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The Asian Elephant: future prospects

J. C. Daniel

The Asian elephant in spite of the close relationship it has had with man since time immemorial, is likely to be the first large mammal to be found only in small numbers and as a domesticated animal by the end of the 21st century. It faces more pressures on its habitat than its African counterpart and its survival is very closely linked to the increasing human population and its demand on natural resources. This is a thesis which has solid historic support when one examines the distribution of the species within the last several millennia. To recapitulate, its known historic distribution was from the Tigris and Eupharates valleys of Syria and Iraq to the Yellow river in China and south to Sumatra. Today only a fragmented population exists from India eastwards.

A settled agricultural human society has always spelt doom for the larger herbivores unless they had been assimilated as a domesticated natural resource and the elephant is a classic example of an animal well on its way to being so assimilated. As the river valleys were converted from forests to agriculture, they were able to support a larger static human population, which in turn demanded more from the surrounding natural resources. This was limited by the regeneration capacity linked to the rainfall regime of the area. There is clear historical evidence, at least in north India, to prove that over the last several centuries, rainfall has progressively decreased. This is probably a result of climatic changes over the centuries but there is certainly evidence that human cultural development as a settled agricultural community has been a major cause for destruction of the original habitat and with it the wildlife dependent on such habitats.

In terms of numbers, the existing population which is believed to be between 34,000 and 54,000 is very small indeed when compared to the current population of about 700,000 of the African elephant. But in terms of conservation, the Asian elephant has a higher survival potential than the African elephant. The crucial factor responsible for this survival potential is the relationship between man and elephant in South East Asia. In almost all the human cultures prevailing in this area, the elephant is a part of the religious ethos and is therefore conventionally protected. How long this protection will stand the strain placed on it and how best these can be overcome for the conservation of the species should be carefully and urgently considered.

In India, which has the largest population of elephants, special attention to their conservation commenced with the formation of the Asian Elephant Specialist Group of the IUCN in 1976. The status survey that was made between the years 1976-80 and reported in the document published in 1980 has not been repeated. In India, the trend turned to research on identified areas of prime elephant habitat, by scientists of the Centre for Ecological Sciences, the Bombay Natural History Society and the Wildlife Institute of India. The sustained interest in the conservation of the Asian Elephant fostered by the IUCN and Indian institutions such as the Bombay Natural History Society, Wildlife Institute of India, and Centre for Ecological Sciences, prompted the Government of India to plan the organisation of a PROJECT ELEPHANT similar in principle to Project Tiger. A task force was established to spell out the problems facing the elephant and to frame a

long term conservation programme for the elephant in India under a specially funded initiative, namely the Project Elephant. The objectives were defined as under:

Objectives of Project Elephant

(a) Ensuring the long-term survival of identified larger populations.

(b) Evolving management plans for the smaller populations, mainly with a view to reducing man-elephant confrontations and ensuring their survival pending further review of the ground situation.

Objectives of Elephant Reserves

(a) Ensuring the long-term survival of identified larger populations [(a) >1000, (b) >2000, (c) <200]: the target in the first phase should be categories 'a', 'b' and category 'c' will cover under 1 (b) above;

(b) by protecting their habitat and existing ranges;

(c) linking up already fragmented portions by establishing corridors wherever possible and protecting corridors at present under threat;

(d) improving the quality of the habitat wherever necessary by attempting ecosystem restoration and other measures keeping in main objective of range protection in view;

(e) attending to the socio-economic problems associated with this, especially the problem of elephant depredation, loss of employment, and problems arising out of restrictions on use of forest produce by the fringe populations.

The Committee appointed by the Government of India identifies the following major problems facing the Indian Elephant population namely loss and fragmentation of habitats, loss of habitat quality or range degradation and the inability of such areas to support existing elephant populations; loss of forest lands to meet the needs of increasing human population. The conservation strategy recommended by the Committee has as its goal (a) ensuring that each elephant holding state maintains one or two natural viable populations of elephant. (b) Assure that the local communities in the environs of such areas are not adversely affected. (c) Ensure that individual problem elephants do not mitigate conservation efforts aimed at the whole population.

The project is now in operation and is on a much lower level of public awareness than Project Tiger and is funded at a much lower level than Project Tiger. In the allocation of funds, studies by the Bombay Natural History Society have brought out very interesting data on elephants and their effect on the habitat. For instance, Sivaganesan's studies on habitat utilisation have shown that over-exploitation of food species does not lead to destruction of the forest community as a whole but the selective disappearance of the most favoured species of tress fed on by the elephants in the different habitat types. What is required are methods for regeneration of favoured food species. The problems facing the wildlife manager in the conservation of the elephant have been clearly brought out by Ajay Desai. In a recent paper he shows that home ranges of herds cover areas with different levels of protection in a conservation area and a herd or for that matter a population of elephants living within a National Park or Wildlife sanctuary is therefore not assured of complete protection throughout its range. It is therefore necessary to assure that there is a strong research component not only to collect basic data but also to examine management oriented problems.

It is now necessary to repeat the status surveys undertaken over a decade ago to determine general population trends and habitat status. There has been considerable difference of

opinion on census methods. The method to be used will vary with ground conditions. This has to be appreciated but there can be no difference of opinion that a status survey of the Asian Elephant population is now imperative. One of the major objectives of Project Elephant is to identify and protect complex of contiguous national parks and sanctuaries as a Composite Elephant Range. These would be the essential conservation target areas for the elephant similar in basic management concepts to the existing project Tiger areas.

A priority requirement is to survey in depth the potential of a complex of sanctuaries as an elephant range for the long-term survival of viable elephant populations through precise assessment of existing elephant populations; assessing habitat status of the component sanctuaries and national Parks; assessing the corridors between the protected areas and their viability; assessing the pressures from human activities and their long-term protected area components of the range; assessing present human/elephant conflict areas, potential human/ elephant conflict areas within the range; assessing impact of future developmental plans on the range as a whole.

This is crucial for all identified elephant ranges as the future of the elephant depends on how best elephant and human needs can be met in a continually deteriorating environmental situation in the country owing to the uncontrolled increase in the human population and the consequent escalating demand on natural resources.

A basic research which will be useful in this context and which is in progress at the moment in one identified elephant range, is data collection on ranging behaviour of elephants from radio collared elephants; to assess exact home ranges; to identify precisely critical areas in the range at different seasons; to identify crop raiders, extent of such raids and probable causes and to determine the extent to which collared elephants range outside protected areas.

Another area for priority consideration is the status of elephants stranded in habitats fragmented by human encroachment. There are several populations which have now been isolated from the main elephant ranges and it is necessary to determine the minimum requirements of such pocketed populations for their continued survival. It is therefore necessary to assess the capacity of such habitats to hold existing populations; to assess the viability of pocketed populations in different habitat types; to assess the pressures on such populations and the long term viability of the habitat and its elephant populations.

The future of non-viable populations is a cause for considerable concern. Culling as is practised in Africa is not acceptable as far as the Asian elephant is considered, at least in India. The only available alternative is capture and domestication. Apparently it is now the Central Government's policy to encourage the use of elephants in forestry practices as they were used in former years. It should also be possible to meet the requirements of non-governmental needs. However, it is essential that a school for the capture, management and training of elephants and mahouts be established immediately. The expertise is available in India and the need is urgent. Capture can now be humanely done using immobilising and tranquillising drugs and the most humane method of training is *kraal* training as is practised in south India.

The major populations in India are genetically isolated. It is now essential to examine the genetic status of isolated populations and to consider ways and means of establishing gene flow between populations permanently isolated. Relationship between clans in stable populations, among domesticated elephants and whether domesticated elephants can be made the gene exchange carriers between permanently isolated populations are problems that now require serious consideration.

The Conservation of the Asian elephant in India cannot be the concern of only the forest department and environmentalists. Conserving the elephant involves the conservation of prime wildlife habitats. This needs a multidisciplinary effort where the local people, the administrators and land use planners at all levels have to be involved. Conserving the elephant therefore means conserving the human environment and it has to be a part of the development plans of the state and the country as a whole.

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News from Sri Lanka

An update on the status of the wild elephants in Sri Lanka was long overdue. The last assessment of the status of the elephants in Sri Lanka was carried out more than 20 years ago jointly by the Department of Wildlife Conservation (Sri Lanka) and the Smithsonian Institution (USA). Dr. George McKay estimated the minimum size of the total population of wild elephants at that time to be between 1,600 and 2,200. A more recent estimate by Mr. A.B. Fernando, (a member of the AESG) puts the figure as anything between 2,800 and 3,250 in the late 80's. Some have even speculated that the number of elephants could be as hig as 6,000. The problem in Sri Lanka is further compounded by the on going ethnic conflict in the north and east which has made many of the elephant areas in these regions inaccessible. Therefore an island wide census of elephants is impossible at present.

Given this situation, the Director of the Department of Wildlife Conservation, Mr. W.A. Jayasinghe initiated a survey of the elephants to monitor the changes in the structure of elephant populations across as large an area as is feasible. The main objective was to provide some training to the field staff so that they could standardize the methods and carry on monitoring the elephants on a yearly basis.

The survey was carried out in June 1993 in the Southern, Central, Eastern, Northwestern and Mahaweli regions and it involved about 800 people, including the field staff of the Department of Wildlife Conservation and NGOs. Estimation of elephant numbers was incidental to the main objective. Much emphasis was placed on the need to monitor the proportion of calves and tuskers - two of the most vulnerable categories - in the local populations.

The survey indicates that the population structure of the elephants is biased in favour of the adult animals. The proportions of the adults, subadults, juveniles and calves on an average were 51.9%, 21.8%, 15.7% and 10.6% respectively. The highest proportion (12.1%) of the calves was seen in the Southern population. The adult sex ratio varied from 1:1 to 1:2.9. The proportion of adult bulls with tusks varied from 2.8% to 15.3%. The national average for the percentage of tuskers among the adult bulls is 7.3. It is estimated that at least about 2,000 elephants (minimum estimate) are present in the five regions in Sri Lanka. A full report of the survey will be published at a later date. **(Ch. S)**

Elephant management and conservation in the Mahaweli project areas

Jayantha Jayewardene

The Accelerated Mahaweli Development Programme (AMDP) is the largest and most ambitious development project that Sri Lanka has undertaken. The Master Plan for this programme provides for the development of 900,000 acres of land with the provision of irrigation facilities. Over 200,000 farmer families were to be settled in the newly developed areas. It was also envisaged that 500 megawatts of hydro-power would be generated by the many dams that were to be constructed across the Mahaweli river, under this programme.

The initial step is to clear the jungle lands before the irrigation system can be constructed and the landless families settled. With the progressive clearing of the jungles, it became obvious that the flora in the area would be destroyed and the fauna would lose their habitats. With regard to the reptiles and smaller mammals this was not too much of a problem in that they were able to inhabit the small patches of jungle that were left when clearing work was done.

The bigger problem however was with regard to larger animals, especially the elephant, whose habitat was being destroyed. When the Master Plan for the AMDP was formulated no thought seemed to have been given to the impact that such a massive development scheme, which necessitated the clearing of large tracts of forest, would have on the environment. When System H, (Fig. 1) the first Mahaweli settlement project, was started, it was obvious that there would be serious problems with the herds of elephants that were being displaced as a result of jungle clearing. With the decision to accelerate the Mahaweli programme and the feasibility studies that were then necessary, it was possible to have a survey of the impact that this programme would have on the environment and obtain recommendations of the measures that could be taken to mitigate these adverse effects.

With jungle clearing and settlement moving forward the herds of elephants were also pushed further and further. In addition to the herds there are also loners and small groups of elephants, who also get pushed along. Initially the elephants move away but with progressive clearing, when the pressure for food and water is felt, they come back to the areas they had inhabited, in search of food and water. With their return they are chased away by the settlers and the elephants go away. The settlers shout, light fireworks and flares, beat tom toms and light fires to keep the elephants away as most elephant forays are in the night. The elephants move away at first as they are not aggressive animals by nature. This is proved by the fact that a wild elephant when caught can be tamed very easily.

When the elephants are continuously chased off and they have nowhere to go, they naturally turn round and retaliate. At first their charges and attacks are not severe or dangerous. Later on they become more determined to get at this tasty and easily available food like banana, papaw and paddy. When their efforts at protecting their crops and habitations from the depredations of the elephants fail, the farmers are compelled to use guns. Guns in the hands of inexperienced farmers will not kill the elephants as intended but will only injure and maim them. Here too the animals are repelled only temporarily. After a while they come back.

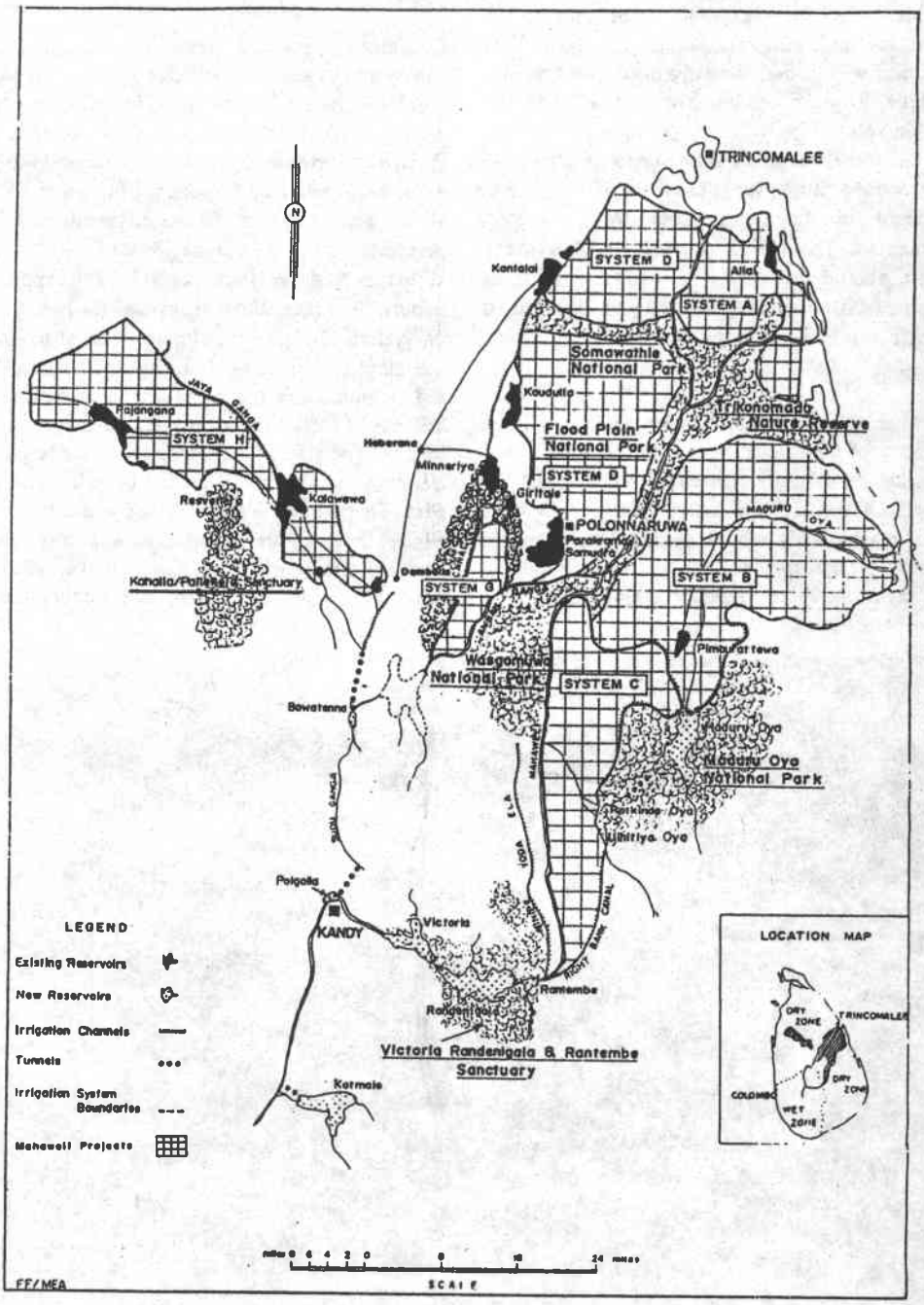


Fig. 1 Map of Mahaweli project area and adjacent reserves.

Meanwhile the gunshot wounds will fester and irritate the animal who will be maddened by the pain and suffering it has to undergo. This situation will turn a normally docile animal into a rogue. Rogues, as they are popularly known, are lone elephants, who do not behave as normal elephants do, but attack human beings and cause destruction. It is very easy to kill a rogue elephant by having it shot by an expert marksman. The point, however, is that every effort should be made to prevent harmless elephants from turning into rogues because of the ill conceived actions of man.

Another very significant point is that a large number of elephants have been killed in and around the Mahaweli areas over the last 10 years. Of the animals killed nearly 75% have been males. This would degrade the breeding quality of the species due to the reduction in the breeding male elephant population.

Elephant Drives

Constant forays by elephants into settlers' cultivations and habitations were reported regularly from System H. The situation got worse as time went on. The Department of Wildlife Conservation, after may requests to do something positive, decided in the interests of all concerned, to drive the elephants causing problems in and around System H to the Wilpattu National Park. This Park is approximately 50 miles away from the furthest point in System H. The Department decided to drive the elephants because noosing and tranquillising, which were the other methods available, had not in earlier instances yielded the expected results. The size of the herds were too large for trapping by individuals as had been done in the past. This would in any case have taken a long time. Driving the elephants was the most humane and sensible approach in the effort to save these animals. Driving the elephants also

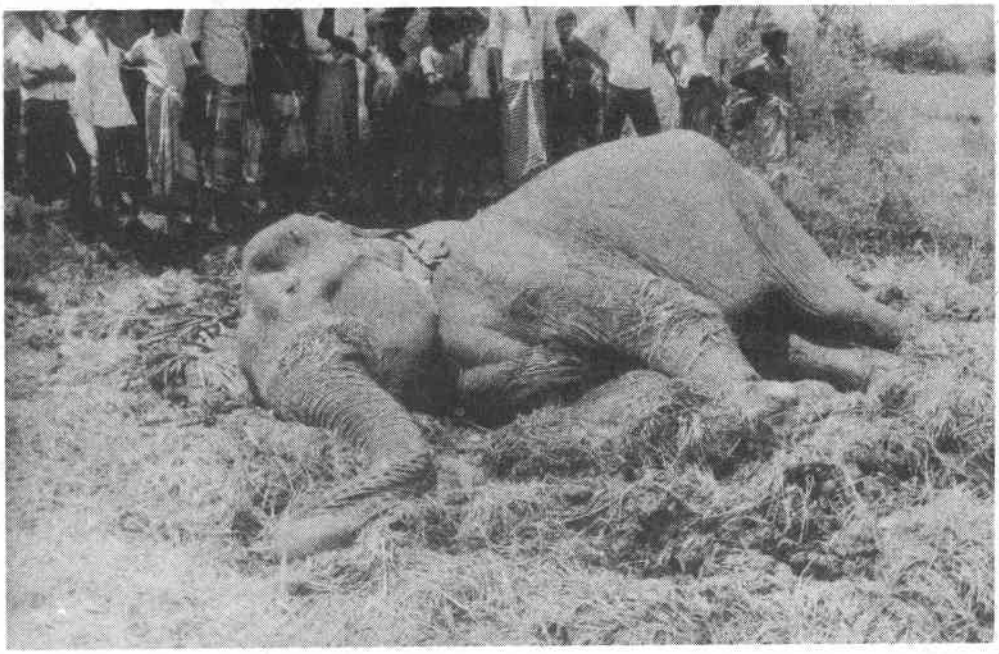


Fig. 2 An elephant killed at Kalawewa in system H.

ensures that all the animals are moved away and no animals are pocketed in small patches of jungle after land development. This happened in earlier settlement projects like Gal Oya and Uda Walawe and caused a lot of problems.

In 1979, about 130 elephants in the Nochchiyagama area in System H were driven across the Puttalam-Anuradhapura road to the Wilpattu National Park and it environs. However, as no precautions were taken to ensure that the animals did not leave this area, most of them returned. These elephants had to be driven back again. In 1981, it was decided to drive the elephants which had collected in the Resvehera jungles to the Wilpattu National Park. Careful and detailed planning was necessary prior to driving elephants. The behaviour and attitudes of the elephants had to be studied before making an attempt to translocate them. There had been no drives of this magnitude in the past, so there was no previous experience to draw on at all.

Driving the Resvehera herd, which was scheduled to commence in 1981, had to be delayed due to unusual rains. Certain parts of the route had not been cleared of scrub etc. and this too contributed to the decision to postpone the drive for the dry period in July-August of the next year 1982. The drive ultimately started in August 1982 when 60 odd elephants were driven towards Wilpattu National Park. Progress was slow. The monsoon rains at the end of the year prevented any effective driving of elephants. All efforts during this time were directed at keeping the elephants from going back.

In March, 1982, Prince Phillip, Duke of Edinburgh, who was the President of World Wildlife Fund, visited Sri Lanka to watch the elephant drive. He viewed it from a platform built in the Kathnoruwa jungle within the System H project area.

In March 1983, the Resvehera herd was finally moved into the Wilpattu National Park, together with several small herds from patches of forest in the Mi Oya basin. They were pushed as far as Pomparippu, but some of them kept returning to the banks of the Kala Oya. The severe drought in early 1983 kept the elephants near the Kala Oya, as this was their only source of water.

The University of Colombo and the Department Wildlife Conservation carried out a project to study the behaviour of the translocated herds and the ecology of the Wilpattu National Park. This study has revealed that the vegetation in the southern sector of the Park is too woody and that certain feeding grounds do not have sufficient water during periods of drought.

A number of problems were encountered during the course of these drives. There were no previous experiences of drives of this nature which the Department could draw upon. There was a great deal of resistance from the villagers all along the drive route, mainly because the elephants, going through their lands caused much damage to property and cultivations and also as they were a threat to the villagers' lives. The curiosity of the people also hampered the drive in that they got in the way, thus creating a big risk for the Wildlife Department staff. In spite of all this, the achievements by the staff have been very creditable.

Towards the latter part of 1984 conflicts within the Department of Wildlife Conservation caused many changes in staff and as a result the wide experience gathered from the elephant drives by a number of their staff was lost. This set back any programme to reduce the man/elephant conflicts that were increasing in the Mahaweli areas. In May 1988 the Department of Wildlife, together with the Mahaweli Economic Agency carried out a pilot elephant drive in System B. This was under the Mahaweli Environment Project (MEP). This drive was to be from the Dimulagala Block area to the Maduru Oya National Park. The drive started off with a herd

of twenty three elephants. However at the end of the drive over 150 animals which were collected as the 20 kilometre drive progressed, were driven into the Park. Most of these animals came out of the Park at different times due to inadequate precautions to prevent them from returning.

A number of objectives necessitated this pilot drive. The main objective was to drive these elephants which were causing considerable damage, to the confines of the Maduru Oya National Park where they could live undisturbed. This would also give the Departmental staff the necessary experience that would be useful in all Mahaweli development areas. It would also give the staff an opportunity to study some aspects of elephant behaviour at first hand. With this drive the staff of the MEP would help educate the settlers in practical elephant conservation. This education and the resultant attitudinal change among the settlers would also help reduce the conflicts betwee settlers and elephants.

Immobilization and capture

The elephants which were left behind in the System H area from the first two drives continued to cause depredations in the project area. Numerous complaints were made by the project management to the Department of Wildlife Conservation regarding the serious problems created by these elephants. These complaints were not acted upon as the Department was hindered by the lack of experienced staff who could deal with the problem. On representations made by the project management, the Director General of the Mahaweli Authority of Sri Lanka summoned the Senior officials of the Wildlife Department, the Mahaweli Authority and local experts on elephants, to a series of meetings designed to find a permanent solution to this problem, which was getting worse. He offered the Department of Wildlife Conservation all the financial assistance they needed. He even agreed to finance any foreign experts who might be able to help solve the problem.

The Department however, was unable to decide on possible solutions, although during the meetings the options had been narrowed down to two (1) to conduct another drive; or (2) to tranquillize the animals and transport them to new locations. The possibility of having another elephant *kraal* was also discussed but this idea was shelved as not being practical in the context of System H.

In early 1985, the Department of Wildlife Conservation decided to conduct a pilot project to immobilise some of the Resvehera (System H) elephants and transport them to the Wilpattu National Park. An elephant drive was not attempted because of the lack of experienced staff. Ten elephants were captured after tranquillisation. One was sent to Wilpattu and another to the Uda Walawe National Park. The others were sold by public auction. All the animals that were sold died subsequently.

In February 1991, the Department of Wildlife Conservation launched a programme to tranquillize and translocate the pocketed and problem-causing elephants in and around System B and H. This was a big and ambitious programme starting initially with the capture of six animals pocketed in Bogaswewa in System B and five elephants that were responsible for the deaths of 12 people in the Resvehera forests. This operation was called off after sometime due to (a) the deaths of most of the animals that were captured, (b) the programme being ill planned and inadequate preparations made and (c) the irresponsible actions of a senior official of the Department.

The tranquillisation and capture programmes carried out so far have given the Department of Wildlife Conservation a wider but yet inadequate experience in the capture of elephants. The problems of translocation and domestication have still to be solved. This can only be achieved with experience. Translocation to the wildlife parks after tranquillisation is one alternative, but there are limits to the number

of animals that these parks can take. There is also the problem of the distances involved. Taming wild elephants has been practised for a very long time in this country and therefore is not problem.

(a) The preferred method, where possible, of translocation to be adopted should be the elephant drive;



Fig. 3 An elephant captured in Resvehera

Recommendations of special committee

In the meantime, the Ministry of State, under which the Department of Wildlife Conservation functioned at that time, appointed a Committee for the translocation of elephants. They were requested to look into the problem of translocating the elephants pocketed in the Mahaweli 'H' area and to make suitable recommendations for its solution. The Committee in its report recommended the following actions and gave reasons for making these recommendations.

"On the Basis of the documentary material available and the knowledge and experience of the members of the Committee, the Committee considers that:

(b) This should be supplemented by immbilisation and movement of immobilised elephants after remobilisation, by monitor elephants and haulage, using suitable vehicles. This method is to be adopted only in regard to elephants which:

- the drive team is unable to dislodge from their habitats;

- having joined the drive, nevertheless backtrack or move away from the other elephants in the drive;

- are troublesome and do not fall in with the drive;

The Committee also stated that;
"It has to be remembered that the Mahaweli

Authority now beset with the problem of these elephants that are the subject of our deliberations, have given what may well be the last opportunity to have these elephants not merely out their way but safely into conservation and propagation. Should the elephants go back, the Mahaweli Authority would, we feel, well be justified from their purely agricultural development and colonisation standpoint, in thereafter viewing the elephants as only an impediment to their progress. They may then either resort to or permit less merciful methods of disposing of their pachydermic obstacles".

Jungle corridors

The Flood Plains National Park, at the northern end of System B, was set up to facilitate the movement of elephants from the Somawathiya-Thrikonamadu area to the Wasgomuwa National Park and vice-versa. Another corridor was proposed with the initial Mahaweli plan, to join up the Wasgomuwa and Maduru Oya National Parks. This was to be through Elakotaliya in System C. Due to the irrigation channels and roadways having to go through this corridor, plans to leave the jungle uncleared was abandoned and the jungles were cleared for settlement.

Corridors need not be National parks or Sanctuaries in the strict sense. It would suffice if they facilitate the unhindered movement of elephants through them. Limited human activity could be allowed. The limited availability of food in an elephant corridor would ensure that the elephants move through quickly. Elephant corridors are important in that they ensure a link between elephant habitats and make their seasonal movements easy. The free movement of elephants between habitats facilitates the gene flow between the breeding herds.

It is now very heartening to note that the Department of Wildlife Conservation has been able to stop all tobacco and paddy cultivation within the Floodplains Nation Park. Cultivation especially during the dry Yala season, was rampant in this Park earlier. This activity together with sand collection and brick making, prevented the elephants from using the Park as a corridor between the Wasgomuwa and Somawathiya National Parks as was intended.

Present status

System H

At present there are three large herds of elephants in the periphery of the project area. There is one herd of approximately 40-45 elephants in the newly declared Kahalla-Pallakele Sanctuary. This herd migrates to Galkiriyagama which is the catchment area of the Kalawewa Reservoir. Seven deaths caused by elephants have been reported from the Galkiriyagama-Madatugama area over the last ten years. With the development of the Kahalla-Pallekelle Sanctuary the problems caused by this herd are likely to be reduced.

The second herd of approximately 25-35 elephants are in the Resvehera area. This was a much larger herd. A part of this herd was driven to Wilpattu in 1984, whilst a part has stayed on in the Karuwalagaswewa AGA's area after the drive. The Resvehera herd deaths have been reported along with constant damage to dwellings and crops.

The third herd is in the northern part of System H. This is a small herd of 10-15 elephants which migrates down from the southern part of the Wilpattu National Park. They too cause damage to crops in the Nochchiyagama area when they are there.

System G

Groups totalling at times up to 50 elephants come across the Amban Ganga from the Wasgomuwa national Park and cause extensive damage to crops in System G. In a few instances there had been damage to the settlers' houses. Five deaths have been reported in the last three years. There are a large number of elephants

in the Dambulukelle/Giritale forest, but due to the barrier caused by the main irrigation channel none of these elephants come across to the settlement area of System G. They however go towards the Naula, Pubbiliya and Kabarawa areas and cause a lot of damage to crops. In fact in 1990 the Department drove some of these elephants across the Amban ganga to the Wasgomuwa National Park. However they all came back soon after. Some of the animals were driven to the Giritale Reserve.

A dangerous trend that has started in this area is the poisoning of elephants by irate farmers. They cut a hole in a pumpkin and put in a large dose of poison and leave the pumpkin in the field for the elephant to consume. The bodies of a number dead elephants have been found around System G in the last two years. The most recent one was at the north end of Dambulukelle in September 1992. If this effective method of elephant destruction catches on there will be mass poisoning of elephants by farmers. Fortunately most farmers are averse to killing elephants. They only want to drive them away from their cultivations.

System B

One group of over 130 elephants from the Somawathiya National Park and the Thirikonamadu Sanctuary come into the settlement area of System 'B' and cause a lot of damage to both humans and crops. The houses of the settlers too have been destroyed. These animals come into the project area mainly because they cannot use the Flood Plains National Park as a corridor to the Wasgomuwa National ark due to intense human activity.

There is another herd that comes from the Wasgomuwa National Park across the Mahaweli river and cause a lot of damage to crops in the western parts of Systems B and C. An elephant drive conducted in 1988 drove around 150 elephants to the Maduru Oya National Park. Most of These animals however seem to have returned. This is because adequate precautions were not taken to keep them in the Park. Most of the deaths reported from System B have been caused by lone elephants. Another group of about 30 elephants come out of the Maduru Oya National Park and cause a lot of damage to houses and crops in the area where Systems B and C share a common boundary.

The Department of Wildlife Conservation was engaged in an exercise to tranquillise and capture the elephants that were causing problems within the System B area. This has been detailed under the earlier section on immobilisation and capture.

System C

The Department of Wildlife Conservation has decided to erect electric fences along some of the boundaries of System C to prevent elephants from the surrounding areas, including the Wasgomuwa and Maduru Oya National Parks, from coming into the cultivated lands and destroying the crops. The proposal is to have 70 kilometres of electric fencing in strategic areas, to prevent elephant entry. One section of the fence has already been erected. This is from the confluence of the Ulhitiya and Mahaweli rivers going northwards to the confluence of the Hungamala ela and the Mahaweli. This fence of 10 kilometres was put in at the most popular elephant crossing. It will be extended southwards to Weragantota and northwards to Yakkure. At present the elephants walk along the 10 km. electric fence and come into System C where it ends.

An electric fence will also be erected on the other side of System C bordering the Ratkinda canal, taking in Pussellawinna and Henanigala and going upto the Maduru Oya National Park. Limited finances have prevented the Department from continuing their electric fencing programme.

There is a herd of 30 elephants at Kuda Sigiriya which is at the north end of System C. These animals come in from the Maduru Oya National Park, which is just across the Ratkinda canal. They come along a small bridge across this

canal and cause a lot of damage to a large cashew plantation that has been started and to cultivations in the southern part of System B. The Department has advised the plantation company and the Mahaweli farmers in that area to organise themselves and make suitable arrangements to prevent the elephants from crossing the bridge.

A number of elephants come into the Zone 2 cultivation areas of System C. Last year around 18 elephants that were in the Hebarawa area were driven across the Mahaweli river to the Wasgomuwa National Park from where they come. Only three animals were left at the end of the drive. However now all these animals have come back. In fact reports seem to indicate that there are now more elephants in System C than were last year.

Proposed solutions

In the Mahaweli areas the farmers expect the officials of the Department of Wildlife Conservation and the Mahaweli to protect their crops. They do not seem to see any obligation on their part to help. The is an attitude that has to be changed early if lasting solutions are to be found to the elephant problems not only in Mahaweli but all around the country.

The following suggestions are proposed for consideration in an attempt to reduce the problems caused by elephants.

1. In the Mahaweli areas, the Department of Wildlife Conservation should, through the Mahaweli community development staff, conduct a programme to educate the farmers on why the elephant population should be conserved and not killed indiscriminately. In addition, there should be a programme to train the farmers to organise themselves to protect their crops.

2. Human activity in the Flood Plains National Park should be reduced greatly so that the elephants could use this Park freely as a corridor between the Somawathiya and Wasgomuwa National Parks.

3. The Department of Wildlife Conservation should ensure that the present elephant habitats are not degraded or reduced in extent through illegal and unauthorised human activity.

4. Every effort must be made by the Department of Wildlife Conservation to develop, enrich and manage the elephant habitats depending on the needs of each individual location. Buffer zones are very important and the Department should actively pursue the development of these wherever possible.

5. A census of the elephant population, at least those in and around the Mahaweli projects, must be taken initially. This would give the basic data on which any elephant management and conservation plans should be formulated.

6. The excess and troublesome elephants should be moved out to another location. This is not easy considering the numbers involved and the limited experience in translocation. There is also a paucity of suitable locations. There are four methods by which elephants could be moved from one location to another. They are:

(i) Driving the elephants to a new habitat.

(ii) Capturing with the aid of tranquil lizers for translocation and tam ing.

(iii) Capturing by the *kraal* method and taming. Kraaled elephants can even be immobilised and translocated to new habitats.

(iv) Capturing elephants by engaging elephant trappers or Pannikars. Due to noosing not being practised very much now, there are only a few experience Pannikars.

There have been suggestions earlier with regard to the setting up of Captive Breeding stations. The forest in the catchment of the Kalawewa/ Balaluwewa reservoir is a suitable location for such a station. This area consists of over 500 acres of forests which a re linked to the newly declared Kahalla-Pallakelle Sanctuary. There is also an abundance of water throughout the year. These are some suggestions that should be taken into account when plans are drawn up to solve the many problems the Department of Wildlife Conservation is faced with. It is imperative that the problem of elephants in Mahaweli be looked at in its totality and initially an over all plan for future conservation and management formulated. Then a prioritised implementation plan based on the available resources (finance, manpower, vehicles, equipment etc.) should be drawn up. Plans to conserve the Mahaweli elephant, which constitutes a large percentage of the island's elephant population, will no doubt be an important segment of this plan.

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A new technique to transport elephant herds

Throughout Asia, as a result of high human population growth and high rates of deforestation, elephant habitats are shrinking year by year thereby leading to the fragmentation of hitherto continuous populations of elephants. An extreme result of such fragmentation is the development of so called "pocketed" herds of elephants. Such animals have no long-term future and are responsible for much of the crop depredation. At times, these "pocketed" elephants attack people. The people then become very hostile and often take the law into their own hands. A number of elephants have been killed by farmers in India, Sri Lanka and Indonesia as a result of the escalation in the human-elephant conflicts.

Now a new technique pioneered by Clem Coetsee of Zimbabwe's National Parks and Wildlife Management Department, to immobilize and transport entire families of elephants from one area to another hundreds of miles away, could be applied in Asian countries too. Coetsee has proven that even middle-aged elephants could be safely sedated up to 48 hrs. using **haloperidol** and **trilafon**, two relatively new tranquillizers. More than 600 elephants have been relocated from Zimbabwe to Bophuthatswana in South Africa, across a distance of 1,050 km overland, with a loss of only 15 animals. As long as there is sufficient water and food available en route to the elephants, there is no limit to the distances sedated elephants could be transported across. This new technique could become useful in relocating chronic crop raiding elephants from an area to more secure reserves **(Ch. S)**.

Estimating elephant numbers in Tabin Wildlife Reserve, Sabah, Malaysia

Shanthini Dawson

Introduction

The Asian elephant *(Elephas maximus)* is a highly endangered species throughout its present geographic range. Total pupolation size is estimated to be between 45,000 - 55,000 individuals. The methods used to arrive at this estimate are varied and in many critical cases only educated guesses (Santiapillai & Jackson, 1990). Assessing current statues and population trends using these estimates is hence very difficult and often meaningless.

The Asian Elephant Specialist Group (AESG) recognized the need to develop census techniques that could be widely applied in different habitats and since 1987 has been actively promoting standardization of methodology to estimate elephant numbers. An indirect method was adopted, modified and tested extensively in India during 1988/89 (Sale *et al.* 1990). The same method has been endorsed by the AESG and recommended as being most useful in dense elephant habitats (Ramakrishnan *et al.* 1991).

Sabah has the largest, and possibly the only population of elephants on Borneo and there is some evidence that it constitutes a distinct race from other populations of the species. The Sabah population is small (several hundred) and, being subject to serious habitat loss due to logging of the rain forest and its clearance for large-scale agriculture, is highly endangered. At present only one (recently gazetted) protected area, Tabin Wildlife Reserve, contains a significant number of elephants. Damage to crops is fairly widespread and frequent. A species management plan for elephant will shortly be prepared with assistance from the UNDP project now providing technical aid to Sabah wildlife Department. It will consider all possible management options, including further protected areas, erection of barriers such as electric fencing and translocation of pocketed groups.

In the light of the above, clearly it is of utmost importance to obtain a more accurate estimate of elephant numbers and their seasonal distribution than that presently available - which due to the great difficulty of sighting the animals in dense rain forest is somewhat sketchy. The estimation of numbers from dung density appears to be a promising method for Sabah conditions, and as it had never been used here before had to be demonstrated to local personnel. Therefore, the Sabah Wildlife Department initiated this Project to demonstrate the usefulness of the indirect method to census elephants in Tabin, and while doing this to give hands-on training to their personnel in all aspects of this technique.

Objectives of the study

- To estimate the size of the discrete elephant population in Tabin Wildlife Reserve.

- To demonstrate the effectiveness of the indirect method of estimation of elephant numbers under Sabah conditions.
- To teach the method to the Sabah Wildlife Department personnel involved in elephant management and to a Sabahan graduate researcher, with a view to it being adopted (with any appropriate modifications) as standard methodology.
- To provide a basis for collecting objective information of elephant numbers as the foundation of a management plan for the species in Sabah.
- To assist standardisation of Asian elephant census methodology which will facilitate comparison between various populations / countries by the Asian Elephant Specialist Group.

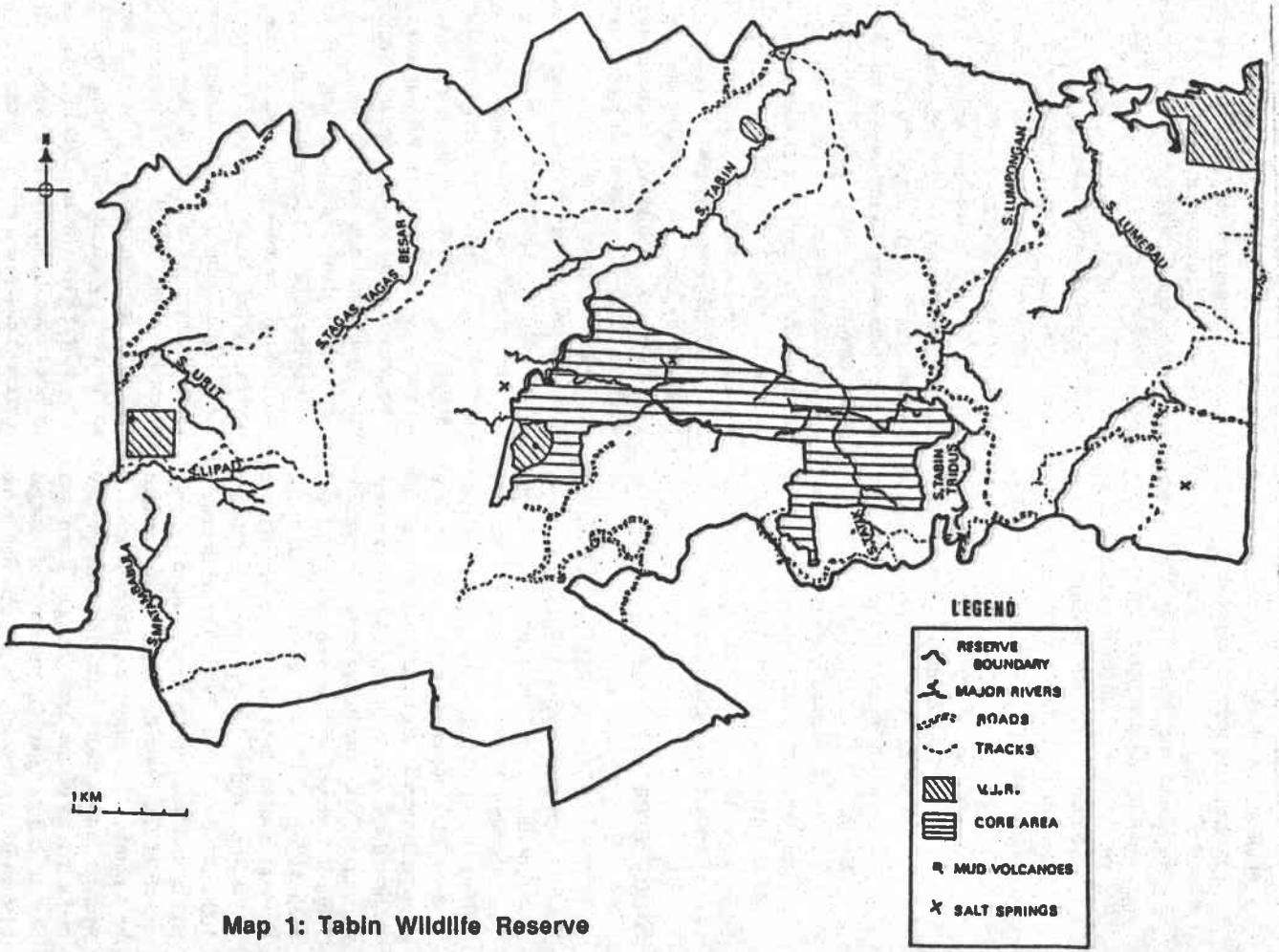
Study area

Tabin Wild life Reserve (=Tabin or Reserve) stretches across 120,000 ha of the central portion of the Dent peninsula in eastern Sabah (between 5°15' and 5°10' N and between 118°30' and 118°45' E. It was gazetted in 1984 as a Wildlife Reserve primarily to conserve three endangered large mammal species, including the Asian elephant, *Elephas maximus* (Andau, 1987). The topography in most of Tabin is highly dissected with steep hills and deep valleys and covers an altitudinal range from sea level to about 500 m, although in much of the Reserve the altitudinal range is between 100 and 300 m (WWF, 1986). The north eastern and central parts of the Reserve have the only stretch of flat lowlands. Tabin is well drained by a number of seasonal and perennial streams which originate in the hills and form the five major rivers of the area. Sungai Tabin and Sungai Lumpongon (a tributary of Sungai Maruap Besar) flow into the Segama Bay in the north-east. Sungai Lipad, Urit and Teagas-tegas Besar tributaries of Sungai Segama which flows near the western boundary of the Reserve. Tabin has a number of natural mineral sources, themost important of which are the two active mud volcanoes found near Sungai Lipad in the west and Sungai Tabin in the central portion of the Reserve. (Map 1)

Apart from a 8000 ha core area and four small patches of Virgin Jungle Reserve (VJR), Tabin represents a former logging concession in which active extraction only ceased in 1989. The area is still criss-crossed with old logging tracks. The primary vegetation was mainly lowland dipterocarp forest; the north-eastern corner contains freshwater swamp forest and a small amount of mangroves. The remaining primary forests are dominated by species belonging to the family Dipterocarpacaea - over 40 species have been identified and include *Shorea leptoclados*, *S. Symingtonii* and *Dipterocarpus caudiferus* (WWF, 1986; Ismail, 1989). Today, apart from the core area and the VJRs, the rest of the vegetation is typical secondary dipterocarp forest with open canopy and dense tangled vegetation in the lower layers. Here *Macaranga spp* dominate together with woody climbers (dominated by the genus *Uncaria*), gingers (over 30 species belonging to 11 genera) and ferns in the understorey (Ismail, 1989). Tree regeneration is slower on the slopes compared to the flat areas. And in areas that have been recently logged elephants frequently use logging tracks to move around.

Mean daily minimum and maximum temperature is 22° and 32° respectively. Rainfall is distributed unevenly throughout the year, the wettest period being between October and March. Total annual rainfall ranges between 2900 - 3000 mm (WWF, 1986). This study was planned for the period of least rainfall (dry season) to facilitate access to the more remote areas. It was generally dry during the study.

Other significant Wildlife in Tabin includes a small population of Sumatran rhino *(Dicerorhinus sumatrensis)*, banteng *(Bos javanicus)*, sambar *(Cervus unicolor)*, barking deer *(Muntiacus muntjac)* and mouse deer



Map 1: Tabin Wildlife Reserve

(Tragulus javanicus and *T. napu).* Seven of Sabah's eight primate species occur in the Reserve, including low densities of proboscis monkey *(Nasalis larvatus)* and orang - utan *(Pongo pygmaeus).* In addition to clouded leopard *(Neofelis nebulosa)* there is a considerable diversity of small carnivores including several species of civets.

Tabin Wildlife Reserve was selected as the study area for two main reasons. First, it is presently the only protected area which contains a significant population of elephants with long - term viability. Secondly, the Reserve boundary to the north, south and most of the west, is shared with oil palm and/or cocoa plantations, restricting the movement of elephants. The eastern boundary until recently was contiguous with large forest tracts within which elephants ranged. However, these forests are being systematically cleared for a FELDA scheme (only a few thousand ha are left), drastically reducing the range of the elephants and potentially restricting them to the Reserve. This situation calls for active management of the Tabin elephant population, and the results of this study will provide baseline data on abundance with which to follow population trends in the years to come. In addition, a management plan for the Reserve is under preparation and will require distribution and abundance information on all major species, including elephants.

Methods

Introduction

Three factors influenced the choice of the method to be used to census elephants in Tabin - the dense tropical vegetation, its size and the expected low densities based on previous surveys (Davis & Payne, 1982). In this situation a method that depends on sighting elephants directly cannot be used unless one is prepared to spend a disproportionate amount of time (and money). Therefore, the indirect method pioneered by Barnes and Jensen (1987) for similar circumstances in central Africa, and widely tested and adapted for Asian conditions (Dawson 1990), was used. Briefly, the method translates the density of dung in an area to elephant density by taking into consideration the rates at which dung enters and leaves the environment through deposition and decay. If these rates are more or less equal, then the quantity of dung in an area will be constant. Hence, if the density of dung is known, this can be correlated to elephant density by applying correcting factors for the daily rate of deposition and decay to it. The equation is thus:

$$E = \frac{D \times R}{d}$$

where E = elephant density; D = dung density; R = rate of decay; d = rate of defaecation.

Dung density estimates

Dung density is estimated by sampling based on standard sampling principles (Cochran, 1963; Norton - Griffiths, 1975) as applied to any other object. The line transect sampling technique described by Burnham *et. al.* (1980) is used to measure dung density as the assumptions it makes are realistic and readily applicable in field conditions.

A reconnaissance of the Reserve was carried out, by vehicle and on foot, over a period of two weeks with two objectives in mind. Primarily, it was to establish any significant elephant usage patterns within the Reserve with a view to stratifying the census area to obtain precise results. This was done by making a note of the frequency with which signs of elephant presence - feeding signs. dung, tracks, calls, elephants themselves - were encountered in an area. In addition information was also gathered by talking to local people and managers of surrounding estates. The second objective of the reconnaissance was to ascertain access to different parts of the Reserve in order to plan the logistics for the actual survey.

The reconnaissance showed typical localised spatial aggregation patterns expected from a long ranging, herding species. However, no distinct patterns of elephant distribution emerged except that the south western and central parts were least used. Because of the limited time available for the reconnaissance it was not possible to investigate distribution patterns further, and firm conclusions could not be drawn to stratify the area. Therefore, it was decided to treat the core area as a separate stratum where the vegetation was mainly primary forest, and the remainder of the Reserve was divided into 3 units of more or less equal sizes for logistic purposes. The aim was to carry out 20 transects of 2 km each in these units, including the core area. However, there was a proviso that if data collected showed definite use patterns by elephants, poststratification would be attempted while analyzing the data. Further, if no clear pattern emerged but variance levels were high within one or more units, more sampling would be carried out according to standard sampling principles.

In each sampling unity line transects were carried out on foot by a team with a minimum of three observers. Each transect ran along a predetermined compass bearing, oriented perpendicular to logging tracks and / or rivers. Right - angle distances to all dung piles seen on either side from the transect line were measured using a tape measure. Transect length was measured by a topofil (an instrument that measures distance by trailing cotton thread from a fixed point at the transect starting point).

The dung density estimate is derived from the transect data, i.e transect length, number of dung piles seen and their respective right - angle distances, using the perpendicular distance model and the Fourier Series estimator via the computer programme ELEPHANT (Dekker and Dawson, 1992).

Dung decay rates

The rate at which dung disappears depends mainly on the agents of decomposition and climatic factors such as rainfall, humidity and temperature (Coe, 1977). Decay rate is also established by sampling. In order to do this a number of samples with known dates of deposition are monitored on a weekly basis, from day 1 until they completely disappear (Dawson, 1990). Any recent evidence of elephant presence was followed up and the site visited to locate fresh samples. Although elephants themselves were seen in only one site, in three further areas calls were heard and fresh tracks encountered, during the reconnaissance.

A total of 70 samples were located in three different parts of the Reserve. Two plots with 9 and 25 samples respectively are located in the north - eastern extreme of the Reserve. One plot with 20 samples is located in the north - central part near Sungai Tabin, while the fourth is near Sungai Urit in the western extreme of the Reserve and has 16 samples. Each sample is given a number and marked with a wooden stake for easy location and identification in subsequent weeks. It is also ranked into one of five decay "stages" which is characterised by the physical appearance of a dung pile, rather than age (Dawson, 1990). At subsequent inspections the samples are recategorised if they have changed, and monitoring continues until they reach the final decay stage when they are deemed to have disappeared. The mean survival time (in days) of a given dung piles is calculated and its reciprocal is the decay rate.

Defaecation rates

The rate at which elephants produce dung is dependent on the quality of food ingested, which in turn is influenced by climatic factors (Dawson, 1990). It is therefore not advisable to use figures from the literature unless it is absolutely impossible to obtain this data by direct observations in the field. If using published figures is the only option available then it must be ensured that figures have been derived from areas with similar environmental conditions.

The best way to obtain comparable data on defaecation rates of wild elephants is to monitor domestic elephants that are allowed to free - range in the census area or those fed entirely on natural fodder. Secondly, whether monitoring domestic or wild elephants, it must be done over 12 - hour periods as there are distinct diurnal/nocturnal rhythms in defaecation times (Dawson, 1990). Rates derived from short observation periods added together may give biased results.

The steady state assumption

The central assumption of the method is that the number of dung piles in the census area is stable, i.e the proportion of fresh dung produced per day is equal to the proportion of old dung disappearing through decay. Although this is a fair assumption to make when censusing within a season or a closed population, the result can be validated if it is shown that this assumption holds. A simple way of doing this, using data collected during transects and decay rate experiments, is described in Dawson and Dekker (1992).

Counterpart training

In order to fulfil objective 2.3 all wildlife officers and senior rangers, and selected rangers and assistant rangers were assigned by roster to join the census team in Tabin, for an average period of one week. This was to give field personnel first hand experience in census design and data gathering for two of the three components of the method, ie, dung density and dung decay. In addition, two workshops were planned; one to discuss theoretical aspects of the method and how to plan a census operation, and a second one to give hands-on training in data handling, analysis and interpretation.

Further, efforts were initiated at the beginning of the consultancy to locate a Sabahan graduate student who could spend the entire consultancy period with me to undergo intensive training in all aspects of an elephant census. In addition to passing on the expertise to someone who could possibly be employed by the Wildlife Department for future elephant censuses, I planned to form a second census team after being fully satisfied that the candidate was proficient enough with the method to collect data independently. This would effectively increase the amount of sampling possible during the survey.

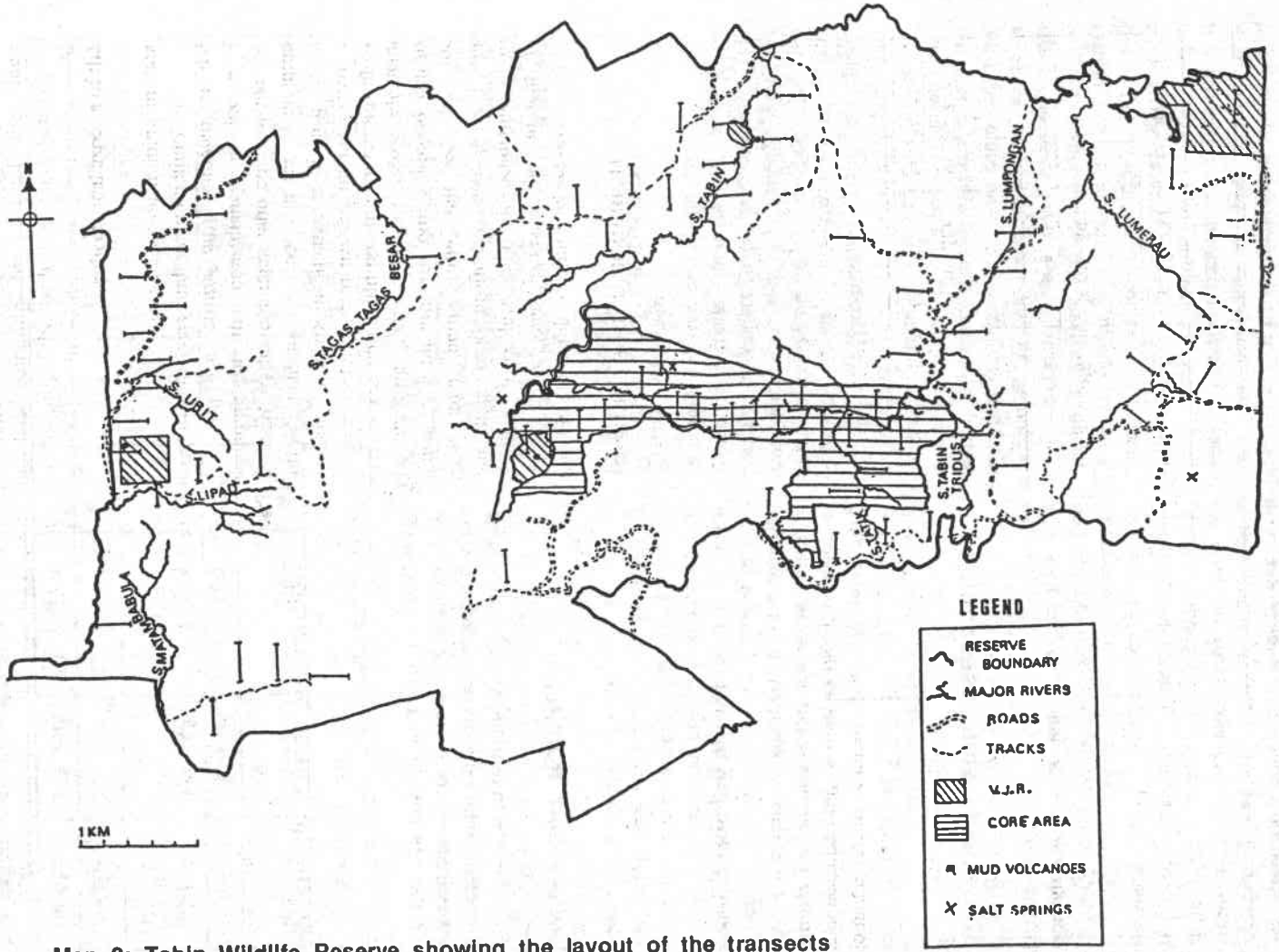
Results and discussion

Dung density

A total length of 118.2 km in 79 replicate transects was completed in the Reserve (Map 2). It was not always possible to complete the target transect length of 2 km in one working day due to the dense vegetation and undulating terrain. The mean transect length was 1.6 km

Sampling unit		Transects			Sample size (dung piles)	Density ± 1.96 SD	Covariance of density estimate
Stratum	Area	RL	L(km)	W(m)			
High Use	60 km^2	8	12.5	7.0	171	162± 480	12.53%
Moderate Use	245 km^2	19	35.5	11.0	288	834± 244	13.15%
Low Use	520 km^2	42	57.7	10.0	105	323± 121	14.84%
Not Used	373 km^2	10	12.5	-	5	-	-

RL = replicate lines; W(m) = transect width in metres.



Map 2: Tabin Wildlife Reserve showing the layout of the transects

(0.434 SD). Although the reconnaissance did not indicate clear use patterns, the data (transect location and number of samples seen per km) showed that within each sampling unit there was some localized clustering, invariably in the vicinity of the river valleys. All transects and their respective sample sizes were mapped and some distinct distribution patterns emerged. On the basis of this the Reserve was post - stratified into four units: high use, moderate use, low use and not used areas. The size and respective densities was calculated for each stratum separately and the results are given in the Table below.

Dung decay

Five cohorts of dung ranging between 5 and 25 dung piles have been monitored for between 16 to 19 weeks. Being located in different parts of the Reserve, the samples are subject to varying environmental conditions. All samples have not decayed completely to date and monitoring continues by staff in the Reserve. However, a decay rate has been estimated by extrapolation. Number of dung piles surviving to date is plotted against time and a regression curve is fitted to the data (a second order polynomial gives the best fit). By extending the regression to beyond the actual observation time, it is possible to predict future dung survival. Actual and predicted values indicate that the mean survival time of a dung pile is 140.84 days, which gives a decay rate of .0071 (.0084 - .0053). This rate is slow when compared to those found in India, the slowest there was 0.0081 (0.0010 - 0.0088).

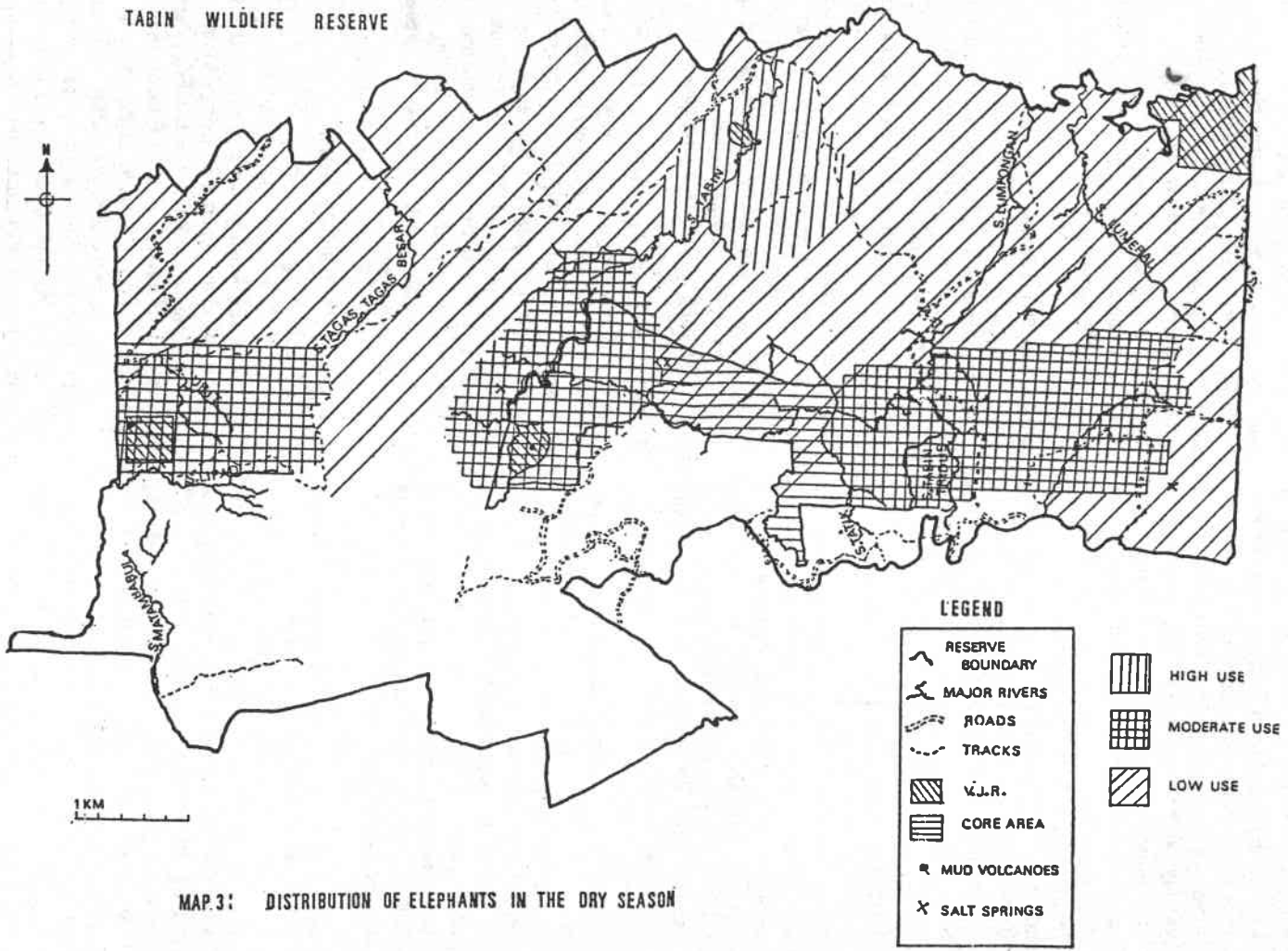
The slow decay rate may be due to two reasons. Firstly, it has been an unusually dry year. Rainfall immediately prior to the study and during the study was itself lower than the previous year (490.1 mm of rainfall during December to February compared to 833.9 mm the previous year, and 509.68 mm from March to June 1992 as opposed to 894.9 mm). Secondly, the conspicuous absence of large decomposing agents such as dung beetles and termites acting on elephant dung. Dung beetles and mechanical breakdown due to heavy rain cause dung to decay at very fast rates in the wet season in other pars of the Asian elephant range, while in the dry season decay rate is relatively slower as termites are the main agents of dung removal (Dawson, 1990); Wiles, 1980). In the case of Tabin, however, it appears that the decay process is almost entirely by bacteria, and therefore very prolonged.

Defaecation rates

Establishing the rate of defaecation for Sabah elephants proved difficult as there are no domestic elephants here. Locating and following wild elephants for continuous periods was next to impossible in the dense, vegetation of Tabin. There was a possibility that some data could be gathered from a recently radio - collared individual, but this was also not possible due to logistic problems. In the circumstances, I have to resort to using published information from other parts of the Asian elephant's range. Olivier (1978) reports defaecation rates of elephants in Peninsular Malaysia. However, there is very little indication on how these rates were obtained and hence not entirely satisfactory. Therefore, I am using the figures applied to estimate elephant densities in the rainforests of southern India which is 13.2033 ± 0.789. It must be noted that similar figures were obtained in Thailand from domestic elephants feeding on natural fodder in lowland dipterocarp forests (Mattana Srichakrachan, pers. comm.).

Elephant densities and distribution

Elephant densities have been calculated for each stratum separately using common decay and defaecation rates. These densities are extrapolated to stratum size to estimate numbers. The sum of the three strata in which elephants occur is the total population in Tabin Wildlife Reserve. (Stratification has greatly enhanced the precision of the results.). It must be reiterated that both distribution and population size of elephants in Tabin obtained by this



MAP 3: DISTRIBUTION OF ELEPHANTS IN THE DRY SEASON

Sampling unit		Elephan densities		Elephant numbers	
Stratum	Area	Mean	Range	Mean	Range
High Use	60 km^2	0.87	0.80 - 0.96	52	48 - 58
Moderate Use	245 km^2	0.44	0.37 - 0.51	108	91 - 125
Low Use	520 km^2	0.17	0.14 - 0.22	88	73 - 114
TOTALS	825 km^2			248	212 - 297

survey pertains to the dry season only (Map 3). Distribution of elephants in Tabin during the dry season appears to be influenced by terrain, food and water availability. Notes of these characteristics were made during the reconnaissance and while doing the dung density transects.

The high use area represents optimal habitat for elephants in Tabin. It is situated in the north central part of the Reserve and includes the Tabin river valley and a patch of primary forest (VJR). Terrain in this part of the Reserve is mainly flat with some gently undulations. Although the surrounding area has been selectively logged, such activity ceased some time ago. Unlike those areas that have been recently logged, these forests have regenerated well possibly due to the higher soil fertility in low-lying areas. Natural regeneration here is characterised by a great diversity of climbers / vines, shrubs and ginger species which are an important source of food for elephants. The tall forest also provide ample shade while Sungai Tabin is a permanent source of water. Very little human disturbance was noted in this part of the Reserve which is bounded by an oil palm plantation in the north. So a combination of all these factors may be the reason for this concentration of elephants during the dry season.

In the moderate use areas some of the same habitat characteristics occur, especially density of undergrowth. A common factor in the three units that make up the stratum is the presence of mineral sources either in the form of mud volcanoes or salt springs. Although this can influence densities, it is not conclusive as there are parts of the Reserve with known mineral sources but have low densities or no elephants at all. On the other hand, the high use stratum has no known mineral source. Having said that attention must be drawn to the fact that terrain in the moderate use areas was generally undulating and may deter greater use of these parts.

An interesting common factor between the high and moderate use strata are the patches of primary forest within them. Although it has been observed that primary forests have a lower density of elephants in general because of lower food availability (Olivier, 1978), this appears not to be the case within Tabin during the census period, ie, dry season. In fact this forest type shows a higher density of dung, and therefore elephant use. Sixty-four percent of samples detected in the high and moderate use areas were found in primary forests. It could be argued that this is a function of better visibility in primary forests, but where dung is concerned it does not hold as dense leaf litter on the forest floor can influence detection. Another point that may be raised is that elephants defaecate more during or after resting periods (Dawson, 1990). Tall primary forests provide good shade, especially important in the dry season, where elephants rest and dung density may be related to this activity. If this is one reason, the usefulness of tall forests to elephants should not be under-estimated and all efforts must be made to retain them.

Although it would appear that water would not be a limiting factor in tropical rainforests for elephants, in Tabin rainfall immediately prior to the study and as well as during the study was much lower than the previous year (total rainfall from December 1990 to June 1991 was 1728.8 mm while it was 999.68 mm for the same period in 1991/92). This dry spell may have limited water availability to the main rivers. In the circumstances, the combination of secondary forests (food) with primary patches (shade) and permanent water sources found in the high and moderate use areas influenced elephant distribution in the period of least rainfall.

The low use stratum, in most parts, had a combination of very undulating terrain and dense secondary forest which were recently logged with little or no natural regeneration. Seventy-eight percent of the samples detected were seen on logging roads or within 50 m on either side. It appears that in these parts elephants used available logging roads to move around and fed on the prolific ginger stands enroute. It can be argued that visibility on logging roads is better than inside dense secondary vegetation, but when taken in conjunction with the fact that other signs of elephants presence (including feeding, spoor and resting areas), were seldom noted within these forests in this stratum, the difference in local distribution of dung appears to be real. The concentration of dung on logging tracks was especially noted in the more recently logged areas.

Steady state

The dung piles in the decay rate experiments are a sample of the dung "population" and the changing decay categories effectively represent how the state of dung changes over a period of time. Dung samples encountered on the transects are also categorised into decay state using the same criteria. This data is a representative sample of the state of dung in the environment at a given time. From the decay rate experiment, which is monitoring a dynamic process, the relative proportion of a given decay stage can be observed. If this sample is truly representative of the changes that occur in the environment, then similar proportions of each decay stage can be expected in the "static" sample obtained on transects at any given time during the survey. Hence, if the observed and expected results show no significant difference, then it is deemed that the environment is in a steady state. This is tested using the simple one-tailed chi-square test. In the case of Tabin the observed and expected values were strikingly similar ($X^2 = 0.157$; $P = <0.05$ with 4 df) indicating that the steady state assumption holds and validates the census results.

Counterpart training

A total of 19 staff members including 6 Wildlife officers / Game wardens, 7 senior rangers and 6 rangers / assistant rangers have been trained. This includes a lady ranger who was assigned to the project for two months to receive intensive training and it is envisaged that she will be a key person in the Department for future elephant censuses. Although it was planned to train a Sabahan graduate student, a suitable candidate could not be found even until a month into the study. Instead, an undergraduate (third year) student was located through the University Kebangsaan Malaysia (UKM) and trained over two months. A one-day seminar was held on 15 May 1992 where all aspects of planning and conducting a census were discussed. Selected senior level staff (6 officers and 3 senior rangers) were invited to a 3 day workshop where data handling, analysis and interpretation was discussed. They also got hands-on experience in data analysis via computer. The two long-term trainees were also given training in data analysis.

Conclusions and recommendations

The density and resulting population size of elephants in Tabin Wildlife Reserve (121-297 individuals) has been obtained for the first

time using a method that is easily repeatable and mathematically sound. The method used isvalidating the results. These results provide the baseline data for comparison with future censuses to monitor the elephant population. This is especially important in the light of the fact that there will be an influx of elephants into Tabin from the east where forests are currently being cleared systematically for large scale oil plantations.

The results of this survey also demonstrate the appropriateness of the dung based estimates for tropical rain forest conditions. Even while using an indirect method, a long duration of field data collection is shown to be necessary, especially when working in predominantly secondary vegetation and highly undulating terrain, with very limited access for vehicles. Estimating elephant densities using a direct sighting technique in these conditions would be next to impossible. As similar conditions occur in other parts of the elephants range in Sabah, this method can be used to obtain comparable results to form the basis of a conservation strategy for the species. With the increasing incidents and levels of conflict between elephant and humans, a pragmatic management plan is urgently required.

The training objectives of this project have been amply fulfilled. The long-term training of one ranger is deemed to be especially important as it is envisaged that she will be a key person to carry out field data collection for future elephant surveys. The training of nearly all Wildlife officers and senior rangers of the Department in all aspects of planning and conducting and elephant census, data handling and interpretation is a vital output of the project. This means that the method can be applied by those presently involved in elephant management, or by those who may be involved in the future.

Recommendations

a. The results obtained by the present survey provides baseline data on population size. In the light of ongoing logging activity on the eastern boundary and the likely influx of elephants into the Reserve, a replicate survey should be carried out by the Wildlife Department in 1994 to ascertain any increase in population size through emigration.

b. Thereafter, censuses should be carried out every five years using the same technique, and preferably during the same time of year, to monitor population trends.

c. A survey should be carried out by the research staff of Tabin to ascertain the relative index of dung in different parts of the Reserve, to establish the distribution and relative abundance of elephants during the wet season.

d. A minimum network of access roads into the reserve should be maintained for vehicular use to facilitate logistics in future surveys (including those of species other than elephants).

e. Dung decay experiments should be carried out be research staff in the key elephant areas over a one year period to ascertain any seasonal differences in decay rates. The results can be used as a data base for use in future surveys when environmental conditions are similar.

f As a foundation for a species conservation plan, the Wildlife Department should carry out, as soon as possible, surveys in the two other key elephant areas, first the proposed Kinabatangan State Reserve and second the Ulu segama including the proposed Greater Danum Valley Wildlife Reserve.

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A preliminary study of the captive elephants in Sri Lanka

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Background

Collection of data on captive elephants was initiated during the Navam Perehera held in Colombo in the month of February 1991. A total of 139 elephants took part in the Perehera on the nights of 27th and 28th of February but data were obtained on only 125 of them. The data were collected by filling a specific data form for each animal and the form itself was prepared by FI especially for this purpose. The relevant data on each animal were filled on these forms while identification photographs were taken simultaneously for later reference. All this was done during day time on the 26th, 27th and 28th while the elephants were tethered at the Viharamahadevi Park.

Subsequently in July 1991 data were obtained on an additional 56 captive elephants during the Esala Perehera in Kandy. As the elephants brought for the Kandy Perehera were not confined to one central location but were scattered around the city and its periphery, data collection was somewhat limited. The data were collected on the 17th, 18th and 26th of July 1991.

These two stages of the survey enabled the FI team to obtain data on a total of 181 domesticated elephants from around Sri Lanka.

Objectives of the survey

This survey was carried out as the initial phase of an all island survey of captive elephants, elephant owners and mahouts in Sri Lanka. The data were gathered at this stage with two main objectives in mind;

1. To record as much detail as possible on domesticated elephants as the initial phase of a statistical census on captive elephants in Sri Lanka.

2. Through collection and analysis of data on the physical features and distinguishing characteristics of captive elephants, to investigate the possibility of applying the same criteria or parameters in the identification of elephants in the wild.

Data collection

The necessary data were collected by filling a separate data sheet for each elephant and taking two corresponding photographs of each animal (front and side view) for later reference. The parameters under which data were collected can be categorised as follows;

1. Name of elephant and identification number.
2. Name and address of owner.
3. Name and address of mahout.
4. Age of mahout, number of years working as a mahout and duration with present elephant.
5. Sex, age and height of elephant.
6. Details on physical features of elephant tusks, head, ears, trunk, tail, depigmentation and shackle marks.
7. Behavioural characteristics of elephant - aggression, musth etc.

8. Food-quantity, composition, preferences.
9. Utilization - nature and duration of work done.

Data analysis

the data collected was transferred from the data sheets to a computer data base. All the different categories of data were entered into two data files created specially for storage and analysis of this data. While one data file contains all data relevant only to the elephants, the other data file contains data pertaining to the owners and mahouts.

The data in the file containing details on the elephants was analysed mainly with reference to physical features, age structure, behaviour, food, utilization and names given to domesticated elephants in Sri Lanka. The data in the file containing details of owners and mahouts were analysed separately to get an idea of the traditional system in which tame elephant are cared for in the island, including the age structure of mahouts and the duration of time they are engaged in this specific occupation.

Results

The results obtained by analysing the data collected on 181 elephants in this preliminary survey can be categorised under different subjects as follows:-

Sex and age structure

The sex of the elephant was recorded in a total of 181 animals and of these 99 were females and 82 were males. The age of each animal was also recorded and categorised under ten year age groups. The results are are given in Table.

From Table 1, it can be seen that the largest number for males were in the 21 - 30 year age group and the 31 - 40 year age group, with 17 animals in each. Analysis of this data indicates that 41.4% of the total number of male captive elephants recorded in this survey are between the age of 21 and 40 years. In the case of females, the largest numbers were recorded in the 31 - 40 year age group and 41 - 50 year age group, with 26 animals coming within each group. Accordingly it can be calculated that 52.5% of the total number of 99 females recorded are between the age of 31 and 50 years. However if the total number of 181 animals on which age data were obtained is taken regardless of sex, it is seen that the largest number of 43 animals are within the 31 - 40 year age group and constitutes 23.7% of the total. Therefore it can be inferred that while most captive elephants in Sri Lanka are between the age of 21 and 50 years at present the majority age group for males is ten years less than that for females.

Table 1 Age groups of elephants

Age Group	Males	Females	Total
1 - 10 years	14	7	21
11 - 20 years	11	13	24
21 - 30 years	17	16	33
31 - 40 years	17	26	43
41 - 50 years	13	26	39
51 - 60 years	8	7	15
61 - 70 years	2	3	5
71 - 80 years	0	1	1
Total	82	99	181

The maximum age recorded in this survey was of a 72 year old female while only 11.6% of the total number of animals recorded are above the age of 50 years. The same percentage was recorded for the animals bellow 11 years of age and the minimum age recorded was of a 2 year old male. Therefore it is seen that a large percentage of captive elephants of both sexes in Sri Lanka are in the breeding, adult age group at present. However very few of these animals are ever used for the purpose of captive breeding, possibly due to the fact that this has not been a traditional practice in this country.

Physical features

The data collectd were analysed with regard to certain external physical features. This included analysis of the relatuionship between sex, age and height of the Sri Lanka elephant. Other pysical features such as the shape, size, tearing and depigmentation patterns of the ears as well as the length, shape and hair pattern of the tail were analysed in detail for the purpose of finding indivdual indentification criteria for possible application in later research on elephants in the wild. Tabulttion and analysis of data yielded the following results.

Correlation betwwn age, sex and height

Age, height and sex were recorded in 173 elephants in the course of the survey and this data was subjected to compartive analysis to determine if there was any correlation between the three factors in *Elephas maximus*. For the pupose of analysis the data were first categorised under five year age groups, while the age was listed under 1 foot (12 inch) categories. The number of males and females in each height-category for each age group was counted separately as seen in Table 2.

Table 2: Height (ft) of elephants

Age group (in years)	Height category in feet <= 6.0 M	F	6.1-7.0 M	F	7.1-8.0 M	F	8.1-9.0 M	F	9.1-10.0 M	F	=>10.1 M	F
0 - 5	5	-	-	-	-	-	-	-	-	-	-	-
6 - 10	4	1	2	2	1	-	-	-	-	-	-	-
11 - 15	-	1	3	1	1	1	-	-	-	-	-	-
16 - 20	-	-	5	2	2	7	-	1	-	-	-	-
21 - 25	-	-	-	3	8	4	6	1	-	-	-	-
26 - 30	-	-	-	1	1	5	2	2	-	-	-	-
31 - 35	-	1	-	3	6	5	1	1	2	1	-	-
36 - 40	-	-	-	1	1	10	4	3	3	1	-	-
41 - 45	-	-	-	3	2	11	2	6	1	-	-	-
46 - 50	-	-	-	-	1	5	2	1	4	-	-	-
51 - 55	-	-	-	1	1	3	-	2	4	-	1	-
56 - 60	-	-	-	-	-	1	-	-	2	-	-	-
61 - 65	-	-	-	-	-	2	1	-	-	-	1	-
66 - 70	-	-	-	-	-	1	-	-	-	-	-	-
71 - 75	-	-	-	1	-	-	-	-	-	-	-	-
Total M/F	9	3	10	18	24	55	18	17	16	2	2	0
Total for Height groups	12		28		79		35		18		2	

Subsequently the same data were analysed to ascertain the maximum recorded height, minimum recorded height, average height, and the height category to which the majority of animals in each five year age group belongs. This was worked out separately for males and females as given in Table 3.

Table 3: Height categories in elephants

Age Group (in Years)	Maximum Height		Minimum Height		Average Height		Majority Height Category	
	M	F	M	F	M	F	M	F
0 - 5	4.4	-	3.6	-	4.0	-	<6.0	-
6 - 10	7.6	6.6	6.0	5.6	6.4	6.2	<=6.0	6.1-7.0
11 - 15	8.0	8.0	6.6	5.10	7.0	6.5	6.1-7.0	<6.0-8.0
16 - 20	8.0	8.0	6.6	7.0	7.0	7.6	6.1-7.0	7.1-8.0
21 - 25	9.0	8.6	7.6	6.6	8.1	7.5	7.1-8.0	7.1-8.0
26 - 30	9.0	8.6	8.0	6.6	8.5	7.8	8.1-9.0	7.1-8.0
31 - 35	10.0	9.6	7.6	6.0	8.3	7.6	7.1-8.0	7.1-8.0
36 - 40	10.0	9.6	8.6	7.0	9.0	8.1	8.1-9.0	7.1-8.0
41 - 45	9.3	9.0	7.6	7.0	8.3	7.9	7.1-8.0	7.1-9.0
46 - 50	10.0	9.0	7.6	7.6	9.0	7.9	9.1-10.0	7.1-8.0
51 - 55	10.11	9.0	7.6	7.0	9.4	8.0	9.1-10.0	7.1-8.0
56 - 60	9.6	8.0	9.6	8.0	9.6	-	9.1-10.0	7.1-8.0
61 - 65	10.0	8.0	8.6	7.6	-	-	8.1->10.1	7.1-8.0
66 - 70	-	7.2	-	7.2	-	-	-	7.1-8.0
71 - 75	6.6	-	6.6	-	-	-		6.1-7.0

Close study of these figures indicates that in general the height of the Sri Lankan elephant is an extremely variable factor when compared with age. However some clear differences were seen between the sexes with regard to height. For instance the majority height category for females in all age groups between the age of 16 and the age of 70 remained at 7.1 - 8.0, with more than 50% of all animals in each age group on which data were obtained coming under this height category. In males on the other hand the majority height category was seen to be generally more variable above the age of 25 while above the age of 45 the majority height category was found to be 9.1 - 10.0. The data also clearly indicates that increase in height is roughly equal in both males and females up to the age of 40 but above this age males continue to grow taller while the growth rate in females decreases or stops completely. It can also be seen that the maximum recorded height in each age group above the age of 20 is always more in males than in females while the minimum recorded height for each age group over 20 is generally lower in females than in males. The only exception to this pattern being that the minimum recorded height in both males and females of the 46 - 50 year age group is equal. Likewise the average height is more for males than for females in all age groups for which sufficient data on both sexes are available to calculate an average. The maximum height recorded for male elephants regardless of age was 10.11 feet at the withers (this being an exceptionally tall animal) while for females it was 9.6 feet. Curiously in the 16 - 20 year age group while the maximum recorded height was equal, the minimum height, average height and majority height categories were all found to be higher in females and lower in males. However in the age groups below the age of 16, once

more the pattern of males being generally taller than females could be seen as in the groups above the age of 20. Unfortunately as there were no females in the age group of 0 - 5 years and no males recorded in the two age groups above 65 years making age/sex comparisons for these three groups was not possible.

Accordingly in can be concluded that although height is a highly variable factor in *Elephas maximus* occurring in Sri Lanka, differences do exist between the sexes in relation to age and growth rate. However the above data analysis shows that height alone is not a factor that can be used do differentiate the sex or age of elephants in the field due to the highly variable nature of this parameter. This is clearly seen when examining the data from examples such as a 35 year old female which is 9.6 feet at the withers while a 70 year old female has a height of only 7.2 feet at the withers. Likewise in males a 35 year old animals was recorded to have a height of 10.0 feet, a 55 year old male had a height of 7.6 feet and an exceptionally tall 52 year old male had a height of 10.11 feet at the withers. Therefore height is not a parameter with which age or sex can be determined in the Sri Lankan elephant. At the same time further investigation beyond this preliminary study with additional data on the age, sex, growth rate relationship could bring about interesting results.

Ears

Detailed information on the external ear pinna which was found to be extremely variable was collected on 170 of the elephants in the survey. Using the data thus collected together with the identification photographs of each animal analysis was done with regard to ear shapd, ear size, ear fold, tearing on ears and depigmentaion on ears.

Ear shape - With regard to shape, the ears of 170 elephants on which data were available were categorised under 3 main shapes as can be seen in Fig. A and the results were seen to be as follows;

1. Short acute angled lobe = 43
2. Elongated acute angled lobe = 46
3. Rounded lobe = 81

Accordingly of the 170 animals sampled 47.6% had ears belonging to the Rounded lobe category indicating that this is the most commonly found ear shape in Sri Lankan elephant. Meanwhile 27.0% of the sampled animals had ears with Elongated acute angled lobes. There was no correlation between the different ear shapes and the sex of the animals.

Ear size - Ear size was examined in proportion to the size of the head (Fig. A) as well as the general size of the animal, under three size categories. Data were collected on 177 animals and the results are as follows;

1. Small = 7
2. Proportionate = 166
3. Large = 4

This data shows that the majority of animals comprising 93.7% of the sample had ears which were proportionate in size when compared with the size of the head. A minority of 3.9% had ears that were small in size while an even smaller number comprising of only 2.2% of the sampled animals had ears that were large in proportion to the size of the head.

Ear fold - A common physical feature of Sri Lankan elephants is the fold or turn over along the top margin of the ear pinna, extending to the top outer edge of the ear. Of the 170 animals sampled with regard to the ear fold only 4 animals were found not to have any folding along the top edge and all four were below the age of 10 years. However the entire sample contained 15 animals in the 1 - 10 year age group and except for the above mentioned 4 animals the other 11 had a certain amount of folding along the upper edge of the ears. On the other hand 137 animals belonging to both sexes and belonging to different age groups had small to medium folding along the top edge of the ears. Extensive folding along the top edge and

outer corner of the ears was recorded in 33 animals of which 25 (75.7%) were found to be above the age of 40 years. It was also noted that out of a total of 8 animals which had extensive folding but were under 40 years of age 7 were males and only 1 was a female. This factor was interesting as the number of females in the sample as a whole outnumbered the number of males.

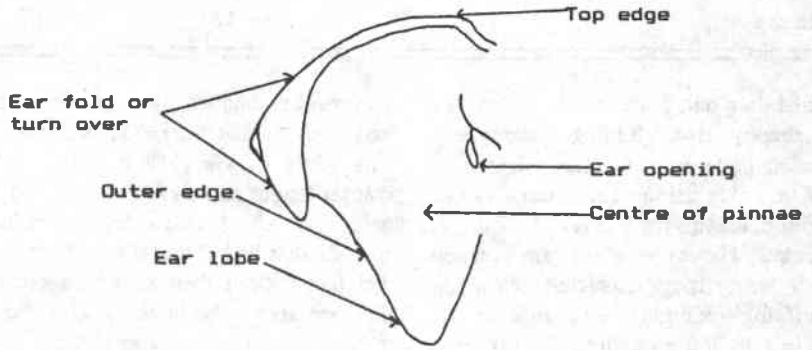
The extent of the ear fold is a commonly used parameter to estimate the age of Asian Elephants but the above stated results of this study did not indicate that this alone is a reliable index to be used in estimating the age of animals. Of the total number of animals in the age group below 11 years of age 73.3% were found to have small to medium top edge folding on the ears indicating that folding is not purely determined by age. Likewise small to medium folding was also evident in many animals of various age groups and both sexes above the age of 10 years. The majority of animals with extensive folding were above the age of 40 years but a minority of 24.2% had extensive folding while their age ranged between 13 years and 35 years. However the results also indicate that the occurrence of extensive folding at a young age seems to be more evident in males than in females. Therefore it may be possible to use the ear fold as a guide in estimating the approximate age of females but this needs further investigation. Although the possibility still remains that the ear fold has some connection to the age of an elephant it is difficult to use the extent of the ear fold alone as a criteria to accurately estimate age in the Sri Lankan elephant.

Ear tearing - Tear marks on the ears were also examined on 170 sampled elephants. 84 animals representing 49.4% of the total number were found to have no tear marks at all, while 63 animals representing 37% of the total had small nicks along the outer edge and 23 animals representing 13.5% of the total had large tear marks along the outer edge of the ears. Most of the largest tears were seen on the top outer edge where the ear folds. One particular animal was seen to have a neat, round hole, about 1.5 inches inward of the outer edge with no tears along the edge itself. Most of the larger tears along the edge were semicircular or V-shaped while the tears on the top corner in some animals looked ragged with entire parts of the flap missing.

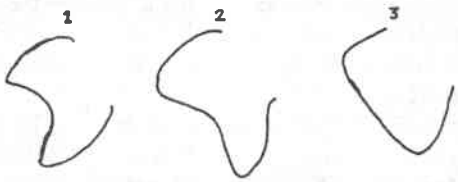
The above data indicates that a large number (49.4% of the sample) of domesticated elephants in Sri Lanka have no tearing on their ears. However tear marks on the ears are very common in wild elephants and therefore this could be a direct result of the vegetation in the natural habitat inhabited by the elephant in Sri Lanka. Accordingly domesticated elephants captured from the wild at an early age and those born in captivity have no tears on their external ears.

Depigmentation on ears - Depigmentation patches and the patterns created by them were found to be extremely varied among individual elephants. These numerous variations can be used for individual identification of the elephants as the pattern of depigmentation on the ears of each animal was almost unique, differing even slightly from all others. Only very young animals were found to have no depigmentation at all on any part of the ears. A large number of animals of both sexes had depigmentation to some extent along the outer edge and on the lobe of the ears. Most of the animals with extensive depigmentation also had it along the outer edge and on the lobe while only a few had extensive depigmentation along the top edge and in the centre of the ear pinna. Even in young animals where depigmentation patches were just beginning to appear they were on the lobe or along the outer edge of the ear. The extent of depigmentation of different areas of the ear pinna was examined in 170 animals and the results give some idea of the possible variations (Table. 4).

FIG. A - Parts of the External Ear Pinnae

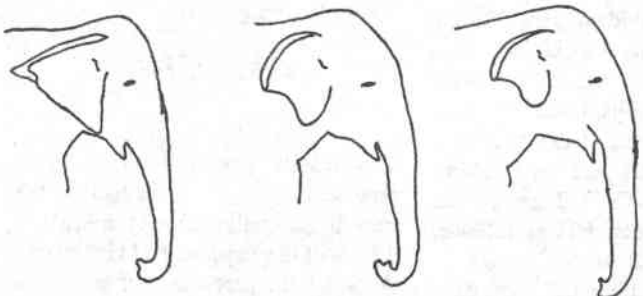


Ear Shape Variations



1. Short acute angled lobe
2. Elongated acute angled lobe
3. Rounded lobe

Ear Size Variations



Large Proportionate Small

Table 4: Ear charateristics in elephants

	Outer edge	Lobe	Top edge	Center
None	31	21	73	105
Low	60	51	85	60
Extensive	79	78	12	05

The combined data on all the ear characteristics including shape, size, folding, tears and depigmentation patterns and extent when analysed show that external ear characteristics can be very useful in identifying individual elephants in Sri Lanka. However there are certain limitations in using these characteristics along when identifying individual elephants in the wild unlike in a domestic situation. For instance, dust or mud could obscure characteristics such as depigmentation while the shape and extent of tearing cold change with time and the extent of ear folding too could change with time. Only the size and shape of the ears would remain constant in adult elephants. Therefore although ear characteristics can be used for individual identification of the Sri Lanka elephant they should be used in combination with other physical features such as height, sex, trunk, head and tail.

Tail

The possibility of using the tail of the Sri Lankan elephant for individual identification was looked into by analysing data collected on the tail length of 175 animals. In addition to this, with the help of photographs taken of each animal the tail shape and hair at the end were also examined in 163 animals and the resulting data are given in Table 5. The tail length was divided into 3 categories (Fig. B1) as follows.

1. Long - almost touching the ground.
2. Normal - reaching the hock joint of leg or a little below.
3. Short - ending above the hock joint of leg.

The results obtained by examining data on tail length show that 8.5% (15 animals) had long tails while 67.4% (118 animals) had tails of normal length and 24% (42 animals) had short tails. The short tail category includes both animals that had short tails by nature and those that had broken their tails at some stage and now are above the hock joint of the hind leg. It is not known however, if these percentages calculated on the basis of captive elephants would be relevant with regard to wild elephants as for instance the exact reasons for tails being broken are not known. A possible reason for a large number of male, wild elephants as opposed to females having broken tails could be a result of fighting among bull elephants in their natural habitat. Therefore the percentage of wild elephants with short tails may be higher than in domesticated elephants.

Tail shape was looked at under two categories as illustrated in Fig. B2. and the categories are as follow;

1. Straight
2. Kinked or coiled

The results obtain show that 142 animals representing 87.1% of the total number sampled had straight tails while 21 animals representing 12.8% of the sampled had kinked or coiled tails. Although the percentage of animals with kinked tails was low it could prove to be a useful individual identification characteristic in the field as each animal with a kinked or coiled tail was distinctive from all others.

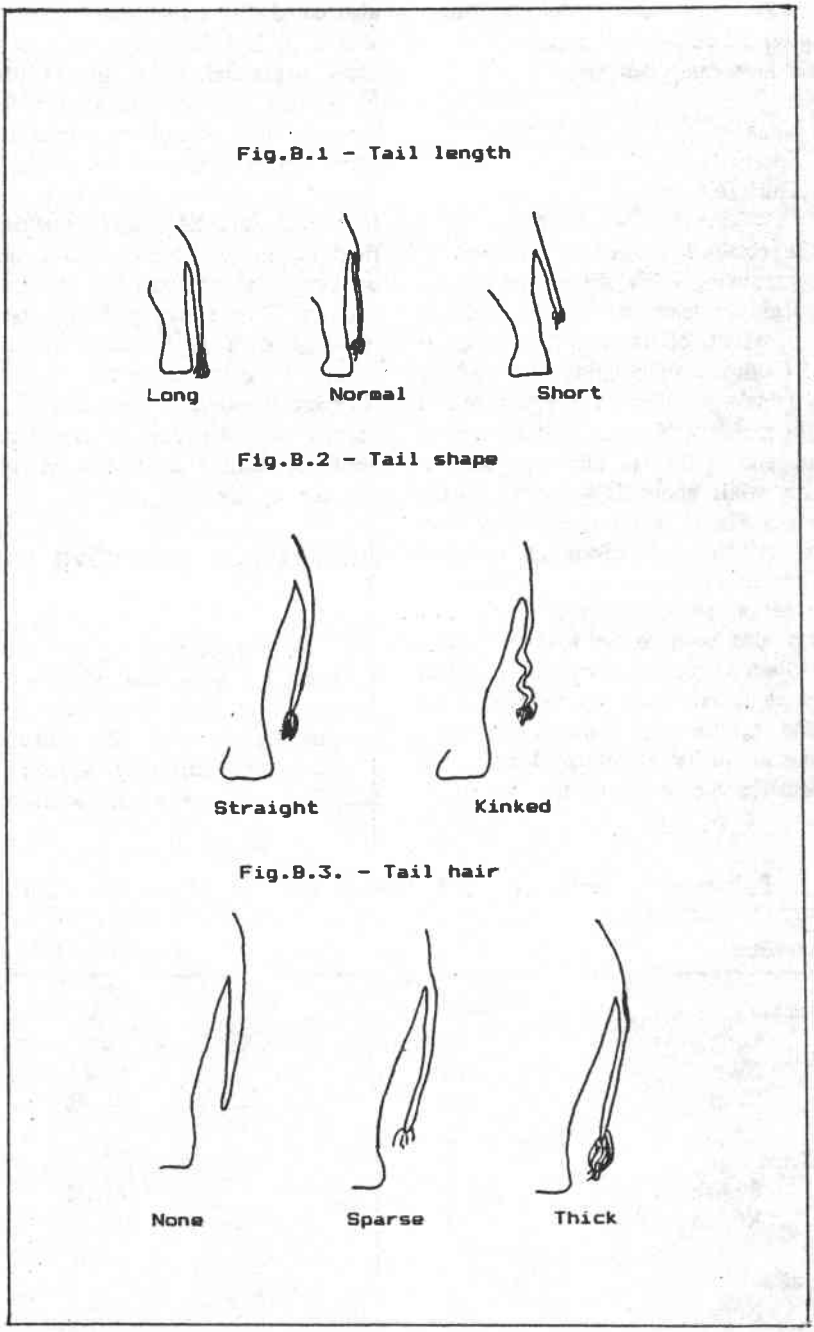


Fig. B - Variations in the elephant tail

The hair that forms a brush at the end / tip of the tail was categorised under 3 groups depending on the quantity as illustrated in Fig. B3. These three categories are;

1. None
2. Sparse
3. Thick / Bushy

The results obtained accordingly are that 12 animals representing 7.3% of the total number sampled had no hair at all, 67 animals representing 41.1% of the sample had sparse hair and 84 animals representing 51.5% of the total had a thick growth of hair at the end of the tail. The majority of animals (75%) with no hair at the end of the tail also had short or broken tails while about 25% had tails of a normal length. Therefore this inverse correlation between no tail hair and broken tails indicates that this characteristic would be dependent to a large extent on the percentage of broken tails which was also seen to be low in captive elephants. Both sparse and thick hair at end of the tail were found in a high percentage of animals and therefore this characteristic would not be very useful for individual identification of elephants in the wild. In the course of collecting and analysing data on tails it was also noted that a few animals had hair which was white in colour in contrast to the normal black at the end of the tail. As this seems to be a rare characteristic in the Sri Lankan elephant it can possibly be helpful in individual identification of animals in the wild, if it occurs in wild elephants. In view of the above it can be said that the tail is only a marginally useful field identification characteristic and can be used only in combination with other physical features. This is mainly due to the low level of variation in the length, shape and quantity of hair at the end of the tail in the Sri Lankan elephant. However to determine the usefulness of tail characteristics in identification it is necessary to have more data on tail beraking, tail hair etc. in wild elephants.

Aggression in captive elephants

With regard to aggression in captive elephants data were recorded for a total of 181 animals of which 82 were males and 99 were females. Of the total 181 animals 58 were recorded to be general ly aggressive while 24 had killed one or more persons. However a clear

Table 5: Length, shape & hair at the end of elephant tail

Characteristic	No. of Animals	Percentage (%)
Tail Length :		
Long	15	8.5%
Normal	118	67.4%
Short	42	24.0%
Tail Shape :		
Straight	142	87.1%
Kinked / Coiled	21	12.8%
Tail Hair:		
None	12	7.3%
Sparse	67	41.1%
Thick	84	51.5%

difference between the sexes was evident in the data regarding aggression. It was found that of the 82 males 33 were generally aggressive and 16 of them had killed humans at some stage. Of the 99 females 24 animals were reported to be generally aggressive in their behaviour but only 8 of them had killed people. Statistical analysis of this data indicates that 40.2% of the domesticated male elephants are aggressive while 19.5% become killers at some stage. In contrast to this only 25.2% of domesticated female elephants become aggressive and of these 8% become killers. However if the statistics are examined regardless of sex it shows that in general about 13.2% of all captive elephants in Sri Lanka are potential man killers while 32% are generally aggressive in their behaviour at all times, even if they have not killed people. From the data collected it was also seen that most of the victims have been the elephant mahouts.

Food of domesticated elephants

The data collected in this survey included information on the food given to captive elephants in Sri Lanka and individual food preferences. Analysis of this data shows that in general domesticated elephants in Sri Lanka are fed on a mixed diet of *kithul* logs, *coconut palm* branches and *jak* branches. In addition to this staple diet some that were based in rural areas were given small quantities of other plant material which included *eramudu, bo, pota wel, thimba, nuga* and *budaliya*. The kinds of food given were recorded for a total of 180 elephants. Of these one was still being fed on milk from its mother and did not come under the normal feeding patterns.

All 179 adult animals on which food data were recorded had some percentage of *Kithul* in their regular diet. A total of 122 elephants (68.1%) were fed continuously on a mixed diet of *kithul, coconut* and *jak* branches with not other variations. A further 39 animals (21.7%) were fed only on a mixture of *Kithul* and *coconut* while just 1 animal was found to be fed exclusively on *kithul*. 17 animals (9.4%) out of the total 179 adults had small quantities of the other plant material named above diet in addition to *kithul, coconut* and *jak*. The quantity of these other plants given to these animals depended entirely on availability as they are wild plants found only in small quantities. However, 11 animals were recorded to have *eramudu*, 7 animals had *bo*, 3 animals had *pota wel*, 1 had *Nuga*, 1 had *budaliya* and 1 had *Thimba* in their diet, in small quantities.

The mahouts of the elephants were also questioned as to the individual food preferences of each elephant and the resulting data were recorded and analysed. Preferences were thus recorded on a total of 149 animals while the others had no clear food preferences according to their mahouts. Of the 149 animals which showed a preference for one type of food over another 138 elephants accounting for 92.6% of the total showed a clear preference for *kithul* while only 13 animals (8.7%) showed a preference for *coconut*. Another 5 animals showed an equal liking for bother *kithul* and *coconut* but preferred bother these to other kinds of food such as *jak* branches. There were 3 animals however that preferred a mixed diet of all three kinds at all times and did not appreciate being given any one kind of food. There was also 1 animal which showed a preference for both *Pota wel* and *Eramudu* rather than the normal kinds of food given while 1 animal preferred only *eramudu* and another preferred *budaliya* to all other kinds of food which were offered.

Analysis of all this data on feeding of captive elephants in Sri Lanka makes it clear that all elephants are given *kithul* in some quantity as a part of their normal diet and over 90% of the animals show a clear preference for it over other kinds of food given to them. The other kinds of food that are commonly given to captive elephants are *coconut*, and *jak* branches. The quantities needed for a day vary according

to the size of the animal, sex, age, the work it does etc.

Work done by captive elephants

Data were obtained from the mahouts regarding the work done by 180 of these domesticated, captive elephants. The average number of days in a month that each elephant works was recorded. The data were categorised under four groups according to the number of working days as follows;

1. None - no working day
2. Low - less than 10 days a month
3. Medium - 10 to 15 days a month
4. High - 16 to 22 days a month

The results obtained by analysing the data under the above categories are shown in Table 6.

Of the working elephants 52.7% fell into the medium work category, doing between 10 and 15 days work per month. Only 24 animals (13.3%) worked more than 15 days a month and none exceeded 22 days a month. A further 32 animals (17.7%) worked only a few days includes uprooting trees, dragging, carrying and loading logs at logging camps and saw mills etc. However besides these traditional kinds of work, of recent times captive elephants are being used in the tourist trade at hotels and other resorts. Here the animals give rides to tourist, they can be touched, fed and photographed by tourists for a fee. Compared to the traditional forms of work they have been used for this new source of work is physically easier for the elephants and brings a substantial income for the owners.

Table 6: Work done by captive elephants

Category	No. of Animals	Percentage
None (0 days)	29	16.1%
Low (<10 day)	32	17.7%
Medium (10-15 days)	95	52.7%
High (16-22 days)	24	13.3%

According to the figures given in Table 6 it is seen that 29 elephants constituting 16.1% of the total number on which work data were available did not work at all; of these 19 animals (16.5%) belonged to religious institutions such as temples and therefore did not have to work to earn a living. 5 animals did not work because they were not old enough and therefore not big enough to do the normal heavy work done by captive elephants in Sri Lanka. Of the other 5 animals that did not work, 1 was an Army mascot and only took part in parades, 2 were not able to work at the time of data collection due to ill health, 1 could not work as it was a lactating female still feeding a calf and 1 did not work as its owner did not want it to work.

In addition to all these forms of work most of these elephants also participate in temple festivals and processions ("perahera") but this is done as a part of Sri Lanka's cultural tradition and not to generate income. It is considered an honour for the elephant, the mahout and the owner of the elephant to be able to participate in these religious festivals and these services are provided to the temples free of charge. All captive elephants in the country are trained to take part in these ceremonies. The largest and most prestigious of these ceremonies is the annual Perahera of the Temple of the Tooth Relic which parades the streets of Kandy for 7 consecutive nights. The honour of carrying the casket containing the relic of Lord Buddha goes

to a special tusker which has to have certain distinguishing points according to tradition. This animal is normally owned by the temple and given special care and attention throughout its life.

Names given to captive elephants

A curious observation which was made in the course of this survey on captive elephants in Sri Lanka is that certain names given to elephants by their owners are very popular. For instance names were recorded for a total of 82 male elephants and of these 28 (34.1%) were named *Raja* while there were 2 named *Jayaraja*, 1 named *Indiraja*, 1 named *Wijeraja* and 1 named *Singharaja*. Accordingly 40.2% of the total number of 82 males had "Raja" at least as a part of their name. Likewise in the case of females of a total 99 animals on which names were recorded 40 were named *Menike* (40.4%), 10 were named *Manika* (10.1%) 2 were named *Podimenike* and 1 was named *Kalumenike*. Accordingly of the total number of females where names were recorded 53.5% were called *Menike / Manika* as their name or a part of their name. The exact reasons for the popularity of these particular names is not known but the meaning of the names gives a clue. The name *"Raja"* means King and it is not surprising that it should be thought of as a fitting name for a male elephant. Likewise *"Manike"* or *"Manika"* means Lady in the Sinhala Language and therefore is popularly used for female elephants.

Mahouts

Personal details such as name, address, age and the number of years working as a mahout were recorded for the mahouts as a part of this survey. The analysis of data collected on the age of the mahouts and the number of years engaged in this particular occupation brought forth some very interesting facts regarding this traditional occupation. It was found that the age of these mahouts varied between 16 and 72 years but the majority of them were between the of 20 and 45. However when the present age and the number of years they had been engaged in this occupation were compared for each mahout it was found that the majority of them started working as mahouts at a very early age as can be seen in Table 7.

As indicated in the above figures it was found that 12.6% (22 mahouts) of the total on which data were obtained had started working with domesticated elephants while they were less than 11 years of age while the youngest age at which a mahout was recorded to have started this kind of work was 5 years. Most of these 22 mahouts had started working as helpers to their fathers or uncles who had also been elephant mahouts. In addition to this a further 55.7% (97 mahouts) had started working as mahouts between the age of 11 and 20 years. 49 other mahouts constituting 28.1% had started working with elephants between the age of 21

Table 7: Age at starting work as an elephant mahout

Age Group	No. of Mahouts	Percentage of Total
<11 years	22	12.6%
11 - 20 years	97	55.7%
21 - 30 years	49	28.1%
>30 years	6	3.4%

and 30 years while only a small minority of 6 mahouts (3.4%) had been above 30 years of age when they started.

A large percentage had at first worked as an assistant mahout to their own fathers or some other relation who was the senior mahout. Having gained experience they then started looking after an elephant on their own under the same employer if there were more than one elephant or else they found employment under another elephant owner. It was also observed that there was a very close relationship between mahout and elephant and that the mahouts understood very well the needs and preferences of the elephants they looked after. This was specially obvious in the mahouts who had been engaged in this same occupation from a very early age. Some of them had even been looking after the same elephant throughout their career and treated the animal more as a friend and companion than a mere source of income. Most of the mahouts also stated that they found it a satisfying occupation and would not give it up for any other job. All there data point to the fact that being an elephant mahout is a traditional occupation which goes from father to son in Lanka. It is also an occupation which is strictly limited to males, as there have never been any female mahouts in the recorded history of Sri Lanka.

Conclusions

1. The collection of all required data on 181 captive elephants, their owners and mahouts was achieved through this initial phase of the survey. Accompanying identification photographs were also obtained on all these animals.

2. The data on age and sex structure of these captive elephants brought forth some interesting information and it was possible to build certain hypothesis regarding correlation between factors such as age, sex and height in the Sri Lankan elephant. However additional data and further analysis are needed to test the hypothesis. The general age structure of captive elephants of both sexes in Sri Lanka at the present time was also calculated using their data.

3. The data obtained on the physical features of the elephants when analysed indicate that certain features in the Sri Lankan elephant are highly variable and can be used as individual identification characteristics. However the degree of usefulness of each feature or combination of characteristics discovered through this survey has to be tested by applying the same criteria for the purpose of individual recognition of wild elephants.

4. Analysis of the collected data also made it possible to get a general understanding on aggression and attacks on humans, feeding and food preferences and work done by captive elephants in Sri Lanka.

5. Certain interesting socio-cultural factors connected with elephants in captivity in Sri Lanka were also observed in analysis of this data. These were mainly with regard to the names given to captive elephants, the traditional occupation of being an elephant mahout and the relationship between the mahout and his elephant.

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Elephant corridors in Uttar Pradesh, India

A. J. T. Johnsingh

Introduction

The elephant habitat in the state of Uttar Pradesh was once continuous from Katerniaghat in Bahraich forest division in the east to river Yamuna in Shivalik forest division in the west. Over the decades, as a result of the growing demand for more land for the increasing human population, this continuity has been broken and now there are five isolated populations. The major population of elephants in this tract (ca. 650) occurs in the proposed Rajaji-Corbett Elephant Reserve (Johnsingh, 1992). This reserve spans from Kosi river which forms the eastern boundary of Corbett Tiger Reserve to river Yamuna on the west (Fig. 1). This forest tract includes the present Shivalik forest division, proposed Rajaji National Park (which includes the three former wildlife sanctuaries: Chilla, Motichur and Rajaji) Sonanadi wildlife sanctuary, Corbett National Park and parts of Lansdowne, Bijnor and Kalagarh forest divisions. Singh (1978) gives details of the distribution of elephants for this area.

Elephant conservation input in Uttar Pradesh should focus on the large Rajaji-Corbett population and its habitat which has already been broken into three isolated areas due to developmental projects. Fortunately the elephant bulls still migrate across the artificial structures thereby bringing about genetic exchange between the populations. This genetic exchange, however, would not continue for long if the fragile habitat continuity between the three areas is not immediately strengthened by the creation of corridors. Johnsingh, *et al.* (1990) have already highlighted the problems faced by the elephant corridors in this area. Panwar (undated) has given detailed suggestions for the improved management of these corridor areas. This paper brings in more information.

The developmental projects and habitat fragmentation

The major developmental project that has almost divided the Rajaji-Corbett elephant habitat into two is the 14-km long Kunaunchilla power channel which was constructed on the east bank of Ganges in the early 1970s. This canal is 22 m wide and, with full flow of water, nine meters deep. The sides of the canal are at an an angle of 45° and cemented, except for 500 m, and therefore do not offer foot-hold to the elephants. There are three places at which the elephant bulls cross the power channel and go the Ganges: one is the passage over Binj rau (rau = dry river bed) where the channel goes under the rau; the second is the 60 m long aqueduct connecting Dogudda with Ganges where in summer 1991 a tusker was seen crossing from Ganges to Dogudda; the third is the bridge across the power channel 2 km from Chilla which is being used by bulls at night in summer. Around the period when the channel was built there were developmental projects on the west bank of Ganges such as establishment of Hindustan Antibiotics factory, Raiwala army camp and the settlement of the evacuees from the submersion area of Tehri dam village. These have put an end to the access of elephant herds from Chilla and Motichur to Ganges (Johnsingh *et al.* 1990).

The second important development that has restricted the movement of elephants between Rajaji and Corbett is the

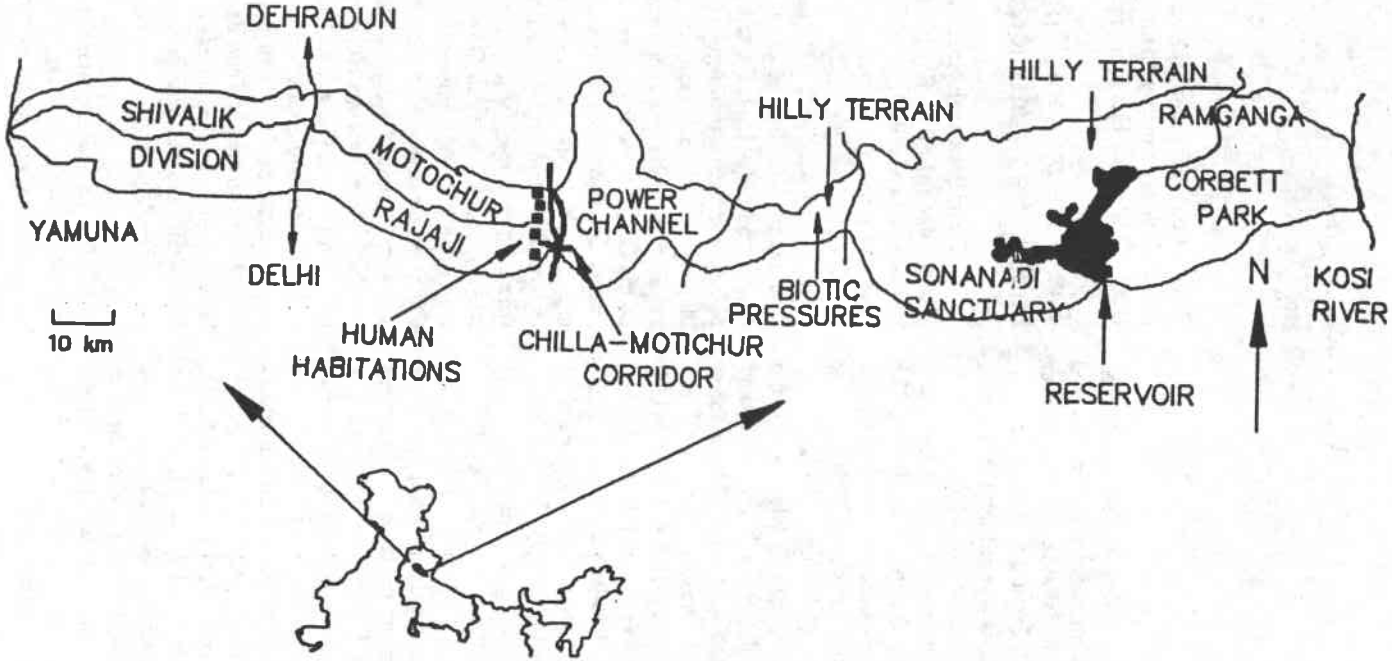


Fig 1. Rajaji - Corbett Elephant Range and factors affecting elephant movement

Kotdwar-Lansdowne road which runs across the narrow Rajaji-Corbett corridor parallel to Koh river. This road construction has resulted in steep edges and building of walls which impede crossing by elephants. This hilly corridor is used only by bulls. Cow groups ceased to cross Koh river when the extensive forests on the southern side of the hilly terrain were cleared for agriculture and human settlements possibly at the beginning of this century. Now this corridor area is beset with numerous problems largely arising out of the intensive biotic pressures from the southern and northern sides of the corridor. Sunderraj *et al*, (in prep) have quantified biotic pressures and steepness of the terrain in the corridor for the area used and avoided by cow groups. They conclude that steep terrain and biotic pressures deter the cow groups crossing Koh river from Rajaji (Table 1)

elephants were never reported during the last 100 years (Singh, 1978). Although it is no longer possible for the elephants to move to the west of Corbett along its southern boundary because of the reservoir township, the elephant movement to Sonanadi has become normal as they have found a way across the hilly Gaujera block.

Measures taken by the Government

In fact precious little has been done to strengthen the habitat continuity where it has been broken by constructions. Across Ganges two corridors (Chilla-Motichur and Binj rau) have been identified by Uttar Pradesh forest department. The Chilla-Motichur corridor is approximately 3 km long and 1 km wide and is situated between Suni sot (sot = spring) in

Table 1 Biotic pressures and terrain rating for the area used and avoided by elephant groups in Rajaji - Corbett Corridor, 1989 - 1990. Data collected along 4 transverse and 11 longitudianal transects.

	Area Used	Area avoided
Steepness of terrain (mean value)	2.73	3.43
No. of people seen	593	1388
No. of livestock seen	246	351

In the past, elephants in Corbett National Park aggregated along the Ramganga river in summer and dispersed towards Adnala, Palain and Sonanadi (Hathikund) ranges of Kalagarh forest division after the rains in July. When the Ramganga reservoir, which was built in the early 70's and extends over an area of 90 sq. km, was filled up by rains in 1974 the dispersal pattern of elephants was upset. Many believed that the reservoir would become a permanent impediment to the migration of elephants to Sonanadi. The confused elephants were seen even in the eastern end of the Park where

Chilla on the east bank of the Ganges and Motichur forests on the west bank of Ganges. The Binj rau corridor lies on the west bank of the Ganges, 7 km north of Chilla-Motichur corridor, between Chilla and the Song - Suswa rivers which drain Motichur.

To give long term protection to the Chilla-Motichur corridor the Uttar Pradesh Forest Department has a proposal to acquire 46.6 ha from the evacuees of the Tehri dam (70 families) and to compensate them with 46 ha in the Patri Reserve Forest and 2.6 million

rupees. In addition, 63 ha from Raiwala army cantonment including the ammunition dump will be acquired. In exchange 220 ha of land will be given to the army and the cost of an ammunition dump construction will be borne by the forest department. There is also a proposal to widen the bridge 2 km from Chilla across the channel at a cost of 20 million rupees to enable herds to cross.

In spite of these proposals which are being discussed for well over seven years very little has been done to strengthen habitat continuity. Meanwhile the Binj rau corridor has become a lost case as numerous well established human habitations have come on the west bank which would deter elephant migration between Chilla and Motichur.

Recommendations for action

Of the three problem areas, except Ramganga area where elephants have resumed their original migratory patterns, the other two need immediate attention. For Rajaji - Corbett corridor and Chilla - Motichur corridor Johnsingh, *et al.* (1990) have given five recommendations which are emphasized below.

1. The narrow Rajaji - Corbett corridor should be totally protected from forestry operations and further development. Ecodevelopment projects should be initiated on the southern and northern side of the corridor area so as to reduce biotic pressures on the forest. The nursery between Kotdwar and Amsod should be closed down and stone walls on either side of Kotdwar - Amsod road in potential elephant crossing sites should be pulled down.

2. Acquisition of land from the evacuees of the Tehri dam and army should be carried out on a priority basis. The army should lead this conservation programme by vacating the area at an early date.

3. We believe that there is no need to widen the bridge. If disturbances around Suni sot (e.g., the gujar hutments) are eliminated even the herds would start using the bridge. The money allotted for the proposed bridge construction could be used to relocate Gangabhogpur village between Dogudda and Binj rau. Otherwise the fodder, firewood and timber needs of this village of 25 huts and 250 people and their livestock situated on the bank of Ganges will eventually destroy the only natural vegetation between the channel and east bank along the entire length of the Ganges. This is the only patch of vegetation along Ganges which is being used by tiger and elephant.

4. After acquiring the land on the west bank, the corridor area should be protected by a suitable electric fence. A 2m high fence (southern fence) should extend from the level crossing along the north bank of Motichur rau to the Ganges and a similar fence (northern fence) parallel to this at least 1 km to the north. There should be one more fence 1 m high on the eastern side of the railway track, from the beginning of the southern fence to the beginning of the northern fence. The fence should however, have a 10 m gap at the southern end with a cattle guard which would prevent cattle from entering the corridor area but would allow elephants to pass through. One meter high electric fence is not a barrier to wild ungulates. This area should be systematically patrolled by guards to prevent fence damage and the cutting of vegetation by local people.

Conclusion

The political climate in the country, the enthusiasm of the Uttar Pradesh forest department and the compliance of the local people living around these corridor areas were much more amenable for conservation five years ago than it is now. One more fact that is emerging out of the present scenario is that any sacrifice, such as shifting of homes we expect the villagers to perform, will be done when they are convinced of the need for such a sacrifice and amply rewarded. Bearing these in mind an action plan needs to be drawn and implemented urgently to strenthen the existing corridors on the lines suggested above.

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News from Vietnam

Vietnam is a heavily populated country. Even close to Saigon, there are some elephants that are under serious threat as a result of escalating conflicts with man. The existence of two small "pocketed" herds of elephants north-east of Saigon was first reported by Do Tuoc & Charles Santiapillai in 1991 who recommended that they be captured and relocated to the nearby Nam Bai Cat Tien National Park. Later Shariff Daim on the basis of his survey in 1992, identified 3 groups totalling 37 animals and recommended their capture and relocation to the same national park.

But costs of moving these animals were so prohibitive that nothing was done until the Vietnamese themselves enlisted the help of a Singaporean company to capture all the elephants. According to Shanthini Dawson, who is working in Vietnam as a consultant for WWF- Vietnam Programme, "the entire cost of the operation is being borne by the company in return for 15 elephants (of their choice) or 40% of the total catch, which ever is greater". Shanthini Dawson estimates the population size of the elephants to be about 40-50 individuals.

According to Shanthini Dawson, the operation began in April 1993, and to date 15 individuals have been caught. Of these 4 adults have died, 6 sub-adults have been trained so far and are being retained by the Ministry of Forestry (MOF), and 5 are awaiting transportation to Singapore or release into a protected area. One Singaporean has been killed by an elephant in the operation. MOF plans to radio-collar some of the captured elephants and release them into the proposed Chu Yang Sinh nature reserve, given its relatively large size (90,000 ha), undulating terrain and small human settlement in the vicinity. Dawson recommends the domestication of these elephants for use by MOF in protected areas to transport tourists. One final thought: How will Singapore get the approval of CITES when it comes to taking the elephants listed in Appendix I, out of Vietnam into Singapore? (Ch. S.)

Minimum Viable Populations for elephant conservation

Raman Sukumar

Introduction and definitions:

It is well known that the smaller the size of a species population the higher the risk of it becoming extinct. This extinction need not be caused merely by deterministic ecological processes such as habitat destruction or hunting but also by chance factors operating on birth and death processes. Thus in a small population all the mature females may fail to reproduce in a given year or all the individuals may die within a short time span due to chance alone.

For small populations it is thus meaningless to talk of average birth, death or population growth rates. Deterministic models of population dynamics provide a reasonably robust approximation of average long - term demographic trends in large populations. These models are, however, quite inadequate for small population in which not only demographic stochasticity but also environmental and genetic stochasticity or catastrophes may drive the population to extinction, even though life table analysis may indicate that the population has on average a positive growth rate.

Small population biology is especially relevant to the conservation of Asian elephants. Loss and fragmentation of habitat, a process that still continues, has given rise to numerous small, isolated elephant populations in most Asian countries (Sukumar 1989, Santiapillai & Jackson 1990).

The crucial question is what is the minimum population size of elephants that should be maintained to prevent its extinction. Population viability analysis (PVA) could provide useful inputs to management decisions for these populations (see Soule 1987 for a review). At the outset we must understand that even for a single species the minimum viable population is not a magic number but varies according to various demographic traits and ecological pressures.

The continued survival of a population can be expressed only in probabilistic terms (Schaffer 1981). No population has a 100% probability of surviving for any given period of time. Thus, the minimum viable population (MVP) is usually expressed as that which has a 95% (or 99%) chance of surviving to 200 (or 1000) years.

The MVP thus varies from one species to another and from one population to another, depending on their peculiar demographic, environmental and genetic factors, and most important, on one's personal definition of MVP in probabilistic terms. A population ecologist may define MVP as one that has a 99% chance of surviving for 100 years (cf. Shaffer 1981); a reserve manger may deem it fit to continue *in situ* conservation measures for a population that has a 90% chance of surviving for 100 years.

Population viability analysis is thus a process that can yield different values of minimum viable population (Boyce 1992). The results reported here are based on a preliminary analysis and provides a first approximation of the MVP in Asian elephants. For this I used programme VORTEX developed by Robert Lacy (Chicago Zoological Society) who in turn used algorithms provided by James Greir (North Dakota State University).

Stochastic modelling

Most of the population parameters used in the modelling are based on data obtained

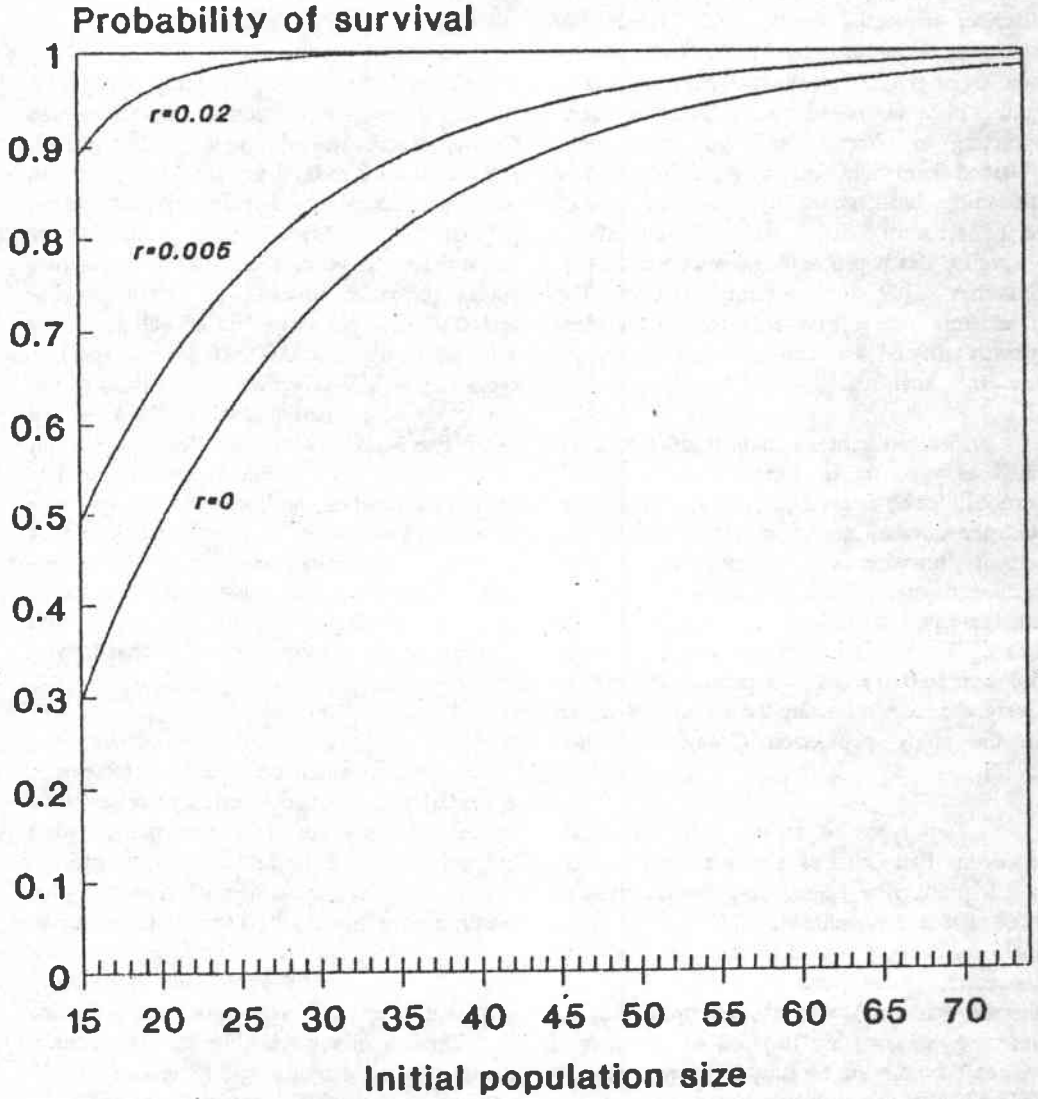


Fig. 1: Probability of survival of various initial population sizes

from a study of the Nilgiri-Eastern Ghats elephant population in southern India (Sukumar 1989).

Population processes are modelled as discrete, sequential events, with probabilistic outcomes determined by Monte Carlo simulation. **Demographic stochasticity** is modelled by taking birth and death probabilities as corresponding to observed average annual rates obtained from field data. In the First round of modelling, birth probability was taken as 0.20 to 0.22/mature female/year, while annual age - specific death probabilities were varied (see Sukumar 1989 for mortality values). The parameters were adjusted so as to yield a desired growth rate and sex ratio under a deterministic life table analysis.

Environmental stochasticity is modelled as variation in annual birth and death probabilities by sampling binomial distributions, with the standard deviation (SD) specifying the annual fluctuations. Two populations were simulated, one with a SD equal to 20% and another equal to 40% of the average probabilities of death. SD in fertility was taken to be 5.0 and 10.0 for the two populations respectively, the latter reflecting the variance observed in the study population (Douglas-Hamilton 1972).

Two types of catastrophes were modelled, the first (such as a severe drought) with a 2% probability of reducing reproduction to 60% and survivorship to 80% (see Corfield 1973 for drought related mortality at Tsavo) of the normal values, and the second (such as a disease epidemic) with a 0.5% probability of reducing survivorship to 75% of the normal values.The carrying capacity (K) was set at 150 (SD=30); this was much higher than the initial size of simulated populations.

Age and sex - structure of the initial population were adjusted to begin with the stable age distribution. Adult sex ratios at stable age distribution under the first scenario were in the range of 1 adult male for every 3 -4 adult females, representative of a natural population not under any serious threat from ivory poaching. All simulations were run 1000 times for 100 years.

Fig. 1 shows the probability of survival for 100 years as a function of population size for populations with different intrinsic growth rates (r) from 0 to 0.02 as calculated from life table analysis of the female segment of the population. To ensure a 99% probability of survival for 100 years, the minimum population sizes required are about 25 - 30 for one growing at r=0.02 (2% per year) and 65 - 80 for those growing slowly at r=0.005 (0.5% per year) or remaining stable. When the probabilities of the two types of catastrophes are doubled for the population with potential r=0.02, a population of 45 animals has a 99% of surviving for 100 years.The survival probabilities for the two populations with low and moderate levels of environmental variance were hardly distinguishable. This implies that a long-lived K-selected mammal such as the elephant is relatively well buffered against environmental stochasticity.

For the population potentially increasing at r=0.02, the male mortality rates were increased so as to result in more skewed adult sex ratios (adult male: female ratio going from 1:4 to 1:16) at stable age distribution. This would reflect the trends seen in many Asian (Sukumar 1989) and African elephant populations (pool & Tomsen 1989) suffering from ivory poaching. The result is a significant reduction in probability of survival (Fig. 2). For instance, the population size needed to ensure a 99% probability of survival increases from 25 - 30 (at 1:4 sex ratio) to about 55 at 1:8 ratio. With a 1:16 sex ratio a starting population of 150 (at K=150) has only a 92% probability of surviving for 100 years. It is only when K is increased to 250 that a population of 120 elephants has a 99% probability of surviving for 100 years.

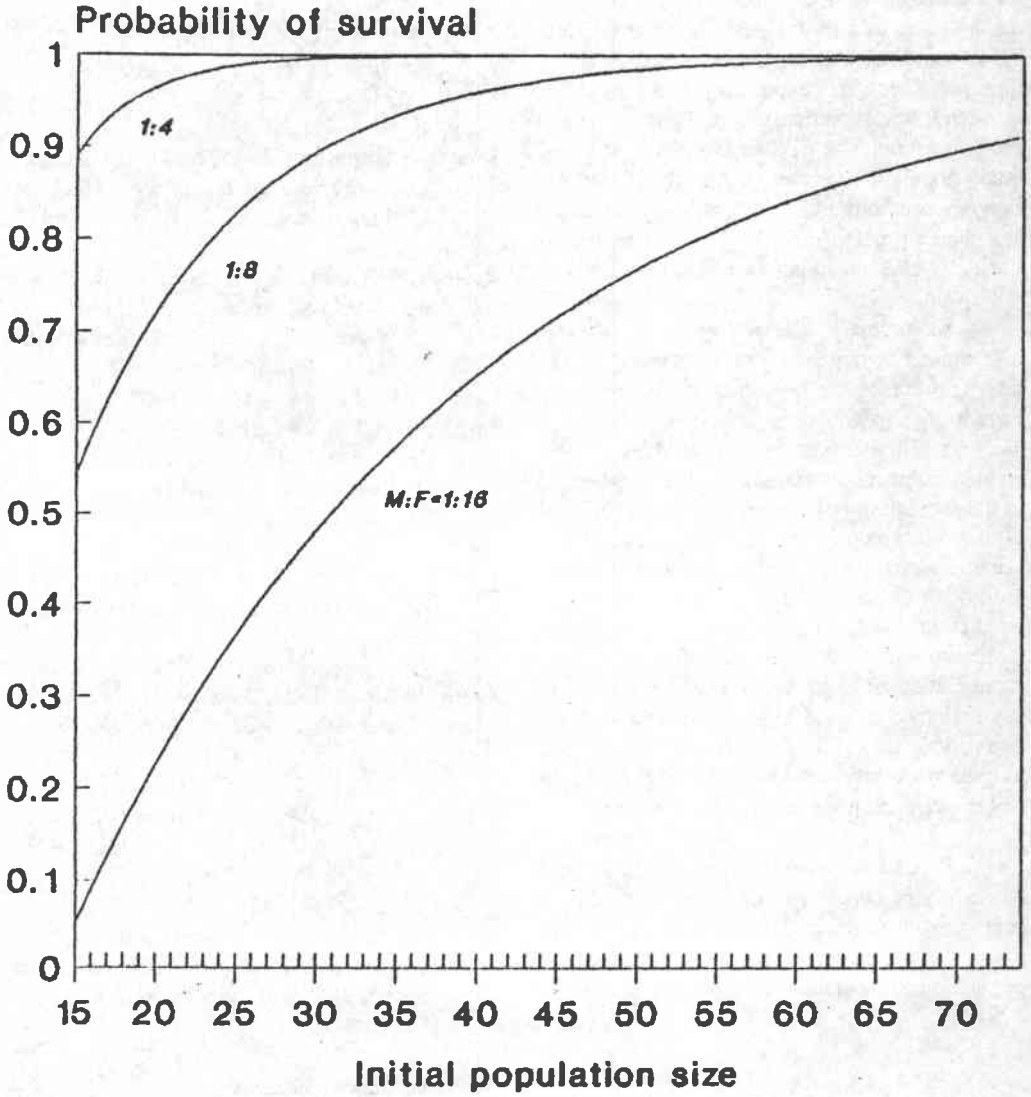


Fig. 2: Probability of survival of various initial population sizes

In the absence of specific data for elephants I did not model the deleterious effects of inbreeding on the population. The genetically effective population size (EPS) of 50 suggested as the minimum number needed to keep inbreeding below a tolerable 1% per generation can be taken as a useful guide for management. This would, of course, translate into a higher total population size depending on the adult sex ratio and the proportion of pre-reproductives in the population. The EPS as a percentage of the total population varies from about 8% in Periyar, southern India (where ivory poaching has been a problem) to 50% in southeastern Sri Lanka (where poaching is not a threat).

In summary, a total population of 100 - 200 elephants, depending on demography, sex ratio and ecological pressures, would not only have a high (>99%) probability of survival for the next 100 years in the face of demographic and environmental stochasticity, but also be safe in the short term from genetic erosion. The goal of managers could thus be to maintain these minimum sizes in isolated elephant populations until other options emerge in the future. Let me emphasize that the figures given above are the minimum sizes recommended for short-term conservation of populations that are not under any serious danger of losing their habitat. Such populations may still be unable to maintain their long-term evolutionary potential. For this much larger population sizes would be required.

Population viability analysis could also be usefully combined with other types of ecological analyses in deciding on management options as, for instance, in dealing with elephant populations in conflict with people (Sukumar, 1991).

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The sad status of elephants in southern Assam, India

S. Deb Roy

I wish to inform you about something startling that has been reported by Peter Thorose of Shillong and subsequently I verified the same from some local sources. In the Eastern Cachar Dist. of Southern Assam, there exists some extensive elephant habitat, from the Cachar - Manipur border in the North to the Inner line Reserve Forest at the Cachar - Mizoram border in the south. The area may be around 1500 sq. km. and had some excellent habitat for elephants in particular. Extensive bamboo *(Meloccana bambosiodis)* and cane brakes mixed with pockets of evergreen forest cover this entire contiguous area and elephants had been resident here amongst many other interesting and important fauna. Several endemic species of plants occur here.

Several elephant 'Mohals' had been in operation here and it is here that in 1958 I had first accompanied a *"Mila Shikar"* party to see for myself and understand the intricacies of this method of elephant capturing. I don't think any reasonably accurate estimate of the elephant population of this area had been done during the earlier days. But my personal experience in this area makes me guess that there could have been 150 to 200 elephants in this area, if not more. I have come across 3 herds of between 31 and 47 elephants in this area during early sixties. But of late I had no idea of what was happening there.

Therefore, I gasped in disbelief, when Peter told me that according to his information there is only one cow elephant with her sub-adult tusker son roaming a part of this area! He told me that many of the elephants had been killed and eaten, by some groups of people for whom elephant meat is preferred food item and may had been captured illegally by local *'Mila Shikar'* "mohaldars" trained those inside the jungles and brought them out on false papers of ownership.

It sounded quite improbable that more than 100 elephants can disappear like this and there was not even a whimper and so I got this information checked through some other sources. But my worst disbelief was said to be a fact. I was further informed that by early this year even the sub-adult tusker was illegally captured by a local Mafia leader of the small township of "Haila kandi", after shooting several shots at the mother, who would not desert her son. When this tusker was being 'trained' the local D. F. O. got wind of the matter and with police help raided the site of training the elephant. But the accused ran away leaving behind a tightly roped young tusker, which had suffered untold torture and died soon after because of severe internal hemorrage, even though veterinary help was provided at the last moment. A case has been registered, but the D. F. O. is under threat and the local civil and police administration is most uncooperative to provide any help. The cow elephant, which had been surely injured, has not been traced again.

A story goes around that some 'expert' people are capable of spiking the lower part of the elephant's hind foot from behind, when they climb hills during foraging. This is done by long pointed bamboo poles on both the hind legs in quick succession. This obviously immobilises the elephant, which generally kneels down. It

is then either speared or disembowelled from the side. I cannot still believe this account. But it seems to be a fact that wild elephants have disappeared from this area, even though the cover conditions have remained conducive for the species. The matter certainly deserves to be properly probed.

Elephant depredation in this region had been a common and widespread happening, even during the British period. I have myself witnessed menacing elephant problem in many localities of their region in the fifties and sixties. People had been harassed and naturally resentment was strong amongst these people. Elephant capturing was the only partial solution to curb this menace, as with capturing of elephants starting, most of the herds moved away from the vicinity of the human habitation. But since elephant capturing had been banned, people have had no respite. This might had been the chief reason, why the terrible news of slaughtering of the elephants (if true) and also about illegal capturing did not filter out. Or is this complete apathy of the Forest Department?

However, this may be a dreaded example of how elephants can disappear from an area, even when the habitat is retained. I have been told that the number of elephants in the North Cachar areas and in the adjoining Khashi hills areas have also sharply declined during the last few years, mainly due to poaching for meat. Probably a thorough and accurate status survey is called for immediately. Unless ways and means are suggested and proper action taken in all earnestness, the elephant may be on its way out from many areas of the North East, despite Project Elephant. Lack of people's support and antipathy towards conservation of elephant will only hasten the decline.

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Book Review

Souvenirs of a Forgotten Heritage. Gamini de S.G. Punchihewa, Government Press, Colombo, 1989. 480 pp. ISBN 955-9073-00-1. Price: 263.75 Sri Lankan Rupees.

This book deals largely with the Veddas (the indigenous people of Sri Lanka) and their vanishing culture. Nevertheless, the chapters on the Flora and Fauna will be a useful reference work for anyone interested in the interactions of man and wildlife in the eastern part of Sri Lanka. The chapters on the elephants provide some useful information on how villagers dealt with the problem of crop depredations by marauding elephants in the Gal Oya region before the area was developed. Mr. Punchihewa mixes facts with myths to make the text interesting to read. Elephants, from the author's personal observations, appear to be migratory, appearing in the area during the Maha and Yala seasons (October to March and April to September), attracted by the ripening paddy, sugarcane, coconut and oranges. The book also deals with some of the salient points about the biology and behaviour of the elephants. There is also a reference to the use of electric fencing to ward off the elephants and how some elephants were able to overcome this obstacle. A chapter deals with the ancient ways of capturing elephants. There are some editorial inconsistencies, particularly with species names, but this should not detract from the value of the book to anyone interested in elephants and the vanishing culture of the Veddas in Sri Lanka. (Ch. S.)

Why do elephants raid crops in Sumatra

Charles Santiapillai &
Widodo Sukohadi Ramono

The Sumatran elephant (*Elephas maximus sumatranus*) has an image problem. Almost all the reports that are published in the media refer to its proclivity to raiding crops and thereby causing economic ruin to the farmers trying to eke out a precarious existence near areas inhabited by elephants. Elephant damage to oil palm and rubber plantations in South-east Asia can run into millions of dollars in economic loss to the country (Blair & Noor, 1981). Much of the crop depredations can be reduced if development planners and policy makers pause to understand why elephants raid crops.

The number of wild elephants in Sumatra is estimated to be between 2,500 and 4,500 animals (Blouch & Haryanto, 1984; Blouch & Simbolon, 1985). Prior to about 1900, when agricultural settlements in Sumatra first led to a substantial degree of deforestation, most of the island was covered with primary forest. Presumably, up to that time, the elephant was more or less continuously distributed throughout the entire island. Less than a century later, the elephant finds itself with its back against the wall. The conversion of primary forest into agricultural holdings, some of which have proved ephemeral and been abandoned, is a particularly serious cause of conservation problem in Sumatra, and the large mammals such as the elephant, rhinoceros and tiger are among the species most seriously affected by it. It is estimated that between 65 and 85% of the forests in the lowlands of Sumatra have already been lost (Whitten *et at.*, 1984). The mountain areas to date have been less seriously affected, but the disruption of continuous cover is already substantial in some cases (Santiapillai & Widodo, 1989), and perhaps 15% of their total area may tentatively be estimated as already removed.

The altitude range of the mountains in Sumatra is such that most of their area would have been rich habitat in the past in their undisturbed state. Although the elephants thrive in seral stages of vegetation, yet in the past when much of the land was under rainforest cover, the animals would have maintained large numbers by seasonally shifting their feeding grounds between the lowlands and the mountains. Many of the past elephant migratory paths extended from the hills to the lowlands and *vice versa* (Groeneveldt, 1938). All this had to change by the turn of the century, when increasing human population and increasing agricultural land use not only reduced substantially the land area once available to the elephants, but more importantly, blocked out certain channels of response such as emigration and dispersion. In extreme cases, the elephant herds have become "pocketed" into isolated, forest patches surrounded by a hostile landscape dominated by man (Olivier 1980). The situation has reversed from one in which man lived in small settlements in areas dominated by the elephants, to one in which the elephants find themselves surrounded by a man dominated environment. This has proved a sure recipe for escalation of elephant-human conflicts in Sumatra since then.

The elephants, like other wildlife have lost so much of their former habitat, that they are often forced to invade the communities that have displaced them (Caufield, 1984). Herein lies the crux of the elephant crop-raiding problem in Sumatra.

To understand why elephants resort to raiding crops, it is important to know something about their ecology. The elephant is a social animal. There are two social units comprising

the elephant populations (Laws, 1970): The first is the family unit or herd consisting of the oldest female (the so called matriarch), her daughters and their offspring. The members of the herd are related to one another and move about as a cohesive unit. In Sumatra, such units typically range in size between 4 and 8 animals. The second social unit is the bull group which is a loose temporary aggregation of often unrelated males (Eisenberg, 1981). Both males and females reach sexual maturity between the ages of 10 and 15 years. Once the male reaches sexual maturity it leaves the matriarchal herd and leads a solitary life. This is a way to prevent inbreeding in the herd. It will seek oestrous females in other herds and attempt to mate. Thus the adult, solitary bull is often more than a rogue elephant; it is a roving gene-pool. A number of adult bulls can meet and form the loose aggregations referred to as the bull groups. In Sumatra, much of the crop raiding is carried out either by solitary bulls or bull groups.

The male elephants also take more risks than do the matriarchal family units (Sukumar & Gadgil, 1988). In Way Kambas National Park, along the unprotected southern border which abuts on cultivated land, more males were responsible for crop raiding than family units. Male elephants also appear to respond to risks during the raids by forming larger groups. Why should this be so?

The elephants are unspecialised feeders: that means they are fairly catholic in their diets, feeding on a wide variety of plant species and not restricted to a few items. More than 90 species of plants are known to be eaten by elephants in Asia (McKay, 1973; Olivier, 1978; Santiapillai & Suprahman, 1986). A probable reason for the lack of selectivity is the need to consume between 6-8% of their body weight a day (Sukumar 1985; Vancuylenberg, 1974). This works out in the case of an adult male weighing 4,000 kg between 240 kg and 320 kg of wet weight per day (or 180-240 kg/day in the case of an adult female weighing 3,000 kg).

Given this background, it is easy to understand why elephants, with their large size and intemperate appetite raid cultivated areas and devour crops when their habitat is encroached by man. When extremely palatable and nutritious crops such as sugarcane, oil palm and paddy are cultivated by the side of elephant reserves, elephant raids are inevitable. Sugar cane and oil palm plantations function like elephant supermarkets, attracting the animals from far and wide (Ratnam, 1984). The proximity of such palatable items as sugarcane, oil palm, paddy etc. make available to elephants nutrient-rich food. It also eliminates searching time and thereby enables the elephants to optimise foraging efficiency. Increased nutrition would also lead to increased body size among the bulls and can ensure success in male-male competitions (Sukumar & Gadgil, 1988). Given the fact that the provision of parental care to the young is the prerogative of the females (mother, aunts and grandmother) and not of the adult males, it is easy to understand why the female herds do not take unnecessary risks by raiding crops frequently. Whenever female herds raid crops, they rarely stray out much farther from the forest boundary.

There are no easy solutions to stop elephants from raiding crops once agriculture becomes the principal land use in the vicinity of elephant reserves. The Directorate-General of Forest Protection and Nature Conservation (PHPA) of the Ministry of Forestry has attempted a number of measures in the past that range from translocation of entire herds of elephants from problem areas to the safety of game reserves, to the capture and domestication of chronic crop raiders for eventual use in Forestry, Agriculture and Tourism. The Elephant Training Centre near the Way Kambas National Park in Lampung province of Sumatra has been successful in training wild-caught elephants. Trained elephants have enormous economic potential and can be used in timber extraction in the Production Forest such as Teak, Eucalyptus and Pine. They also, unlike the heavy machinery, cause the least damage to

the environment. Domestic elephants form the backbone of timber extraction in Burma (Gale, 1974). There is no reason why they should not succeed in Sumatra as well.

However it would be naive to believe that capturing chronic crop raiders and training them in itself would solve the elephant-human conflicts in Sumatra. It is at best only a temporary measure and should not become institutionalized practice accepted as routine. Mitigating elephant-human conflicts would require more effective methods such as the use of electrified fences in combination with trenches in areas where elephants pose a serious threat to the plantations or crops (Piesse, 1992). But even these are unlikely to completely eliminate the conflicts as long as elephants are confined to a patch work of parks and reserves surrounded by hostile landscape dominated by man. Setting up of parks and reserves as viable self-sustaining ecosystems alone may prove poor bets for the long term if we fail to address the factors that have led to the conflicts.

On the one hand, people are tempted to have more and more consumer goods, and on the other, they are asked to preserve natural resources: these two are incompatible (Mishra, 1985). The problem concerning the elephant in Sumatra provides yet one more compelling argument for ending the indiscriminate felling and deforestation which have been sweeping across the island. While the need to retain large tracts of undisturbed forest is axiomatic, it is not essential *ipso facto* to stop commercial exploitation of timber in forest to be managed as habitat for the elephant. It is simply necessary to control it strictly.

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Asian elephant in Sumatra Population and Habitat Viability Analysis

Raman Sukumar & Charles Santiapillai

The Directorate General of Forest Protection and Nature Conservation (PHPA) of Indonesia and the IUCN/SSC Captive Breeding Specialist Group convened a workshop on the Population and Habitat Viability Analysis of the Asian Elephant in Sumatra (8-10 Nov. 1993), which was attended by more than 40 participants from Indonesia, Malaysia, Thailand, New Zealand, Australia, United Kingdom, USA, Ireland, India and Sri Lanka. The success of this workshop was largely due to the efforts of Ir Komar Sumarna (Director of Nature Conservation, PHPA), Mr. Widodo Sukohadi Ramono (Director: Species Conservation, PHPA), Dr. Ulysses S. Seal (Chairman: IUCN/SSC Captive Breeding Specialist Group) and Dr. Ronald. L. Tilson (Director of Conservation, Education & Research, Minnesota Zoo, USA). The international zoo community provided a generous grant that enabled many of the overseas participants to attend the workshop.

The workshop provided on opportunity to reassess the status of the Asian elephant in Sumatra in the light of the recent changes in the human demography and forest cover. The last survey of the elephant in Sumatra was carried out almost a decade ago by Blouch & Haryanto (1984), Blouch & Sibolon (1985) and Santiapillai & Suprahman (1984). The total population size of the Asian elephant in Sumatra was estimated tobe between 2,800 and 4,800. Much of the information on the number of elephants in Sumatra was gathered from local villagers and wildlife personnel. The information given by the wildlife chiefs from the provinces of Sumatra during the workshop indicates that there could be anything between 3,600 to 4,500 elephants in Sumatra today. This indicates an increased value for the minimum estimate given earlier but the maximumrecorded is still less than what was projected earlier.

In the past, Santiapillai & Jackson (1990) identified 44 separate populations which by 1992 had been reduced to 41 as three populations of elephants became extinct locally. Subsequent work in the northern province of Aceh indicates the fragmentation of large pupulations so that at the workshop, the PHPA identified 47 populations in Sumatra of which, 9 populations comprised less than 25 animals and were considered nonviable, while the remaining 38 populations with more than 25 animals each are distributed as follows:-

9 in national parks	(963-1,173)
5 in game reserves	(710- 860)
3 in protection forests	(130- 180)
21 in production forests	(1,895-2,320)

The important finding is that the largest number of elephants (1,895-2,320) are found in the Production forests whose status varies. There are 3 kinds of Production forests: (a) limited production forests, (b) permanent production forests, and (c) conversion forests. The latter category can be converted to other land uses (such as agriculture, human settlement, mining etc.). Therefore the long term security of many of the elephants in such production forests appears bleak.

As a result of the decline in the forest cover and increase in the human population growth, the elephant-human conflicts in Sumatra have escalated. In extreme cases, the PHPA had

been forced to capture chronic crop raiders and rogue elephants with the view to minimising the human-elephant conflicts. This has led to the establishment of a number of Elephant Training Centres across Sumatra. Table 1 provides data on the status of the elephants in these centres.

Table 1: Number of elephants in captivity in Sumatra

Province	year of establishment	number captured	number at present
Lampung	1985	152	83
Aceh	1987	60	40
Riau	1989	45	41
South Sumatra	1990	40	40
Bengkulu	1992	13	13
Total		310	217

Some of the captured elephants have been trained and are being utilized by logging agencies, zoos and safari park. However, unless there is substantial improvement in the veterinary care of the elephants, and sufficient financial and trained manpower resources are available, such increased capture of elephants cannot be justified. Furthermore, care must be taken to see that the annual off take of elephants in the wild is sustainable.

The population modelling group consisting of Raman Sukumar (India), Zainal-Zahari Zainuddin (Malaysia), Yayu Ramdhani (Indonesia), and Charles Santiapillai (Sri Lanka) used the VORTEX model produced by Robert Lacy (Brookfield Zoo, USA).

Life history variables:

Much of the demographic data on the Asian elephant comes from the studies of Sukumar (1989) in southern India, supplemented with some data on population structure of elephants in Way Kambas, Sumatra, in Santiapillai & Suprahman (1986). It is recognized that life-history variables are likely to be different for the southern Indian and the Sumatran elephant populations, as these inhabit tropical deciduous forest and equatorial rain forest respectively. In particular, it has been argued by Sukumar (1989) that elephants in the moister, more climatically "stable" rain forest habitats are likely to have evolved relatively more "k-selected" traits than would the elephants in the drier, more unpredictable habitats. Life-history variables for the Sumatran elephants thus reflect this expected difference.

The following variables were used in the VORTEX modelling:

Breeding system:

The elephant is a polygynous species. Although males are sexually mature when they are about 15 years old, they may not actually be able to mate until 20 or 25 years due to social reasons. Field studies in India show however that in the absence of older males the younger males can breed from the age of 15 years. Age at first reproduction was thus taken to be 15 years and 20 years under two scenarios modelled. Further, it was assumed that only 80% of the adult males are in the breeding pool in a given year.

Female reproductive rates:

Age at first reproduction in females was taken to be 15 years and 20 years. The latter figure may be more likely to be true of elephants in rain forest habitats (Sukumar 1989). Inter-calving interval has been found to be 4.5 to 5 years in southern India, but some data from Way Kambas indicates that females may reproduce only every 6 years on average (Santiapillai & Suprahman 1986). Thus, birth probability was taken to be 0.16/mature female /year; this was increased marginally to 0.18/ mature female/year in later instances in order to achieve a higher deterministic instrinsic growth rate. Litter size is taken as 1; twinning is very rare in elephants (c. 1% of births) and therefore, inconsequential.

Maximum longevity:

Elephants in captivity are known to have survived until 75 years or more in the case of females and about 60 years in males. How ever female elephants cease reproduction by about 60 years. Thus the maximum longevity was taken to be 60 years. A precise figure is not very important because the proportion of old elephants in the population would be negligible and thus contribute little to reproduction.

Sex - ratio at birth:

A large sample (>260) of births in captivity shows a slight bias towards male calves although this is not statistically significant. We used a 1:1 sex ratio at birth but also explored the effects of a male biased ratio (55:45).

Correlation between EV (reproduction) and EV (survival):

We assume that a correlation exists between these.

Mortality rates:

Mortality rates were adjusted within small limits in order to vary the (deterministic) intrinsic growth rates. In general mortality of female elephants was taken to be 8-15% (age 0-1 year), 4% (age 1-5 years), 2% (age 5-15 or 20 years) and 1.5-2.5% (adult age) per year.

There is evidence that in elephants (as in other polygynous mammals) the mortality of males is higher than that of females under natural conditions. This is reflected in the female-biased sex ratios observed in all elephant populations. Male mortality rates were thus taken to be 15% (age 0-1 year), 5% (age 1-5 years) and 3% (ages above 5 years, including adult) per year.

In populations where selective poaching of males for ivory occurs the mortality rates in sub-adult and adult males should be even higher than the above figures. Simulations were also run with a 5% mortality probability in males above 5 years.

Environmental stochasticity

In VORTEX environmental stochasticity is modelled as variation in annual birth and death probabilities by sampling binomial distributions, with the standard deviation (SD) specifying the extent of variation. SD on both birth and death rates were taken to be 20% of the mean rates. This figure is based on the southern Indian study, assuming that environmental variation in rain forest habitat is lower than in drier habitats. In any case, environmental variation seems to make some change to the final results.

Carrying capacity

Carrying capacity (K) was generally set at about 20% higher than the initial population size except in case of a population size of 10 for which it was set at 30. Small variations in

K may again not make any difference to the final outcome and was hence ignored. In one set of simulations a trend in *K* was taken as a loss of 0.5% of *K* per annum for 25 years.

Inbreeding depression

Although there are no data available on inbreeding depression in elephants, several studies on mammals in captivity have shown that it is important. We modelled scenarios without and with inbreeding depression. Inbreeding depression used a Heterosis model with a level of 3.14 lethal equivalents which represents the mean of over 40 mammalian species studied.

Catastrophes

Potential catastrophes affecting elephant populations are drought and disease epidemics. Very low probabilities were assumed for both these factors; serious drought is not likely in rain forests and there is no historical evidence of an epidemic such as anthrax. A 4% probability of drought lowering fertility by 40% and killing 5% of individuals, and a 1% probability of disease killing 10% of individuals were assumed. The probability of drought was later reduced to 2% for populations to achieve a higher deterministic growth rate.

Harvest

Elephants from the Sumatran populations are being captured if they are crop raiders. Some poaching of elephants also occurs. Two rates of harvest were considered. Under a low harvest rate four elephants (1 adult female, 1 juvenile female, 1 juvenile male and 1 adult male) were removed from the population every four years for 25 years, while under a high harvest rate the same number was removed for 50 years.

Population sizes were varied from 10 to 100 elephants as appropriate. All simulations began at stable age distribution and were run 500 times for 100 years.

Results

Basic scenario - Deterministic growth rate close to zero (r=0.002), no inbreeding depression, no harvest.

Under this scenario an initial population of 10 elephants had a 65% chance of surviving for 100 years. Raising this to 25 elephants increased the probability of survival to 95% and to 50 elephants to >99% over 100 years. For the two larger populations for which the carrying capacity was set at levels close to initial population size, the stochastic growth rate was still negative and the surviving populations would continue to reduce in size on average over the 100 year period.

Scenario II - r close to zero (0.002), inbreeding depression, no harvest

The outcomes are not particularly different except in the case of very small populations. Probabilities of survival for different initial sizes are 57% (pop. size 10), 96% (size 25) and >99% (size 50). This seems to indicate that inbreeding depression may not be a major factor in the survival except in very small elephant populations.

Scenario II - r close to zero (0.003), inbreeding depression, low harvest

Probabilities of survival for 100 years are 1% (pop. size 25), 10% (size 50) and >99% (size 100). There is a dramatic difference between initial population sizes 50 and 100 in their chances of survival under conditions of a low harvest as defined earlier. Thus harvest of even one elephant per year on average for 25 years would almost certainly drive any population under 50 to extinction. With a staring population of 100 there is a high chance of survival, but even this population would reduce to about half its original size after 100 years.

Scenario IV - r close to zero (0.003), inbreeding depression, high harvest

When the harvest of four elephants every four years is continued for 50 years, the probabilities of survival decrease to a certain extent. These are 2% (size 50) and 97% (size 100).

Scenario V - r increase to about 1% (0.01), inbreeding depression, no harvest

The probabilities of survival increase as compared to scenario II, these being 80% (size 10), 99% (size 25) and >99% (size 50).

Scenario VI - r about 1% (0.01), inbreeding depression, high harvest

With harvest continuing for 50 years, the chances of survival are 0% (size 25), 3% (size 50), 87% (size 75) and 98% (size 100). The surviving populations would however reduce in size during the 100 year period.

Scenario VII - r increased to about 2% (0.02), inbreeding depression, high harvest

Even with a population that can potentially grow at r=0.02, the probabilities of survival are quite bleak (<5%) for population sizes less than 50 elephants. For higher sizes the chances of survival are 89% (size 75) and >99% (size 100).

Summary of results

Elephant populations smaller than about 25 animals to begin with are at a very high risk of extinction. These populations should be supplemented with captured animals or managed as part of a metapopulation. If harvest of elephants (either through capture or poaching) is not envisaged, then a population of about 40-50 elephants whose habitat is secure would have a high chance of survival. If any harvest is envisaged this would be absorbed only by populations in the vicinity of 100 elephants.

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