984). Finally, the nearly hairless condition leaves the animals unprotected against radiation and causes problems with integument dehydration (Lillywithe and Stein, 1987).
Elephants show several mechanisms that are presumably adaptations to facilitate heat loss. This includes the lack of a fur, which allows a quick transfer of excess heat from the body or the huge pinnae, which are effective thermoregulatory organs (Phillips and Heath, 1992) due to their high surface/volume ratio. Another mechanism is the prominent and extensive vascular supply. Vasodilatation in the pinnae and simultaneous ear flapping, frequently shown under warm ambient conditions, increase convective heat loss (Wright, 1984).

Other reactions facilitating heat loss are increased blood flow to thermal windows (Wright 1984; Williams 1990), and the use of shade, wind, water and dust (McKay, 1973).

The anatomy of the dermis and epidermis of elephant skin enables significant water loss by evaporative cooling. Hydration of the skin promotes heat loss and helps to maintain heat balance (Lillywithe and Stein, 1987).

On the other hand, elephants are confronted with cold climate conditions due to their natural dispersal, for example on the mountain plains in Africa or the Himalaya region in Asia, and also during nighttime in West Africa, where temperatures below 0°C are not rare (Spinage, 1994). Elephants are also exposed to low temperatures at zoological gardens and circuses, where frost nips especially on the thin earlobes have been reported (Benedict, 1936).
Langman *et al*. 2004 examined acclimatization in African elephants, but found no changes in either internal or external insulation throughout the year (but see Sikes, 1971). They showed no seasonal thermal neutral zone shifts.
Altogether, the thermoregulatory mechanisms available to elephants are very effective. However, it remains unknown how elephants sufficiently increase heat loss to withstand the enormous heat load experienced in most parts of their natural dispersal. Information about elephants´ temperature regulation in the cold is scarce and there is a lack of relevant data for adequate husbandry at zoological gardens that house elephants in the cold.
This paper deals with the requirements of the elephants´ thermoregulatory system in dependence on surrounding climate conditions and presents new data regarding the thermophysiological needs and constraints of elephants. This will help to develop species-appropriate zoo management and suitable conservation measures.

Methods:

Animals and Housing (1)
Thermographic examinations of elephants under cold and temperate climate condition have focused on the elephant group at Vienna Zoo, Schoenbrunn (Schwammer and Pechlaner, 1997). Four adult (aged between 19 and 46) and two juvenile African elephants (*Loxodonta africana*) were scanned. Furthermore, five adult Asian elephant cows (*Elephas maximus*) (aged between 12 and 46 years) at Munich Zoo Hellabrunn were thermographically studied. Additional photographs were taken from African (n=9) and Asian (n=6) elephants at the Berlin Friedrichsfelde. All elephants were kept “hands on” in a free contact system (Otten, 1994; Schwammer et al., 2002).
The elephants at European zoos were thermographically observed in their in- and outdoor enclosures at a distance of approximately 10 to 30m.

Animals and Housing (2)
For the thermoregulation study under hot environmental conditions, Asian elephants of different age, size and sex were thermographically examined at the Pinnawala Elephant Orphanage in Sri Lanka. During the study period 75 elephants were housed under semi-wild-keeping-conditions. Twenty-six individuals of both sexes (aged between 4 and 30) were examined in more detail. The elephant orphanage measures about 9.7 ha. Animals roamed freely during the day in a herd structure and were chained during nighttime. Twice a day they had a two-hour bath at the nearby river.

Data Collection and Work Procedure (1)
The main examinations at the European zoos were conducted from December 2004 to February 2005. The elephants were thermographically examined on 11 days at Vienna Zoo and on 6 days at Hellabrunn with an infrared-camera (ThermaCamTM P60®Flir) at regular intervals of 20 min in the indoor and outdoor facilities between 12:00 and 16:00. Using specific computer software (ThermaCam Researcher 2002®Flir), thermo-profiles were drawn up. “Temperature courses” were calculated for defined surface regions (head, trunk, fore leg, hind leg, torso and ear) by a linear regression analysis (Bortz, 2005) (for more details see Weissenboeck, 2006).

Data Collection and Work Procedure (2)
The IR-study of elephants under hot climate conditions took place during February 2006 in Sri Lanka. A thermographic overview of many individuals was done, whereas 26 animals were examined more closely.

The elephants were examined during different daily situations from 8:00 until 17:00. Special focus was placed on a comparison between morning and evening thermograms as well as on a detailed analysis of the thermoregulatory importance of the ears. Body surface temperature was calculated for the torso, ears and the whole body. Heat radiation under selected situations was calculated for 8 individuals (formula see Schmidt-Nielsen, 1999). The defined dimensions were measured with a yardstick and surface area was calculated using the formula of Sreekumar and Nirmalan (1990). The surface area ranged between 12.87 and 15.77m².

Recording of Additional Data

Air temperatures were registered with a minimum maximum thermometer and the humidity with a hair hygrometer. The weather conditions (wind, clouds etc.) were subjectively recorded. The ambient temperature during the measurements in Vienna ranged between 16 and 20 °C in the interior space and -6.7 to 13.3 °C in the outdoor enclosure. In Munich the inside temperature ranged from 15.4 to 19.6 °C and the outside temperature from 0.4 to 11.6 °C.
Air temperatures at the Pinnawala Orphanage were between 23 and 27.7 °C in the morning and 30.7 and 33.7 °C in the evening.

Statistical Analyses

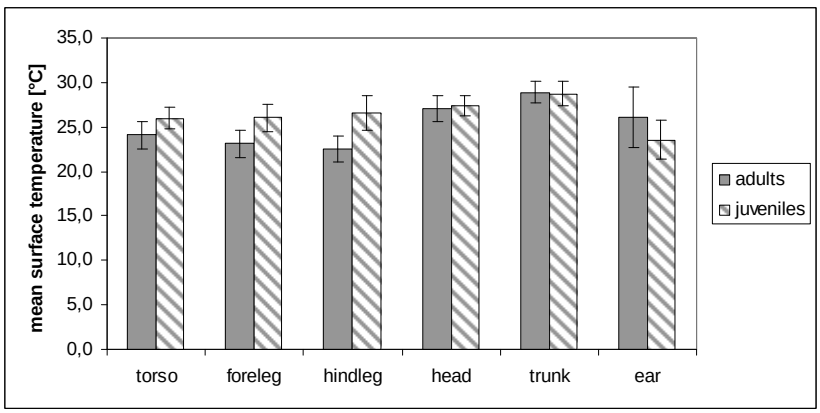
Linear regressions were performed using Sigma Plot version 9.0.
Data are represented as means ± SD. The software SPSS 11.5 for Windows was applied for statistical data processing. To record species-specific variations, a Mann-Whitney-U-test and, for larger samples, one-way ANOVA (post hoc: Scheffé-procedure) was applied. To check for differences between single body sections a Wilcoxon-test was used, whereby the respective ascent of the linear regression analysis was compared. A Spearman-Rank-test was chosen to determine correlations ($\alpha = 0.05$).

Results:

Thermoregulation of Elephants under Cold and Temperate Climate Conditions

In the indoor enclosures (air temperature: 17.7±1.9 °C) the examined adult African elephants at Vienna Zoo showed lower surface temperatures at the body regions with great mass, like the torso, the fore- and hind leg (23.0±1.6 °C). The warmest surface was the trunk (29.0±1.2 °C). The surfaces of torso, ear, fore- and hind leg of the juveniles had significantly higher temperatures (2.0 °C) than the corresponding regions of the adults (U-test, $p \leq 0.001$). The two groups had similar head and trunk temperatures (U-test, n.s.) (Fig. 1)

Fig. 1: Comparison between mean skin temperature of defined body regions of African elephants (mean air temperature: 17.7±2 °C).



Under indoor conditions (air temperature: 17.9±1.4 °C) the body surfaces of the Asian elephant group at Hellabrunn Zoo measured 28.8±2.6 °C. There were no inter-individual differences (U-test, n.s.).
The skin temperatures of body appendages (ear, trunk, tail, nose, and feet) under cold climate conditions were highly variable. The anterior surface of the ear was always the coldest body region in the outdoor enclosure. Most of the time, the tail was also cooler. On rare occasions, the surface temperatures of the feet were significantly cooler than the remaining skin. Even at very low ambient temperatures (below 0 °C) the trunk was the hottest part of the body (Fig. 2).

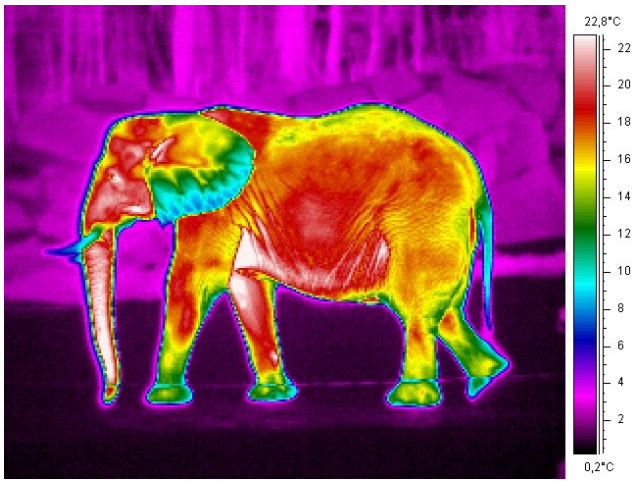
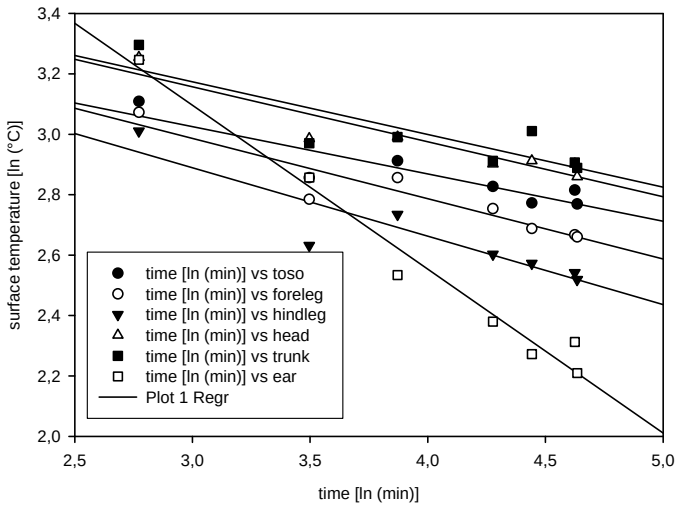


Fig. 2: Thermogram of an adult African elephant at Vienna Zoo. Air temperature: 2.7 °C; Air humidity: 69.5%. IR image taken after 51 minutes at the outdoor enclosure.

The examined African and Asian elephant groups showed no inter-individual differences in temperature loss while staying in cold ambient conditions (U-test, n.s.). In contrast, the single body regions showed significantly different cooling patterns (Wilcoxon-test, $p \leq 0.001$). The steep decline in the surface temperature of the pinnae, mostly along the ear margins, was remarkable (Fig. 3). Lowest skin temperatures (0 °C) were measured for an elephant calf after a 32-minute stay at -6.7 °C.

Fig. 3: Temperature course of defined body surfaces of an adult African elephant (air temperature: 3.0 °C; air humidity: 59.1%).



There were no inter-individual differences in surface temperature increases among adult elephants after their return into the indoor enclosure (U-test, n.s.). In contrast, both juvenile African elephants showed a slower increase while warming-up than the adults (U-test, $p \leq 0.05$). The largest differences in the warming-up of single body areas were measured between the ear surface and the remaining body regions (U-test, $p \leq 0.05$).

Correlation between Surface Temperature and Environmental Conditions

The mean surface temperatures of single body regions were highly correlated with air temperature ($0.842 \geq r_s \leq 0.917$) (Fig. 4). A correlation between surface temperature and air humidity was determined only for Asian elephants ($0.644 \geq r_s \leq 0.833$).

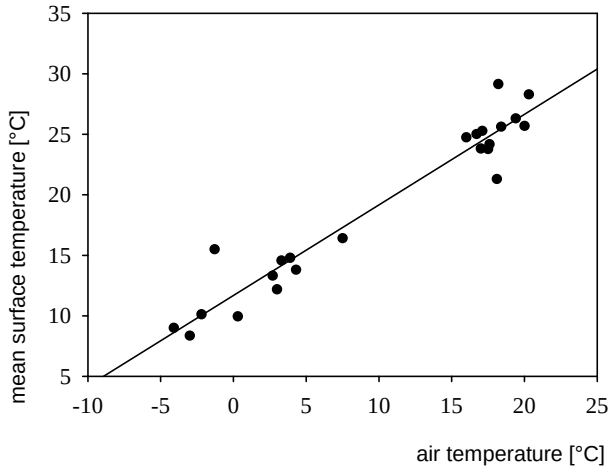


Fig. 4: Correlation between mean temperature values of the ear surfaces of African elephants and prevailing air temperatures

Thermoregulation of Asian Elephants under Hot Climate Conditions

Only minor inter-individual differences were recorded in the thermograms: there was no significant difference in skin temperature among the 26 elephants (ANOVA, Scheffé-procedure, n.s.).

In contrast, the surface temperatures recorded in the morning (air temperature: 26.1±1.4 °C) and the evening (air temperature: 31.9±1.2 °C) differed significantly, as did the skin temperature of the ears and the torsos (Wilcoxon, $p \leq 0.001$). The elephants showed a homogeneous surface temperature allocation at the evening (torso: 34.4±1.0 °C, ear: 34.2±1.1 °C). In the morning the ears (26.5±1.7 °C) were distinctly cooler than the rest of the body (torso: 28.7±1.1 °C) and a more non-uniform temperature pattern was observed Figs. 5 and 6). Especially in the ears, a definite increase in surface temperature occurred during the day: in the morning ear temperature approximated ambient temperature, during the day it exceeded it.

The heat radiation of the 8 examined elephants differed only minimally between the morning and evening (Wilcoxon-test; n.s.) and among the individuals. Only one individual (adult female; body surface 13.5m²) showed significantly different heat radiation (97±13.5W/m²) compared to the rest of the group (ANOVA, Scheffé-procedure, $p \leq 0.05$). Heat radiation of the other 7 elephants measured was typically between 221 and 303W/m².

Fig. 5

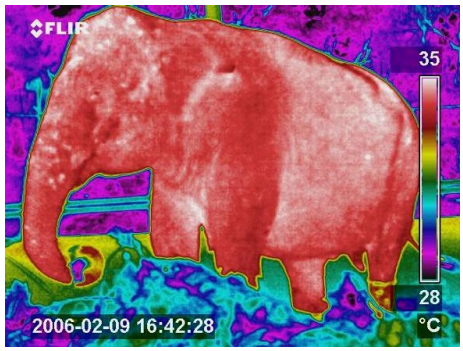


Fig. 6

Fig. 5: Morning-thermogram of an adult Asian elephant at the Pinnawala orphanage (air temperature: 26.2 °C; air humidity: 85%)

Fig. 6: Evening-thermogram of an adult Asian elephant at the Pinnawala orphanage (air temperature: 30.7 °C; air humidity: 68%).

Discussion:

IR-Thermography has been successfully applied several times in the past for surface temperature measurements of elephants (e.g. Cena and Clark, 1973; Phillips and Heath, 1992; Williams, 1990). This examination is the first comprehensive study of thermoregulative features in elephants in various climates using an IR-camera, revealing new findings about the highly sensitive thermophysiology of elephants.

The examined elephants showed physiological adjustments in cold winter days to prevent excessive heat loss. The high surface/volume ratio of the ears and the extensive vascular supply (Wright, 1984) predestines them for massive heat loss. The low ear surface temperatures we measured point to vasoconstriction – an effective mechanism to reduce heat dissipation (Phillips and Heath, 1992). Accordingly, freezing of the pinnae potentially poses a risk for elephants (Benedict, 1936). Low skin temperatures of the ear margins at air temperatures below the freezing point indicate a health hazard, especially for young elephants.

The high surface temperatures of juveniles suggest an increased heat flux in their bodies (Eckert et al., 1993); nevertheless, they "cooled down" to the same extent as adults. Physiologically, a forced heat flux causes greater heat loss under the same environmental conditions (Eckert et al., 1993). The juveniles therefore had to compensate their increased heat dissipation by enhancing their metabolism. In general, the surface temperatures of juveniles increased more slowly while warming-up than the adults. This might reflect inadequate adaptation to the environment and could indicate that young elephants reach their lower-critical-temperature earlier than adults do. They therefore need more time to warm up. The juvenile-adult differences might be due to an interplay of many factors such as different surface/volume ratios, age-specific basal metabolism (Pflumm, 1996) and a thinner subcutaneous fat layer for juveniles (as shown for humans (Klinke und Silbernagel, 2001), black rhinos (Hilsberg, 2000) and grey seals (Boily und Lavigne, 1996)).

The recorded differences in temperature behaviour between the defined body areas might be explained best by different heat conduction abilities reflecting differences in the circulation of the skin, in insulation and surface/volume ratio (Paul, 2001; Wright, 1984).

Elephants differ physiologically from most other animals. Homoeothermic animals can reduce blood circulation in their body appendages (ears, tail, nose, feet) in cold climates to minimize heat losses and prevent cooling down (e.g. Eckert, 1993). The elephants in this study showed this phenomenon only for the ears and the tail. The feet surfaces were typically not significantly cooler than the torso, for example. The trunk was always the hottest.

Climate conditions enormously affect elephant thermo-profiles. Therefore, the dissipated heat stream (under cold conditions) depends directly on the difference between body surface and ambient temperature

(e.g. Schmidt-Nielsen, 1999). Our paper confirmed this correlation. Furthermore, we demonstrated that the skin temperatures of the Asian elephants, but not of the African elephants, depended on the humidity. This may reflect an adaptation of Asian elephants to their natural habitat, which is mostly humid (Spinage, 1994).
As in the cold, there were no inter-individual differences in surface temperature among adult Asian elephants in hot and humid climates.
Morning- and evening-thermograms differed, especially for the ears. The pinnae were the coldest in the morning, indicating vasoconstriction to minimize heat loss. Skin temperature increased during day due to exposure to the sun and higher air temperatures. Because heat transfer by conduction, convection and radiation is basically proportional to the temperature difference between body surface and the environment (Jessen, 2001), the elephants´ non-evaporative mechanisms of heat loss were often reduced. In the evening, body temperatures became more uniform, than in the morning, with smaller differences between torsos and ears, for example, indicating maximal vasodilatation of ear vessels. Although the thermograms revealed variability, heat loss via radiation was the same at both times of day. This can be explained by the same difference between air and body surface temperature in the mornings and the evenings. Heat radiation typically ranged from 221 to 303W/m². Only one individual differed: this elephant usually showed slightly lower surface temperatures than the others. No obvious explanation for this phenomenon due to different husbandry, treatment or health status was found.
Much still remains unknown about the sensitive thermoregulation in elephants. Studies like the present one contribute to our knowledge about the temperature balance of the largest mammal on earth today and set new impulses for a husbandry approach that is appropriate to the species.

Prospects:
Many features – great body mass, low surface/volume ratio, reduced opportunities for heat dissipation in hot and humid environments – indicate that elephants make use of heterothermy to handle the conditions they encounter. Future studies will examine whether elephants show a fluctuation in body core temperature by exceeding normal circadian oscillation, as is characteristic for heterothermy. According to Aschoff (1982) and based on observation on horses (Piccione *et al*. 2002), we can expect a 24-h variation in body core temperature of elephants from slightly below 1 °C. Thermo-profiles of body surface temperature will be related to the course of body core temperature, which will be measured with temperature data loggers fed to the animals.

Acknowledgements:
The author wishes to thank Dr. Harald Schwammer, Vice director of Vienna Zoo, for support in every imaginable way. Thanks go to the zoological gardens Hellabrunn and Friedrichsfelde and to the staff from Pinnawala Orphanage for their hospitality.

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Managing human-elephant conflict in Assam: An integrated approach

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The Himalayan foothills of north-eastern India provide one of the last remaining strongholds of the endangered Asian Elephant. In Assam, widespread human-elephant conflict results in the loss of both elephant and human lives, and expert groups have listed this region a top priority for mitigation action. Our paper describes a methodology that combines GIS-based research with community-based conflict management. Patterns and characteristics of crop-raiding are recorded, movements of elephants observed and mapped, and historical habits of elephants reconstructed from local knowledge. In tandem with this, we use a participatory approach of engaging communities to construct and maintain low-cost deterrent methods (e.g. tripwire alarms, chilli, etc). Community members help collect observational data and coordinate the deterrent trials, in the aim that these villages may soon take charge of their elephant problems themselves. Our preliminary results suggest that while elephants appear to follow seasonal routes of migration, their habitual movements are highly sensitive to human interventions. While mitigation of acute conflicts is required to help both elephants and people in the short term, region-wide monitoring is essential for a full understanding of the effects of interventions and to assist local authorities in developing long-term protected area and conflict management policies.

INTERNATIONAL ELEPHANT CONSERVATION AND RESEARCH SYMPOSIUM

October 21-22, 2006
Copenhagen Zoo, Denmark

POSTER PRESENTATIONS

Impact of elephant's behaviour on the dynamic of vegetation in the W-Regional Park: The case of elephants in the north of Benin

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Programme Régional Parc/ W-ECOPAS/ CENAGREF
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The current study titled " Impact of elephants behaviour on the dynamic of vegetation in the W Regional Park: the case of elephants in the North of Benin " is allowed us to pick up and to identify 101 vegetable species over forty three plots of 30 m x 30 m into five types of vegetables formations: gallery forest, clear forest, savannah full of tree, wood full savannah and savannah. Diversity analysis of elephant's natural surroundings shows that it luxuriance species is 19 to 22 vegetables species. According to statistics, data (Shannon's sign H = 3,26 ± 0,35 bits and Pielou's sign E = 0,77 ± 0,04), which have been calculated, proved that these species diversified and have been equitable distributed. The relativity threatened vegetables by the elephants are the shrubs savannahs for grazing since they are susceptible to give great damage of plants throughout the favourites species such as *Acacia* contrary to gallery forests which are not in danger.

The analysis of all this observations allows to point out that the specific diversity of the frequented places by the elephants is better than those obtained from dropping's analysis. From this, we meaning is that the elephant feed in the park and its cynegetic areas didn't affected any ease for the moment the normal evolution of the different ecosystems.

Nevertheless, from they feeding pattern, the elephants destroy enough forest or savannah's vegetation. Therefore, the broken stems and the uprooted trees are secondary feeding behaviour. The impact of elephant over places or trees and bushes restoration is an essential park's landscape dynamic, but also over the fauna's parts and over the vegetable's diversity. These pachyderms are great importance so it is in do to take care of them so as to safeguard diversity in general and vegetable community particularly. Although, the control living creature the elephants' density in order to have better interaction between elephants and their natural surroundings.

Key words: Impact, elephants, dynamic, vegetation, W regional park.

1. Introduction:

La dynamique des écosystèmes est une phase essentielle dans les études de la biodiversité. Les types de formations végétales de la zone soudano-sahélienne du nord du Bénin constituent un habitat et une ressource alimentaire importante pour la faune sauvage. L'éléphant fait preuve d'une souplesse écologique stupéfiante (Pfeffer, 1989). En tant qu'un strict herbivore sauvage, il présente une gamme de structures variées et de mœurs dans les savanes des aires protégées. Il ingère principalement des graminées, des feuilles d'arbres ou des buissons et des fruits. Les fruits paraissent comme un élément important du régime alimentaire des éléphants de forêt (White et *al.*, 1993). Le mode d'alimentation des éléphants et ses mouvements permanents entre divers écosystèmes leur confèrent un rôle écologiquement important. Ils dispersent un grand nombre d'espèces d'arbres au point où sans eux la diversité des ces espèces ne serait maintenue et que les espèces comme *Balanites wilsoniana* disparaîtraient dramatiquement de la forêt guinéenne (Hawthorne et Parren, 2000). L'éléphant n'a pas qu'un seul rôle positif dans la vie des forêts et des savanes ; il peut aussi directement ou indirectement détruire les arbres. En Afrique de l'Est, l'éléphant à lui seul explique l'arrêt de la dynamique successionnelle des formations buissonnantes vers les forêts (Eggeling, 1947). Par ailleurs, les travaux de Laws (1970), de Wing et Buss (1970) réalisés dans la même

région de l'Afrique ont montré que l'éléphant prélève l'écorce de certains arbres, comme les *Terminalia*, qui une fois écorcés, résistent mal aux feux de végétation. Selon Barnes (1983), les éléphants de savane sont responsables des dommages permanents causés aux espèces ligneuses des savanes. Le régime normal de l'animal, quand sa densité ne dépasse pas un seuil critique, fixé par Fower et Smith (1973) à 0,5 éléphant par km² pour des régions savanicoles, est composé de fruits et de pousses d'espèces héliophiles d'environ de 2 à 5 m de haut (Müller-Dombois, 1972) et d'un diamètre inférieur à 10 cm (Wing et Buss, 1970). Ce n'est que lorsque les populations de vastes territoires sont conduites à trouver refuge dans des parcs nationaux où la densité peut devenir très grande (3,5 éléphants / km² par exemple) que l'animal s'attaque aux écorces des quelques espèces d'arbres pour trouver le calcium qui lui est nécessaire.
Cependant, l'importance des éléphants se ferait sentir quand ils vont cesser d'exister dans les écosystèmes. Les éléphants de forêt produisent de la biomasse (52 % pour les herbivores) dans la forêt pluviale gabonaise jouant ainsi un rôle clé dans les écosystèmes des forêts pluviales d'Afrique (Hawthorne et Parren, 2000). Par ailleurs, le rôle écologique joué par l'éléphant est reconnu de diverses façons. Il a été suggéré que le mode d'alimentation peut être utile pour le contrôle des arbres exotiques envahissants (Milewski, 2002). Hawthorne et Parren (2000) s'inquiètent par rapport aux répercussions que causerait l'extinction locale des éléphants sur la composition botanique des forêts et savanes et ils pensent que ce rôle joué par l'éléphant mérite une attention particulière. Toutefois, certains auteurs pensaient que cet usage sélectif des habitats par les éléphants freine la régénération des forêts (Laws, 1970 ; Laws et *al*., 1975). Cette question devient plus importante dans la mesure où la survie de certaines espèces caractéristiques est compromise, étant dit que leur régénération est en grande partie assurée par les éléphants. Donc l'extermination de cette espèce pourrait engendrer des perturbations de ces écosystèmes encore mal connus aujourd'hui (Alfa Gambari, 2002). Leur présence dans les grandes forêts et savanes est plutôt bénéfique et contribue largement à l'équilibre de la flore et de la faune garantissant ainsi aux réserves forestières naturelles africaines une diversité spécifique qui mérite d'être sauvegardée dans l'intérêt de la conservation de la nature ainsi que de la biodiversité qui en dépend.

2. Démarche méthodologique:

2.1 Méthodes de collectes de données
2.1.1 Identification des groupements végétaux et réalisation des inventaires forestiers
2.1.1.1 Prospection de la zone d'étude et choix des sites de relevés
Des sites d'installation des placettes ont été choisis en fonction de leur fréquentation ou non par les éléphants (lieux d'alimentation, d'abreuvement et de repos, trajectoires ou couloirs de passage, etc.). Pour ce faire, une prospection de ces lieux dans le parc et dans les zones cynégétiques a été réalisée au préalable dans le but d'identifier les habitats régulièrement fréquentés ou non par les éléphants. Cette phase a été combinée à l'utilisation de la carte de végétation pour l'identification des sites. A cette étape, les différentes formations végétales sont caractérisées et leur degré de fréquentation par les éléphants est a priori connu.

2.1.1.2 Installation des placeaux
En tenant compte des observations relatives aux aires des relevés de la végétation de l'Afrique de l'Ouest à travers plusieurs bibliographies (Agbani, 2002), des placeaux carrés de 30 m x 30 m soit une aire de 900 m² ont été installés sur les habitats fréquentés par les éléphants pour leur alimentation, abreuvement et repos et sur leurs couloirs de passage. Ces habitats sont définis et bien connus dans le parc et les zones cynégétiques et de chasse après une exploration de terrain. De petits placeaux de 10 m x 10 m soit de 100 m² délimités à l'intérieur des placeaux de 900 m² ont permis de mesurer les paramètres de la régénération naturelle des espèces au sein de chaque phytocénose. Ces placettes de régénération ont concerné les arbres et les arbustes ayant un diamètre inférieur à 10 cm. Les arbres et les arbustes ayant un diamètre supérieur ou égal à 10 cm ont été systématiquement inventoriés. Puisqu'il s'agit de la régénération des espèces fruitières, les inventaires d'espèces concernent les ligneux.
Les sites ont été choisis dans les zones suivantes:

* dans le parc, les zones comme: Point Triple, Koudou, Cabane aux éléphants et Kaoubagou sont ciblées pour l'emplacement des placeaux.

* dans les zones cynégétiques de la Djona et de la Mékrou, les lieux comme Agbotadi, Bandaaman, Ignikouta, Sourou, Mare 12, Iniédoudou et le site d'abreuvement d'Alfakoara ont été considérées.

Au total 80 placeaux (50 dans le parc et 30 dans les zones cynégétiques compte tenu de certains critères écologiques qui prédominent dans chaque zone) ont été distribués sur les lieux choisis. Le tableau 1 présente la distribution desdits placeaux et les caractéristiques de chaque zone choisie.

Tableau 1: Distribution des placeaux sur les différents sites de relevés

Sites	Zones	Caractéristiques des lieux d'installation des placeaux	Activités menées par les éléphants	Nombre de relevés
Parc national du W	Point triple	Galerie forestière, point d'eau, savanes boisées et arbustives	Abreuvement, alimentation, repos, défécations	10
	Koudou	Galerie forestière, savane boisée, point d'eau	Abreuvement, alimentation, repos, défécations	12
	Cabane aux éléphants	Zones marécageuses, forêt claire, savane arborée, point d'eau	Abreuvement, alimentation, repos, défécations	12
	Kaoubagou	-	Abreuvement, alimentation, repos, défécations	15
Zones cynégétiques de la Djona et de la Mékrou	Agbotadi	Formations buissonnantes, savanes arborée et arbustive, point d'eau	Alimentation, repos, défécations	5
	Bandaaman	Forêt claire et savane arborées à *Isoberlinia doka*, point d'eau	Alimentation, repos, défécations	5
	Ignikouta	Galerie forestière et savane arbustive, point d'eau	Abreuvement, alimentation, repos, défécations	4
	Sourou	Point d'eau, savane boisée	Abreuvement, alimentation, repos, défécations	4
	Mare 12	Galerie forestière	Abreuvement, alimentation, repos, défécations	4
	Site d'abreuvement	Formations buissonnantes, galerie forestière, savane arborée, point d'eau	Abreuvement, alimentation, repos, défécations	4
	Iniédoudoun	Galerie forestière forêt claire	Lieu de repos en saison pluvieuse et saison sèche	5
Total				80

2.1.1.3 Reconnaissance préliminaire des espèces végétales
La majorité des espèces peuplant des habitats ciblés pour l'installation des placeaux a été déjà identifiée dans des études antérieures (Alfa Gambari, 2002; Ayégnon, 2002; Toko, 2002). Les espèces restées inconnues ont été identifiées sur place en langue locale Mokolé, Bariba et Gourmantché par l'aide des pisteurs et des Garde-faunes. La correspondante est faite par la suite au niveau des noms d'espèces en latin avec l'appui d'un herbier (de Souza,1988) des espèces complémentaires non identifiées.

2.1.1.4 Inventaires forestiers
A l'intérieur des placeaux de 900 m², l'inventaire de toutes les espèces végétales a été réalisé. Les relevés d'espèces ont été effectués selon la méthode de Züricho-Monpellerraine (Braun-Blanquet, 1932; Akoegninou, 1984; Sinsin, 1993; Sokpon, 1995). Il a été question d'identifier toutes les espèces avec les informations suivantes qui ont été notées: le sol (couleur, texture et hydromorphie), la topographie de la zone (position et pente), le type de formation végétale, le recouvrement global de la formation végétale, l'abondance/dominance par espèce, les activités humaines, la superficie de la placette, les coordonnées GPS et la date.

2.2 Analyse de la diversité spécifique des groupements végétaux
L'analyse des résultats des placeaux a tenu compte de la classification des ces derniers en types de formations végétales retrouvées lors des relevés. L'analyse de la diversité des placeaux, la richesse spécifique et la régularité de Piélou sont des paramètres pris en compte. Le logiciel informatique Excel a permis de faire le calcul des différents paramètres.

La diversité floristique des 43 placeaux au total est appréciée par rapport à la diversité des familles et la richesse spécifique des phytocénoses. Certains indices et modèles mathématiques proposés pour l'étude de la diversité ont été retenus:

- La richesse spécifique R : c'est le nombre d'espèces total, toutes espèces végétales confondues.
- L'indice de diversité de Shannon H:

$H = - \Sigma Pi \times \log_2 Pi$, $Pi = Ni/N$ où Ni = effectif de l'espèce i et N = nombre total d'espèces.

* Si la valeur de H est comprise entre 0 et 2, elle est faible: le régime alimentaire des éléphants ou le milieu est peu diversifié;
* Si la valeur de H est comprise entre 2 et 3, elle est moyenne : les éléphants ont un régime alimentaire (ou un milieu) moyennement diversifié ;
* Si la valeur de H est comprise entre 3,5 et 5, elle est élevée: le régime alimentaire des éléphants (ou le milieu) est diversifié.

- L'indice de régularité ou d'équitabilité de Pielou E:

$E = H/\log_2 S$, où S = nombre d'espèces recensées et E appartient à [0 ; 1].

* Si la valeur de R est comprise entre 0 et 0,5: elle est faible et beaucoup d'espèces sont rares et mal réparties dans les habitats fréquentés par les éléphants ;
* Si la valeur de R est comprise entre 0,6 et 0,7: elle est moyenne et dans ce cas, les espèces végétales sont moyennement distribuées ;
* Si la valeur de R est comprise entre 0,8 et 1: elle est forte, ce qui indique que toutes les espèces végétales sont équitablement représentées.

- La fréquence en pourcentage de chaque espèce végétale renseignant la part de chacune dans l'ensemble.
- Les densités moyennes Dm au niveau des placeaux de chaque type de formation végétale sont calculées.

3. Résultats:

3.1 Répartition des placeaux et degré de similitudes entre les groupements végétaux
Les résultats de relevés floristiques ont montré des différences entres les divers groupements végétaux retenus après l'analyse des données.
3.1.1 Répartition des placeaux de relevés au niveau des groupements végétaux

Au total cinq formations végétales ont été observées au niveau des 43 placeaux relevés : les galeries forestières (GF), les forêts claires (FC), les savanes boisées (SB), les savanes arborées (SA) et les savanes arbustives (Sa). Il est bon de noter que les savanes herbeuses ne sont pas représentées puisque les relevés ont concerné seulement la végétation ligneuse.

3.1.1.1 Diversité spécifique et composition floristique des galeries forestières

► Diversité spécifique

Trois placeaux ont été relevés au niveau des forêts-galeries. La richesse spécifique R, le nombre N d'espèces végétales, la densité D des individus, la diversité de Shannon H et la régularité de Pielou E de cette formation ont été calculés et mentionnés dans le tableau 2.

Tableau 2 : Richesse spécifique (R), densité (D), diversité de Shannon (H) et Régularité de Pielou (E) au niveau des galeries forestières.

Paramètres					
N ° de placeau	R	N	D (tiges/ha)	H (Bits)	E
Placeau (P1)	22	135	1.500	3,91	0,87
Placeau (P2)	21	124	1.377,8	3,78	0,86
Placeau (P3)	22	137	1.522,2	3,55	0,8
Moyenne	21,67	132	1.466,7	3,75	0,84
Ecart-type	0,47	5,72	63,51	0,15	0,03

Source: Données de terrain, Alfa Gambari (2003-2004).

L'analyse du tableau 2 montre que la richesse spécifique des placeaux relevés au niveau des forêts-galeries est pratiquement constante avec en moyenne 21,67± 0,47 espèces végétales et une densité moyenne importante. Au regard des valeurs moyennes des indices de diversité de Shannon et de régularité de Pielou, les espèces végétales sont diversifiées et bien réparties dans les galeries forestières.

► Composition floristique

La flore ligneuse recensée au niveau des galeries forestières est composée de 43 espèces végétales dont les plus représentées sont: *Flueggea virosa*, *Feretia apodanthera*, *Anogeissus leiocarpus*, *Diospyros mespiliformis*, *Mitragyna inermis* et *Terminalia glaucescens*. Les espèces faiblement représentées dans cette formation sont *Gardenia erubescens*, *Kigelia africana*, *Lannea acida*, *Pterocarpus erinaceus* et *Vitex doniana*.

3.1.1.2 Diversité spécifique et composition floristique des forêts denses sèches

► Diversité spécifique

Les groupements de forêts denses sèches ont concerné 7 placeaux. Le tableau 3 indique les différentes valeurs obtenues pour la richesse spécifique R, le nombre N d'individus, la densité D, la diversité de Shannon H et la régularité de Pielou E de chaque placeau.

Tableau 3: Richesse spécifique, densité moyenne, diversité de Shannon et Régularité de Pielou des forêts denses sèches.

N° de placeaux	R	N	D (tiges/ha)	H (bits)	E
Placeau (P1)	14	86	956	3,01	0,79
Placeau (P2)	16	94	1.044	3,66	0,91
Placeau (P3)	26	107	1.189	3,96	0,84
Placeau (P4)	12	99	1.100	2,67	0,74
Placeau (P5)	27	178	1.978	3,78	0,79
Placeau (P6)	11	426	4.733	3,57	0,75
Placeau (P7)	19	281	3.122	2,24	0,52
Moyenne	17,86	181,57	2.017	3,27	0,76
Ecart-type	6,47	128,34	1.426	0,64	0,12

Source: Données de terrain, Alfa Gambari (2003-2004).
La densité moyenne des placeaux et la richesse spécifique des forêts denses sèches sont importantes. La composition végétale dans cette formation est assez diversifiée. C'est ce qu'indique les valeurs relativement élevée des indices de Shannon de chaque placeau. Cette diversité est confirmée par la régularité de Pielou qui est en moyenne de 0,76±0,12 dans les groupements de forêts denses sèches.

► Composition floristique
Au total, 58 différentes espèces ont été recensées au niveau de 7 placeaux réalisés au niveau des forêts denses sèches. Globalement, 5 espèces sont en tête de liste tenant compte de leur fréquence en % dans les relevés. Il s'agit de : *Flueggea virosa*, *Dichrostachys cinerea*, *Anogeissus leiocarpus*, *Feretia apodanthera* et *Terminalia glaucescens*. Les espèces les moins représentées dans ces relevés sont *Cissus populnea*, *Desmodium velutinum*, *Dioscorea abyssinica*, *Khaya senegalensis*, *Maytenus senegalensis* et *Vitex doniana*.

3.1.1.3 Diversité spécifique et composition floristique des savanes boisées
► Diversité spécifique
Le tableau 4 présente d'une part les différentes valeurs obtenues pour les indices de diversité (H) et de P régularité de Pielou (E) et d'autre part, la densité moyenne (D) et la richesse spécifique (R) au niveau des savanes boisées dans les 7 placeaux classés dans cette formation.
N représente le nombre d'espèces végétales recensées dans chaque placeau.

Tableau 4: Richesse spécifique (R), densité moyenne (D), diversité de Shannon (H) et régularité de Pielou (E) au niveau des savanes boisées.

N° Placeau	R	N	D (tiges/ha)	H (Bits)	E
Placeau (P1)	15	125	1.388,89	3,16	0,81
Placeau (P2)	9	87	9.66,67	2,2	0,69
Placeau (P3)	34	215	2.388,89	4,26	0,83
Placeau (P4)	19	183	2.033,33	2,95	0,69
Placeau (P5)	26	266	2.955,56	3,57	0,76
Placeau (P6)	20	256	2.844,44	3,1	0,71
Placeau (P7)	27	333	3.700,00	3,77	0,79
Moyenne	21,43	209,29	2.325,40	3,29	0,75
Ecart-type	8,30	85,13	945,92	0,66	0,06

Source: Données de terrain, Alfa Gambari (2003-2004).
Une brève analyse des données consignées dans le tableau 4 montre qu'au niveau des savanes boisées, beaucoup d'espèces sont présentes et variées. C'est ce que prouve la valeur obtenue de la richesse spécifique et la diversité de Shannon. La densité moyenne des arbres y est importante. Par ailleurs, la valeur moyenne de la régularité de Pielou permet de dire que les espèces relevées sont assez équitablement réparties dans les habitats des savanes boisées.

► Composition floristique
Au total, 56 espèces végétales ont été recensées et identifiées dans les savanes boisées. Les espèces les plus représentées sont *Combretum glutinosum*, *Combretum collinum*, *Piliostigma thonningii*, *Pteleopsis suberosa*, *Terminalia avicennioides* et *Crossopteryx febrifuga*. Les espèces faiblement représentées sont *Acacia sieberiana*, *Balanites aegyptiaca*, *Combretum micranthum*, *Khaya senegalensis* et *Opilia celtidifolia*.

3.1.1.4 Diversité spécifique et composition floristique des savanes arborées
► Diversité spécifique
La richesse spécifique moyenne (R) et la densité moyenne des placeaux relevés au niveau des savanes arborées de même que la diversité de Shannon (H), la régularité de Pielou (E) et le nombre d'individus (N) sont mentionnés dans le tableau 5. Ici, il y a 14 placeaux concernés par ce type de formation végétale.

Tableau 5: Richesse spécifique (R), densité moyenne (D), diversité de Shannon (H) et régularité de Pielou (E) des savanes arborées.

N° de placeau	R	N	D (tiges/ha)	H (Bits)	E
Placeau (P1)	16	91	1.011	3,43	0,85
Placeau (P2)	20	139	1.544	3,45	0,8
Placeau (P3)	18	91	1.011	3,17	0,76
Placeau (P4)	17	52	578	2,72	0,78
Placeau (P5)	9	86	956	1,67	0,52
Placeau (P6)	19	93	1.033	3,57	0,84
Placeau (P7)	30	110	1.222	3,9	0,76
Placeau (P8)	20	193	2.144	3,03	0,7
Placeau (P9)	22	179	1.989	3,57	0,8
Placeau (P10)	20	109	1.211	3,57	0,82
Placeau (P11)	25	419	4.656	3,52	0,76
Placeau (P12)	26	99	1.100	3,47	0,73
Placeau (P13)	26	190	2.111	3,16	0,68
Placeau (P14)	17	151	1.678	3,04	0,74
Moyenne	20,36	143	1.589	3,23	0,75
Ecart-type	5,26	90,25	1.003	0,54	0,08

Source: Données de terrain, Alfa Gambari (2003-2004).
Les placeaux relevés dans les savanes arborées sont riches de plus ou moins 20 espèces végétales avec une densité relativement considérable. Par ailleurs, la diversité de Shannon et la régularité de Pielou assez élevées prouvent que les espèces y sont diversifiées et assez réparties dans les savanes arborées.

► Composition floristique
Au niveau des 14 placeaux relevés dans les savanes arborées, 70 différentes espèces végétales ont été recensées et identifiées. Les espèces les plus présentes dans cette formation sont *Flueggea virosa*, *Combretum glutinosum*, *Feretia apodanthera*, *Piliostigma thonningii*, *Acacia machrostachya* et *Crossopteryx febrifuga*. Les espèces comme *Khaya senegalensis*, *Kigelia africana*, *Pterocarpus erinaceus* et *Strychnos spinosa* sont les espèces les moins représentées.

3.1.1.5 Diversité spécifique et composition floristique des savanes arbustives

► Diversité spécifique

Le tableau 6 présente la densité moyenne (D) des savanes arbustives et la richesse spécifique (R) de chacun des 12 placeaux. La diversité de Shannon de et la régularité de Pielou ont été également calculées et mentionnées dans le même tableau 6.

Tableau 6: Richesse spécifique (R), densité moyenne (D), diversité de Shannon (H) et régularité de Pielou (E) des savanes arbustives.

Placeaux	R	N	D (tiges/ha)	H (Bits)	E
Placeau (P1)	15	101	1122	2,96	0,76
Placeau (P2)	13	111	1233	2,55	0,69
Placeau (P3)	13	124	1378	2,57	0,69
Placeau (P4)	11	211	2344	2,79	0,8
Placeau (P5)	13	80	889	2,15	0,85
Placeau (P6)	11	50	556	2,93	0,84
Placeau (P7)	18	167	1856	2,57	0,61
Placeau (P8)	16	256	2844	2,67	0,66
Placeau (P9)	20	178	1978	3,27	0,76
Placeau (P10)	19	138	1533	3,1	0,73
Placeau (P11)	13	98	1089	2,82	0,76
Placeau (P12)	12	94	1044	2,79	0,78
Moyenne	14,5	134	1489	2,76	0,74
Ecart-type	3,09	59,11	657	0,29	0,07

Source: Données de terrain, Alfa Gambari (2003-2004).

L'analyse du tableau 6 indique que la richesse spécifique moyenne des placeaux est inférieure à 15 espèces dans les savanes arbustives bien que la densité soit importante. De même, au regard des valeurs obtenues des indices de Shannon et de Pielou, les espèces végétales des savanes arbustives sont peu diversifiées et mal réparties.

► Composition floristique

Au total, 12 placeaux ont été relevés au niveau des savanes arbustives. Les relevés floristiques ont fourni 52 différentes espèces végétales. Les espèces les mieux représentées dans ces placeaux sont *Combretum molle*, *Grewia cissoides*, *Grewia mollis*, *Parkia biglobosa*, *Piliostigma reticulata* et *Prosopis africana*. Au niveau de ces relevés, environ 7 espèces sont faiblement représentées telles que *Combretum glutinosum*, *Combretum collinum*, *Crossopteryx febrifuga*, *Flueggea virosa*, *Vitellaria paradoxa* et *Burkea africana*.

3.1.2 Degré de similitude entre les groupements végétaux obtenus

Le paramètre pris en compte ici est la richesse spécifique moyenne (Rm). La figure 1 permet de comparer la richesse spécifique des différentes formations végétales.

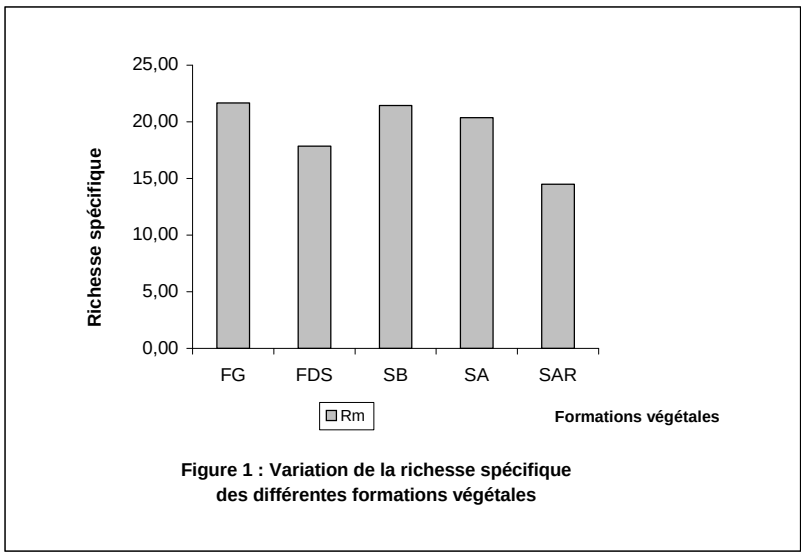

Figure 1 : Variation de la richesse spécifique des différentes formations végétales

Légende: FG: forêts galeries, FDS : forêts denses sèches, SB: savanes boisées, SA : savanes arborées et SAR: savanes arbustives.

L'analyse de la figure 1 montre que la richesse spécifique a varié au sein des différentes formations végétales. Elle est importante dans les galeries forestières, les savanes boisées et les savanes arborées avec R supérieure ou égale à 20 espèces. Par contre, dans les forêts denses sèches et les savanes arbustives, elle est inférieure à 20 espèces. Les habitats relevés dans les galeries forestières, les savanes boisées et les savanes arborées sont plus riches que ceux relevés dans les forêts denses sèches et les savanes arbustives.

Composition floristique des sites observés et fréquence relative de chaque espèce germée *in situ*.
Les différentes espèces végétales germées sur place ont été relevées et identifiées sur les sites d'observations. Globalement, la composition floristique des sites est de 14 espèces végétales représentées à la figure 2.

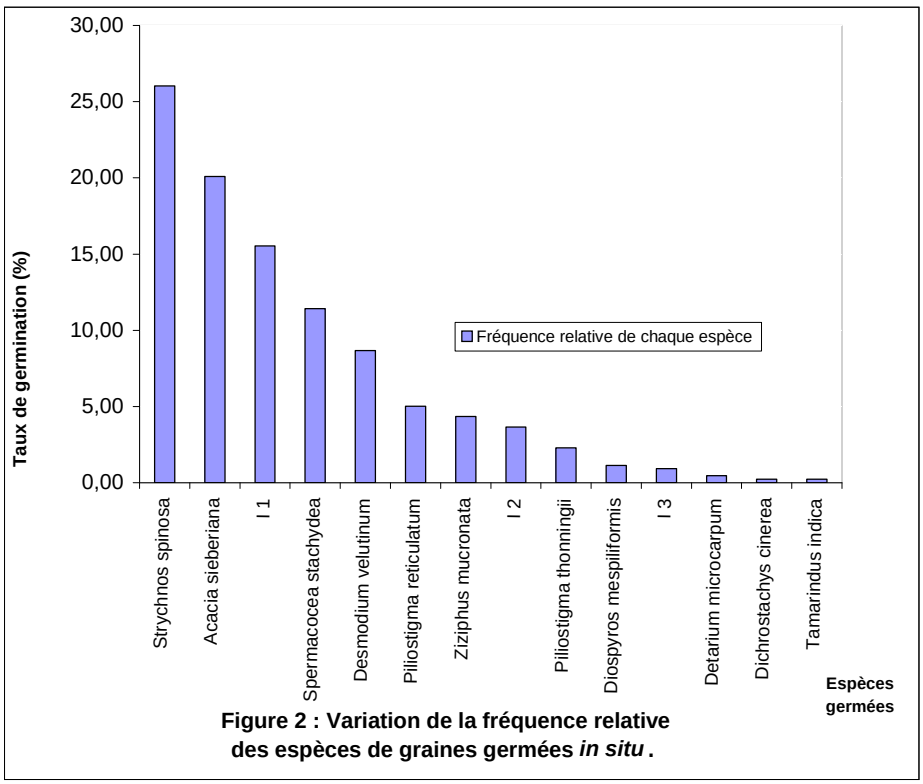

Figure 2 : Variation de la fréquence relative des espèces de graines germées *in situ* .

Ii: espèce inconnue non identifiée.
L'analyse de la figure 2 montre que la fréquence relative de germination des semences contenues dans les crottes varient 0,02 à 0,26. Mieux, aucune espèce végétale sur les 14 n'a atteint une fréquence de 0,50. La plus forte fréquence est notée pour l'espèce *Strychnos spinosa* (0,26), suivie de *Acacia sieberiana* (0,20), de l'inconnue 1 (0,15), de *Spermacoce stachydae* (0,11) et de *Desmodium velutinum* (0,8). Les plus faibles fréquences sont notées au niveau des espèces comme *Dichrostachys cinerea* et *Tamarindus indica* (0,2), etc. .

4. Discussion:

4.1 Diversité spécifique et composition floristique des formations végétales identifiées
Au total, 101 espèces végétales ont été relevées et identifiées sur 43 placeaux de 900 m² de surface chacun. Suivant une répartition aléatoire du nombre de placeaux par type de formation végétale, 5 types de formations végétales ont été principalement identifiées: les forêts-galeries, les forêts claires, les savanes arborées, les savanes boisées et les savanes arbustives. Du point de vue de l'analyse de la diversité spécifique, une grande variation a été notée au sein de ces différentes formations. Les différentes valeurs moyennes obtenues pour les indices de Shannon (H = 3,26 ± 0,35), de Pielou (E = 0,77 ± 0,04) et de la richesse spécifique (R = 19,16 ± 3,01espèces végétales) traduisent ce qui suit :

- les divers habitats régulièrement fréquentés par les éléphants sont riches de 19 à 22 espèces végétales différentes;
- les habitats diversifiés abritent d'abondantes espèces végétales;
- toutes les espèces végétales en sont assez équitablement réparties et chacune d'elles est largement représentée dans le milieu.

L'analyse de la diversité spécifique de ces habitats indique en conséquence que les différents habitats fréquentés par les éléphants sont relativement à l'abri d'une éventuelle destruction (dégradation) comme l'on le pense à première vue. Ainsi, les galeries forestières sont exemptes de toutes menaces par les éléphants (selon les indices de Shannon H = 3,75 et de Pielou E = 0,84). D'ailleurs, la densité moyenne obtenue dans les forêts-galeries confirme ce fait. Ces observations expliquent que les forêts-galeries sont généralement utilisées par les éléphants pour leur repos et très peu pour leur alimentation. Les types de formations végétales relativement menacées sont les savanes arbustives qui sont indispensables pour le broutage car ces formations sont susceptibles de leur fournir une quantité importante de fourrages à travers les espèces préférées comme les *Acacia*. Les valeurs des indices de Shannon H = 2,76 et de Pielou E = 0,74 obtenues sont moyennes pour les savanes arbustives et confirment ce fait. Par ailleurs, les études de Dale (1991) et de Cumming et *al.* (1997) ont montré que l'influence des éléphants sur la végétation en général et sur une espèce particulière, *Colophospermum mopane*, altère l'évolution de la savane herbeuse vers la savane arbustive et convertit la savane arbustive en savane herbeuse. Les sols qui favorisent les taillis de *C. mopane* produisent des savanes arbustives moins stables lorsqu'ils sont associés à des éléphants que les sols favorisant les savanes arbustives avec de grands arbres, non buissonneux. La dynamique de ces savanes est plus déterminée par le renouvellement des arbres qui est lui-même influencé par les agents tels que d'autres herbivores ou par la fréquence ou la répétition saisonnière des feux de végétation (Peter, 1989; Dale, 1991 ; Barnes et *al.*, 1994).

Par contre, au regard des indices de diversité et de régularité, les groupements de forêts denses sèches et de savanes boisées et arborées sont des formations faiblement utilisées par les éléphants et les espèces sont diversifiées avec une distribution moyennement équitable sur le milieu. De ce fait, les questions de l'utilisation abusive de l'habitat par les éléphants pouvant engendrer des pertes de la biodiversité des écosystèmes des aires protégées (AP) au Bénin n'est pas de l'heure une situation alarmante en ce qui concerne les populations d'éléphants d'environ 1000 individus évoluant dans le complexe ces AP. Une analyse de la densité des populations d'éléphants serait alors une étude indispensable pour mieux contrôler la situation.

4.2 Impact négatif des éléphants: rôle de «destructeurs» des habitats

A priori, de par leur mode de s'alimenter, les éléphants sont de gros destructeurs de la végétation de forêts ou de savanes. Les points de vue sont divergents à ce niveau. Mais la présente étude a prouvé que pour ce qui est des écosystèmes du parc du W et de ses zones périphériques, il n'y aurait aucune inquiétude. Ainsi, les éléphants ne pourraient guère constituer un danger pour les divers habitats qu'ils fréquentent régulièrement. Cependant, beaucoup d'autres études ont contredit cette idée en pensant que tous les grands herbivores tels que le rhinocéros, l'éléphant et l'hippopotame ne sont d'aucune utilité parce que ces trois mammifères mastodontes exercent une très forte pression sur le pâturage par leur prélèvement de tous les fourrages de premier choix et qu'il faut, par conséquent, autoriser leur extermination (Aglinglo et *al.*, 1998). Par ailleurs, le rhinocéros noir et l'éléphant sont des animaux phyllophages qui broutent des feuilles, des rameaux, des racines et des écorces d'arbres. Ce caractère biologique distinctif de ces gros herbivores les rend *a priori* responsables de la destruction d'une partie non négligeable de la flore des réserves forestières et savanicoles africaines (Ishwaran, 1983; Aglinglo et *al.*, 1998 ; Roques et *al.*, 2001, Calange et *al*., 2001). Le même constat a été fait par les études de McNaughton et Sabuni (1988) et de Brits et *al.* (2002) dans le Parc National de Kruger en Afrique du Sud où l'absence presque totale d'individus ligneux dans les voisinages immédiats des points d'eau a été notée; la densité des arbustes augmente lorsqu'on s'éloigne des points d'eau changeant ainsi la structure de la végétation des savanes. Cependant, Afolayan (1975), Cumming et *al.* (1997), Mapaure et Mhlanga (1998), Manlius et Pfeffer (1999) et Grettenberger (1984) rapportent ce fait à la densité des éléphants en un endroit donné (0,5 éléphant par km^2) pouvant constituer un facteur capable des dommages irréversibles à la végétation de savane. Mais tel n'est pas le cas dans la zone de Namembere au Zimbabwe où la réduction du nombre d'éléphants pourrait hypothéquer la conservation de la biodiversité.

4.3 Importance écologique des éléphants: rôle positif de «régénérateurs»

Les dommages causés à la végétation par les éléphants peuvent être considérables dans les écosystèmes africains mais la perte de cette influence de la végétation par les éléphants pourrait constituer un danger à la dynamique de cette dernière face aux perturbations humaines de la végétation. Les résultats obtenus durant la présente étude corroborent cette idée. En effet, beaucoup d'auteurs pensent que les éléphants jouent un rôle très significatif dans la structure de la végétation des forêts humides d'Afrique de l'Ouest. Cependant, la conservation des éléphants serait une première préoccupation et l'aménagement des phytocénoses permettrait de les promouvoir et *vice versa*. C'est ce qui explique les recherches vaines effectuées dans le but de défendre l'hypothèse du déclin de la végétation des écosystèmes car l'extinction locale des populations d'éléphants explique l'échec observé au niveau des régénérations. Pareillement, la régénération de nombreuses espèces végétales dépend absolument ou même parfois exclusivement des éléphants tels que *Balanites* et *Panda* (Hawthorne et Parren, 2000). Ainsi, par leur rôle de disperseurs de graines, les éléphants contribuent à long terme à la survie des plantes et influencent profondément la structure de la végétation des forêts en transformant progressivement les forêts en savanes et *vice versa*. L'effet des éléphants sur les habitats (ouverture du milieu) ou sur la régénération des arbres et arbustes est un élément essentiel dans la dynamique des paysages du parc, mais aussi sur le reste de la faune et sur la diversité végétale (Western et Lindsay, 1984 ; Barnes et *al.*, 1999 ; Bourgarel et *al.*, 2001). Cependant, de par leur habitude alimentaire ainsi décrite, ils facilitent la repousse et la multiplication de certains végétaux qui, sans broutages, nécessiteraient pour leur survie des élagages et des coupes périodiques, qui ne pourraient se faire que par intervention humaine. De plus, beaucoup d'espèces végétales rampantes ou de petites tailles doivent également leur survie à l'énergie lumineuse qui ne pourra les atteindre dans une forêt trop fermée. Néanmoins, la grande partie des petits ruminants sauvages qui constituent la majorité de la communauté dominante du gibier prélevé par les populations humaines s'alimente de ces espèces de petite taille. Aussi, leur déplacement dans la forêt et même dans la savane est-il facilité par le passage des gros animaux dont l'hippopotame, l'éléphant et le rhinocéros mais également le buffle (Aglinglo et *al.*, 1998). Cependant, le fait que les éléphants poussent et déracinent les arbres semble fait partie d'une stratégie alimentaire qui améliore la disponibilité de nourriture en saison sèche et le nombre d'arbres consommés croît avec l'augmentation de la densité d'arbres au-delà de 300 arbres/ha là où l'intensité de consommation reste constante aussi bien pour les espèces végétales sélectionnées que pour d'autres (Crawley, 1983, Jachmann et Bell, 1985).

De même, ont affirmé que l'écorçage des troncs d'arbres tels que *Afzelia bipendensis*, *Coloncoba welwitschii*, *Bridellia ferruginea* et *Terminalia superba*, le brisage des tiges et le déracinement des arbres sont des activités secondaires du comportement alimentaire. De ce fait, les éléphants sont d'une grande importance qui mérite d'être entretenue pour l'intérêt de la diversité des êtres vivants en général et de la communauté végétale en particulier.

5. Conclusion:

Les résultats obtenus au terme de la présente ont prouvé que les divers habitats fréquentés par les éléphants ne sont encore aujourd'hui victimes d'une pression de la part de ces pachydermes à travers leurs habitudes alimentaires. La diversité spécifique des habitats est de loin meilleure à celle obtenue dans les défécations. Ceci signifie que les aliments prélevés par les éléphants se sont concentrés sur les seules et même espèces végétales qu'ils rencontrent régulièrement. De plus, le suivi de la germination *in situ* (régénération naturelle) de quelques sites de défécations a prouvé que nombre d'espèces végétales ont la chance de germer à partir des laissées d'éléphants remplaçant ainsi la part prélevée dans les phytocénoses en tant qu'aliment.

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Future keeping of elephants at Heidelberg Zoo

Stefan Aspegren

Zoo Heidelberg

Since 1957 Heidelberg Zoo has been keeping elephants. Over the years house and outside exhibit became outdated. Fortunately the way of keeping elephants has changed at many places during the last years. Progressive zoos made their decision to rethink their way of presenting elephants. Small enclosures made of concrete, single or pair keeping of elephants and circus shows vanish more and more and make room for new ideas to enrich the life of captive elephants.
Heidelberg plans to be a facility for those surplus animals that cannot be integrated into breeding groups and still deserve a life enriched with social interaction and change.

The first step was taken in 2004 when the new outside yard was built. The yard is 2000 m^2 large and includes a pool, mudbath and different enrichment decvices.
The new house is planned to be 900 m^2 large, it will be built with the option to keep elephants in protected contact. It is divided into: A larger free roaming area with a smaller pool with waterfall, mudbath, 2 artificial trees with various enrichment devices, haynet feeders, browse feeders and other enrichment devices for pellets, fruits etc. The flooring will consist of a layer of sand on top of a natural substrate floor .
There will be 4 boxes, 2 of them with pc walls and rubber flooring and two boxes with sand. Inbetween the boxes and the outside yard there will be a restraint chute.

Today our 2 asian female elephants (*Elephas* maximus) share their outdoor exhibit with Axis deer (*Cervus nippon pseudoaxis)* and Blackbuck antilopes (*Antilope cervicapra*). In the new house we are planning a stall for them so that they can interact with the elephants inside as well as outside.
The overall idea is to give the elephants more control over their lives and reduce keeper interference to actions which have a direct benefit for the animals.

Comparison of trunk wash results matched to Multiantigen Print Immunoassay (MAPIA) in a group of captive Asian elephants (Elephas maximus)

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Introduction:
Between 1994 and June 2005, there were 34 confirmed cases of tuberculosis in elephants in the U.S. population. Thirty one Asian (*Elephas maximus*) and three African (*Loxodonta africana*) elephants were affected. *Mycobacterium tuberculosis* was the etiologic agent in 33 cases and *M. bovis* in one case. Cases of tuberculosis caused by an unusual nontuberculous mycobacteria, *M. szulgai* have recently occurred as well.(Gamble AAZV 2005)

Currently, TB in elephants remains a diagnostic dilemma. The sensitivity of trunk wash culture, the currently recommended test for diagnosis, is unknown. False negatives have been documented (trunk wash negative elephants that were subsequently found to be culture positive at necropsy). Other non-culture techniques for TB diagnosis include ELISA,[1] and PCR.

A novel technology, MultiAntigen Print ImmunoAssay (MAPIA) and lateral-flow technology (Rapid Test) [2] has been evaluated and used to diagnose tuberculosis in captive elephants with encouraging results.[2] One concern with this serological testing is the possibility of mycobacterium other than tuberculosis (MOTT) cross reacting with the antigen used in the Rapid Test or the MAPIA and leading to a false positive. With numerous MOTT routinely cultured from trunk washes, this is a valid concern.

Methods and Materials:
A retrospective analysis was done at Busch Gardens Tampa Bay and Chembio Inc that matched trunk wash results to serum samples. All serum was collected within 7 days of the trunk wash and analyzed with the Rapid Test and MAPIA. Four Asian elephants with a total of 18 samples met this criteria and had serum submitted for testing.

Results and Discussion:
Table 1 listed the results and the organisms cultured. While the sampling is limited in this pilot project, it appears that MOTT does not evoke a response when assayed with the Rapid Test or MAPIA. The recent cases of *M. szulgai* do demonstrate the potential usefulness for this test when a disease develops from MOTT. The usefulness of this new technology, taken in conjunction with other clinical data including trunk washes when indicated, is a valuable tool in the healthcare of captive elephants.

Table 1. Trunk wash mycobacterial culture with matched Rapid Test (RT) and Multiantigen print immunoassay (MAPIA) results.

Elephant	Serum Date	Trunk wash date	Mycobacterium cultured	RT	MAPIA
1	15-Jul-2004	15-Jul-2001	M. avium complex	-	-
	21-Jun-2001	22-Jun-2001	M.asiaticum	-	-
2	1-Sep-2001	21-Aug-2001	M fortuitum	-	-
	9-Apr-2001	10-Apr-2001	M terrae	-	-
3	24-Feb-2003	6-Mar-2003	M abscessus	-	-
	20-Oct-2001	23-Oct-2001	M avium complex	-	-
	16-Aug-2001	21-Aug-2001	M flavenscens	-	-
	21-Jun-2001	20-Jun-2001	M mucogenicum	-	-
	9-Apr-2001	9-Apr-2001	M avium complex	-	-
	5-Apr-2001	9-Apr-2001	M nonchromogenicum	-	-
	8-Aug-2000	10-Aug-2000	M gordonae	-	-
4	17-Feb-2003	19-Feb-2003	M fortuitum	-	-
	17-Feb-2003	18-Feb-2003	M intracellulare	-	-
	21-Jan-2002	18-Jan-2002	M avium complex	-	-
	23-Aug-2001	21-Aug-2001	M chelonae	-	-
	27-Jun-2001	20-Jun-2001	M avium complex	-	-
	27-Jun-2001	20-Jun-2001	M gordonae	-	-
	3-Apr-2001	5-Apr-2001	M simiae	-	-

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Serum cortisols in captive Asian elephants (*Elephas maximus*) in different management systems at Busch Gardens Tampa Bay

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Introduction:
Cortisol is a widely acceppted measure of stress in wild and captive animals. In the past, captive elephant management systems have been criticized as potential stress inducers. The analysis of fecal cortisols are non-invasive and have been used to give long term evalutions of social and ecological pressures in elephants and other species. [2] Salivary cortisols have also been used as a minimally invasive technique to measure social stress in captive elephants.[1] The herd of Asian elephants at BGT changed from a tradional contact managemnt (Free contact, FC) to a protected contact (PC) system utilizing positive-reinforcement based operant conditioning in 2004. Serum cortisols were measured after the change and evaluated along wth banked samples from before. Long term sampling will be utilized to measure this transition but evaluating a single process will hopefully reflect the overall changes that can be expected with this change in management. While the individual variations are notable and other issues potentially confound the issue, it appears that this transition has lowered the serum cortisols in this herd. In addition to serum cortisol measurements, the actual process of collecting the samples appears to be less stressful behaviorally. Pathological processes should not be discounted when considering cortisol levels in evalauting stress in captive elephants.

Methods and Materials:
Six female Asian elephants (Studbook numbers 30, 32, 304, 34, 35, 3) had been managed in a free contact system for many years. Studbook number 304 was captive born and the others were wild born. Serum was collected intermittently during this management system to bank and for reproductive hormone analysis. The elephants were placed in lateral recumbency by the handlers and blood collected from the ear vein on the caudal aspect of the down ear. Reproductively sound animals were bled more frequently than the others. Serum was frozen at -80C until utilized.

In August 2004, the first group of three animals was moved to the new barn and started the new positive-reinforcement, PC management system. Within five weeks, all animals had been moved over. All animals had been trunk washed and were negative for *Mycobacterium tuberculosis* and negative on the newly developed MultiAntigen Print ImmunoAssay (MAPIA) and lateral-flow technology (Rapid Test) developed to detected antigen to *M tuberculosis*.

As the caudal aspect of the ear was used for sampling, each elephant was asked to station in a static chute designed to allow training of voluntary ear-presentation for manipulation and blood collection. Handler safety and creating an effective learning environment for the elephants required training each to proceed to the chute solo and station there calmly. General desensitization techniques were applied as session durations were increased. Within the chute, individual elephants had significant room to maneuver. Since no physical restraint or sedation was utilized animals were trained to cooperate fully and voluntarily allowing for blood sampling and other husbandry procedures. By May 2005, training for voluntary bloods draws was firmly established on all six animals.

The first approximately 20 samples collected under this new system were matched against the samples collected in the previous system. Samples were selected against if the animal had an active problem or was on therapy for any reason. Several animals had undergone a drug trial and these samples were selected against as well. Serum was again stored in -80C freezer until analyzed at Conservation and Research Center (CRC) Endocrine Research Laboratory, Smithsonian Institution, National Zoological

Park, Front Royal, VA. T-tests were utilized to discern any statistically significant results in the mean serum cortisols collected from animals before and after the implementation of the new husbandry systems. Results were considered significant at alpha levels < 0.05.

Results:
The results and simple means of serum cortisols are listed in Table 1. Elephant Nos. #34 and 34 had essentially the same level as cortisol in both systems. Elephant No. 32 had a reduction in the mean cortisol level of approximately 32% (20.84 vs. 14.28 ng/ml) from the FC to the PC system. Elephant No. 304 had a similar reduction of 37% in the mean cortisol (22.59 vs. 14.29 ng/ml). Statistical analyses results reported here (means, standard deviations, t-test results).

Discussion:
Serum was chosen over salivary and fecal sampling as a means to measure cortisol for several reasons. While fecal and salivary cortisol changes can reflect stresses within a reasonable period after the stressor (approximately 24hrs), [1,6] serum cortisols is more likely to be reflective of the stressors closer to the moment of sampling. The methodology is more straightforward and less subject to the hazards for sample storage. Timeliness of the sample result is also a benefit to serum sampling. Blood sampling is a required husbandry practice in all elephant holding facilities belonging to the American Zoo Association. While fecal cortisol samples may be useful to look at over a long term period to evaluate the transition from FC to PC, we choose to additionally look at how one specific task, blood collection, was affected by making this transition. Fecal cortisols have been used to measure stress in transportation and environmental stress in some species, but are not thought to be reflective of the stress in a diagnostic procedure itself. [4] For this evaluation, the lag time period between the potential stressor (blood collection) and the means to measure the stressor are same.

Elephants Nos. 304 and 32 both had significant reductions in the mean serum cortisol levels. Both are in good health and had no apparent inflammatory problems. The logical deduction here is that the sampling process itself is less stressful in the PC management than the FC management. Elephant 34 and 30 had essentially the same level of serum cortisol as measured by the mean in the different management systems. Elephant 34 has developed significant uterine leiomyomas during the time period measured. Elephant 30 has recently had clinical bouts of anterior enteritis and is suspected of having a dietary hypersensitivity to wheat. Even with these two pathological processes, the serum cortisol did not rise.

Elevations in cortisol are quite often explained as resulting from social, behavioral, or environmental causes and little attention is paid to inflammatory causes. Associations between infections and elevated cortisols[3,5] have been noted in wild animals. It is reasonable to assume that if these two processes did not exist, these levels would indeed be lower. Based on the other two elephants, a reduction of approximately 30% could be expected. Overall it appears that collecting blood from the elephants at BGT in the PC system is less stressful that the FC system. As this is an example of how the routine husbandry and medical husbandry is now conducted, it can be expected that the overall net effect is going to be lowered stress in the elephants at BGT.

Acknowledgements
We would like to thank the Pachyderm Palace (Elephant management) Team and the Veterinary staff at Busch Gardens Tampa Bay, but especially the six elephants for their patience with us.

Table 1:
Serum cortisols from Asian elephants at Busch Gardens Tampa Bay in Free Contact management (FC) and Protected Contact management (PC). Dates and results in bold are prior to the change in management systems.

#34 DOB: 1970			#30 DOB: 1972			#304 DOB: 1972			#32 DOB:1969		
	ug/dl	ng/ml		ug/dl	ng/ml		ug/dl	ng/ml		ug/dl	ng/ml
8/27/2002	3.24	32.40	**5/16/2002**	**1.26**	**12.6**	**1/30/2002**	**1.60**	**16.00**	**1/22/2003**	**2.73**	**27.30**
9/4/2002	3.36	33.60	**5/25/2002**	**1.14**	**11.4**	**3/29/2002**	**1.88**	**18.80**	**1/29/2003**	**1.79**	**17.87**
9/25/2002	0.84	8.40	**6/1/2002**	**2.17**	**21.7**	**5/25/2002**	**2.00**	**20.00**	**2/7/2003**	**1.49**	**14.93**
10/2/2002	1.30	13.00	**6/8/2002**	**1.99**	**19.9**	**6/15/2002**	**1.67**	**16.70**	**2/17/2003**	**2.83**	**28.32**
10/8/2002	0.77	7.70	**6/15/2002**	**2.32**	**23.2**	**6/27/2002**	**0.99**	**9.90**	**2/24/2003**	**1.92**	**19.19**
10/15/2002	1.15	11.50	**6/22/2002**	**1.7**	**17**	**7/5/2002**	**1.98**	**19.80**	**3/5/2003**	**1.24**	**12.39**
10/23/2002	2.53	25.30	**6/25/2002**	**1.85**	**18.5**	**7/20/2002**	**4.76**	**47.60**	**1/11/2004**	**2.66**	**26.63**
10/30/2002	1.82	18.20	**7/6/2002**	**2.14**	**21.4**	**8/6/2002**	**5.94**	**59.40**	**3/11/2004**	**1.73**	**17.25**
11/5/2002	2.52	25.20	**7/13/2002**	**2.24**	**22.4**	**8/13/2002**	**1.35**	**13.50**	**4/7/2004**	**4.67**	**46.66**
11/11/2002	3.14	31.40	**7/20/2002**	**2.35**	**23.5**	**8/20/2002**	**1.02**	**10.20**	**5/5/2004**	**3.39**	**33.86**
11/19/2002	1.08	10.80	**8/6/2002**	**1.61**	**16.1**	**8/27/2002**	**1.74**	**17.40**	**5/15/2004**	**1.42**	**14.24**
11/27/2002	0.77	7.70	**8/13/2002**	**1.4**	**14**	**9/25/2002**	**1.43**	**14.30**	**6/1/2004**	**0.69**	**6.92**
12/4/2002	3.54	35.40	**8/20/2002**	**1.37**	**13.7**	**10/2/2002**	**2.95**	**29.50**	**6/9/2004**	**2.35**	**23.54**
12/11/2002	1.47	14.70	**8/27/2002**	**1.58**	**15.8**	**10/26/2002**	**1.53**	**15.30**	**6/15/2004**	**1.12**	**11.19**
4/28/2005	1.91	19.10	**9/4/2002**	**1.44**	**14.4**	**10/30/2002**	**2.81**	**28.10**	**6/30/2004**	**2.25**	**22.54**
5/10/2005	0.70	7.00	**9/25/2002**	**1.12**	**11.2**	**11/11/2002**	**1.21**	**12.10**	**7/15/2004**	**1.08**	**10.78**
5/17/2005	1.81	18.10	**10/2/2002**	**0.87**	**8.7**	**11/19/2002**	**1.26**	**12.60**	6/7/2005	1.70	17.00
5/23/2005	2.29	22.90	**10/8/2002**	**1.58**	**15.8**	**11/20/2002**	**1.38**	**13.80**	6/14/2005	1.25	12.54
5/31/2005	0.88	8.80	**10/15/2002**	**1.2**	**12**	**12/4/2002**	**3.21**	**32.10**	6/23/2005	1.32	13.23
6/7/2005	2.04	20.40	**10/23/2002**	**1.56**	**15.6**	**12/11/2002**	**3.11**	**31.10**	7/5/2005	1.11	11.09
6/14/2005	1.29	12.90	**10/30/2002**	**2.05**	**20.5**	**12/19/2002**	**2.64**	**26.40**	9/2/2005	1.49	14.86
6/23/2005	6.93	69.30	**11/5/2002**	**1.95**	**19.5**	**12/26/2002**	**3.24**	**32.40**	9/27/2005	2.16	21.57
6/28/2005	4.12	41.20	**11/11/2002**	**0.69**	**6.9**	6/8/2005	1.12	11.20	10/5/2005	0.68	6.79
7/6/2005	4.94	49.40	**11/19/2002**	**3.91**	**39.1**	6/14/2005	3.28	32.80	10/20/2005	1.01	10.08
7/14/2005	2.96	29.60	**11/27/2002**	**1.96**	**19.6**	6/28/2005	1.51	15.10	11/14/2005	1.72	17.20
7/19/2005	0.57	5.70	**12/4/2002**	**3.27**	**32.7**	7/6/2005	1.07	10.70	11/29/2005	1.47	14.72
7/26/2005	3.01	30.10	**12/11/2002**	**1.89**	**18.9**	7/19/2005	0.53	5.30	12/14/2005	2.09	20.91
8/2/2005	0.68	6.80	6/21/2005	1.22	12.2	8/2/2005	0.34	3.40	12/20/2005	2.04	20.37
8/9/2005	0.81	8.10	6/28/2005	3.14	31.4	8/26/2005	1.04	10.40	12/27/2005	0.83	8.28
8/23/2005	1.65	16.50	7/8/2005	2.61	26.1	9/1/2005	1.08	10.80	1/3/2006	1.80	18.03
8/30/2005	1.88	18.80	7/19/2005	2.25	22.5	9/8/2005	1.54	15.40	1/10/2006	1.78	17.83
9/6/2005	1.68	16.80	8/2/2005	1.89	18.9	9/14/2005	0.48	4.80	1/24/2006	0.61	6.06
9/14/2005	2.66	26.60	8/9/2005	2.51	25.1	9/20/2005	0.72	7.20	1/30/2006	0.94	9.39
9/20/2005	1.47	14.70	8/16/2005	1.17	11.7	9/28/2005	1.08	10.80	2/10/2006	1.31	13.09
9/27/2005	1.54	15.40	8/30/2005	2.18	21.8	10/4/2005	1.87	18.70	2/13/2006	1.82	18.23
10/4/2005	2.26	22.60	9/6/2005	0.97	9.7	10/14/2005	3.34	33.40			
10/11/2005	0.78	7.80	9/14/2005	1.05	10.5	10/18/2005	1.08	10.80			
10/19/2005	1.46	14.60	9/20/2005	1.36	13.6	11/3/2005	1.21	12.10			
10/25/2005	2.32	23.20	9/29/2005	1.01	10.1	11/7/2005	1.16	11.60			
11/1/2005	3.15	31.50	10/5/2005	1.12	11.2	11/14/2005	2.18	21.80			
11/7/2005	1.52	15.20	10/11/2005	1.43	14.3	11/21/2005	1.60	16.00			
11/14/2005	2.63	26.30	10/18/2005	1.53	15.3	11/28/2005	1.43	14.30			
11/22/2005	1.76	17.60	11/1/2005	1	10	12/5/2005	1.73	17.30			
11/28/2005	0.26	2.60	11/7/2005	2.13	21.3	12/11/2005	2.05	20.50			
12/5/2005	2.15	21.50	11/16/2005	3.23	32.3						
			11/21/2005	1.97	19.7						
			11/28/2005	1.05	10.5						
			12/5/2005	1.92	19.2						
			12/13/2005	1.47	14.7						
Mean FC		**19.66**			**18.004**			**22.59**			**20.85**
Mean PC		**20.68**			**17.368**			**14.29**			**14.28**

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Supporting elephant conservation across southern Africa: the megaparks for metapopulation initiative

Jason Bell

IFAW

Some 350 000 savanna elephants live in Africa - nearly 220 000 of these occur in eight clusters of conservation areas that have been established across eight neighbouring southern African countries. These countries stretch over an area of about 6 million km^2. Elephant numbers are increasing across most of these countries and often come into conflict with people. Elephants also destroy native vegetation and affect habitats for other species in some of the conservation areas in the region. Local conservationists therefore have to manage elephant numbers. Their management options include contraception, culling and translocation. More recently, the restoration of metapopulation dynamics has emerged as an option. Such a restoration effort calls for the development of a series of megaparks that will stretch across the southern African distributional range of elephants. In line with present-day conservation theory, it should lend opportunity for the regional elephant population to stabilize by 1) including both occupied and vacant habitats for elephants, 2) include a full gradient of ecological conditions to allow for asynchrony in sub-population demography, 3) include linkages and corridors to enable dispersal and 4) allow for local extinctions to be followed by colonization events. At the socio-economic and political levels, it calls for regional stability, incentives that recognize sustainable resource extraction as part of conservation, community and political involvement and the delineation of megaparks as ecological rather than socio-economic units. It also calls for the development of a regional conservation management strategy and the development of local conservation management capacity. IFAW is closely involved in supporting research and development into the "megaparks for metapopulation" research initiatives as an alternative conservation management strategy for elephants across the subregion.

Cunningham Stephen Brian

A New Facility Alongside Non-Confrontational Management Equals Breeding Success.

The Park has been open to the public since 1971 and has always maintained a herd of African Elephants, *Loxodonta africana*. The present herd consists of one adult bull, one juvenile bull, four adult cows and two female calves.

Currently we use two types of elephant management for safety reasons. The adult and juvenile bull are both managed through protective contact. The four cows and two calves are managed through a **non-confrontational free contact** method. This has changed from the way in which they were managed seven years ago. Then the elephants were chained over night and through the daytime walked over a distance of 2.4 km to an area within the safari drive, which covered 1000m^2. They were left in this area for a minimum of seven hours then walked back to the elephant house. This was stressful for both staff and elephants. The management method that was used when this regime was in place was free contact as laid down in a lot of elephant training handbooks.

With the arrival of a new curator in 1999 chaining of elephants **stopped**. A new style of elephant management was introduced called non-confrontational management. The main guiding principles for non-confrontational management of elephants are listed below:

- **NO** aggressive or threatening behaviour is used towards the elephant.
- Every command is rewarded by positive reinforcement there is **NO** negative reinforcement.
- To allow the elephant to express as much natural behaviour as possible with little or no human intervention.

The old out-dated elephant house, which was originally built in 1971, was extended. The new facilities within this house permit us to hold a mature bull in musth. The new house has the facility to hold six adult cows in an open pen. There is no separation of the cows at night. There is a facility to isolate an individual cow if necessary, but still retain contact with both the bull and the rest of the herd through bars. The facility also has an outside bullpen. This doubles up as an outside night pen which the cows are given access to. The outside paddock had to be redesigned, as there was only a very small concrete yard. The outside paddock now consists of three different substrates these are as follows:

- Concrete hard standing area of 1.2 acres = 4856 m^2.
- Sand paddock area of 1.6 acres = 6474 m^2.
- Grass paddock area of 9.6 acres = 34803 m^2.

The total area of outside paddocks that we now have is 12.4 acres = 50181 m^2. Within this paddock there is a natural mud wallow and a pool with fresh clean water for the elephants to bathe freely.

Within two years of the new changes to the elephants lifestyles i.e. free roaming paddocks, non confrontational management and interaction between all members of the cow herd, all the cows started to show oestrus cycles when urine sampled. Whereas the first urine samples taken in early 2000 showed none of the cows were cycling. Now in 2006 we have had three calves and are preparing for our fourth in summer 2007.

Within the next two years Knowsley is looking to re-build the old house and incorporate an indoor visitor area. We aim to integrate a weighing scale and a restraint chute for medical purposes into the house, along with other elephant enrichment features i.e. high-level feeding chutes, large rocks and tree stumps for scratching upon.

Using faecal analysis as an indicator of dental condition; a case study at Chester Zoo

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Can changes in captive elephant faeces be used as early signs of dental problems, prompting more specialized dietary management?

Elephant dentition is unique among mammals since they never have more than two molar teeth in functional occlusion in each side of the upper and lower jaw at any one time. They undergo dental eruption 6 times beyond the teeth they are born with and teeth migrate in linear progression (horizontally) along the jaw. As a tooth wears it is pushed forward to the front mouth, the root is absorbed and it slowly forms a shelf which will break off and the remaining fragment be pushed out of the mouth. Molars have pronounced ridges that act as coarse rasps to shred the plant tissue consumed and grinding surfaces must meet correctly in order to break down foods to a more digestible particle size. The final set of molars have no other teeth pushing them forward into position and in time they too will wear down, greatly decreasing the elephants' ability to grasp and grind feed. Incomplete processing of food due to malocclusion or age-related dental changes leads to incomplete digestion and poor nutrient absorption, with weight loss, changes in body condition and demeanour likely symptoms. Dental abnormalities may also cause more acute gastrointestinal problems as a result of inadequate reduction of plant fibres, such as colic, intestinal impactions or constipation.

The herd at Chester comprises 9 Asian elephants *Elephas maximus* (2♂: 7♀). Keepers observed two of the females (Sheba and Maya) regularly passing faeces containing visibly longer fibres, relative to faeces from the other elephants eating the same diet. At 50 years old, poorer chewing ability was not unexpected for Sheba. Maya's provenance is less certain thus the change in faecal quality might indicate her estimated age of 34 years to be incorrect; alternatively, other dental or digestive issues may be implicated. To investigate further, faecal samples were collected during July and August 2006 from the focal animals (Sheba and Maya) and two other members of the herd as controls, chosen due to their comparable size and ease of sampling. A representative bolus was weighed, measured and photographed. Fibre composition was determined by sub-sampling faecal material both on the surface and from inside each bolus. Samples were washed to remove fine particulate matter, air-dried and the fibres remaining sorted according to length. Faeces were also sent for chemical analysis to assess nutrient digestibility relative to the other elephants. Fibre length of forage (grass hay and fresh grass) was measured. Observations of feeding behaviour and food preferences were made and tooth condition was assessed by a combination of oral palpation and video footage of chewing action.

Dental abnormalities in wild elephants ultimately result in death due to starvation; in captivity the physical form of the diet can be adjusted to assist in the particle size reduction normally accomplished by chewing. We will present results of the analyses described above and discuss dietary management options.

The crisis in captive elephant welfare and management in India: Report from an all-India survey

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Compassion Unlimited Plus Action (CUPA
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The management, health-care and trade in captive elephants in India have not been surveyed or analysed in a comprehensive all-India basis. Here we report our experiences of a nation-wide project (Survey of Captive Elephants and Mahouts – SCEM - in India) currently underway to assess the status of captive elephants, their owners and mahouts in all provinces.

Our initial results indicate that among Assam, Bihar, Kerala, and Jaipur, there is tremendous variation in a number of variables measured including preferences, management styles, elephant trade and use, elephant health, care, age and gender classes.

We found that Kerala represents an intensive, commercial usage of the animal in temples as display during festivals. Jaipur supports a population of 115 elephants exclusively as appendages to the tourist trade. Kerala shows a strong preference for male elephants, while in Jaipur only female elephants are preferred. In both states, the demand is spiked by a voracious trade in illegal acquisitions of animals for commercial returns.

Bihar seems to be traditionally and today, the center of active open trade. The Sonepur Mela along with cattle trades in elephants and there is a true to style display of feudal wealth and class power. Animals showed a predominance of male tuskers. Females and juveniles constituted 43% of the display population. Most were sold, exchanged or replaced, depending on the price commanded.

Assam, the classical elephant country, seemed the most suited to elephant-keeping but in spite of having well managed camps and the most relaxed population of captive elephants, the sheer number of calves present a very vulnerable group. Assam's relative distance and isolation from the rest of India has assured an effective illegal trade encouraged by a lax government, political instability and poverty. Though captive elephants have got displaced from the timber trade after the 1996 ban, yet Assam's lush landscape and perennial sources of water ensure survival of the animals. The availability of both captive bred and wild calves, juveniles and sub adults have been feeder to southern and central Indian demand from ashrams and temples.

Overall, our survey indicates that captive elephant welfare in India is in crisis. In all the provinces, treatment and training of elephants, welfare standards and in the implementation of existing laws, India falls well below standards of other nations in Europe, UK, and USA. Similarly, mahouts and trainers in charge of elephant care are marked by high employment turnover, poor training, inadequate salary and housing, and are often substance and alcohol abusers.

We argue that elephants cannot be used for trade, as commerce and welfare are unlikely partners. Unless all efforts are made in the field of awareness, creation of rescue centres, and alternate livihoods of people dependent on this trade, the captive elephant in India is threatened by ill-heath, faulty systems of management and lack of training both in the veterinary and caretaker skill and knowledge.

Hand-rearing of elephant calves: a comparison between common milk replacer regarding their physiological efficiency

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When elephants are held under human care it is sometimes necessary to hand-rear orphaned calves or young elephants, whose mothers refused lactation. The nutrient of milk is specific for each mammalian species, although the major constituents, water, fat, protein, sugar and ash, are the same. To ensure normal growth and development of a hand-reared calf, the best nutrition based on the knowledge of the exact composition of elephant milk has to grant to the infants. The available literature about the composition of elephants´ milk is very limited and the information about the nutrient contents varies a lot. This might be due to many influencing factors, like individual variation, nutritional status of the cow, lactation interval etc. Stage of lactation has also a great effect on the milk composition, which is usually neglected during hand-rearing of elephant calves.

This study deals with a comparison between commercial milk replacer regarding their physiological efficiency in context to the natural composition of elephants´ milk in dependency of the stage of lactation.

Milk analyses of an African elephant (*Loxodonta africana*) were done in the zoological garden Schoenbrunn in 2001/2002. 48 milk samples were collected weekly in the first year post partum. The major components, fat, protein, lactose and pH were detected after freezing via IR-spectroscopy (MilkoScan FT 6000). Fat content was analysed with Roese-Gottlieb and the isolated fat was examined for fatty acids using gas chromatographic analysis.

The results of milk composition in this investigation were compared to information in previous studies and were used for verification in the effectiveness of different milk replacer.

There are just a few milk replacer formulated especially for elephant calves and their composition are different. In some places, when these milk replacer are not available easily, milk replacer for humans or the milk of other mammalian species are used although it is unsuitable for elephant calves as the nutrient of elephant milk differs in some points and health problems often appear. First and foremost the lipid fraction varies a lot to other species. The amount of short-chain saturated fatty acids (Capric) is extremely high. When young elephants are hand reared it is difficult to overcome this problem, as it is rare for fats to contain such large amounts of Capric acid. Due to its chemical composition coconut oil would appear to be the most suitable substitute.

This study sums up the complexity of feeding young elephants. Differences between African and Asian elephants are taken into account.

The effect of human contact on African elephant heart rate

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Abstract:
We studied the effect human touch upon the heart rate of an adult female elephant. In horses and dogs it has been found that grooming or petting lowers heart rate. Our data suggests that this is true in elephants, also. Our preliminary results suggest that direct human/elephant contact can help calm the animals and thus can be useful in the management of captive African elephants. Future studies will look at some of the factors that might affect this response, including the elephant's familiarity with the human, and the human's level of excitement as reflected in his or her heart rate.

Introduction:
The role of human contact in the management of captive elephants remains a topic of debate. The debate involves many issues (health, safety, tractability, etc), some of which, e.g. health, are amenable to experimental study. We looked at the effect of human touch on an elephant's heart rate, as an indication of the effect of such contact on the animals' health and well-being. There is a large body of research on dogs (e.g. Lynch and Grant, 1968) and horses (e.g. Lynch et al 1974) that show that human touch can lower the animal's heart rate, even when the animal is stressed.
The purpose of this study was to provide preliminary data on whether this is true in elephants, also. In the absence of physical exertion, changes in heart rate can be taken as a rough index of changes in excitement or stress. Thus a decrease in an elephant's heart rate during human touch would indicate that such touch has a calming effect, which has implications for the management of elephants in captivity.

Methods:
We used a Polar Equine heart rate monitor to record the heart rate of an unrestrained adult female elephant under the following conditions:

- Baseline: 5 minutes with no contact with the handler (visual or tactile), followed immediately by
- Experimental: 5 minutes of tactile contact with the handler.

One experiment was conducted each day at the same time of day. The experiment was repeated 6 times for each keeper. The keeper each day was selected at random.

Results:
Because the elephant was unrestrained, she was free to move about the exhibit. When she did this, she would typically move away from the front of the exhibit and stand in another part of the exhibit without moving (thus with little effect on her heart rate). The handler did not follow her when this occurred, and thus the amount of time the elephant actually received human contact in the experimental trials varied. Our results show that when contact occurred for more than 50% of the time, the heart rate decreased, both when compared to the trial's baseline (Figs 1 &2), and as an absolute measure (Figs 3&4)

Conclusion:
While this experiment needs to be replicated, human contact does does appear lower the African Elephant's heart rate. The amount that the heart rate is lowered is dependent on the amount of physical contact the elephant receives from the human handler.

While there are many factors involved in deciding whether free or protected contact is appropriate for a given situation, the calming effect of human touch on an elephant should be one of the factors considered.

Figure 1: Change in elephant's heart rate relative to baseline for Handler #1

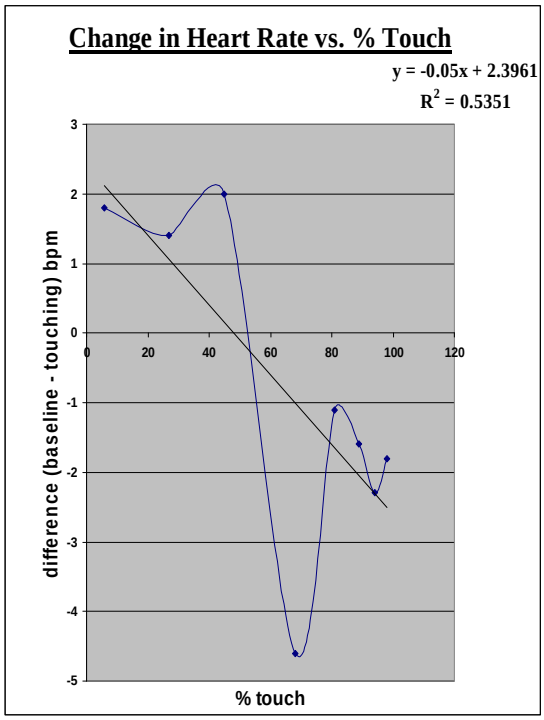


Figure 2: Change in elephant's heart rate relative to baseline for Handler #2

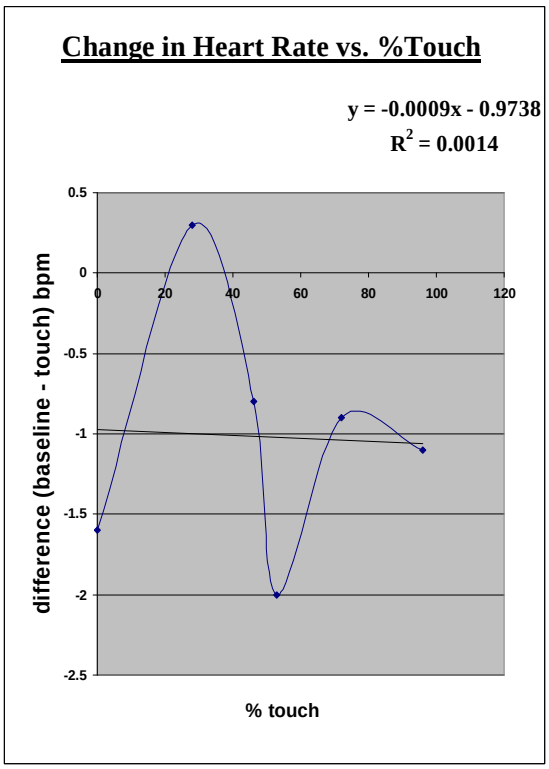


Figure 3: The elephant's heart rate when touched by Handler #1

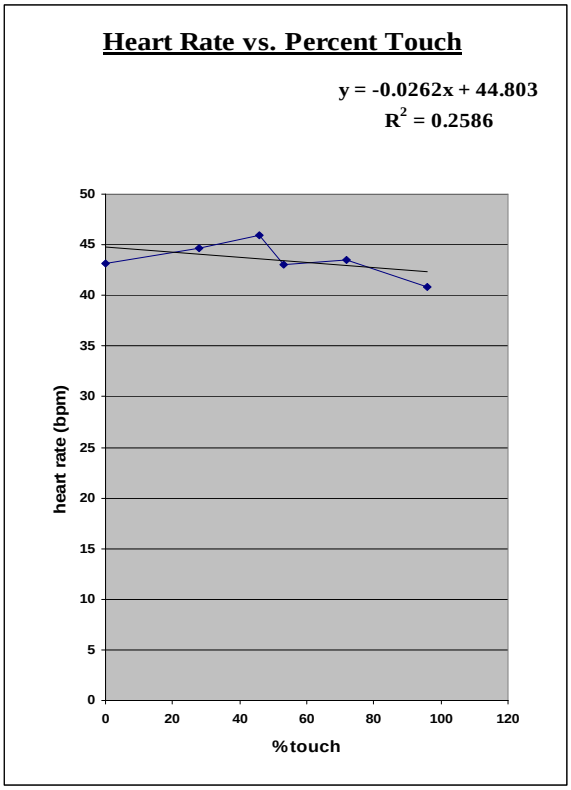
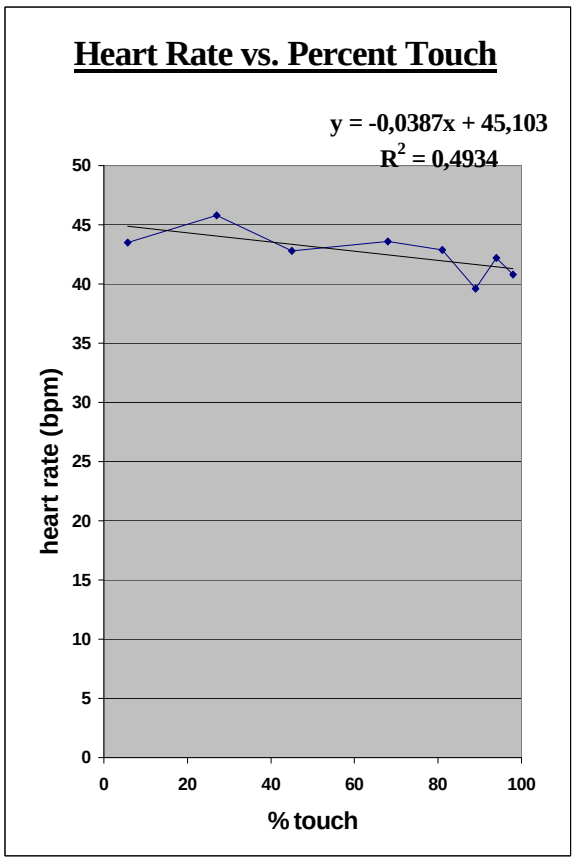


Figure 4: The elephant's heart rate when touched by Handler #2



Sound invention in African elephants (*Loxodonta africana*)

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The biggest terrestrial mammal, the African savannah elephant (*Loxodonta africana*), lives in a fission-fusion society (Moss & Poole, 1983), and is well known for it´ s complex acoustic communication system and the use of different types of calls, especially the low-frequency rumbles (Fig. 1) for long distance communication (Langbauer, 2000).

Rumbles are graded in nature with no classification into distinct subtypes (Soltis et al. 2005; Lintner et al., in prep.). In addition to the low-frequency rumble, the call repertoire of elephants includes high-frequency calls like trunks calls (trumpet and snort), barks, roars, screams, distress calls and cries (Langbauer, 2000). African elephants are capable of vocal learning and imitation (Poole et al., 2005). The African elephant is thus a member of a disjoint group of vocal learners that further includes birds, aquatic mammals, bats and humans (Poole et al., 2005).

African elephants have also the ability to invent new and idiosyncratic calls (Poole et al., 2005). Elephants possess an extraordinary vocal flexibility, which might be due to their vocal apparatus. The hyoid apparatus and associated laryngeal musculature of elephants differ from the basic mammalian scheme. The hyoid structure has five rather than nine bones, and part of these bones are joined loosely to the crania via muscles, tendons, and ligaments (Langbauer 2000, Shoshani, 1998), resulting in a greater flexibility of the larynx, which might enable elephants to produce a variety of new and strange sounds.

In this paper we describe three different types of sound inventions recorded of three African elephants, one adult female (“Sabi”), one male calf (“Abu”) and one female calf (“Mongu”) at the Vienna zoo, Austria in 2003 and 2005. The whole group of African elephants at the Vienna zoo consisted of one adult male, three adult females, one male and one female calf (Table 1). The Females were kept separately from the male. The elephants spend the night unchained in the indoor stall (2100 m^2) within the family and are released into their outdoor enclosure (4700m^2) for the day. During summer (May to October), they can also use the outdoor enclosure during the night. The Bioacoustic Group has recorded and analysed the calls of the elephant group at the Vienna zoo since 2001. Recordings were made with a DA-P1 DAT recorder and the condenser microphone AKG C 480 B with the omni directional condenser capsule AKG CK 62. Data recording took place both indoors and outdoors and the distance between the elephants and the microphone ranged from 1 to 30 meters. For the analysis of the recorded signals we used S_TOOLS-STX from the “Acoustic Research Institute of the Austrian Academy of Sciences Vienna” and defined acoustic and physical properties.

In the first case we recorded an atypical vocalisation produced by the female calf “Mongu” (Fig. 2). The sound production of “Mongu” took only place in combination with constructions next to the elephant-park. The signals from “Mongu” were similar to the noise of construction equipment.
The second case of sound invention was produced by the male calf “Abu” with his trunk (Fig. 3). While “Abu” and the other elephants of the group were standing in the outdoor enclosure waiting for their daily care and shower routine in the indoor area, “Abu” emitted a strange trunk sound. He forced air out of the trunk while pressing the tips of the trunk together. The trunk has been additionally winded.

The final case of sound invention was made by the adult female "Sabi" in the outdoor enclosure of the elephant-park (Fig. 4). The elephants were standing outdoors next to the door and were waiting for to come in the indoor enclosure. "Sabi" pressed her lips together, forced the air out of the mouth and emitted a novel sound.

The results show that each call has a unique structure (Fig. 2, 3 & 4) and there exists structural variation between the typical African elephant calls and the three atypical calls from "Mongu", "Abu" and "Sabi". Moreover, the sound productions obviously had no communicative function since none of the other elephants of the group showed a behavioural reaction. All three calls were regularly produced and heard by the keepers.

The idiosyncratic sound made by "Mongu" may also present evidence for vocal learning. Recent studies on vocal mimicry indicate that African elephants are able to imitate strange sounds, like truck-sounds (Poole et al., 2005). Future studies should confirm whether the novel calls made by "Mongu" exhibit vocal imitating or not.

One possible explanation for the strange trunk call made by "Abu" and for the sound invention emitted by "Sabi" is that these calls might function as some kind of self-entertainment.

Inventing and mimicking sounds may play an important role in the vocal development of elephants. These findings support the vocal variety already shown in infant elephants (Stoeger-Horwath, 2006) and demonstrate the extraordinary vocal flexibility of the biggest terrestrial mammal, the African elephant.

Acknowledgment:
We thank the Vienna zoo to undertake the research in Vienna. Further, a special thank to the Vienna zoo, the FWF Austrian Science Fund and AKG Acoustics for the financial and the equipment support.

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Table 1. Study animals at the Vienna zoo

Name	Gender	Birth	Age
Tonga	Female	1985	21
Sabi	Female	1985	21
Drumbo	Female	1975	31
Abu	Male	2001	5
Mongu	Female	2003	3
Pambo	Male	1992	14

Legends:

Figure 1: Spectrogram shows a low-frequency call, the rumble, produced by an adult elephant at the Vienna Zoo.
Filter Bandwidths: 2 Hz, Overlap: 75%, Duration: 6,29 s, Fundamental frequency minimum (f0 min): 13,158 Hz, Fundamental frequency maximum (f0 max): 17,248 Hz, Fundamental frequency mean (f0 mean): 15,803 Hz.

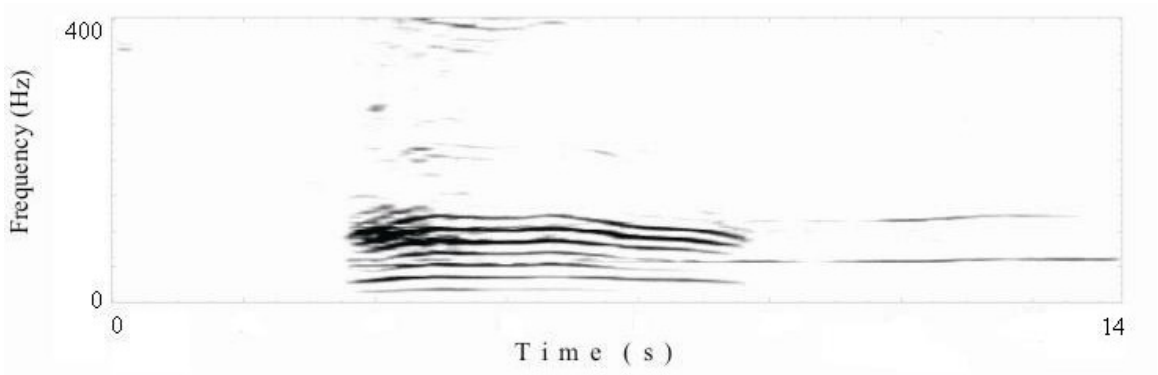


Figure 2: Spectrographic presentation of "Mongus" novel call.
Filter Bandwidths: 22 Hz, Overlap: 75%, Duration: 2,772 s, f0 min: 60,825 Hz, f0 max: 205,516 Hz, f0 mean: 101,469 Hz.

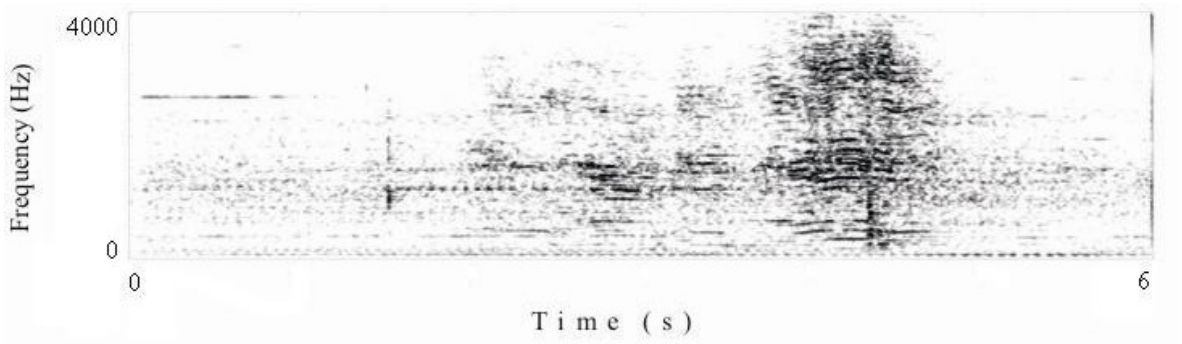


Figure 3: Spectrogram shows the strange trunk call made by the male calf "Abu".
Filter Bandwidths: 22 Hz, Overlap: 75%, Duration: 1,358 s, f0 min: 70,705 Hz, f0 max: 134,6 Hz, f0 mean: 105,963 Hz.

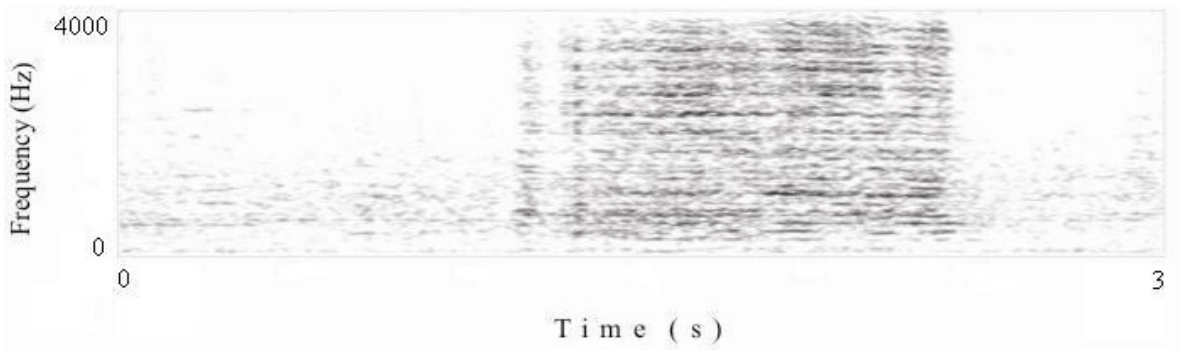
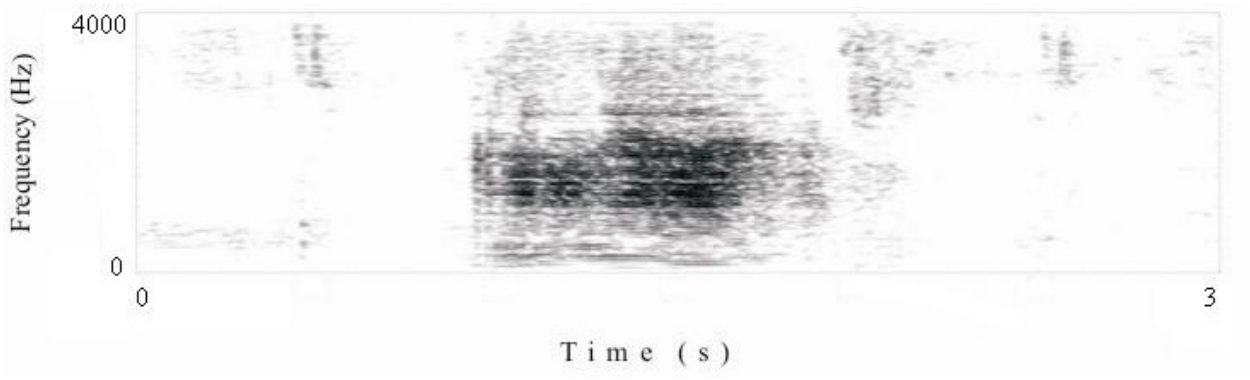


Figure 4: Spectrographic presentation of "Sabi" strange call.
Filter Bandwidths: 22 Hz, Overlap: 75%, Duration: 0,997 s, f0 min: 56,875 Hz, f0 max: 134,9 Hz, f0 mean: 83,751 Hz.



Towards 24 hours of enrichment

Camilla Norgaard

Copenhagen Zoo

Time budgets and activity patterns for the Asian elephants at Copenhagen zoo were surveyed after 15 nights of video recording. Acknowledging the elephant's nocturnal behaviour we will be able to enrich their night environment without interfering in desired behaviour. Six behavioural aims were reached as an obtainable goal for further enhancement of the natural behaviour - all around the clock.

The first African elephant project in Hungary

Endre Papp and László Gajdos

Sóstó Zoo

The first and only elephant house in Hungary was built 140 years ago in the Budapest Zoo, which is home to two Asian elephants.
Sóstó Zoo, which is located in Nyíregyháza, a town of 120 thousand inhabitants in the eastern part of Hungary, was established ten years ago. In 2006, as conclusion of its ten-year development programme, the Zoo built an elephant house and runway for African elephants.

The house covers 600 square-metres, and contains four 37-square-metre booths, and a 300-square-metre common area with a small pool. The height of the building is 11 metres, and in winter, visitors can watch the animals from upstairs through safety glass.
The zookeepkers operate the stainless steel mechanical doors, and thus separate the animals, from a suspended corridor located above the booths.
When handling the animals, they apply protected contact principle.

The building was designed to house four female African elephants, and the management is about to start the construction of a building for male elephants. One side of the elephant house communicates with a one-hectare runway, surrounded by a dry ditch. The animals can walk down from the runway to the ditch, which is bordered by a three-metre-high stone wall.

When entering or leaving the building, the animals have to go through an equipment that is suitable for constraining them if a need to treat the animals arises.
The runway includes a large natural pool, where the animals are free to wallow.
On the other side of the building, a 3,000-square-metre runway is found, built in a similar system as the one described before, and is suitable for holding one male elephant. The new elephant house to be built will be connected to this runway.

Currently, the Zoo has a six-year old male elephant, which came from the Warsaw Zoo through the EEP, and a 16 year old female elephant, named Yoki and her one-and-a-half-year-old baby boy, which came from the Tel Aviv Zoo. The project aims to build up a breeding group of four females and one bull.
For now, the male and the female elephants can only see each other from a distance but they do communicate and watch each other.
Under the supervision of Zoltán Takács, chief zookeeper, a staff of five people take care of the elephants from 7 a.m. to 7 p.m. Veterinary care is provided by the Zoo's young vet, Dr. Endre Papp.

Foot diseases in the working elephants in eastern India

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Introduction:
The foot of an elephant is a highly evolved appendage that can not only support the enormous weight of the largest terrestrial mammal but also can withstand enormous concussion as well. It however appears that even though the anatomical structure of the foot is eminently suited for elephants in the wilderness; in captivity, foot diseases probably constitute the most numerous and potentially damaging of ailments that torment them.

In the decade since the blanket ban on the timber industry in India's North East by the Supreme Court of India rendered an overwhelming number of the region's elephants engaged in logging jobless, incidences of foot problems in captive elephants have perhaps increased due to neglect and lack of wear.

The practice of keeping elephants in captivity in India's North East, particularly Assam is age-old and in spite of the ban on the timber industry, the single largest occupation of the captive elephant population here for over a century, elephant owners are continuing to earn from alternative engagements. The elephants are an indispensable part of wild life management in the Forest departments as they are extensively deployed the anti-poaching patrols, communications, transportations and eco-tourism. Modern day trend of using captive trained elephants as *koonkies* for chasing away the crop raiding wild herds from human habitations is emerging as a promising way of countering human-elephant conflict. What unfortunately remain to change significantly are management practices for keeping elephants in captivity making the elephants vulnerable to numerous diseases and ailments. An overwhelming number of these captive elephants particularly suffer from numerous foot ailments as a result of being tethered in unhygienic surroundings and these afflictions often aggravate due to utter negligence and lack of awareness regarding proper care and treatment. Foot problems are seen in 50 per cent of captive Asian elephants at some time of their lives (Csuti *et al.* 2001).

For instance, Pododermatitis, which is a very painful chronic condition characterized by proliferative or degenerative lesions in and around the sole of the foot of elephants, and which is complicated by pyogenic and fungal infections, is widespread among the region's captive elephants. What is of concern is that these affections are either extremely difficult to cure by ordinary means or are not curable at all. Chronic foot problems may also lead to serious disabilities or may even result in deaths of elephants. It is therefore extremely important to detect these affections at an early stage and then seek proper treatment.

No precise and extensive data regarding the incidence of foot problems of elephants in eastern India, home to perhaps the largest captive elephant population in the world, is available as any focused and extensive study embracing the entire population over a significant period of time is yet to be carried out. The authors can however authoritatively claim from the experience of their clinical practice with the region's elephants that incurable foot diseases constitute one of the most frustrating aspects of treating the region's captive elephants and have witnessed several cases of permanent disabilities afflicting working elephants arising out of chronic foot ailments. The author's are also therefore in a position to claim that the most effective way of dealing with this widespread problem is prevention and in order to ensure that, periodic pedicure of

elephants in captivity is *de rigueur* and should form an integral part of modern management practices of captive elephants.

The diagnosis and treatment of foot diseases necessitate an understanding of the anatomy of foot and pathogenesis of foot affections that occur following these infections. The present paper is aimed at documenting the findings of a study undertaken under the aegis of the Project Elephant Directorate, Ministry of Environment and Forest, Government of India, New Delhi; part of which is documented in the present communication. The incidence of various foot affections were studied in the selected captive elephant populations of the region in respect of the presence, extent and duration with special reference to different keeping conditions viz. zoos, camp elephants of wildlife departments and the logging elephants of the private owners. The type of lesions, clinical symptoms and isolation and identification of the microorganisms causing the diseases were also undertaken.

Materials and Methods:
The present study is a survey conducted (year 2003-2005) in different areas of the region including Assam, Arunachal Pradesh and North Bengal and randomly selected representative elephant populations were screened and various incidences of foot affections and pedicure practices were recorded. Altogether 312 elephants were studied out of which 72 were from North Bengal, 28 from Arunachal Pradesh and 212 from different areas of Assam. In elephant population studied in Assam, 126 elephants belonged to the Forest Department, Government of Assam and deployed in the various parks and sanctuaries such as Kaziranga, Manas, Nameri, Orang, Pobitora, Sonai-Rupai and Guwahati zoo and the remaining 86 was privately owned. All the 72 elephants of North Bengal belonged to Jaldapara and Gorumara forest camps and a moving circus and all 28 elephants studied in Arunachal Pradesh were privately owned logging elephants.

Incidence of pododermatitis was studied in relation to its type, age, sex, limbs, season, different keeping conditions (Substrate types) and work assignments. The extent as well as the duration of the foot lesions was also taken into consideration during the study. Lesions were classified according to gross tissue changes (erosive/ vegetative), appearance (dry/ moist) and location (nail, interdigital space, pad-skin junction or pad).

All the animals were examined thoroughly for any gross foot abnormalities in the standing position, and then the animals were allowed to walk to identify any signs of lameness. The affected limb showing lameness or any gross foot abnormalities were examined in detail in recumbent position after proper cleaning of the foot region. The postural changes of the limbs were also examined in the standing position .The sole of the foot was examined for cracks, overgrowth of tissues or over wear. The nails were examined for their overgrowth, ingrowths, splitting and ring formation. The interdigital space was examined for infection, overgrowth of cuticles and abscess.

Ascertaining Causative Agents: Samples for investigation of bacteria, fungi or parasites associated with different foot lesions of afflicted elephants were collected from the depth of the lesions with the help of sterile cotton swab and examined and classified following standard methods.

Results and Discussion:
Incidence: Percentages of elephants affected by various kinds of foot afflictions in Assam were as follows: Kaziranga-38.00, Orang-27, Manas-30.77, Nameri-25, Pobitora-37.50, Guwahati Zoo-20 and private elephants 78.65. The private elephants of Arunachal Pradesh had a much higher incidence at 82.14 and the camp elephants of North Bengal had lowly 27.77 percent afflictions involving some structure of the foot. Overall, 49.06 percent of the elephants had foot afflictions. In spite of the near natural living conditions, half of the captive elephant population had foot afflictions and the affected numbers was comparable to that of the western elephant holdings (Csuti *et al.* 2001).

Substrate wise, the North Bengal elephants has a dry sand and pebbled condition, Arunachal Pradesh elephants live and work in high and hilly rocky mountainous conditions and the privately owned logging elephants of Assam also work in similar conditions except three months break off period where they are

shifted to their owner's places in the villages in the plains to live in muddy conditions. Out of the camp elephants of Assam, Manas has conditions similar to that of North Bengal and conditions in the rest of the parks remain muddy for about 8-9 months of the year. Observations from the present study indicate that muddy conditions were more likely to cause foot afflictions. The logging elephants had a much higher incidence of foot afflictions due to greater exposure to injuries from rocks and logs and lack of foot care. In comparison to the departmental elephants, foot care practices were abysmal in the logging elephants of both the states.

Sex wise, males (62 out of 118) had a higher incidence (52.54 per cent), compared to the females (95 out of 194) with 48.97 per cent of foot afflictions. Healthy male elephants in the middle age group kept on good diets generally develop *Musth* and had to be kept chained for months, making maintenance of stall hygiene and administration of foot care difficult and therefore, making them prone to foot afflictions more easily compared to the females that were generally cooperative to the administration of foot care.

The present study also revealed that advancing age also progressively increased incidences of foot afflictions. Highest incidence of foot affliction was recorded in the elephants of 50years and above age group (76.92%), followed by 41-50 (76.66%), 31-40 (70.02%), 21-30 (52.38%), 11-20 (37.14%) and least in the 0-10 (22.80%) years age group. A detailed look into the type of afflictions revealed that lesions of infectious origin were more frequent in the older elephants and lesions of traumatic origin were frequent in younger age groups. Various organisms, later invaded the injuries that the elephants received while young, and when not cared properly led to infections. Obviously, ageing also compromises the tissue resistance to injuries and infections; besides arthritis and reduced activities also make the older elephants prone to foot afflictions (West, 2001). The reports of other western zoos also mentioned higher incidences of foot afflictions in the animals of higher age group (Wayne *et al*. 2001).

Some interesting observations were made while studying the limb wise distribution of the various foot disorders. Percentage wise, the hind limbs had significantly higher incidences of foot affections (40.35% of all hind feet) than the fore limbs (26.63%). In 33.33 per cent elephants, lesions were encountered in all the four legs.

Affections like split nails, *kari* (septic degenerative or proliferative pododermatitis in the sole-heel junction) cracked sole, and cracked heel were more frequent in the hind feet. Overgrown cuticle, overgrown sole, ingrown nails and laminitis rings were frequently encountered in the forefeet. Most of the lesions also affected the contra lateral limbs.

Different kinds of foot lesions: A total of 14 different foot lesions were recorded in the study population in the present investigation.

Over grown nails: A very high incidence (20.57%) of overgrown nails was recorded from the elephants in the present study. Overgrown nails were generally due to lack wear, which was mostly due to inadequate exercise of the animal and wet substrate conditions. The nails became oddly shaped, roughened having a layered appearance. Fowler (1978) observed overgrown nails extending as far as 12 to 25 cm beyond the foot level. Over growth of the nail led to the splitting of the nails.

Overgrown cuticle: Overgrown cuticles appeared as a roughened area of skin over the coronary band proximal to the nails. In some cases, the cuticles appeared between the toes causing impediments in the locomotion and resulting in lameness. The percentage of overgrown cuticle was 13.54 and was more frequent in the forelimbs. Over growth of cuticle was painful to the elephant. Elephant feet without cuticle trimming developed fluid pockets behind the overgrown cuticles. It appeared that when the sweat gland, which sit around the curve of the nails are covered by an untrimmed cuticle they became locked, and small pockets of clear fluid accumulated. After cutting of excess cuticle and drainage of the pockets the elephant recovered.

Split nails: Breaking of a stride over the elongated toe put undue strain over the toe and led to its splitting. Generally middle toe of the hind leg was affected with this condition (11.19%) and bilateral involvement was more common. The split which started at the free border, extended upwards and even reached up to the coronary band (Fig-1) into the sensitive laminae causing severe pain in several cases. The split was filled with mud and grass and were nidus for infections and pain. Split nail condition was generally associated with overgrown sole of the toe region, probably due to shifting of weight towards the heel or might itself have been the cause of the splitting. An effective technique was trimming the smaller side of

the crack so that it did not bear weight (Balasko, 1997). To decrease weight bearing, the side of the crack needs to be rasped and trimmed every 14 to 30 days with an equine hoof knife. Although the acrylic and epoxy patches were not used during the study, they are reported to be effective in the treatment of extensive nail cracks (McConnell, 1996, Rakes, 1996). Moist conditions softened the nails and inadequate wear or trimming puts unusual pressure on the softened nail, causing it to split (Fowler, 1978). The findings in the present investigations corroborated to his observations, only except that split nail conditions were also a common malady in the dry substrate.

Fig. 1

Cracked sole: Cracked sole condition occurred in 9.38% of the total affections in the present study. This condition was observed more frequently in the older age group. Contrary to the observation of Fowler (1978), the cracked sole condition was more common in the dry substrate. Those animals affected, had cracked sole involving all the four feet (33.33%), which also indicated the fault with the substrate. Dry conditions associated with the loss of elasticity of solar tissues in older elephants were probably responsible for cracked sole condition. Cracks are normal in the pad of an elephant's foot, but without proper care, even these could lead to problems (Roocroft and Oosterhuis 2001).

Pitted sole: An interesting appearance of the sole that could be described as pitted sole was occurring in 9.11% out of the total affections. This condition did not cause any lameness and was mostly seen in the elephants of the forest department and in both dry and moist substrate. Perusal of available literature revealed that no previous workers have reported it or may be that the similar condition did not occur elsewhere. It appeared that the gyri would only be bearing the weight of the animal and the unequal weight distribution might lead to some complications in the long run. The foot pads of the elephant in the wild are not smooth or manicured; they have deep grooves and cracks. Excessive trimming or slicing the pad of an elephant foot is a common practice in the western facilities. The deeper the trim the lighter the sole of the foot becomes. Sufficient pad needs to be left intact. The elephant should not feel pain when walked on hot ground and rocks. During the trimming of the sole the bleeding from the sole should be avoided. If the pad was trimmed too thin the elephant could cause substantial damage to itself Csuti *et al.*, (2001).

Kari (septic pododermatitis): Though this disease occupied a relatively low percentage of the affections (8.33%), it was the most dreaded and worst kind of foot problem. It is a very painful condition characterized by proliferative or degenerative lesions in and around the sole of the foot of working elephants, which was frequently complicated by pyogenic and fungal infections (Fig-2). These affections were also difficult to treat by ordinary means. Most of the affections in the present investigation were recorded from the moist substrate and history revealed that the beginning was generally after the flood season or after an episode of *musth*. Higher incidences of *kari* could be correlated to dirty substrates particularly of elephant excreta origin. Hind limbs were more frequently affected (65.62%). The reason for the hind limbs being more susceptible was probably the way the male elephants are hobbled during *musth* at the hind legs over the same place for a considerable length of time without provisions for cleaning the excreta. Microbial examinations of the lesions revealed involvement of several bacteria and fungi. Steel (1885) also identified fungal infections usually occurring round the rim of the back feet, at the edge of hoof slipper.

Fig. 2

Fig-2: Very chronic case of Kari (Septic pododermatitis).

The disease first appeared in the sole-skin junction at the rim and mostly on or near the heel area. In the beginning, the lesion appeared as a crack in the area, exuding a moist sero-mucous secretion. Favourable moist conditions allowed the lesion to expand both sideways and downwards and even under the nail. Interestingly, the lesions did not show tendencies to grow upwards to the skin. In very long standing cases, extension of the lesions eroded part of the footpad exposing inner soft tissues and caused lameness. In two very chronic cases, extension of the lesions caused sloughing off the toe nails as was observed by Gilchrist (1841). The author attributed sloughing of the nails to internal extension of the *kari* under the nail having no vent for drainage. Steel (1885) identified *Kari* as a penetrating sore and noted that neglected *Kari* leads to a condition similar to "Quittor".

Overgrown sole: Out of various foot affections, overgrown sole occurred in 7.29% of the cases. Inadequate and uneven wear, because of faults in weight distribution; faulty conformation, complementary lameness, moist substrate and lack of exercise (walking) were the reasons for the occasional overgrown sole. The soles appeared ragged, irregular, and layered similar to the observations of Fowler, 1978. The overlapping layer formation led to lodgment of small pebbles and hardened coal tar between the layers and was the cause of lameness, pruritis, fissures, secondary infections and abscessation and complementary over worn sole in the healthy part (Fig-3).

Fig. 3

Over worn sole: Over worn sole constituted 5.97 per cent of the feet maladies in the present investigation in the affected elephants. The elephants when made to work in moist substrate constantly and forced to work on hard abrasive surface might cause over wear of sole. Fowler (1978) also reported similar observation.

Cracked heel: Cracked heel was generally found in elephants of the middle age (7.03%). It was mostly seen from the dry substrate. In the elephants of the private owners the incidence was more. Cracked heel can be attributed to constitutional causes, and it is a serious unsoundness owing to its liability to recur every rain. The junction between the sole and the skin in the hind part of the foot becomes dry and starts

cracking. Discharge may also come from the cracks. These cracks usually lead to infection from the ground, which become chronic in nature if remained untreated.

Ingrown Nails: Ingrown nails (3.19%) were generally seen in elephants suffering from chronic laminitis. The phalanges get rotated and the nails grow in different direction. Elephants especially those working in muddy substrate were liable to ingrown nails. The ingrown nail also caused pain and lameness. The nails generally grew obliquely downward. These nails can be trimmed with the help of a short pointed knife and its presence reflected lack of even minimum of foot care.

Laminitis: Both acute laminitis causing severe pain with lameness and chronic laminitis with rotation of toes were recorded**.** Laminitis rings were seen on the nails of many middle aged and older elephants. Cases of acute laminitis could be connected to long road marches on rocky surfaces without sufficient rest particularly in unconditioned elephants. High fever, increased heat around the footpad was noticed and in a severe case, the elephant used his knees to progress (Fig-4).

Fig. 4

Fig-4: Acute laminitie rendering the elephant unable to walk.

Fig. 5

Fig-5: Inner aspect of the toe nail showing sensitive laminae

Evans (1910) opined that in laminitis the sensitive sole is the chief seat of inflammation; the lameness was always severe, so much so that the animal was unable to stand for any time. There was heat and tenderness all about the foot and there was oozing at the margin of the hoof slipper. Steel (1885) mentions that shedding of the hoof slipper was not uncommon on account of effusion between the horny structures and the sensitive parts, which produce them. The author also noted that death has been known to result from mortification. In the event of the hoof-slipper being cast, the foot must be kept perfectly clean and thoroughly protected till a new slipper has been produced. Fowler (1993) questioned the concept of the disease laminitis on the ground that elephants' nails do not have laminae; thus they could not develop laminitis. Interestingly, in another related study, we found (unpublished) that the elephants do have a thin sensitive laminae on the inner side of their nails (Fig-5).

Injury: Injuries to the foot of the elephant was not very uncommon (2.30%). Several types of injuries were recorded; some sharp objects like a nail or a sharp piece of bamboo, shoot of burnt *birina* grass (*Vetiveria zezonoid*) or even a shed antler caused penetrating injuries to pad of the sole.

Abscess: Abscess was commonly seen in many captive elephants, and their causes are usually not obvious (Roocroft and Oosterhuis 2001). In the present study incidence of abscess was found in only 0.78 per cent. Abscesses can also occur in pad of the foot. These could be caused by a puncture from a sharp object, abscessation of the foot is common sequel to injury or poor foot care, due to the thickness and toughness of normal or overgrown sole; many abscesses of the foot are readily observable externally as a fluctuant swelling (Fowler, 1978). Foot abscess could lead to fever, lameness, pain and swelling of the entire foot above the nails. Untreated infections could result in the sloughing of one or more nails, or the entire sole.
Arthritis: Arthritis of the limb joints is another condition that can lead to foot problems. The soreness in an elephant's joints would result in decreased joint flexibility. This will lead to an altering of the elephant's gait and, abnormal pressure on the nails and pads (Roocroft and Oosterhuis, 2001). However, in the present study the incidence of arthritis was found to be very low (0.52%). It might be due to the fact that the elephants in the Assam condition get sufficient exercise; their diet contains low energy when compared to that of their counterparts in the western facilities. So, they are not over weight and the exercise keeps their joints in a healthy state.

Ascertaining Causative Agents:
In the present study, large numbers of commonly found bacteria were isolated from elephant's foot affected with pododermatitis. Most common isolates were *Staphylococcus, Bacillus, Pseudomonas, Corynebacterium and Streptococcus*. Rect *et al.* (1997) also isolated a variety of bacteria from the foot lesions of elephants as well as from the regional lymph nodes, among which *Staphylococcus agalactiae* was found to be the most consistent. *Dicholobacter nodusus* was stated to be mostly involved with foot diseases in ruminants was also isolated from two cases in elephants. West (2001) isolated *Proteus mirabilis, Enterobacter*, and *Bacteriodes* from the foot lesions. Chakraborty *et. al***.** (1991) recorded *Staphylococcus aureus* and *Streptococci pyogenes* from the foot of the elephants of Assam. Barn and yard cleanliness was important in preventing the build up of bacteria as well as removal of debris directly from the elephant feet as reported by Sampson (2001). Schmidt (1986) observed that elephant in the west usually developed bacterial infection in the foot during the winter because the elephants are generally kept inside the barn during the winter season. The urine keeps the area moist, which allow bacteria to colonize on the skin that can initiate the development of foot rot. The bacteria are generally soil origin. Injury on the foot region lead to discontinuity of the skin and bacteria get the chance to invade into the deeper tissues.
Antibiotic sensitivity test: The bacteria isolated were resistant to most of the antimicrobial agents. In the present study, enrofloxacin was found to be most effective against almost all the bacterial isolates, in conformity to the observation of West (2001).
Mycological studies: Different types of fungi were isolated from the chronic lesions of the foot. The most commonly found fungi were *Aspergillus, Phycomycetes* and *Trichophytons*. *Candida*, and *Blastomycetes. Yeast* was also found in some cases. Chakraborty *et. al*. (1991) recorded fungus form the foot affected with chronic infection, like *Trichophyton terrestre* and *Aspergillus niger*. Steel (1885) identified fungal infection usually occurring round the rim of the back feet, at the edge of the hoof slipper, which he attributed to imperfect removal of urine and fasces from the picketing ground. Chatterjee (1984) also recovered fungi from the foot lesions of the elephants. This problem was controlled when the elephant was allowed to spend more time outdoors. This might be due to the fact that in western facilities the elephants were mostly kept indoors during winter, which favored the fungus growth due to increased moisture and unhygienic conditions. The animals cannot throw dust over their body and dry up themselves as they do in there natural wild conditions.
Parasitological investigation: Unidentified pathogenic mites and filarial parasites were isolated from the foot lesions. Chatterjee (1984) also recovered parasites from the foot lesions of the elephant. Chakraborty (2002) recorded filarial parasites from the foot lesions of the elephant of Assam. The mite would have been in its transitory phase.

Summary and conclusion:
Majority of the captive elephants of eastern India are engaged in various kinds of commercial activities and live in primitive facilities. The area is characterized by high rainfall and humid conditions. Most of the elephant facilities have muddy substrate conditions and lacks in foot hygiene and foot care. The

management attach minimum importance in foot care and the mahouts administer some primitive pedicure at irregular intervals. The knowledge of foot anatomy, care and pedicure techniques are pathetically low.

A total of 312 randomly selected captive elephants of the region were studied for various kinds of foot affections during 2003-2005. Out of the study population, 123 elephants belonged to various elephant camps and zoos of Assam, 72 were camp elephants of North Bengal, 98 were privately owned logging elephants from Assam and 19 were from Arunachal Pradesh. Fourteen different kinds of foot affections were recorded; half of the elephant population of the region was affected with foot diseases in their total life. Males were relatively more affected because of their low tolerance for foot care particularly during the period of *musth*. Hind limbs were more susceptible and lesions were also severe in the hind limbs. Advancing age made the elephants more susceptible. Remarkably higher percentage of privately owned elephants was affected with foot affections. There is a general lack of attention towards foot health of elephants in the region. A host of bacteria and fungi were isolated from the foot lesions. No bacteria or fungus was singularly responsible for causing foot affections. Unidentified mites and filarial worms were also isolated from foot lesions. Most of the *Kari* (septic pododermatitis) cases began after incarceration for *musth* or rainy season. Moist substrate was worse in terms of foot health. Training the elephants to accept foot care is essential. The present investigation proved that even adult elephants could be easily trained for cooperation during foot care. Foot protection shoes were very useful in the treatment of chronic foot affections.

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Acknowledgement:
The authors wishes to place on record the help received from the fellow faculties and the authority of Assam Agricultural University, Khanapara, Guwahati, Project Elephant Directorate, Ministry of Environment and Forests, Government of India, New Delhi, Carol Buckley and A. C. Williams in the studies and documentations of the observations for the present communication.

Veterinary care for elephants used for clearings works in the devastated areas after the tsunami in Banda Aceh

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Abstract:
After the tsunami on the 26th December 2004 the *Department for Nature and Species Conservation in Aceh* employed 8 elephants to support rescue and clearing works in the destroyed areas of the town Banda Aceh. Working in areas covered with debris exhausted the animals and caused many injuries. The *elephant family* (ef) funded *Veterinary Care Support program* (VCS) provided daily veterinary care over period of more than two months to secure the health of the working elephant utilized in this extremely difficult working surrounding.

Background:
The Tsunami from the 26th 12. 2004 had devastated an area of more 100 km² only in the town of Banda Aceh. The *Department for Nature and Species Conservation in Aceh* (BKSDA-NAD) and their staff themselves were badly effected, many members and/or their families lost, the department devastated and their private houses destroyed. To support rescue and clearing works after this disaster the BKSDSA-NAD brought 8 working elephants which are under their responsibility to the City of Banda Aceh. The elephants themselves are usually kept in a camp about 45 km south from the town Banda Aceh in a hilly area which was not effected by the tsunami. But brought to Banda Aceh this elephants had to work in areas covered in rubble, shattered glass, sharp metal and wooden debris and the elephants suffered from regular wounds in their feed, legs and trunks. Badly impacted BKSDA-NAD and its staff were unable to provide the necessary veterinary attention and maintenance for the elephants used in this extremely difficult situation. As a result from this the *Veterinary Care Support* program from 05.01.2005 – 19.03.2005 stayed with the elephant team to provide daily veterinary care and organized food and water supply for the elephants.

Treatments conducted:
Injuries ranged from slight abrasion to deep cuts and wounds mostly in feet, legs and trunks, which in several cases caused sever swellings and lameness, due to which the elephants beside treatments needed to be suspended from work for several days. Daily after work the elephants were checked for injuries and wounds were treated twice daily using antiseptics and if needed antibiotics and NSAPs.
All Mahout were equipment with small bottle with 10% Povidon Iodine solution to be able disinfect new wounds directly on the spot. The elephants were vaccinated against tetanus twice in four week intervals, and received anti-parasitic treatments

Drugs used:

Drug	Dosage	Treatment intervals
Povidon Iodin 1% and 10%	Ad libitum / local	Twice a day
Peroxide 2,5%	Ad libitum / local	Twice a day
Povidon Iodin ointment	Ad libitum / local	Twice a day
Penicillin-Streptomycin 200.000 IU – 200mg/ml	10.000IU – 10mg/kg BW / i.m.	In 24h intervals for 7 days
Amoxicillin LA 150mg/ml	12 mg/kg BW / i.m.	In 48h intervals for 7 days
Ibuprofen 400mg/tablet	5mg/kg BW / p.o.	Twice a day
Ivermectin 1%	0,2mg/kg BW / rectal	Single treatment
Tetanus vaccine	1 dose (horse vaccine)	Twice in 4 week interval

Food supplementation:
No food and clean drinking and bathing water was available in the areas where the elephants were used for work and also not in the place where the elephants were kept during the night. Therefore it was crucial for the VCS veterinary team to immediately after its arrival organise sufficient food and water supply, ensuring the basic preconditions for the elephants healthiness and fitness. As there was no source for sufficient food available inside the devastated town of Banda Aceh, food had to be searched daily in villages close to the town but located in areas not effected by the tsunami and to be brought inside the town by truck.

Food supplied:

Supply	Quantity	Frequency
Coconut palm leaves	30 pieces	Daily
Banana trees	4 pieces	Daily
Bananas	4 shrubs	Daily
Sugar cane	25 sticks	Daily
Grass	15 kg	3 x week
Paddy	15 kg	3 x week
Palm sugar	2,5 kg	3 x week
Drinking water	200 Litre	Daily

Conclusion:
Over a period of two and a half months a total of 488 treatments were administered, before the elephants finally on the 20th of March 2004 were send back to their camp. Luckily it can be reported that all elephants were healthy and in a good nutritional condition at that time. The successful conduction of veterinary care and maintenance for this elephants used in an extremely difficult situation and hazardous situation was supported by Australia Zoo and Singapore Zoo by donations of drugs and Vaccines, funds raised by Fauna Flora International and a German vet group for the purchase of food, drinking water provided by the federal agency for technical relief Germany.

First report of pregnancy by artificial insemination with chilled semen of an Asian elephant in Thailand

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Although Asian elephant has been listed as appendix I of Convention International Trade in Endangered Species (CITES) since 1972, the population throughout Asia still declines due to habitat loss and poaching. As numbers of wild elephants continue to decline, maintaining healthy captive populations is vital. Because of difficulties in transporting a bull elephant from on institution to another for natural breeding, artificial insemination (AI) is a powerful tool for genetic management in this species. Thus far, elephant calves have been produced following AI with chilled semen (Schmitt *et al*., 2001; Brown *et al*., 2004). Our previous studies in Thailand showed that acceptable semen quality can be obtained after freezing and thawing; however, pregnancy was not established after AI with frozen-thawed semen (Thongtip *et al*., 2003). The present study reveals the first successful AI of Asian elephant with chilled semen in Thailand by using endoscope-guided and transrectal ultrasonography. Three AI trials were conducted in June 2005. Semen was collected by manual rectal stimulation from a bull kept at the Thai Elephant Conservation Center, Lampang, Thailand. Motility of fresh ejaculate was 75% with a concentration of 124.5×10^7 Sperms/ml. Twenty six ml of the sperm sample was diluted with TEST extender to a final volume of 150 ml and slowly cooled to 4ºC. Fifty ml of sperm suspension was inseminated per day. Sperm was deposited into the external os of the cervix via insemination catheter on -1, 0, 1 of the ovulated LH peak detected by enzyme immunoassay (EIA, Brown et al., 2004). The progressive motility of chilled semen samples were 65, 55 and 55% on the first, second and third day of insemination, respectively. Based on transrectal ultrasonography conducted 2 and 4 months after AI, enlargement of the uterine body was found. Pregnancy was monitored weekly by assessing serum progesterone using EIA (Brown *et al.*, 2004). Elevated progesterone has been found and still maintains at 2-4 ng/ml until present dates. Based on the ultrasound images and serum progesterone levels, we conclude that this female elephant is pregnant. The first successful AI in Thailand is a stepping stone in applying this technology to manage genetic of Asian elephant population in this country.

Keywords: artificial insemination, Asian elephant, LH, chilled semen, pregnancy, ultrasound

Elephant family groups may cause little environmental damage in the Kruger Park

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Recent scientific literature that has focused on elephant and vegetation interactions is not in agreement on the effects elephant have on the woody vegetation. Most studies on vegetation impact by elephants concentrate on the impact of an entire population, in large ecosystems, using predetermined survey plots. These studies do not take gender differences in elephants into account.

We followed, on foot, a family group of elephants in the Kruger Park, South Africa, and collected feeding data from approximately 480 plots covering all four ecological seasons (early dry season from May to July; late dry season from August to October; early wet season from November to January and late wet season from February to April).

Within the feeding plots, data on woody species selection, frequency, feeding method, plant parts utilized as well as height of utilization were collected.

The primary impact of our family group was stems broken (51.42%) and leaves stripped (30.74%). All this damage is ecologically sustainable (ie. the plants easily recover from it). Approximately 100 different woody species were recorded in the feeding plots while the family groups foraged on only 27 different species. The average diameter of the stems that were broken was 23.37mm while the average heights of utilization on the woody vegetation were 1.1m. More severe damage such as plants pulled, pushed, and dug out comprised only 17.84% of the impact (percentages can add up to over 100% because the same plant can be fed on in multiple ways). Even this more severe damage is not necessarily fatal to the plant (e.g. pushed over plants often continue to grow). In the most severe utilization categories the following species were primarily targeted: *Pterocarpus rotundifolius*, *Grewia bicolor*, *Albizia forbesii* and *Dalbergia melanoxylon* – not the baobab (*Adansonia digitata*) and marula (*Sclerocarya birrea*) trees that are commonly thought to be sensitive to elephant damage.

Our results imply that family groups may account for little of the ecological damage attributed to elephants, and that elephant bulls may be responsible for the majority of such damage. This has implications for the management of elephant populations in closed ecosystems.

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ZOO COPENHAGEN

IEF INTERNATIONAL ELEPHANT FOUNDATION

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October 21-22, 2006
Copenhagen Zoo, Denmark

ENDOTHELIOTROPIC ELEPHANT HERPESVIRUS (EEHV)

International Elephant Foundation Conservation and Research Symposium - Endotheliotropic Elephant Herpesvirus (EEHV) Workshop Report

Jon Cracknell, Thomas Hildebrandt, Lauren Howard, Ramiro Isaza, Mike Keele, Erin Latimer, Deborah Olson, Laura Richman, Willem Schaftenaar, Dennis Schmitt, Harald Schwammer

In 1995, a 16-month-old female Asian elephant at Smithsonian National Zoo died suddenly after a brief illness. National Zoo pathologists Laura Richman and Richard Montali discovered the cause of death as a novel herpes virus that produces a hemorrhagic disease in elephants. This discovery of a new herpesvirus called Endotheliotropic Elephant Herpesvirus (EEHV) led to the identification of additional cases worldwide and the ongoing research into the means to diagnose, treat, and prevent EEHV. The onset of EEHV is sudden and death can occur as early as hours after the first clinical symptoms are observed (or even without clinical symptoms), or the elephant may exhibit clinical symptoms for a week prior to death. Necropsy results show that EEHV infects the microvascular endothelial cells of the heart, liver, tongue and variably other organs. Viral-induced endothelial injury leads to critical hemorrhages with death attributed to cardiac failure.

EEHV is a world wide problem. Since identification of the disease, a substantial proportion of reproductive failures and young elephant deaths in Europe and North America have been attributed to EEHV. Multiple elephant mortalities attributed to EEHV have been reported to have occurred on the continent of Asia since 1995 (Montali et al, 2001) but the prevalence of this disease in the Asian captive and wild elephant population is still undetermined. Thirty-seven cases have now been identified worldwide between the years 1983-2005, 24 cases in North America of which only 3 survived, 11 cases in Europe of which one survived, and two deaths in Asia. Most EEHV cases are in animals less than 10 years of age. Clinical signs are variable and include lethargy, anorexia, mild colic/discomfort, swelling of the head, neck, trunk, cyanosis of the tip of the tongue, ulcers in hard palate, and blood-shot eyes. Treatment is still poorly understood but it is believed that providing Famciclover orally or rectally as soon as EEHV is suspected can aid in survivability. Supportive therapy includes analgesia, antibiotics, nutritional support, fluid therapy, and diuretics.

Herpesviruses have existed for over 300 million years evolving and establishing a host-parasite relationship so that usually only the very young host or those with concurrent infections exhibit serious or fatal disease. In elephants, herpesviruses were first described in 1971 in pulmonary lymphoid nodules of otherwise healthy African elephants in Kruger National Park (McCully et al., 1971). Pilaski described genital herpetic lesions in Asian circus elephants in 1987 (Pilaski et al, 1987, 1988). In both cases, Polymerase Chain Reaction (PCR) was unavailable for confirmation. Since then, seriologic determination of previous exposure to herpesvirus infections has been accomplished through screening for antibodies to one or more of the herpesvirus antigenic proteins. (PCR) on DNA extracted from whole blood confirms active (viremic) cases of EEHV.

Diseased tissue obtained from deceased Asian and African elephants indicates that for most of the conserved herpesvirus genes, the protein sequences have higher identity to the betaherpesviruses than to the alpha- or gammaherpesvirus subgroups, with some notable exceptions. Two prominent differences are the presence of a thymidine kinase gene in both Asian and African herpesviruses, and the presence of the small subunit of ribonucleotide reductase in at least one of the viruses. Neither of these two genes has been previously described within the betaherpesvirus group. The elephant endotheliotropic herpesviruses may therefore constitute the first examples of a new subgroup of herpesviruses (Richman, unpublished). This whole blood PCR test developed specifically for EEHV of both African and Asian elephants is, to date, the definitive test to diagnose the disease (Richman et.al., 1999, 2000).

Initially, EEHV was thought to be the result of housing African and Asian elephants in the same exhibit. More recent information has found fatal infections in captive Asian elephants in North America, Europe and Asia have occurred without direct exposure to African elephants (Montali, et al 2001). In 1999, Richman et al. identified via PCR and sequenced Endotheliotropic Elephant Herpesviruses (EEHV– 1, 1b and 2; Fickel et al 2001). EEHV– 2 has been detected in pulmonary nodules of healthy wild African elephants and has resulted in hemorrhagic syndrome in two African elephants in North America, but as of yet has not been found in Asian elephants. EEHV–1b has only been detected in Asian elephants (Fickel et al.2001), while EEHV– 1 causes dissseminated disease in Asian elephants and has been found in vaginal/vestibular and skin lesions in African elephants (Richman et.al., 1999, 2000). The point of exposure for these cases, the mode of transmission and the incubation period of the EEHV are unknown. EEHV sequences in Asia were identical to sequences in North America and Europe with no known contact or translocation of elephants from Europe / North America to Asia / India.

Additionally, several stillborn Asian elephants have had EEHV sequences in target organs and the same sequences recovered from the placenta and inclusion bodies were seen within the trophoblastic layer. Therefore it is likely that Asian elephants carry at least one EEHV strain in an anatomic location that has yet to be determined. Thus, it is debated whether the Asian elephant itself, or another host species serves as a potential source of EEHV or if the mode of transmission is indirect; or even whether EEHV is truly a novel virus for the Asian elephant as there is also no explanation for the EEHV—1b strain that has only been found in the Asian elephants. Based on the disease presentation of EEHV and the tissue tropism, some Asian elephants appear to be a naïve foreign species for herpesvirus. However, not all Asian elephants exposed to this virus display clinical disease.

Elephants that are PCR positive are gravely ill with all or many of the classic clinical signs of EEHV disease although two elephants in Europe tested PCR positive with no signs of illness but after suffering traumatic injuries. An immunoassay was developed to detect previous infection/exposure to EEHV. The assay is now used to provide epidemiologic data on virus transmission patterns within a herd by predicting earlier, or recent exposure that could result in virus shedding and transmission to non-immune elephants. Some elephant herds have had multiple young elephant deaths attributed to EEHV, and banked serum samples from members of those herds can be retrieved to measure EEHV antibody titers. It is thought that a juvenile elephant naive to EEHV within such a herd will, at some point, be exposed to an elephant shedding EEHV and either seroconvert with unapparent/mild illness or develop

disseminated EEHV disease. Preliminary data suggests that at least some infected elephants will develop a high EEHV antibody titer

The International Elephant Foundation united and mobilized the international EEHV research community in September 2005 in an EEHV workshop co-sponsored by the Houston Zoo and again in October 2006 at the International Elephant Conservation and Research Symposium in Denmark. The international delegates - pathologists, epidemiologists, virologists, microbiologists, veterinarians and elephant management experts - unanimously agree that EEHV is a serious threat to all populations of Asian elephants and the diagnosis, prevention and treatment of EEHV is a high priority for the international elephant community.

As a result of the first EEHV workshop a study has been initiated in the United States using banked and newly collected serum and whole blood samples, both retrospective and prospective studies will be performed and results correlated to epidemiological findings within the North American elephant population. Asian elephant holding facilities in North America will collect and bank serum and whole blood from each Asian elephant on a weekly basis for a period of two years. One sample per month will be sent to Dr. Richman's lab for testing and evaluation. Elephants demonstrating a high titer to the EEHV through the ELISA will be further scrutinized by testing their banked samples using ELISA and PCR. Results will create a comprehensive database of the serologic status of Asian elephants in North America. A base serology on each individual can aid in chronologically evaluating those individuals that may seroconvert in the future and potentially determine time of exposure. Once titer trends have been analyzed, then patterns will emerge that will aid in determining herd management and elephant translocation strategies.

For example, elephants with high EEHV titers may be carriers of EEHV and may periodically shed the virus (with or without clinical signs). It is assumed, that elephants with high EEHV titers have been previously exposed/infected and may have protective immunity against EEHV. Elephants with no EEHV titers are probably immunologically naïve. These elephants should be considered "susceptible" to infection. Elephants with intermediate EEHV titers may have previous exposure and/or be potential carriers. These animals may require serial sampling to determine their EEHV status.

In addition, a detailed epidemiology of the Asian elephant population in North America has begun with the collecting of information on both affected and unaffected elephants including housing, social structure of the herd, diet, illnesses, breeding, travel etc. This information will be contrasted and compared to longitudinal EEHV serology information. This information along with demographic and qualitative data will provide valuable epidemiologic information in order to aid in the determination of the source and means of transmission of this disease.

In the past year an ELISA has become available in Europe. Multiple elephant serum and whole blood samples are requested from each elephant from each institution for study. Detailing the European Asian elephant population's EEHV status would be invaluable to the study of this disease. As in North America, results will also create a comprehensive database of the serologic status of Asian elephants in Europe aiding in formulating global herd management and elephant translocation strategies. The preliminary results indicate that several elephants that have never shown clinical signs have antibodies that remain high for a period of 2-3 years.

The 2006 EEHV Workshop on October 19-20 continued the discussion of EEHV research activities and action plans, and resulted in 9 high priority recommendations.

Workshop recommendations

1) Post mortem diagnostics - Testing all elephants that die looking for latent infections in necropsy tissues is an extremely high priority using histopathology, PCR, ELISA and targeting the following organs: heart, tongue, lymph nodes, spleen, liver, blood, and any odd appearing lesions. The assembling of a necropsy team would be highly desirable.
2) Validation of ELISA assay – This assay should be validated in 2007 through the US based study collecting blood samples from each Asian elephant on a weekly basis.
3) Epidemiological study – This study has been initiated in the United States but it is equally important that one be initiated in Europe as well.
4) Biopsy lymph notes of all EEHV survivors and of those individuals that have high EEHV titers using the described ultrasound guided retro-pharyngeal lymph node method.
5) Refine treatment protocols
6) Develop a poster to be distributed to all elephant barns to inform keepers and other staff the importance of inspecting each elephant for oral lesions daily, starting treatment early if EEHV is suspected, training each elephant for blood sample collection, noting available laboratories for sample analysis and listing samples needed for further diagnosis and research purposes.
7) Set up laboratories in Asia to determine the prevalence of this disease in captive and wild elephants in Asia.
8) Continue viral culture attempts by developing elephant cell culture lines and culturing infected necropsy tissues.
9) Investigate the TK gene. A TK gene is present within alpha and gammaherpesviruses, but has not been described in any of the currently sequenced beta-herpesviruses. TK is necessary for Famciclovir to be effective.

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INTERNATIONAL ELEPHANT CONSERVATION AND RESEARCH SYMPOSIUM

October 21-22, 2006
Copenhagen Zoo, Denmark

IN MEMORIAL

Dr. Bets Rasmussen
Pankaj Sarmah

IN MEMORIAL

DR. BETS RASMUSSEN

Many of us sadly learned of the passing of Bets Rasmussen about ten days ago. The news was surprising as most of us did not know of Bet's illness or the seriousness of the disease. Bets chose to keep these personal details private.

Her scientific contributions have been phenomenal including more than 130 publications in peer-reviewed journals with world-wide readership, spanning the discipline of neuroscience, endocrinology, biochemistry, behavior, anatomy and chemical communications.
Her work with elephants has helped to illustrate the importance of learning from elephants in our care and applying what we've learned to help range country conservation efforts. In April, 2004 she was featured in a film, "Stopping Elephant Raids."
Dr. Bruce Schulte sent this tribute to the Save the Elephants News Service: Bets Rasmussen: A Great Matriarch Passes On

"On Sunday September 17, 2006, family, friends, scientists, and elephants lost a great ally. Dr. L.E.L. (Bets) Rasmussen succumbed to illness while in the presence of close family in Seattle, Washington.

To the scientific and elephant world, Bets may be known best for her 15-year quest to identify the estrous pheromone in Asian elephants. Along with collaborators, she succeeded in this task, determining the compound structure to be Z-7-dodecenyl acetate. When published by Rasmussen et al. (Nature 1996), this was a remarkable breakthrough. For a mammal, it was astounding that a single compound would have such profound importance to reproduction. Further, many moths use the same compound as part of their pheromone, a fascinating case of chemical convergent evolution. Most scientists rarely have one landmark discovery in their lifetime. Bets Rasmussen was just beginning to increase our understanding of elephants.

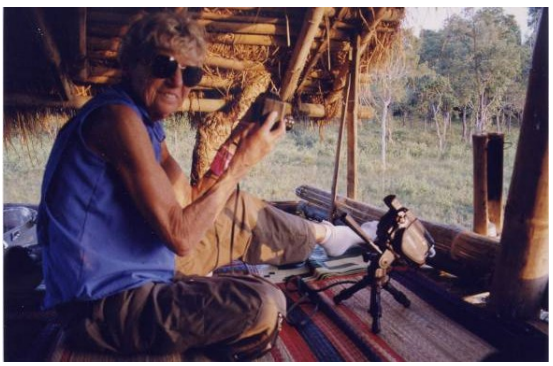
Along with collaborators, Bets revealed the chemical signature of "moda" (or honey) musth in young male Asian elephants (Nature 2002). She also helped understand the chemical dynamics of another elephant pheromone convergent with an insect pheromone, namely frontalin (Nature 2005).
Bets worked proficiently in multiple areas including biochemistry, chemistry, behavior and molecular biology. While she also studied numerous other species such as sharks and whales, her passion were elephants. Bets assisted elephant conservation in the wild and in captivity. She cared deeply about elephants and about the people who worked with and for elephants. Bets Rasmussen was a tireless worker, a vibrant speaker and the best of friends.

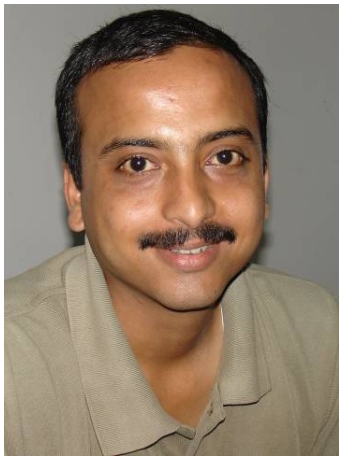
Many of us sadly learned of the passing of Bets Rasmussen about ten days We have lost not only a great scientist, but one of the most enthusiastic and nicest people you could ever meet. Our sympathy and love go out to her family."
She was an inspiration to so many of us.

Deborah Olson
International Elephant Foundation









IN MEMORIAL

PANKAJ SARMAH

WWF India regrets to inform that Pankaj Sarmah, one of the team member of North Bank Landscape (NBL) working with the Asian Elephant and Rhino Conservation Programme, passed away. Medical reports have indicated that he was suffering from cerebral malaria due to which he was shifted to Guwahati from Tezpur on 27th September and despite intensive medical attention, Pankaj succumbed last night.

Pankaj was associated with NBL conservation work since 2001 and was one of the earliest recruits in the programme. Pankaj dedicated his work towards mitigating human elephant conflict in Assam and did the first studies for WWF-India in the area of NBL and the Kaziranga landscape. Most recently he had been instrumental committed to Manas Conservation Alliance, a coalition of 20 NGOs and individuals committed to conserving Manas. Pankaj represented WWF in several symposia including the elephant symposium in Colombo. He was to attend another elephant symposium in Denmark to present a paper on elephant conservation in conflict areas.

Pankaj´s parents live in Tezpur with one of his brothers Anupam Sarmah, who is also working with WWF-India in the NBL programme. Pankaj, the youngest of 3 siblings, had a Masters degree in Zoology from the University of Tezpur and was a first class student. We were truly fortunate to have a person of such a strong commitment and dedication as Pankaj in our team. He has left behind for conservation his deep understanding of elephants in the NBL based on actual observation and scientific study. Pankaj´s positive attitude and exceptional good nature, sincerity, cheerfulness and courage will be missed by all his friends and colleagues. The loss is personal to WWF India and we sill remember him by continuing the important work initiated and towards ensuring its success.

Ravi Singh
Secretary General & CEO
WWF India

Curriculum Vitae

Name: **Pankaj Sarmah**

WWF-India, NBL Field Station
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Educational Qualification: Masters in Zoology with specialization in Ecology and Wildlife Biology.

His work was:
He worked for WWF-India in **'North Bank Landscape Program on Elephant Conservation'** in Assam and Arunachal Pradesh since 2001. He looked at Elephant Presence Absence, Human Elephant Conflict and Mitigation thereof, GPS Tracking of Critical Elephant Movement paths, Ground Truthing of Satellite Images. Recently started looking at the 'species research' component of the program. Also developed a proposal for subsequent phases of the program.

His field of Interest:
Development and Implementation of Conservation Strategy for Large Mammal (Flagship Species) in Eastern Himalayas using GIS, Radio-Collaring and other relevant tools.

His Experience:

- Worked for one year in a Ministry of Environment and Forest funded project on Exploration of Amphibian Fauna in Dehang Debang Biosphere Reserve in Arunachal Pradesh.
- Worked for one (1) year on Behavioural aspect of fledglings of Greater Adjutant Stork (highest threatened of all stoks) in two (2) sites of Kamrup and Nagaon district as a part of M.Sc. dissertation.
- Participated in Tiger Census'97 in Orang National Park.
- Did socio-economic survey (1995) to assess anthropogenic pressure on the forest of Burachapori Bird Sanctuaty which happens to be one of the last stronghold for one of the highly endangered species of bird, i.e. Bengal Florican.
- Did Biodiversity Assessment in Pakke-Nameri area for WWF-India in Technical collaboration with Centre for Biodiversity Management, Queensland, Australia in 2003.

Special Training:

- Training on Large Mammal Monitoring Techniques with special emphasis on Tigers organized by WWF-India in collaboration with Wildlife Conservation Society, Washington DC in Tadoba Andheri Tiger Reserve, Maharashtra.

- Training on Vegetation Sampling Methods organized by WWF-India in collaboration with Centre for Biodiversity Management, Australia held in Bhalukpong and adjoining areas in 2003.
- Training on Logical Framework designing of Project organized by WWF-India in collaboration with WWF-UK in Mussorie in 2003.
- Training on Conservation Biology organized by ATREE, Banglore in Bagdogra and Meghalaya in 2003.

Born: April 23, 1975 Died: October 03, 2006

International Elephant Conservation and Research Symposium

October 21-22, 2006
Copenhagen Zoo, Denmark

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October 21-22, 2006
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