LION-TAILED MACAQUE
Macaca silenus

POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

Held at Arignar Anna Zoological Park, Madras
11 to 14 October 1993

REPORT

Coimbatore,
February 1995

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A Collaborative Workshop

Anna Arignar Zoological Park
Tamil Nadu Forest Department
Indian Zoo Directors' Association
Central Zoo Authority of India
A.Z.A. Species Survival Plan for Lion-tailed Macaque
San Diego Zoological Park
Woodland Park Zoo
IUCN/SSC Captive Breeding Specialist Group
Zoo Outreach Organisation / CBSG, India

LION-TAILED MACAQUE *Macaca silenus* POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

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Section I

Executive Summary and Recommendations

EXECUTIVE SUMMARY

The Lion-tailed macaque *(Macaca silenus)* or "LTM" is a species of primate which is endemic to the rain forests of the Western Ghats. Presently it is estimated that 3000 to 4000 Lion-tailed Macaques survive in the wild in the 3 southern Indian states of Kerala, Karnataka and Tamil Nadu.

Factors such as habitat fragmentation, reduced patch size and isolation of populations leading to inbreeding depression and vulnerability to random events makes the Lion-tailed macaque a highly endangered species despite its relatively large free-ranging population. The modelling exercise clearly indicated that intensive management, or manipulation, must be carried out on these small, wild populations in order to ensure their survival.

Manipulation can take the form of translocation of (doomed) animals that cannot be protected or reintroduction of captive born animals, or their genetic material through assisted reproduction. About 570 Lion-tailed Macaques are held in captivity around the world which can act as a crucial back up population. The captive population in Indian zoos in particular needs intensive genetic and overall management.

The Captive Husbandry Group has examined the captive breeding program both globally and regionally. A Global Animal Survival Plan was created. It was strongly emphasized that the Indian captive population has to be managed genetically and demographically to ensure that all available genetic diversity is retained and appropriate age structure and sex ratio maintained.

The Census and Distribution Group, having assessed the state of information about Lion-tailed Macaque numbers and location, recommended a survey of all rain forest patches in the entire range of Lion-tailed Macaque to determine patch size, contiguity and the status of the Lion-tailed Macaques within.

The Threats Group surveyed all the threats to the population. As a result of their deliberations as well as the output of the computer simulation, which indicated that the loss of a single individual due to poaching had a dramatic effect on population growth of the group for years to come, the Group recommended that all habitats holding viable Lion-tailed Macaque populations should be declared as "protected areas". These would have full legal protection as well as protection through forest management strategies.

Ecodevelopment projects should be implemented for the tribal and rural populations living in and adjacent to the Lion-tailed Macaque habitats to reduce their impact on the forests. In order to ensure survival of Lion-tailed Macaque and success of conservation projects within and around the forest areas where animals and human beings share space, a sustained education and publicity campaign will create awareness for conservation; for Lion-tailed Macaque particularly

The modelling exercise also indicated that a minimum of 30-40% breeding age females is crucial to ensure stability and growth. The modelling group suggested supplementing population lacking in breeding age females, which will also increase the percentage of heterozygosity and reduce the degree of inbreeding.

Research should be carried out in an aggressive manner for improving management. The carrying capacity of some patches needs to be ascertained. Some basic biological information with respect to fertility, mortality, and migration rates needs to be collected as well as sampling and screening done to determine parasite load, presence of virus and other pathogens. In addition, environmental events such as catastrophes needs to be more closely monitored. It was suggested that research partnerships between zoos, field managers, universities and research institutions be created for mutual assistance in study of Lion-tailed Macaque It was also recommended that a field centre near a wild population be established for preparation operations required for intensive interactive management of the species..

RECOMMENDATIONS*

Census and Distribution

1. As LTM populations in most of the areas are yet to be reliably estimated, it is recommended that estimation should be taken up in the areas where information is lacking. It is vital to survey all rain forest patches (in LTM range) to determine patch size, contiguity, and status of LTMs. Methodology for population estimation should be standardized, using methods appropriate for different areas.

2. The contiguity of the habitat of LTM across the Western Ghats need to be assessed in order to: identify distinct populations, critical habitats, and areas where corridors could be established. Vegetation maps, aerial photographs, satellite imageries, and field studies should be used for this purpose.

3. It is recommended that a total group count of LTM be done in many areas as a cooperative project of Forest Department, researchers of identified institutions, NGO's, etc. who have been briefed or trained. This is to be followed by periodic monitoring of LTM done by the survey teams.

4. An assessment of various vegetation associations as potential LTM habitat need to be undertaken to determine what areas of the evergreen forest is LTM habitat, and a survey of LTMs should be carried out to reflect differences between vegetation association.

5. A central coordinating unit for LTM may be established in one of the range states where a database of LTM distribution and population can be developed, surveys coordinated, and results collated for better management of populations within individual states and also overlapping populations. Other information, such as on disease problems and treatment may also be included in the database and shared with all field staff and researchers.

Threats

6. The modelling exercise has indicated that a minimum of 40% of breeding age females are necessary in any isolated population of LTMs to ensure stability or minimal growth of the population. Monitoring of the demographic structure of populations should be done with this factor in mind, so that groups with less than 30 individuals should be made viable by supplementation.

7. The computer modelling demonstrated poaching to be one of the important factors to be considered in LTM management, as, a loss of one individual per group per year reduces the population dramatically to numbers which cannot increase or be sustained for decades to come. All viable LT'M populations should be included in the protected area network to ensure that all provisions of the Wildlife Protection Act (1972) for LTM are enforced effectively.

***** The recommendations of the Modelling Group have been incorporated with the recommendations of different working groups according to their relevance. The model, justification and comments follow in the working group report.

8. A variety of threats impinge on the potential survival of the LTM, which should be controlled A complete and accurate record of all fire incidents for the purpose of mapping should be done as prophylactic measure against the threat of fire. Application of pesticides/fertilizers in and around LTM habitats has to be researched and monitored as well as the effect of fruit, lliana and other MFP extraction on LTM ecology.

9. Ecodevelopment measures for the rural populations living in and adjacent to Lion-tailed macaque habitats and help to reduce their dependence on the forest are strongly recommended.

10. According to the modelling exercise, the amount of heterozygosity retained by any of the populations assessed is very low, with and without incorporation of inbreeding and is as low as 80%. Retention by manipulation must be carried out in order to save the wild population. Genetic material (from either captive or wild) should be continuously infused into wild groups of 20 - 30 individuals, adding one male and two female adult LTMs to a group every three years to maintain the level of heterozygosity and reduce inbreeding depression.

It is, therefore, necessary to identify and implement management strategies for the maintenance of genetic variability in long-term breeding populations of LTM both in captivity and in the wild. For captive LTMs these should include centralization of all records on LTM and including basic information (origin, age, pedigree, behaviour, health record).

11. The collection of biological samples (blood, semen, tissue, or hair) on 12-15 individuals sampled from the two extremes of the geographical range of the LTM may be organized by the Ministry of Environment and Forests taking the help of experienced scientists and observing due caution for the safety of the animals. The analysis of these samples will provide crucial information which can be used to determine geographic origins of captive LTMs where capture location is not known and assist the Indian Species Coordinator and CZA in preparing their Breeding Plan as well as to effectively assess the genetic variability of the wild population.

12. The assistance of molecular biologists should be taken in sorting out genetic questions.

(As the CZA has since taken up a project with the Centre for Cellular and Molecular Biology in Hyderabad for carrying out genetic analyses on different species of endangered wildlife, they may be requested to carry out recommendations of this working group -- eg., initiate studies such as population genetic analysis and comparison of populations by estimating genetic distance between them. Analysis of these results will suggest in general terms what needs to be done to preserve a genetically healthy LTM population over the long term.)

Disease and Health

13. The Central Zoo Authority has codified regulations on animal care health and treatment as well as for basic veterinary facilities and enclosure design. These should be strictly followed. Further, zoo safety measures for LTM should be codified and implemented to prevent accidental injuries and stress.

14. Sustained research should be carried out on LTM to generate a data base on infectious and other diseases, both known and suspected, and health conditions affecting the species in the

wild. This should include screening for viruses and parasite load. Zoo animals should be screened for opportunistic zoonotic as well as anthroponotic viral infections.

15. A course on disease of LTM for zoo vets should be carried out with refresher course to incorporate new information and inform newly posted vets. An international, inter-institutional group may be formed to assist in organizing the training of Indian veterinarians, zoo personnel, and scientists, and other aspects of technology transfer, research opportunities for undergraduate and graduate students and funding of same.

Reintroduction and Translocation

16. The computer simulation demonstrated that small populations of less than 7 individual of LTM are almost certainly doomed to extinction; they are not viable in the wild due to skewed sex ratio or unbalanced demography. These should be either taken into captivity and used to strengthen existing captive population or translocated to supplement other wild populations.

17. The feasibility of "artificial migration" between small protected groups using captured males, and on the capture of whole, small groups of "living dead" or doomed animals and their relocation into zoos or other protected areas should be investigated.

18. The feasibility of collecting sperm samples from males in small populations that cannot be protected, for use in artificial insemination or *in vitro* fertilization should be investigated.

19. Introduction of 1.2 adults into a population of 20 - 30 animals should be done every 3 years. This improves the chance of survival of the group significantly by maintaining the level of heterozygosity, reducing the amount of inbreeding and increasing the percentage of breeding females.

Education

20. The Education Working Group recognizes that both formal and informal education conducted by NGO's and clubs, directed toward local people living near LTM habitat and other target groups, are critical to the successful conservation of suitable habitat for the LTM. Education may include propaganda against poaching, use of the animal for medicine, etc., as well as practical instruction on protection of habitat against accidental fire, etc.

21. The Workshop recommends establishing the LTM as a flagship species for the conservation of the entire region of the Western Ghats.

Captive Management and Husbandry

22. According to the Report of the Modelling Group, the maintenance of a healthy stock of LTM in captivity is crucial for intensive metapopulation management, e.g. providing genetic material for wild population by reintroduction of live animals or of germ plasm.

23. All breeding of LTM is to be conducted under the recommendations of the Regional Species Co-ordinator who will be responsible for liaisoning with the International Studbook

Keeper and coordinating the eight zoos identified as Conservation Breeding Centres for the country. These Centres shall manage their LTMs according to the National Coordinated Breeding Programme, observing genetic and demographic principles and cooperating with International efforts such as the Global Animal Survival Plan for LTM.

24. In order to achieve conservation management goals, each animal is to be individually marked, by a tattoo or transponder and each animal is to have an individual record card and veterinary history. A copy of this should accompany the animal being moved from one institution to another.

25. Husbandry measures for LTM should be of highest quality in modern management including regular veterinary screening of both LTM's and their keepers; enclosures designed with consideration of the behavioural and biological characteristics of the animals; inclusion of environmental enrichment devices; training in modern methodology for staff and keepers with regular updates; exchange of information between the facilities holding the species. Diet should ensure that all animals receive optimal nutritional requirements, especially animal protein as vertebrates and invertebrates make up 3 7.3 % of the diet in the wild.

Research

26. The Modelling exercise calls for basic biological information such as fertility, mortality, and migration rates, and environmental influence such as catastrophes, which was not available with the researchers and field managers of LTM. For successful management of LTM and, for saving the species from extinction, research and monitoring to elucidate these aspects is crucial.

27. Partnerships between areas of expertise should be created and fostered: e.g., zoos, wildlife biologists and research institutions. The latter may be requested to help create areas within each zoo for basic research with minimal equipment such as refrigerator and freezer

28. A field centre near a wild population may be established to study and determine the feasibility of acclimatizing the animals for observation, monitor non-invasively the menstrual cycles, interbirth intervals, etc., and prepare for further operations required for interactive management of this species.

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Section II

Problem Statement and Overview

PROBLEM STATEMENT AND OVERVIEW

THE LIFE HISTORY, ECOLOGY, DISTRIBUTION AND CONSERVATION PROBLEMS IN THE WILD

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The objective of this section is to give a comprehensive description of the life history, ecology, distribution, and conservation problems of the Lion-tailed Macaque in the wild. There have been a few reports on the distribution and population status of the Lion-tailed Macaque (Sugiyama 1965; Green & Minkowski 1977; Kurup 1978; Ali 1985; Karanth 1985; Bhat 1994; Kurup 1994; Ramachandran 1994; Kumar in prep.), and two long term studies on its ecology and behaviour (Green & Minkowski 1977; Kumar 1987, Kurup & Kumar 1993). There has been, however, only one study on the demography (Kumar 1987, 1994). Most of the demographic data presented here, therefore, come from this study which was carried out in the Indira Gandhi Wildlife Sanctuary in Tamil Nadu (previously Annamalai Wildlife Sanctuary) during 1978-84. Some data on group composition is also taken from a survey of the Lion-tailed Macaque carried out in 1987-90 (Kumar in prep.). Data on ecology and behaviour come from studies carried out at Varagaliyar, Indira Gandhi Wildlife Sanctuary, during 1978-84. Ecological and behavioral studies were carried out on a group close to the elephant camp, for 9 months in 1978-80 and for 15 months in 1982-84. Details of the study site and methodology are given elsewhere (Kumar 1987, 1994).

LIFE HISTORY

Group size and composition

Data on group size and composition come from 20 groups. Ten groups were counted, six of them repeatedly at regular intervals, during the ecological study of the species in the Indira Gandhi Wildlife Sanctuary during 1978-84. Eight groups were counted during a survey of the Lion-tailed Macaque in 1987-89. For those groups which were censused repeatedly (at the Indira Gandhi WLS), the mean of group sizes on 1 April on each of the monitored year is taken as the typical group size. The frequency distribution of group size is shown in Figure 2 and group composition is shown in Table 1. The mean group size was 18.8 and the median 17.4, the smallest group size being 7 and the largest being 41. The number of adult males (more than about 8 years of age) varied from 1 to 3, with a mean of 1.5 and median of 1. Most of the groups had only one adult male. The number of males increased as the group size increased. The mean adult sex ratio was 4.9 females per male, and the median was 6.3.

The mean group size of the lion-tailed macaque is slightly less than that reported for other macaques, in the range of 20-30 animals. Moreover, as in the case of Pig-tailed Macaque (*M. nemestrina),* the adult sex ratio in a group is more biased towards the females, with about 5-6 females per male compared to 2-3 females per male reported for most other macaques. There is no indication of any significant geographical variation in group size and composition. The populations south and north of the Palghat Gap have similar group sizes (18.4 and 19.1, respectively). Their age/sex compositions are also not significantly different.

Table 1. The age / sex composition of 20 groups of Lion-tailed Macaques.

Age/sex	Mean no	Median no	Range	% comp
Adult males	1.5	1.0	1-3	9.0
Sub-ad males	1.4	1.0	0-5	8.0
Adult females	7.3	6.3	3-14	41.5
Immatures	8.0	8.0	1-21	41.5

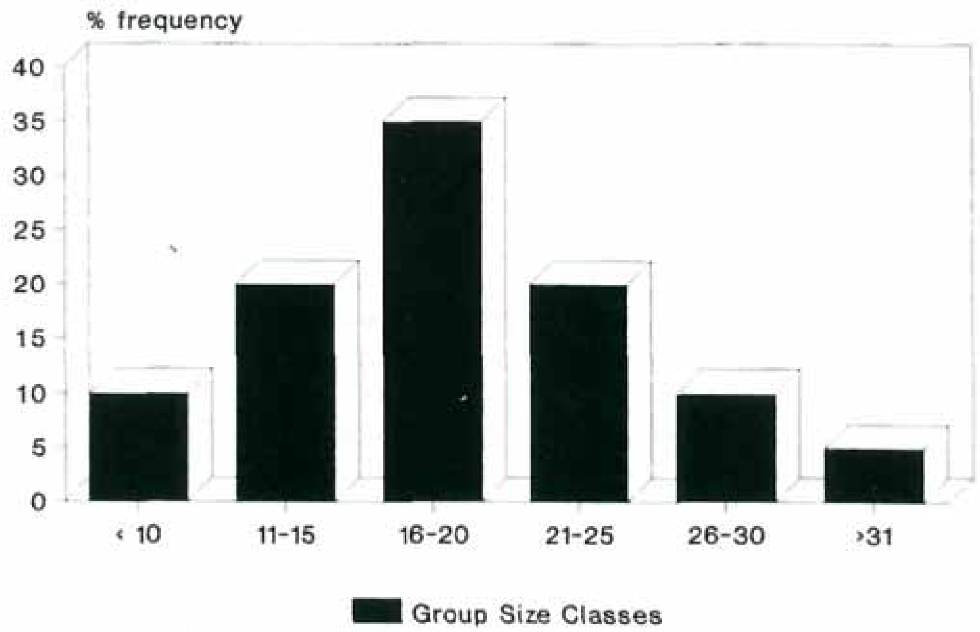

Fig. 1. The percentage frequency distribution of group sizes in the Lion-tailed Macaque (n=20 groups)

Birth rate

Birth rate is defined as the proportion of adult females which give birth in a year out of the total number of adult females under observation. Data on birth rate come from 8 groups. A varying number of females (10 to 50) were monitored each year from 1978 to 1984. The birth rate varied between years, from 0.22 in 1979-80 to 0.40 in 1982-83, with a mean of 0.2966 (SD=0.0725). Direct observation of interbirth interval was made on 3 identifiable females in the main study group. These 3 females gave birth twice each during the six year study period, with interbirth intervals of 30,28 and 31 months (mean=29.7 months or 2.47 years).

Data on age at first birth is available from five females in the main study group. One gave birth at 6 years of age, three between 6 and 7 years, and one between 7 and 8 years of age. The mean age at first birth is thus estimated as 6.6 years (SD=0.55), and the median as 6.5 years.

Mortality rate

Mortality rate was estimated as the proportion of animals which disappeared out of the total number of animals which were monitored in a year. In total, 320 animals years (the sum of the number of animals which were monitored each year from each group) were monitored from five groups in 1978-84 for the estimation of mortality. Mortality had to be assumed in all cases upon the disappearance of an animal. In total 13 animals disappeared. The gross mortality rate for all the age/sex classes combined varied from 0.0904/year in 1981-82 to 0.0130 in 1979-80, with mean of 0.0450 (SD=0.0342). The estimated mortality rate for each age/sex class is given in Table 2.

Male Mortality

Among the macaques emigration from groups is almost entirely confined to the subadult and adult males, and is indistinguishable in the field from mortality. Therefore, the mortality estimate for subadult and adult males represents emigration and mortality. Since the groups had only few males only 37 animal years of data could be collected on them. There were 3 cases of disappearance, giving a mortality/emigration rate of 0.0810 (SD=0.0448). This is the minimum estimate since emigration or death of a male followed by immigration of another male into a group (other than the main study group) might not have been detected.

Adult Female Mortality

In total 118 animals years of data were collected to estimate mortality rate of adult females. Only 4 females disappeared, giving a mortality rate of 0.0339/female/year (SD=0.0167).

Immature Mortality

Immature or pre-reproductive mortality refers to mortality up to six years of age. As mentioned earlier the females give birth for the first time at about 6.6 years of age, or conceive at 6 years of age. For males, however, there is a prolonged subadulthood from about 6 years of age to probably 8 years of age. During this stage mortality rates for the adult males, estimated above, is assumed to apply. For want of data, infants (0 to 1 year of age) are considered along with the juveniles, and no distinction is made between the sexes. In total, 164.4 animal years of data were collected to estimate mortality rate at the pre-reproductive stage. Eight animals disappeared, giving a mortality rate of 0.0487/year (SD=0.0168).

Male Immigration

During 17 group-years (the sum of the number of years for which each group was monitored), immigration into a group occurred at least 6 times. The immigration rate thus could be estimated as 0.3 5 males/group/year. All the six cases were by adult or subadult males.

The demographically important life history parameters of the Lion-tailed Macaque seem to be exceptional compared to the other macaques. The high age at first birth, low birth rate, and low mortality rates at all stages of life are noteworthy features. These indicate that the life history parameters of the Lion-tailed Macaque are highly adapted to its relatively stable habitat or are K-selected. The inevitable consequence of the above set of parameters is that the Lion-tailed Macaque would have very low capability to track rapid changes in resources and to recover from population perturbations caused for example by diseases or hunting.

FEEDING ECOLOGY

The information on feeding ecology come from field studies on a group at Varagaliyar, Indira Gandhi Wildlife Sanctuary, for nine months in 1979-80 and for 15 months in 1982-84. During this period, the group was followed from dawn to dusk for six days each month. Each day data on activity pattern and behaviour were collected using group scan. Age/sex differences were studied using focal animal sampling.

The Lion-tailed Macaque feeds exclusively on food items which are rich in simple carbohydrates or lipids (ripe fruits, seeds, nectar, gums and resins), and proteins (chiefly invertebrates, but also could include birds' eggs and nestlings, and giant squirrels). The annual diet consists of 57.5% of fruits and seeds, 37.3% of animal matter, and 5% of other plant parts such as nectar, resins, and flowers. A group spends about 25% of the day time on foods of plant origin, and about 18% on foods of animal origin. A large number of plant species are used for food items. Over a 3 year period, the study group used 93 plant species belonging to 39 families, for 97 food items. The number of plant species used each month varied from 8 to 25. Most species (56.0% in the Annamalai Hills) are exploited only for the ripe fruit flesh. Some of these are drupes (e.g. *Mangifera indica, Gnetum ulae* and *Semecarpus travancoricus),* but majority are small berries with thin pericarp and many seeds. Many species (16.5% in the Annamalai Hills) are used for their seeds. Few species (e.g. *Artocarpus hirsuta* and *A. integrifolia)* are used for both the seed and the mesocarp, and few others for nectar (e.g. *Bombax malabaricci).* Gums or resins of selected species are also used (e.g. *Gnetum ulae* and *Vepris bilocularis).* The only species exploited for its flowers is *Xanthophyllum flavescens.* Other plant food items include mushrooms, lichens, and moses. Feeding on leaves is negligible and confined to infrequent and short bouts of feeding on some grass species.

The Lion-tailed Macaque derives most of its protein requirements from foods of animal origin, primarily invertebrates, but also include snails, birds eggs and nestlings, and giant squirrel nestlings. It spends considerable time looking for invertebrates (mean=27.4% of day time) and feeding on them (mean=18%). A number of substrate provide these invertebrates. Green leaves are, by far, the major source (77.2%), especially of caterpillars, pupae, insect eggs, spiders, praying mantis, etc. Other substrates are bark (6.2%), clusters of dry leaves including discarded nests of giant squirrels (8.7%), and dead wood (2.4%). The forest floor is rarely used as a source of invertebrates as the group spends very little time there.

Thus, the diet is dominated by plant parts (fruit flesh, seeds, nectar and resins) which are rich in simple sugars or polysaccharides, but poor in protein. The Lion-tailed Macaque, therefore, depends more on animal protein compared to other macaques. The availability of fruits and seeds, and green foliage throughout the year, therefore, is critical to the survival of the Lion-tailed Macaque. Only the very high diversity of plant species in the rain forests can ensure the availability of fruits and seeds, and invertebrates throughout the year. The same high plant species diversity also buffers against variations between years in the availability of fruits, seeds and invertebrates.

A comparison of the feeding behaviour of the same group in 1979-80 (when the group size was 12) and in 1982-84 (when the group size was 22) showed that there was closer tracking of food availability when the group became bigger. The group was more selective when it was small in size, the number of plant food species eaten showing no correlation with availability. On the other hand, when the group became larger, the number of plant species used for food was strongly positively correlated with the number of food species available. It could be, therefore, concluded that food species diversity could be a major factor which could limit group size and population density.

During both the study periods, the months with least food availability was September-October, the period just preceding the second and weaker north-east or retreating monsoon During both the study periods, the group spent less time on plant foods, and more time on foraging and ranging. Food availability during these months, therefore, might be critical to the survival and density of the species in an area.

It follows from the above that plant species diversity of the habitat might be very critical in determining density of the Lion-tailed Macaque for the following reasons:

1. At any given time food availability might be proportional to plant species diversity. Although no data exist to this effect, most of the rain forest plants depend on animals for dispersal rather on mechanical means like wind.

2. A higher plant species diversity would be a better buffer against seasonal variations in food availability, particularly with reference to lean periods as mentioned above.

3. A higher plant species diversity would also be a better buffer against inter-year fluctuations in food availability resulting from environmental factors like drought.

DISTRIBUTION

The Lion-tailed Macaque, endemic to the rain forests of the Western Ghats, was even within historical times distributed as a contiguous population from the southern end of the Western Ghats to well into the state of Maharashtra. Over the past many centuries, however, its distribution range in the north has shrunk to just north of the Sharavati River in Karnataka, as most of the rain forests in the states of Maharashtra and Goa were wiped out. Similarly, the lowland rain forests in Kerala and Karnataka was also wiped out, thus confining the Lion-tailed Macaque to higher elevation of the Western Ghats. Human activities in the last 100 years or so, not only reduced the extent of the rain forest further, but also fragmented the remaining forests into numerous small isolated patches. Presently, therefore, the Lion-tailed Macaque occurs as numerous small populations (Figure 1).

Natural distribution

The natural distribution of the Lion-tailed Macaque is strongly affected by plant species diversity. In the Western Ghats, plant species diversity in the wet-evergreen forest decreases as the latitude increases, largely because the number of dry months increase on a south to north gradient (Pascal 1988). A similar reduction of plant species richness is also seen with an increase in altitude (Pascal op.cit). It could then be expected that the density of Lion-tailed Macaque should also show a similar gradient, decreasing in density with latitude and altitude. Densities were estimated for nine areas, based on a survey carried out in 1988-89 which covered the area from Sharavati River in the north up to Annamalai Hills in the south. A total of 23 groups were seen during the survey. The density was estimated as an index of number of groups per kilometer walked. It was found that the density of the Lion-tailed Macaque decreased with latitude and altitude (Spearman rank correlation coefficient =0.78).

The above pattern allows us to make an assessment of habitat quality as far as Lion-tailed Macaque is concerned. Southern low elevation evergreen forest would be the best. As the altitude increases habitat quality decreases rapidly, so also with increasing latitude. The northern high elevation forest would be of the lowest habitat quality.

Present distribution

Karnataka

A good description of the available habitat in Karnataka is given by Karanth (1985). In Karnataka, the wet evergreen forest is mostly confined to the steep western face of the Western Ghats. In some places such as Hosanagara, Agumbe, Kudremukh and Kalasa Forest Ranges, fairly large extent of wet evergreen forests occur also on the eastern face. The Western Ghats itself is of a lower elevation through most of Karnataka (up to 700m), compared to Kerala and Tamil Nadu.

In Karnataka, the Lion-tailed Macaque occurs from slightly north of Sharavati River up to the southern most part, Srimangala Forest Range, adjoining Kotiyur forests in the Kannoth Forest Range in Kerala. The narrow band of evergreen forests on the western face of the Western Ghats in Karnataka is by and large contiguous through most of its length, with major discontiguities in two places. Based on these, the Lion-tailed Macaques in Karnataka can be divided into four populations.

1. North of Sharavati River and south of Aghanashini River is a remnant population mostly in the Siddapur Forest Range. A small population might also occur in the Kumta Range. The habitat is highly fragmented, and has been surveyed by Bhat (1994).

2. South of Sharavati River, the habitat is largely contiguous up to Belthangadi Range. The Wildlife Sanctuaries and Forest Ranges included in this area are: Sharavati, Mookambika and Someshwara Wildlife Sanctuaries, the proposed Kudremukh National Park, and Forest Ranges of Shankaranarayana, Hosanagara, Agumbe, Karkala, Mudbidri, Kudremukh, Srin-geri, and Kalasa. This stretch is however cut across by at least three state highways, leading to local discontiguities. Moreover, large extent of forests in Hosanagara, Agumbe, Kudremukh, Sringeri and Kalasa are on the eastern side of the Western Ghats. As mentioned earlier these forests are low in plant species diversity and probably cannot support resident populations of Lion-tailed Macaque. Nonetheless, these forests are often within the seasonal ranges of populations from the western slopes. Considerable extent of wet evergreen forests occurs at low elevations in this area, especially in Mookambika, Someshwara and Shankaranarayana ranges.

3. The above population is separated from the large extent of contiguous forest in Kodagu district, by a large discontiguity in the Belthangadi and Mudigere ranges. There is however a small remnant population in the Charmadi Hills of the Belthangadi range.

4. Kodagu population: South of the Mangalore-Sakleshpur road, the habitat is again contiguous and mostly at a low altitude, extending up to Kotiyur forests in Kannoth Range in Kerala. Most of these forests come in Kodagu district. This area covers forest Ranges of Subramanya, Sampaji, Bhagamandla, Makut, Mundrote, and Srimangala. Three state highways, however, cut across this area creating local discontiguities. In terms of habitat quality, this is undoubtedly

the best in Karnataka, being the southernmost, at low elevation and not logged intensively. However, the population has been severely suppressed by poaching from Kerala and Kodagu sides. The population density is therefore very low, compared to what is expected from the pattern evident from the latitude-altitude gradient.

A rough estimate of the area of potential Lion-tailed Macaque habitat in Karnataka is possible from the maps of the vegetation types produced by Pascal (1986). The area under each vegetation type was estimated after digitizing. The vegetation types suitable as Lion-tailed Macaque habitat, their altitude, aspect, habitat quality, area and estimated population (by the population working group) are given in Table 2. For an assessment of habitat quality, the following general rules were applied:

1. For low altitude (0-850 m), forests on the western side are considered good quality compared to the east, but the quality decreases from south to north.

Table 2: The extent of each vegetation type in the wet evergreen forests of the Western Ghats in Karnataka which are potential Lion-tailed Macaque habitat, its habitat quality (see text), altitude, aspect and the estimated number of Lion-tailed Macaque groups. The vegetation types follow Pascal (1988) and the area was estimated from the vegetation map (Pascal 1986).

Ltm population	Vegetation type	Altitude	Aspect	Habitat Quality	Area (sq. km)	Est. LTM groups
North of Sharavati River	1 2	low low	E-W W	med med	80 30	
Total area					110	10
Mookambika-Someshwara area	2 3 4 5 6	low low low med low	W W E E-2 W	med good low low high	235 187 138 70 75	
Total area					705	26
Charmadi Hills	7	low	W	high	24	2
Kodagu area	7 8 9	Low med med	W E-W E-W	high low med	697 324 30	
Total area					1051	10

Vegetation types: 1. *Persea macrantha-Diospyros-Holigarna spp;* (2) *Dipterocarpus indicus-Diospyros candolleana-Diospyros oocarpa,* (3) *Poeciloneuron indicum fades* of (2); (4) *Dipterocarpus indicus-Humboldtia brunonsis-Poeciloneuron indicum;* (5) *Palaquium ellipticum-Poeciloneuron indicum-Hopea ponga;* (6) *Dipterocarpus indicus-Kingiodendron pirmatum-Humboldtia brunonsis-Poeciloneuron indicum;* (7) *Dipterocarpus indicus-Kingiodendron pinnatum-Humboldtia brunonsis;* (8) *Mesua ferrea-Palaquium ellipticum',* (9) *Cullenia exarillata-Mesua ferrea-Palaquium ellipticum.*
Altitude: low=0-850m, med=600- 1400m;
Aspect: E=East, W=West side of the Western Ghats.

2. For medium altitude (600-1400), habitat quality is low, since plant species density decreases with altitude. The *Cullenia exarillata-Mesua ferrea-Palaquium ellipticum* and *Palaquium ellipticum-Poeciloneuron indicum-Hopea ponga* associations in the medium elevations are

considered of lower quality compared to low elevation forest at the same latitude. Between latitudes, the former southern association is considered better than the latter northern association.

3. Forests on the eastern slopes of the Western Ghats are considered a low quality habitat, since species diversity is likely to be markedly less here. Large extent of forests in the Agumbe and Hosanagara ranges belong to this category.

4. Forests above 1400m are not considered Lion-tailed Macaque habitats in Karnataka. Very little forests occur above this altitude in Karnataka, however.

A total of about 1890 sq.km Lion-tailed Macaque habitat occurs in Karnataka. The most extensive habitat is in Kodagu District with nearly 1050 sq.km., followed by the Mookambika-Someshwara area. However, this includes considerable extent of relatively suboptimal habitats; nearly 325 sq.km. of medium elevation forests in Kodagu, and nearly 200 sq.km. (out of 700 sq.km. in total) of eastern and medium elevation forests in the Mookambika-Someshwara area. The population north of Sharavati is estimated at about 10 groups, and that in Mookambika-Someshwara area is estimated at 26 groups. Although Kodagu contains the best habitat, both in terms of quality and contiguity, the population is estimated at only about 10 groups. This could be attributed to hunting over the past many years.

Kerala and Tamil Nadu

Compared to Karnataka the wet evergreen forests in Tamil Nadu and Kerala, occur at a higher elevation mostly above 700m. The best quality low elevation habitats have all been cleared. The status of Lion-tailed Macaque and its habitat in these two states are taken up together because these are adjacent. An assessment of the Lion-tailed Macaque habitat in these two states is severely handicapped because of the absence of a vegetation map, comparable to the one available for Karnataka Although Kerala accounts for nearly 50% of the population and Tamil Nadu for 25%, in both these states the habitat and populations have been severely fragmented. The only exceptions are Silent Valley-New Amarambalam area, Ashambu Hills, and to some extent the Cardamom Hills. There are about seven populations in these two states together, but except in the three areas just mentioned the population are further fragmented into smaller populations (Table 3).

1. North of Nilambur: This population is confined entirely to Kerala. The northern most is the Kotiyur forest, in Kannoth Range which is contiguous with the Kodagu population in Karnataka. The extent of forest in Kerala in however very small (less than 20 sq.km.?). There are three other isolated populations, with 1-4 groups each, in Periya, Manjeri, Kovilakam and Nadukani. Some of these have been underplanted with cardamom, and all populations are under poaching pressure.

2. Silent Valley-New Amarambalam: This is also almost entirely confined to Kerala, and is the largest population in the state, and the best habitat in terms of quality and contiguity. The population is estimated to be about 600 animals (30 groups). Although relatively free from major habitat loss, poaching has been reported recently.

3. Siruvani-Attapadi: Although contiguous with the Silent Valley population till recently, this is now an isolated population. At an elevation of above 900m, the *Cullenia* dominated forest

has a population of about 3-5 groups.

4. Annamalai Hills: Annamalai Hills probably had the largest extent of wet evergreen forests in Western Ghats, till about 200 years back. Large areas were cleared for reservoirs, plantations, and tea and coffee estates. Presently the Lion-tailed Macaque habitat is highly fragmented and surrounded by tea estates. Many of the patches are at a low altitude (600-700m), compared to other parts in these two states, and therefore the density is relatively higher than in most other areas, including the higher elevation forests in the much southern Ashambu Hills. The total population in the Annamalai Hills is probably about 23-31 groups in Kerala and 20-27 groups in Tamil Nadu, with nearly 800-animals in total. Except for the Karimala Gopuram-Sholayar forests, with about 12-16 groups, the remaining populations are all small mostly with 1-2 groups, isolated in forest fragments ranging in area from 15 to 2000ha. Many of these fragments are also under cardamom cultivation under private ownership and highly degraded (eg. Puthuthottam and Korangumudi estates). While most of the areas in Tamil Nadu come within the Indira Gandhi Wildlife Sanctuary, large areas in Kerala are outside the Parambiculam WLS.

5. Munnar: Most of the forests in Mannar have been cleared for tea estates and what remains are at high elevations and not suitable for lion-tailed macaques. Perhaps the only remnant population (of 1-2 groups) is in the Pappathi shola.

Table 3. The distribution and approximate population of Lion-tailed Macaque (as estimated by the Census and Distribution Working Group) in Kerala and Tamil Nadu

LTM population	Kerala	Tamil Nadu	No. of groups	Remarks
North of Nilambur	Kotiyur, Periya Manjeri, Kovilakam Nadukani	--	4-8	Fragmented except for Periyar
Silent Valley New Amarambalam	Silent Valley & New Amarambalam	-	>30	Contiguous population
Siruvani Attapadi	Siruvani & Attapadi area	Boluvampatti	4-5	Contiguous population
Anamalai Hills	Nelliampathi Parambiculam WLS Sholayar	Indira Gandhi WLS, private forests	43-58	Highly frag-mented 1-5 groups each
Munnar	Pappathi, Vattavada	--	1-2	One small fragment
Cardamom Hills	Periyar Tiger Reserve, Ranni& Konni Forest Divisions	Megani Valley, Sirivilliputhur	21	Fragmented into 3-4 populations
South of Achan Koil	Thenmala, Chenduruny & PepparaWLS, Neyyar, Kulathupuzha	Kalakkad-Mundanthurai Tiger Reserve,		Contig. in Tamil Nadu, Fragmented in Kerala, but contig. with Tamil Nadu

6. Cardamon Hills: South of Silent Valley the largest and most contiguous forests are in the Cardamom Hills, between Periyar and Achankoil. Most of these forests are in Kerala, partly in Periyar Tiger Reserve, and in Ranni and Konni Forest Divisions. Although the working group estimated the population to be about 17 groups, and the habitat area to be about 250 sq.km, considerable extent of these forests are either semi-evergreen or at high elevations which may not be optimal lion-tailed macaque habitat. There is also a small and probably isolated population (of about 4 groups) on the eastern side in Tamil Nadu (Sirivilliputhur).

7. South of Achankoil and Ashambu Hills: The forests in Kerala, south of Achankoil, are perhaps contiguous with extensive forests in Ashambu hills which largely fall in Tamil Nadu. The total population is estimated to be about 50-55 groups, which is nearly 25% of the entire lion-tailed macaque population. The forest in Tamil Nadu has retained its contiguity in the Ashambu Hills and isolated small populations are not likely. In Kerala, there has been extensive forest loss, and small isolated populations are likely, although the southern part of this range is contiguous with Tamil Nadu.

CONSERVATION PROBLEMS

The major problems of conservation of the Lion-tailed Macaque are:

1. Habitat and Population Fragmentation: Most of the rain forest in the Western Ghats has been lost and the remaining habitat occurs mostly as small patches with 1 -4 groups each. The Working Group on Census and Distribution identified at least 40 isolated populations, of which 26 had less than two groups each, nine had between 3 and 10 groups, and only five had more than 10 groups. The areas with substantial, but fragmented, populations are Annamalai Hills and Cardamon Hills. Charmadi Hills in Karnataka and north of Nilambur population in Kerala, also have a few small populations confined to small patches of habitat. In Kodagu area, a small population is confined to a large stretch of habitat, a consequence of many years of hunting pressure. South of Achankoil also there might be isolated small populations in Kerala.

It is now well known that such small isolated populations face a high probability of extinction because of random variations in demography and environment, catastrophes such as cyclones and diseases, and inbreeding (see PHVA results).

2. Hunting: Poaching is a serious problem in certain places. It had been prevalent in Kodagu forests for many years. As a result the population in this ideal habitat has been reduced drastically. Hunting is also a problem in the population north of Nilambur, and in Cardamom Hills. Recently, hunting has also been reported from Silent Valley Area. Given the low birth rate and high age at first birth, the Lion-tailed Macaque does not have the ability to recover even from low levels of hunting. This is revealed by PVA (see PVA results).

3. Habitat degradation: Almost all the small patches of rain forests have already been degraded as a result of logging, cardamom planting, and by fuel and timber wood collection to meet the requirements of the human settlements which often surround the patches. The overall impact of habitat degradation is to reduce plant species diversity and food availability, and to prevent regeneration of forests. The long term survival of the Lion-tailed Macaque in the small patches is thus seriously threatened also by habitat degradation.

4. Logging: Although logging in wet evergreen forests has been given up for about a decade, considerable areas of the existing habitat has been opened up by logging. Many of the forest patches under private ownership are often logged either to meet shade requirements of cardamom and fuel wood requirements of labourers. This has already reduced the Lion-tailed Macaque population in some patches in recent years (eg. Puthuthottam and Korangumudi estates), and continues to be the major immediate threat to many small populations in Annamalai Hills, Manjeri Kovilakam forests in Nilambur, and Sirivilliputhur and Periyar areas.

5. Private ownership: Many of the small patches are under private ownership, especially in the Annamalai, Cardamom, and Ashambu Hills. This offers the Lion-tailed Macaque and its habitat very low protection from logging, poaching, fuel wood collection, etc. Logging in such privately owned patches have become a serious threat to resident populations in recent years.

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LION-TAILED MACAQUE *Macaca silenus*
POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

February 1995
Coimbatore, India

Section III

Working Group Reports

CENSUS AND DISTRIBUTION GROUP

The working group identified and assessed the following populations from across the range of the LTM based on the knowledge of all the committee members as well as information from the briefing book. The Group attempted to ascertain which populations had been reliably estimated and assess the quality of the data. They also looked at the census methodology utilised to do the estimates. In conservation of LTM one of the more important factors is contiguity of habitat as individual LTM groups need to interact and intermingle.

It was noted that not all of the evergreen forest might necessarily be LTM habitat so study of the vegetation associations will be advisable to reliably estimate distribution areas. The group also discussed the need for a centralised database for LTM distribution so that coordination of effort between states could be done.

The various populations and the locations are enumerated as detailed below, followed by recommendations.

Kerala State	**No.**	**Groups**
Aralam, Kotiyur	1-4	20-80
Periyar	1-4	20-80
Manjeri Kovilakam	1	20
Nadukani	1	20
Silent Valley-New Amarambalam Area	>30	600
Attappadi-Siruvani	3-5	60-100
Nelliampathi	3	60
Parambiculam-Vengoli	1	20
Kuriarkutti, Pulikkal,	4-6	80-120
K.gopuram, Sholayar, Munnar	12-16	240-320
Pappathi Shola, Munnar Div.	[-2	20-40
Periyar to Acchankoil	17	340
South of Achankoil (with Tamil Nadu Ashambu Hills)	20-25	400-500
Total	**94**	**1880**

Tamil Nadu State

Indira Gandhi WLS	Groups	No
Anakunthi	2	40
Varagaliyar, Banathiar, K.kamathi	6-7	120-140
Urulikkal, Manamboli. Powerhouse	2-3	40-60
Puthuthottam Estate	1	20
Kurangumudi	1	20
Murugali Estate	1	20
Tata Finley Estate (Coffee)	**1**	20
Sankarankudi	1-2	2040
Iyerpadi Estate	1-2	20-40
Kavarkkal Shola	1	20
Shekkal Mudi	1-3	20-60
Waterfall Shola	1-2	20-40
Andipparai	1(?)	20
Sirivilliputhur-Rajapalayam Deviar, Sethur, Kavu.	4	64
Kalakkad-Mundanthurai Chinnapullu (Sivasilam beat)	1	15-25
Kanthamparai (Kannikatti beat)	1	15-20
Valayar, Kuthalapen (Kodamedi beat)	7	90-100
Nalumukku (Singampatti beat)	3	52*
Nambikoil beat	1	6*
Sengaltheri beat	3	69*
Mylar beat	3	45*
Ashambu Hills (contig. with Kerala)	10	200
Total	**53**	**956**

Karnataka State

	Groups	No.
North of Sharavati	**10**	200
Sharavati, Mookambika		
Someswara	**21**	420
Kudremukh, Andar, Naravi	**05**	100
Charmadi	**02**	040
Coorg	**10**	200
Total	**48**	**960**

Karnataka, Kerala, Tamil Nadu States

Total	**183 groups**	**3660 numbers**

** Actual data; others projected with the mean troop size of 20 (Ajit Kumar, 1987), however the mean size may be 15 (Rauf Ali, pers comm.) or less than this.*

Fragmentation:

The following is the extent of fragmentation:

Groups per patch	No. of patches
1-2	26
3-5	5
6-10	4
>10	5

Recommendations

1. Populations in most of the areas are yet to be reliably estimated. Good data exist only for the following areas:

    a. North of the Sharavati river,
    b. Someswara Wildlife Sanctuary,
    c. Silent Valley,
    d. Anamalai Hills,
    e. Senduruni Wildlife Sanctuary

Estimation of populations in other areas should be taken up.

2. Methodology for population estimation need to be standardized. We recommend more than one method, depending on local conditions.

    a. Long term ecological studies on LTM in any area should also try to estimate LTM population in large areas around the ecological study site.

    b. An initial total count of groups should be done in many places involving Forest Dept., researchers, identified institutions like KFRI, SACON, IISc, AVCC, WII, BNHS, NGOs, SFS and IFS trainees. Adequate training should be given to such survey teams

3. Once a total count has been made, periodic monitoring of LTM should be done by the survey teams.

4. The contiguity of the habitat of LTM across the Western Ghats need to be assessed in order to:
    a. Identify distinct populations
    b. Identify critical habitats
    c. Identify areas where corridors could be established

Vegetation maps, aerial photographs, satellite imageries, and field studies should be used for the above purpose.

5. An assessment of various vegetation associations as potential LTM habitat need to be undertaken. This is considered necessary since not all of the evergreen forest may be LTM habitat. A survey of LTMs should be carried out to reflect differences between vegetation association.

6. A centralized database of LTM distribution and population needs to be developed, to coordinate surveys and collate the results with State Coordinators and a National and an International Coordinator.

7. Funds need to be raised to initiate the above activities.

THREATS AND DISASTERS

The Threats and Disasters Working Group listed the important threats to LTM and also the possible catastrophes which might occur. Small populations are extremely vulnerable to catastrophic events, which can wipe out an entire population or sufficient numbers as to render it totally unviable. The Group took information from researchers and field managers in the PHVA as well as reports in published literature.

The Group listed the following as the major threats and disasters for the wild LTM populations:

a. Habitat loss and fragmentation (logging, clearing of natural forest for cultivation, logging in private plantations).
b. Poaching.
c. Fire.
d. Developmental projects.
e. Drought.
f. Disease.
g. Cyclones/landslides.
h. Collection of Minor Forest Produce,
i. Use of pesticides.

The Working Group then categorized the threats according to their probability and severity of occurrence.

The Group assessed habitat loss and fragmentation to be the greatest threat to the wild LTM population. Illegal felling of rain forest trees both within and outside of protected areas, illegal clearing of rain forest patches for the cultivation of narcotic plants, raising plantations and felling in private plantations are the major reasons for this loss and fragmentation. It is estimated that at present the rate of loss due to a variety of reasons is very low (0.005% of existing LTM habitats on an annual basis) but the effect of fragmentation is very significant.

The trees targeted for cutting are normally those species which are preferred LTM food and roost trees.

The Working Group noted that poaching has a high impact on LTM. It is estimated that 1 LTM/group/year is lost due to poaching. This loss is not evenly distributed across all the groups. When animals are taken from small and isolated populations, even if only every 5 or 10 years, this can have a very depressive influence on these populations because of their low birth rate.

However, fire was felt by the group to be a moderate threat only. Grass fires affect edges of LTM habitat leading to death of saplings affecting regeneration. Fires could also cause shrinkage and fragmentation of LTM habitats though at very low rates. All fires are due to human activities: (1) Deliberate burning of grasslands by graziers. (2) Accidental fires by honey gatherers, poachers, cooking fires, etc

The Working Group identified developmental projects as one of the greatest potential threats for LTM. At present there are no plans for any projects in LTM habitats in Tamil Nadu. In Karnataka the Sharavathi tail race project has already begun which would destroy LTM habitat in the northern most range and isolate the northern population. There is a proposal for construction of a dam in Pooyan Kuti area of Periyar river basin in Kerala. Any major developmental project will result in considerable habitat loss which will have a significant negative effect on the overall conservation status of LTM. Such projects are a possible major threat for LTMs.

Drought was considered by the group to be a low threat. Droughts will have an indirect effect on the LTMs. Droughts will affect fruit production which in turn affects food availability for LTM. Reduction in food availability will possibly depress reproductive rate in LTM. The effect of drought will be magnified as the level of habitat fragmentation increases and there is a reduction in patch size.

Diseases were not considered to be a major threat except in the area of Kyasanur Forest disease (KFD). No data is available on free ranging LTMs. A combination of other threats could affect LTM nutrition and thereby their condition. This would possibly increase their parasite load as well as make them more susceptible to disease.

The Group considered cyclones/landslides to be moderate threat. A major cyclone which induces landslides occurs once every 50 years. This results not only in loss of habitat but also causes mortality of LTM which is estimated to be 40 animals for every landslide.

The Working Group noted that collection of minor forest produce poses a moderate threat. All MFP collection in LTM habitat is illegal. The most important impact is the collection of fruits which are fed on by LTM. Species collected by people include *Mangifera indica, Artocarpus hirsuta, Callophyllum austroindicum, Myristica spp.* and *Garcinia gummi-gutta.*

The Group concluded that use of pesticides did not pose a very great threat based on the information available. However, there is no information on the effect of pesticides on these arboreal creatures.

Recommendations

1. It is vital to survey all rain forest patches (in LTM range) to determine patch size, contiguity, and status of LTMs.

2. As far as possible it is important to include all viable LTM populations in the protected area network and also to ensure that all provisions of the Wildlife Protection Act (1972) are enforced effectively.

3. It is of paramount importance to ensure effective and complete protection to all patches holding viable LTM populations.

4. Efforts should be made to initiate and implement ecodevelopment measures for the rural populations living in and adjacent to LTM habitats and help to reduce their dependence on the forest

5. Effective protection against poaching has to be implemented. It is also important for educating the tribal and adjacent rural populations of the importance of conserving LTM and their habitat.

6. Since most fires are accidental, it would be of benefit to educate people to take adequate precautions. Complete control over graziers who deliberately set fire to grasslands has to be ensured.

It is important for the concerned forest officials to maintain a complete and accurate record of all fire incidents giving details like extent of area burnt, damage caused, date and also to map these incidents.

7. Research needs to be initiated to determine the carrying capacity of various patches of LTM habitat especially with reference to ability to cope with resource crunches. It is also essential to determine the effect of fruit, lliana and other MFP extraction on LTM ecology. Since no data is available on the disease status of LTM in the wild it is crucial to determine their parasite load and also to screen them for viruses. This sampling has to be done across the populations throughout their range.

8. Application of pesticides/fertilisers in and around LTM habitats has to be controlled and monitored

HEALTH ISSUES

Disease Monitoring in Zoo and Wild Populations

Infections by *Tuberculosis bacilli* (human strain?), Polio, Ancyclostomiasis *{Ancyclostoma duodenale),* conjuctivitis, urogenital disorders, ring worm and fungal infections have been reported in the captive LTM in Madras and Kerala zoos. Cystic liver and hepatitis have been reported in LTM from zoo populations.

Cases of accidental death as a result of zoo hazards such as infanticide, fall injuries, darting, accidental drowning, head injuries and shock diseases caused by deficiency (Rickets) etc. have also been observed.

However, no information is available on the diseases in the wild population. The viral disease, Kyasanur Forest disease has been known to cause heavy epizootics in certain areas of Karnataka in Bonnet macaques and Hanuman langur, since 1957. LTM would be a likely victim of this virus if it is susceptible. Susceptibility studies may determine whether the LTM is sensitive or refractory to the virus.

Recommendations

1. Sustained and critical studies to be carried out on LTM to generate a data base on infectious and other diseases affecting LTM.

2. Zoo safety measures for LTM should be codified and implemented to prevent accidental injuries and stress.

3. Investigations on unknown diseases should be carried out and treatments should be formulated. Zoo animals should be screened for opportunistic zoonotic as well as anthroponotic viral infections. Whenever opportunity arises, wild populations also should be screened. Isolated small wild populations should be given special attention while screening for anthroponoses as they are likely to come more in contact with the human population. They should also be screened against simian infections whenever there would be an epizootic in other sympatric simian species.

4. Animal care health and treatment norms prescribed by Central Zoo Authority should be meticulously implemented

5. The basic veterinary facilities prescribed by Central Zoo Authority should be made available and properly maintained

6. Establishment of a national database on disease problems of LTM is recommended

7. A refresher courses on disease of LTM for zoo vets should be carried out periodically.

POPULATION MODELING

Introduction:

Lion-tailed macaque habitat is highly fragmented, thereby dispersing the population into many small, isolated sub units. As per the information gathered during the workshop, the entire population is fragmented to nearly 26 populations, each with one to more than ten groups with an estimated total of 3700 individuals (Census and Distribution Report). There is variation in estimates of the average group size, e.g. 15 (Rauf Ali, pers. comm.), and 20 (Ajith Kumar, Census and Distribution Report). Groups with 16 - 20 animals are the most frequent, followed by group size classes 11-15 and 21-25 (Kumar and Kurup, 1993). These figures are from relatively undisturbed areas. There are also some groups with individuals totalling more than 35 and the highest number is 41 (Ajith Kumar, pers. comm.).

At present, the degree of fragmentation, as estimated by the working group, is by the number of patches where one or more groups of lion-tailed macaques reside. The total number of such patches distributed over the three states of Karnataka, Kerala and Tamil Nadu are about forty. (Census and Distribution Report).

The Lion-tailed macaque is classified as "Endangered" by the IUCN Red Data Book. A variety of threats that are driving them towards extinction, e.g. disease, poaching, loss of habitat, habitat degradation and the effects of genetic and environmental stochasticity that threaten small population. The population modelling group simulated various demographic and genetic processes for small populations in a Population Viability Analysis programme called VORTEX (See last section of the report).

Small populations often undergo random shifts in size due to events that may occur either naturally (environmental) or due to mans' influence. When similar events occur in a larger population, the effects are minimal and the random fluctuation does not affect the population. The same event, however, imploding an artificially small population can cause a dramatic shift or fluctuation, which might be so destructive to the population as to cause total extinction. VORTEX helps model this stochasticity, interactions of the multiple variables, and the outcome thereof.

Basic biology of the species and the values for factors such as catastrophe, poaching, carrying capacity, etc. were gathered from the different working groups. These values were, in turn, used to model the Lion-tail macaque populations under different scenarios.

The PHVA analysis simulated more than 200 populations of lion-tailed macaques in each scenario to assess the probability of survival for 100 years. The basic demographic data came from the work of Kumar (1987) on a single population of LTMs in the Annamalai hills of southern India.

Various scenarios were modelled by changing selected parameters. In all the scenarios, the basic biology that had been adapted from Ajith Kumar's population was used.

Assumptions of the Base-line Model:

1. Population Size & Carrying Capacity:

Initial population sizes were varied from 12 animals to 200 animals (begining with the stable age distribution), with carrying capacities being 70 for sizes up to 50 individuals and approximately 20% higher than initial sizes for larger populations.

This report shows the population trend of groups with initial population size varying from 12 to 60. Populations with sizes below 12 and above 60 have not been modelled because their behaviour can be extrapolated. The carrying capacity was fixed at the values given above has been assigned to represent a range of small population sizes that have been observed.

2. Reproductive Rates :

Females begin reproducing at age 6 years and males at 8 years. The probability of a mature female giving birth in a year is 30%.Two basic secenarios of 40 and 30 per cent female fertility per year were modelled. Only 75% of the adult males were assumed to be in the breeding pool.

3. Mortality:

The maximum life span was taken as 22 years. Annual probability of death was 5% (SD=1.7) for infants, juveniles and sub-adults of both sexes, 3.4% (SD= 1.7) for adult females and 8% (SD=4) for adult males.

4. Catastrophes :

Two types of catastrophes were modelled simultaneously, one with a 2% probability of a 25% reduction in survival and another with a 5% probability of 25% reduction in survival and no effect on reproduction. These two catastrophes were kept constant in all the runs allowing for natural calamities that might be present in any given scenario.

5. Inbreeding Depression :

This factor was modelled although no valid studies have been made either in wild or in captivity. Given the extensive fragmentation and the cumulative effect it has on the genetics of a small population, four sets of values were considered for inbreeding. All the models were constructed with 0, 0.3, 1.7, 3.14 and 5.7 lethal equivalents. These values are equivalent to no inbreeding depression, inbreeding depression close to that of captive crab-eating macaque *(Macaca fascicularis),* and Celebes black-ape *{Macaca nigra)* (K. Ralls, *et. al.* 1988), average mammalian value and a presumed high value, respectively.

Various scenarios were considered with the combination of these base-line assumptions. Before that an ideal, best case scenario was modelled with no catastrophies, inbreeding depression, higher female fertility and a large carrying capacity.

The scenarios considered were :

1. Single populations without poaching.
2. Single populations with poaching
3. Metapopulation without poaching.
4. Metapopulation with poaching.

A sample VORTEX input file is included.

Sample Input File

15n40b3i.out ***Output Filename***
Y ***Graphing Files?***
N ***Each Iteration?***
500 ***Simulations***
100 *** Years***
10 ***Reporting Interval***
1 ***Populations***
Y * * * Inbreeding Depression? * * *
H * * *Heterosis Or Lethals* * *
0.30000 ***Lethal Equivalents***
Y ***EV correlation?***
2 ***Types Of Catastrophes***
P * * *Monogamous Or Polygynous* * *
6 * * *Female Breeding Age* * *
8 * * *Male Breeding Age* * *
22 * * *Maximum Age* * *
0.500000 ***Sex Ratio***
1 * * *Maximum Litter Size* * *
N ***Density Dependent Breeding[9]***
60.000000 * * *Population 1: Percent Litter Size 0* * *
40.000000 ***Population 1: Percent Litter Size 1 ***
10.000000 * * *E V-Reproduction* * *
5.000000 ***Female Mortality At Age 0***
1.700000 * * *E V-FemaleMortality * * *
5.000000 * * *Female Mortality At Age 1 * * *
1.700000 ***EV~FemaleMortality***
5.000000 ***Female Mortality At Age 2***
1.700000 * * *E V--FemaleMortality * * *
5.000000 ***Female Mortality At Age 3***
1.700000 * * *E V--FemaleMortality * * *
5.000000 ***Female Mortality At Age 4***
1.700000 * * *E V-FemaleMortality * * *
5.000000 ***Female Mortality At Age 5***
1.700000 * * *E V-FemaleMortality * * *
3.400000 * * * Adult Female Mortality* * *
1.700000 * * *E V- AdultFemaleMortality * * *

5.000000 ***Male Mortality At Age 0***
1.700000 * * *EV--MaleMortality * * *
5.000000 * * *Male Mortality At Age 1 * * *
1.700000 ***EV--MaleMortality***
5.000000 ***Male Mortality At Age 2***
1.700000 ***EV--MaleMortality***
5.000000 * * *Male Mortality At Age 3 * * *
1.700000 * * *E V--MaleMortality * * *
5.000000 ***Male Mortality At Age 4***
1.700000 * * *E V--MaleMortality * * *
5.000000 ***Male Mortality At Age 5***
1.700000 * * *EV--MaleMortality * * *
5.000000 ***Male Mortality At Age 6***
1.700000 ***EV-MaleMortality***
5.000000 * * *Male Mortality At Age 7* * *
1.700000 ***E V--MaleMortality* **
8.000000 ***Adult Male Mortality***
4.000000 * * *EV--AdultMaleMortality* * *
2.000000 ***Probability Of Catastrophe 1***
1.000000 * * * Severity-Reproduction* * *
0.750000 *** Severity-Survival***
5.000000 ***Probability Of Catastrophe 2***
1.000000 ***Severity-Reproduction***
0.750000 ***Severity--Survival***
N ***A11 Males Breeders[9]***
Y ***Answer--A--Known?***
75.000000 ***Percent Males In Breeding Pool**
Y * * * Start At Stable Age Distribution[9]* * *
15 * * *Initial Population Size* * *
70 ***K***
0.000000 ***EV--K***
Y ***Trend In K?***
10 *** Years Of Trend***
-1.000000 * * *Percent Change In K* * *
N ***Harvest?***
N ***Supplement?***
y ***AnotherSimulation?***
15n30b3i.out ***Output Filename***
Y ***Graphing Files?***
N ***Each Iteration?***
500 ***Simulations***
100 *** Years***
10 * * *Reporting Interval* * *
1 ***Populations***
Y ***Inbreeding Depression?***
H * * *Heterosis Or Lethals* * *
0.30000 ***Lethal Equivalents***

Y ***EV correlation?***
2 * * *Types Of Catastrophes* * *
P * * *Monogamous Or Polygynous* * *
6 * * *Female Breeding Age* * *
8 * * *Male Breeding Age* * *
22 * * *Maximum Age* * *
0.500000 ***Sex Ratio***
1 * * *Maximum Litter Size* * *
N * * *Density Dependent Breeding? * * *
70.000000 ***Population 1: Percent Litter Size 0***
30.000000 ***Population 1: Percent Litter Size 1 ***
10.000000 * * *EV--Reproduction* * *
5.000000 ***Female Mortality At Age 0***
1.700000 * * *EV--FemaleMortality* * *
5.000000 ***Female Mortality At Age 1 ***
1.700000 ***EV--FemaleMortality***
5.000000 ***Female Mortality At Age 2***
1.700000 * * *EV-FemaleMortality * * *
5.000000 ***Female Mortality At Age 3***
1.700000 * * *EV--FemaleMortality * * *
5.000000 ***Female Mortality At Age 4***
1.700000 * * *E V--FemaleMortality * * *
5.000000 ***Female Mortality At Age 5***
1.700000 * * *E V--FemaleMortality * * *
3.400000 * * * Adult Female Mortality* * *
1.700000 * * *E V-- AdultFemaleMortality * * *
5.000000 ***Male Mortality At Age 0***
1.700000 * * *E V--MaleMortality * * *
5.000000 ***Male Mortality At Age 1***
1.700000 * * *E V-MaleMortality * * *
5.000000 ***Male Mortality At Age 2***
1.700000 * * *E V-MaleMortality * * *
5.000000 ***Male Mortality At Age 3***
1.700000 ***EV~MaleMortality***
5.000000 ***Male Mortality At Age 4***
1.700000 ***EV--MaleMortaIity***
5.000000 ***Male Mortality At Age 5***
1.700000 ***E V-MaleMortality* **
5.000000 ***Male Mortality At Age 6***
1.700000 ***EV~MaleMortality***
5.000000 ***Male Mortality At Age 7***
1.700000 ***EV--MaleMortality***
8.000000 ***Adult Male Mortality***
4.000000 * * *E V--AdultMaleMortality* * *
2.000000 * * *Probability Of Catastrophe 1 * * *
1.000000 ***Severity-Reproduction***
0.750000 * * * Severity-Survival* * *
5.000000 ***Probability Of Catastrophe 2***

1.000000 ***Severity--Reproduction*** 0.750000
Severity--Survival N * * * All Males
Breeders?***
Y * * * Answer- A-Known?* * *
75.000000 ***Percent Males In Breeding Pool***
Y ***Start At Stable Age Distribution?***
15 ***Initial Population Size***
70 ***K***
0.000000 ***EV-K***
Y ***Trend In K?***
10 ***Years Of Trend***
-1.000000 ***Percent Change In K***
N ***Harvest?***
N ***Supplement?***

I. Single populations without poaching

This scenario was modelled with a combination of the two fertility percentages (40% & 30%) of the females with different inbreeding coefficients.

Results of all the runs are tabulated showing the input values, population growth and probabilities of extinction at certain years. Following the tables are charts that represent some salient result graphically.

Results :

All scenarios show a distinct fall in the probability of survival of lion-tail macaques as the inbreeding value increases. Further, it is seen that the percentage of female lion-tailed macaques in the breeding pool has a conspicuous impact. All the models were run with two percentages of females in the breeding pool - 40% and 30%. The models with 40% of females breeding definitely has a healthy outcome in 100 years with no inbreeding as compared to 30% females breeding. The latter shows a distinct fall in the probability of surivival. While an initial population of 12 animals (40% female fertility) show 86% probability of survival in 100 years, compared to 52% probability with 30% female fertility.

As the initial population size increases, chances of survival in both the cases have only a minor difference. This unfortunately is not the case in the wild as many population have less than 20 individuals, where the survival probabilities is very low. According to studies, low female fertility seems to be more prevalent in the wild.

The series of tables shows the probability of extinction as modelled for different population sizes and parameters.

Fig. 1. Probability of extinction with increasing inbreeding among the different populations; % Female breeding = 40

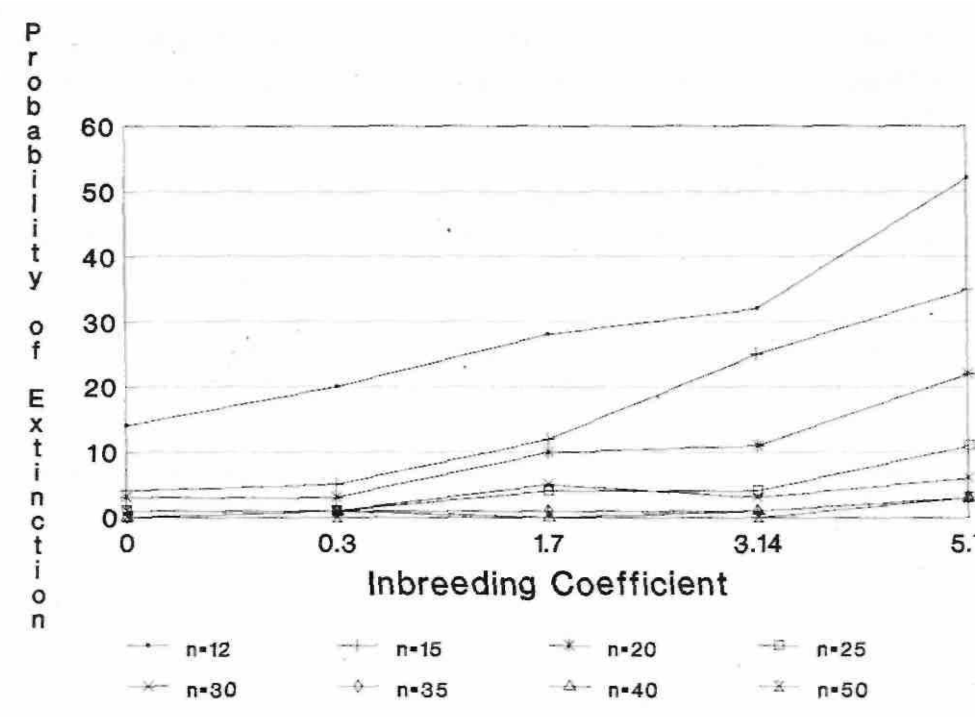
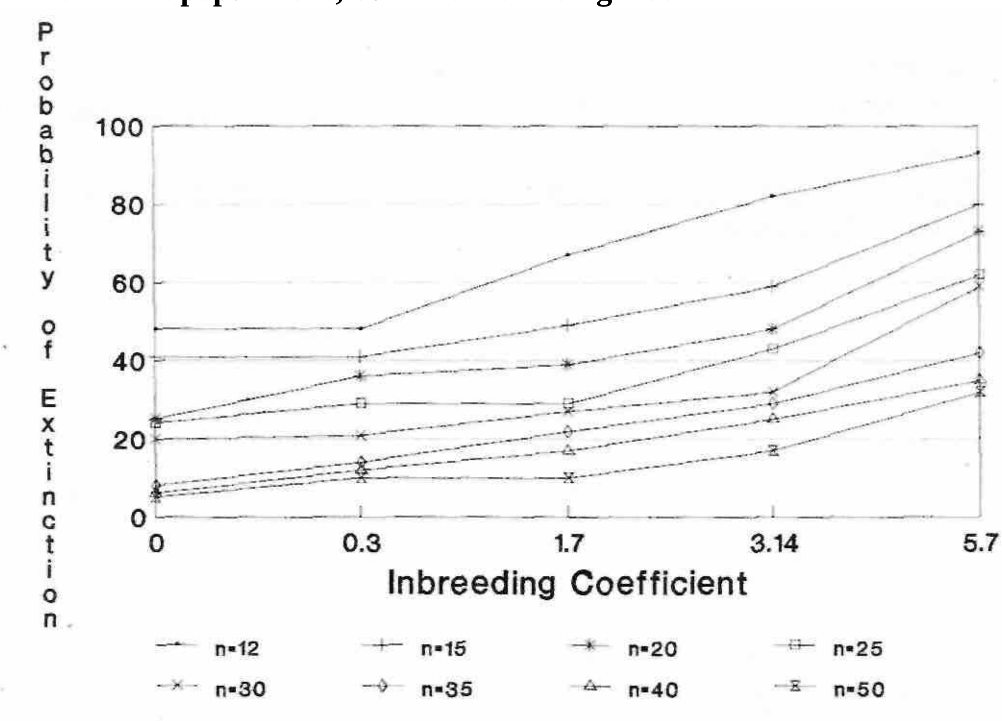


Fig. 2. Probability of extinction with increasing inbreeding among the different populations; % Female breeding = 30



Explanation of Tables:

Tables 1-10 are results of the simulations with the carrying capacity and mortality being constant for all models and all populations. Different levels of inbreeding depression and two levels of female fertility have been tested. Each permutation of the two parameters with all of the population sizes total up to 10 different scenarios. The unchanged data set of carrying capacity and mortality with the range of population sizes constitute a basic model.

The tables give the stochastic growth rate and the probabilities of extinction of any population for 20, 50 and 100 years and with any extinctions, the mean time to extinction.

The deterministic growth rate(r) of populations is also included. This value is a function of the fertility and mortality schedules.

The scenarios with 30% female fertility shows an intrinsic or deterministic growth rate(r) of 0.011, while those with 40% female fertility show a deterministic growth rate(r) of 0.034.

The abbreviations on the table head read as follows.

1. Init. Pop. (n) = Initial population.
2. % F Br = Percentage female breeding
3. K = Habitat carrying capacity
4. Deter r = Deterministic or intrinisic growth rate.
5. Stoch r = The mean population growth rate of the simulated populations, averaged across years and iterations.
6. SD (r) = The variation in r expressed as a standard deviation across years.
7. PE%=Probability of extinction, the proportion of simulated population going extinct within 100 year simulations.
8. N=Mean population size at the given year of those simulated population that remained extant.
9. H = The mean heterozygosity (gene diversity) of the extant final populations, presented as a percent of the initial gene diversity.

Table 1. Single population without poaching

Inbreeding Coefficient = 0 ; Juvenile Mortality = 5%
% Female Breeding = 30 ; Carrying Capacity = 70 (1% decrease over 10 years)

FILE	INPUT VALUES									RESULTS								
	INIT POP	%F BR.	K	POPULATION GROWTH			20 YEARS				50 YEARS				100 YEARS			
				DETER	STOCH	SD	PE%	N	SD	H%	PE%	N	SD	H%	PE%	N	SD	H%	TE
12N30B	12	30	70	.011	-.004	.149	9	15	7.8	96.4	27	23	16.7	80.1	48	34	18.9	73.4	48
15N30B	15	30	70	.011	-.001	.139	5	20	10.2	97.5	22	28	17.5	85.9	41	38	21.8	72.9	57
20N30B	20	30	70	.011	-.0004	.135	3	24	12.4	97.0	14	31	16.3	85.5	25	35	19.7	74.8	49
25N30B	25	30	70	.011	0.029	.107	0	47	14.5	98.0	2	52	12.3	91.2	24	55	12.7	79.4	37
30N30B	30	30	70	.011	0.001	.126	1	37	14.6	98.7	6	36	17.7	92.0	20	38	14.9	81.7	65
35N30B	35	30	70	.011	0.005	.117	0	40	16.0	98.5	1	41	17.4	92.0	8	39	16.3	85.6	70
40N30B	40	30	70	.011	0.004	.118	0	44	14.2	98.7	1	39	17.2	93.8	6	40	13.0	86.4	66
50N30B	50	30	70	.011	0.005	.112	0	50	12.7	99.0	0	45	16.3	94.6	5	39	12.3	86.5	74
60N30B	60	30	80	.011	0.005	.113	0	50	12.5	99.2	3	46	15.2	95.0	4	41	16.0	88.4	74

Table 2. Single population without poaching

Inbreeding Coefficient = 0.3 ; Juvenile Mortality = 5%
% Female Breeding = 30 ; Carrying Capacity = 70 (1% decrease over 10 years)

FILE	INPUT VALUES						RESULTS												
	INIT POP	%F BR.	K	POPULATION GROWTH			20 YEARS				50 YEARS				100 YEARS				
				DETER	STOCH	SD	PE%	N	SD	H%	PE%	N	SD	H%	PE%	N	SD	H%	TE
12N30B3I	12	30	70	.011	-.004	.148	6	16	9.7	96.8	32	29	17.8	83.7	48	32	18.1	73.1	45.5
15N30B3I	15	30	70	.011	-.004	.145	3	18	8.8	97.8	22	26	16.0	83.9	41	36	20.2	70.7	51.7
20N30B3I	20	30	70	.011	-.004	.135	1	25	13.1	97.9	13	32	19.2	88.7	36	32	16.8	79.4	60.8
25N30B3I	25	30	70	.011	-.005	.138	0	29	14.1	98.7	9	28	16.1	90.2	29	33	19.2	81.3	61.2
30N30B3I	30	30	70	.011	-.0003	.126	0	36	15.4	98.8	3	38	18.8	91.3	21	38	16.9	82.1	70.6
35N30B3I	35	30	70	.011	.001	.118	0	41	14.2	98.9	4	39	17.5	91.8	14	40	19.0	82.2	63.8
40N30B3I	40	30	70	.011	.0007	.118	0	41	15.3	99.2	5	41	16.3	92.7	12	39	17.6	82.8	65.6
n5b3i3	50	30	70	.011	-.001	.121	0-	43	14.1	99.4	6	42	15.7	93.7	10	35	18.4	84.8	65.5
n6b3i3	60	30	80	.011	-.003	.114	0	56	12.9	99.4	0	48	17.5	95.8	5	42	19.3	86.4	-

Table 3. Single population without poaching

Inbreeding Coefficient = 1.7 ; Juvenile Mortality = 5%
% Female Breeding = 30 ; Carrying Capacity = 70 (1% decrease over 10 years)

FILE	INPUT VALUES						RESULTS												
	INIT POP	%F BR.	K	POPULATION GROWTH			20 YEARS				50 YEARS				100 YEARS				
				DETER	STOCH	SD	PE%	N	SD	H%	PE%	N	SD	11%	PE%	N	SD	H%	TE
1230B17I	12	30	70	.011	-.013	.150	9	15	8.7	97	35	22	15.9	81.2	67	24	21.0	76.0	50
1530B17I	15	30	70	.011	-.017	.154	5	19	11.5	96.7	28	22	16.0	84.3	64	26	18.8	71.9	56
2030B17I	20	30	70	.011	-.009	.135	0	24	10.5	98.3	11	26	17.7	89.6	39	26	16.5	78.1	63
2530B17I	25	30	70	.011	-.004	.126	1	30	13.0	98.5	6	32	17.3	90.4	29	33	17.6	81.3	67
3030B17I	30	30	70	.011	-.006	.123	1	39	14.0	98.6	2	37	16.4	92.4	27	32	19.1	83.4	76
3530B17I	35	30	70	.011	-.001	.126	0	39	15.0	98.6	5	38	17.4	92.7	22	35	17.7	86.5	70
4030B17I	40	30	70	.011	-.013	.116	0	42	14.20	98.7	3	40	15.8	93.6	17	34	18.7	83.0	68
5030B17I	50	30	70	.011	-.001	.119	0	50	10.88	99.4	1	44	16.1	94.3	10	37	17.5	87.5	81
6030B17I	60	30	80	.011	-.0004	.114	0	47	11.57	99	1	42	15.2	95.5	9	33	16.8	84.7	72

Table 4. Single population without poaching

Inbreeding Coefficient = 3.14 ; Juvenile Mortality = 5%
% Female Breeding = 30 ; Carrying Capacity = 70 (1% decrease over 10 years)

FILE	INPUT VALUES						RESULTS													
				POPULATION GROWTH			20 YEARS				50 YEARS				100 YEARS				
	INIT POP	%F BR.	K	DETER	STOCH	SD	PE%	N	SD	H%	PE%	N	SD	H%	PE%	N	SD	H%	TE
1230B31I	12	30	70	.011	-.025	.166	8	14	7.9	96.8	45	16	12.4	81.0	82	13	12.7	72.6	48.8
1530B31I	15	30	70	.011	-.015	.149	1	20	9.0	97.8	15	22	14.1	88.3	59	19	14.6	80.0	43.9
2030B31I	20	30	70	.011	-.013	.144	2	23	11.9	97.9	18	27	17.7	88.9	48	25	17.8	83.2	44.1
2530B31I	25	30	70	.011	-.013	.135	2	30	13.7	98.7	12	29	17.8	91.1	43	25	16.9	85.4	58.8
3030B31I	30	30	70	.011	-.010	.129	0	34	14.8	98.8	13	32	17.7	93.2	32	25	17.2	85.9	85.2
3530B31I	35	30	70	.011	-.003	.118	0	41	14.9	98.9	0	38	15.8	93.3	29	29	18.0	86.8	82.0
4030B31I	40	30	70	.011	-.007	.122	0	42	14.0	99.2	3	38	18.3	93.0	25	30	17.7	86.8	-
n5b3i3	50	30	70	.011	-.005	.121	0	46	12.7	99.4	2	37	16.9	95.1	17	29	16.8	84.9	-
n6b3i3	60	30	80	.011	-.004	.115	0	54	13.1	99.4	0	45	19.1	96.5	15	34	18.4	86.7	-

Table 5. Single population without poaching

Inbreeding Coefficient = 5.7 ; Juvenile Mortality = 5%
% Female Breeding = 30 ; Carrying Capacity = 70 (1% decrease over 10 years)

FILE	INPUT VALUES						RESULTS													
	INIT POP	%F BR.	K	POPULATION GROWTH			20 YEARS				50 YEARS				100 YEARS				
				DETER	STOCH	SD	PE%	N	SD	H%	PE%	N	SD	H%	PE%	N	SD	H%	TE
1230B57I	12	30	70	.011	-.034	.176	10	14	7.8	97.5	49	14	13.4	85.8	93	16	15.1	73.4	48.2
1530B57I	15	30	70	.011	-.026	.156	2	17	9.0	98.1	31	18	14.5	87.5	80	13	7.4	82.9	57.3
2030B57I	20	30	70	.011	-.025	.152	3	23	12.0	98.5	31	23	15.8	88.3	73	18	14.8	84.5	58.7
2530B57I	25	30	70	.011	-.018	.136	1	30	13.3	99.1	8	27	17.9	92.5	62	17	12.7	79.4	70.0
3030B57I	30	30	70	.011	-.020	.136	0	33	15.0	99.0	13	31	17.9	91.5	59	20	15.0	81.7	70.6
3530B57I	35	30	70	.011	-.017	.130	0	38	16.4	99.2	6	33	18.8	94.9	42	19	16.3	85.6	68.0
4030B57I	40	30	70	.011	-.013	.123	0	46	14.2	99.0	3	38	17.4	95.2	35	21	13.0	86.4	76.2
n5b3i5	50	30	70	.011	-.014	.122	0	45	12.8	99.6	3	35	15.4	94.9	32	21	12.3	86.5	75.8
n6b3i5	60	30	80	.011	-.012	.123	0	55	13.8	99.4	2	41	18.1	96.5	20	24	16.1	88.4	79.3

Table 6. Single population without poaching

Inbreeding Coefficient = 0 ; Juvenile Mortality = 5%
% Female Breeding = 40 ; Carrying Capacity = 70 (1% decrease over 10 years)

FILE	INPUT VALUES						RESULTS												
	INIT POP	%F BR.	K	POPULATION GROWTH			20 YEARS				50 YEARS				100 YEARS				
				DETER	STOCH	SD	PE%	N	SD	H%	PE%	N	SD	H%	PE%	N	SD	H%	TE
12N40B	12	40	70	.034	.025	.124	5	23	11.8	95.5	8	43	18.7	85.1	14	50	14.0	75.6	39
15N40B	15	40	70	.034	.027	.118	2	31	15.0	96.0	1	49	15.3	87.1	4	52	13.2	79.7	35
20N40B	20	40	70	.034	.027	.116	1	35	15.9	97.4	1	51	13.8	88.8	3	53	13.1	80.6	35
25N40B	25	40	70	.034	.030	.107	0	47	14.7	98.0	1	53	12.3	91.2	1	55	10.0	83.6	36
30N40B	30	40	70	.034	.029	.106	0	49	13.5	98.1	0	52	13.6	92.2	1	53	11.1	84.8	58
35N40B	35	40	70	.034	.027	.109	0	52	13.2	98.5	0	53	13.4	92.6	0	52	13.7	85.7	-
40N40B	40	40	70	.034	.031	.102	0	55	9.8	98.6	0	54	11.5	94.3	0	56	8.5	85.9	-
50N40B	50	40	70	.034	.027	.107	0	56	9.9	98.8	0	54	10.2	94.4	0	52	11.9	87.9	-
60N40B	60	40	80	.034	.028	.105	0	56	8.7	99.0	0	54	10.4	94.4	0	52	13.0	87.2	-

Table 7. Single population without poaching

Inbreeding Coefficient = 0.3 ; Juvenile Mortality = 5%
% Female Breeding = 40 ; Carrying Capacity = 70 (1% decrease over 10 years)

FILE	INPUT VALUES						RESULTS												
				POPULATION GROWTH			20 YEARS				50 YEARS				100 YEARS				
	INIT POP	%F BR.	K	DETER	STOCH	SD	PE%	N	SD	H%	PE%	N	SD	H%	PE%	N	SD	H%	TE
12N40B3I	12	40	70	.034	.022	.129	5	23	12.1	95.7	14	41	18.9	84.7	20	53	12.5	77.7	38.6
15n40b3i	15	40	70	.034	.026	.114	2	29	13.9	96.4	4	47	16.3	86.5	5	53	13.5	77.1	32.8
20N40B3I	20	40	70	.034	.028	.108	0	40	14.3	97.1	3	51	12.7	91.0	3	56	10.9	82.7	31.7
25N40B3i	25	40	70	.034	.027	.108	0	***43***	16.2	98.1	0	49	15.3	91.6	1	53	10.6	84.4	82.0
30N40B3I	30	40	70	.034	.027	.106	0	47	14.6	98.0	1	53	11.3	92.2	1	54	11.3	84.4	31.0
35N40B3I	35	40	70	.034	.027	.107	0	52	12.7	98.4	0	54	11.4	93.5	1	53	12.2	86.2	100.0
40N40B3I	40	40	70	.034	.028	.106	0	52	11.0	98.8	0	54	12.1	93.5	1	55	11.1	87.0	52.0
n5b4i3	50	40	70	.034	.021	.106	0	54	10.1	99.2	0	50	11.4	94.4	0	45	15.2	88.2	-
n6b4i3	60	40	80	.034	-	-	0	63	9.6	99.3	0	59	13.3	95.0	0	56	15.2	88.5	-

Table 8. Single population without poaching

Inbreeding Coefficient =1.7 ; Juvenile Mortality = 5%
% Female Breeding = 40 ; Carrying Capacity = 70 (1% decrease over 10 years)

FILE	INPUT VALUES						RESULTS												
				POPULATION GROWTH			20 YEARS				50 YEARS				100 YEARS				
	INIT POP	%F BR.	K	DETER	STOCH	SD	PE%	N	SD	H%	PE%	N	SD	H%	PE%	N	SD	H%	TE
1240B17I	12	40	70	.034	.011	.134	6	21	12.9	95.5	16	37	21.1	83.9	28	43	18.4	72.6	48.8
1540B17I	15	40	70	.034	.017	.120	2	29	15.5	97.1	7	41	17.8	87.5	12	46	18.2	80.0	44.0
2040B17I	20	40	70	.034	.021	.112	1	38	16.1	97.3	7	49	16.0	89.9	10	51	15.5	83.2	44.1
2540B17I	25	40	70	.034	.020	.110	0	44	15.5	98.3	2	49	14.3	93.4	5	51	12.8	85.4	58.8
3040B17I	30	40	70	.034	.022	.108	0	49	14.2	98.5	0	51	14.4	93.4	4	50	13.4	85.9	85.2
3540B17I	35	40	70	.034	.024	.107	0	53	12.2	99.0	0	54	12.2	93.5	1	49	12.3	86.8	82.0
4040B17I	40	40	70	.034	.023	.108	0	53	11.8	98.5	0	52	11.7	94.8	0	52	13.5	86.8	-
5040B17I	50	40	70	.034	.024	.107	0	55	9.6	98.8	0	54	10.9	94.4	0	48	**16.3**	86.3	-
6040B17I	60	40	80	.034	.025	.103	0	56	9.6	99.3	0	54	10.2	94.4	0	51	12.9	88.3	-

Table 9. Single population without poaching

Inbreeding Coefficient = 3.14 ; Juvenile Mortality = 5%
% Female Breeding = 40 ; Carrying Capacity = 70 (1% decrease over 10 years)

FILE	INPUT VALUES			RESULTS															
	INIT POP	%F BR.	K	POPULATION GROWTH			20 YEARS				50 YEARS				100 YEARS				
				DETER	STOCH	SD	PE%	N	SD	H%	PE%	N	SD	H%	PE%	N	SD	H%	TE
1240B31I	12	40	70	.034	.005	.135	7	22	11.9	97.2	16	35	18.4	85.9	32	35	20.0	75.6	50.6
1540B31I	15	40	70	.034	.010	.127	0	27	12.9	98.3	0	38	19.0	87.8	25	44	16.4	80.9	62.4
2040B31I	20	40	70	.034	.015	.116	0	37	16.1	97.6	2	46	16.0	91.1	11	44	16.7	84.3	71.1
2540B31I	25	40	70	.034	.016	.110	0	45	14.4	98.0	0	47	15.2	91.7	4	43	17.2	86.1	78.3
3040B31I	30	40	70	.034	.018	.109	0	47	14.7	98.2	3	52	13.5	93.8	3	48	15.0	85.9	38.7
3540B31I	35	40	70	.034	.019	.107	0	49	13.2	98.6	0	51	14.4	93.4	1	47	16.1	86.9	57.0
4040B31I	40	40	70	.034	.018	.108	0	53	11.5	99.1	0	52	12.3	94.4	1	48	15.9	86.8	92.0
n5b4i3	50	40	70	.034	.020	.106	0	54	10.0	99.2	0	50	11.4	94.4	0	45	15.2	88.2	-

Table 10. Single population without poaching

Inbreeding Coefficient = 5.7 ; Juvenile Mortality = 5%
% Female Breeding = 40 ; Carrying Capacity = 70 (1% decrease over 10 years)

FILE	INPUT VALUES						RESULTS												
	INIT POP	% F BR.	K	POPULATION GROWTH			20 YEARS				'50 YEARS				100 YEARS				
				DETER	STOCH	SD	PE%	N	SD	H%	PE%	N	SD	H%	PE%	N	SD	H%	TE
1240B57I	12	40	70	.034	-.007	.145	4	21	12.6	96.8	25	29	18.7	87.4	52	25	18.5	81.4	54
1540B57I	15	40	70	.034	.0003	.129	1	29	14.0	97.0	6	35	19.3	88.9	35	33	17.2	82.8	69
2040B57I	20	40	70	.034	.004	.123	0	35	16.1	98.8	3	40	19	91.5	22	35	16.7	84.2	73
2540B57I	25	40	70	.034	.009	.116	0	46	14.3	98.9	2	46	16.5	93.0	11	34	18.5	85.7	72
3040B57I	30	40	70	.034	.009	.113	0	45	15.8	98.9	0	47	15.3	94.3	6	36	17.9	87.4	65
3540B57I	35	40	70	.034	.015	.107	0	52	11.9	99.1	1	52	11.9	94.0	3	43	16.0	88.5	65
4040B57I	40	40	70	.034	.016	.107	0	54	12.6	99.2	2	53	10.5	94.6	3	42	15.7	88.0	53
n5b4i5	50	40	70	.034	.015	.107	0	54	9.6	99.2	1	48	11.9	95.3	3	40	15.6	87.8	50
n6b4i5	60	40	80	.034	.018	.103	0	62	10.5	99.5	0	57	13.6	96.3	2	49	18.1	90.8	65

II Single populations with poaching

Poaching is a threat to LTM mostly because they are mistaken for Nilgiri Langurs which are hunted for their medicinal value. However, at some places, locals wielding muzzle loaders do target the animals for no apparent reason (R. Krishnamani, pers. comm).

Poaching was modelled as harvesting 3 macaques (one infant, one adult female and one adult male) every three years up to the 50th year. This was modelled as harvesting six individuals once in six years consisting of 2 adult males and adult females each and an infant male and infant female. Poaching was considered as harvesting and not included under catastrophe. In all the models including poaching, the two catastrophes were unaltered.

Result:

When poaching was factored, the populations with less than 25 individuals initially always went extinct. Even large initial population sizes were unstable. The final size of all the populations remained small and they became highly inbred. At a lower fertility rate of 30%, all the populations irrespective of their initial size went extinct. Hence, the tables 11 and 12 show the effects of poaching on initial population size of 25 and above. The stochastic growth rate none-the-less shows a negative for all the populations whether or not inbreeding was incorporated.

TABLE 11. Single population with poaching
40% Female Breeding, K = 70, Deter r = 0.034
No Inbreeding Coefficient

INIT POP	PE	N	SD	H	STOCH	SD	TE
25	87	56.69	18.05	78.1	-0.4396	0.3581	28.63
30	60	54.88	16.60	81.1	-0.3241	0.2918	32.50
35	41	57.32	14.12	82.0	-0.2557	0.2455	34.29
40	35	56.02	13.36	82.4	-0.2328	0.2563	37.04
50	25	58.17	12.35	85.1	-0.1847	0.2069	40.00
60	13	55.49	12.43	84.9	-0.I5II	0.1804	41.08

Table 12. Single population with poaching
40% Female Breeding, K = 70, deter r = 0.034
Inbreeding Coefficient = 0.3

INIT POP	PE	N	SD	H	STOCH r	SD	TE
25	86	48.21	20.38	75.3	-0.4303	0.3204	28.01
30	63	52.70	15.71	77.9	-0.3161	0.3067	36.33
35	53	52.77	17.29	78.1	-0.2774	0.2970	33.%
40	37	55.56	16.81	81.3	-0.2178	0.2342	43.30
50	27	56.01	13.89	84.3	-0.1808	0.2223	44.63
60	18	54.88	13.43	84.5	-0.1417	0.1527	44.88

Table 13. Metapopulation without poaching, n = 15; No Inbreeding;
Female Breeding = 30%; 3% Migration; Deterministic r = 0.011; At 100 years

Population	PE%	N	SD	H	TE	Stoch r	SD
1.	40	10.64	6.23	81.3	22.33	-0.0028	0.1390
2.	38	10.69	6.54	80.1	24.25	-0.0008	0.1345
3.	41	10.01	5.91	79.8	22.03	-0.0031	0.1372
4.	41	10.21	6.04	80.0	45.11	-0.0030	0.1396
5.	45	9.77	5.81	78.3	20.25	-0.0041	0.1401
6.	44	9.82	5.97	80.1	20.16	-0.0038	0.1411
7.	39	11.12	6.98	81.2	33.77	-0.0007	0.1354
8.	39	10.98	6.88	82.3	35.9	-0.0028	0.1381
9.	40	11.11	6.90	80.12	32.3	-0.0031	0.1331
10.	35	12.01	7.17	82.5	42.12	-0.0017	0.12%
Meta - pop.	36	107.14	10.32	80.3	37.7	-0.0021	0.0136

III Metapopulation without poaching

Although most of the groups are distinctly isolated from each other, and observed to 'lose out' while trying to migrate, or interact with other groups, individuals do migrate to contiguous patch with multiple group composition.

A metapopulation was thus considered with 10 groups each with 15 individuals. The migration rate between the groups was taken to be 3% per year. Factors such as poaching and inbreeding were not considered while the two catastrophes were retained as is.

Results :

The meta-population sustains itself for hundred years though the individual populations have on an average 35 probability of extinction. This is seen in a healthier scenario of higher female fertility. The same populations do not survive very well when the female fertility comes down to 30%, which is more realistic in the wild. In this case, the probability of extinction is as high as 40% among individual populations and 36% for the metapopulation. There is a difference of 10 between the percentages of heterozygosity retained between the two runs.

Table 14. Metapopulation without poaching, n = 15; No Inbreeding; Female Breeding = 40%; 3% Migration; Deterministic r = 0.034; At 100 years

Population	PE%	N	SD	H	TE	Stoch r	SD
1.	2	28.83	14.17	90.6	70.50	0.0237	0.1263
2.	2	29.31	13.62	91.5	73.50	0.0245	0.1261
3.	4	25.92	15.83	91.3	76.20	0.0214	0.1318
4.	0	27.01	16.09	90.9	-	0.0216	0.1290
5.	1	24.10	15.31	90.8	59.00	0.0218	0.1281
6.	3	29.31	13.63	91.3	69.00	0.0226	0.1291
7.	5	26.56	15.39	92.6	51.00	0.0208	0.1333
8.	5	26.65	14.72	90.9	75.33	0.0203	0.1326
9.	4	29.18	13.69	90.3	68.75	0.0243	0.1280
10.	3	26.87	16.30	91.7	71.00	0.0212	0.1311
Meta - pop.	0	260.41	28.92	91.3	-	0.0290	0.1361

IV Metapopulation with poaching

Poaching three individuals every three years such as in the single population model was considered for each of the populations in the metapopulation with a size of 15 per population.

Result:

Meta-population with no inbreeding effects and low or high female fertility when exposed to poaching did not survive. All the populations within the meta-population had a probability of extinction of 78% or more.

Discussion and Recommendation

After collection of information from biologists, researchers, zoo personnel and field managers at the P.H.V.A. for Lion-tailed macaque, several models were constructed also projecting inbreeding effect of different degrees. It should be noted that although the credibility of inbreeding effect has been questioned by some scientists and managers, there is now a body of published scientific evidence pointing to its veracity and no published evidence otherwise. Therefore the burden of proof is on those who claim there is no significant effect on wild populations due to inbreeding. Therefore a set of heterosis lethals were used as values for modelling the Lion-tailed macaque populations.

As observed in the four scenarios described in the earlier discussion on modelling, populations or groups for which there is no inbreeding appear to have a greater probability of survival. The graphs (Fig. 1-6) provide a clear picture of the probability of a population's ability to survive, or its inability to do so.

The amount of heterozygosity retained by any of the populations assessed is very low, whether or not inbreeding was incorporated. The graphs (Fig. 8-10) show that the percentage of heterozygosity retained increases coincident with the number of individuals within each group, or with an increase in heterozygous lethals. Since no population -- either a single population or a meta-population, -- with or without poaching, can retain 95% of their heterozygosity, retention by manipulation must be carried out in order to save the wild population.

Genetic material -- either from the captive LTMs or from other groups in the wild -- needs to be continuously infused into the wild groups of 20 to 30 individuals. An exercise of supplementation -- adding an adult male and two adult females to a group every three years -- will help maintain the level of heterozygosity and reduce inbreeding depression.

According to the model, a minimum of approximately 40% or more of breeding age females that successfully conceive in a given year is required to insure stability or minimal growth of the population. The populations tested for 30% breeding females face a greater degree of risk of extinction, which may be as high as 80% when combined with group size less than 15 and inbreeding. The threshold between decline and growth lies somewhere

Fig. 3
PROBABILITY OF EXTINCTION
Ic = 0; % Female Breeding = 40 & 30

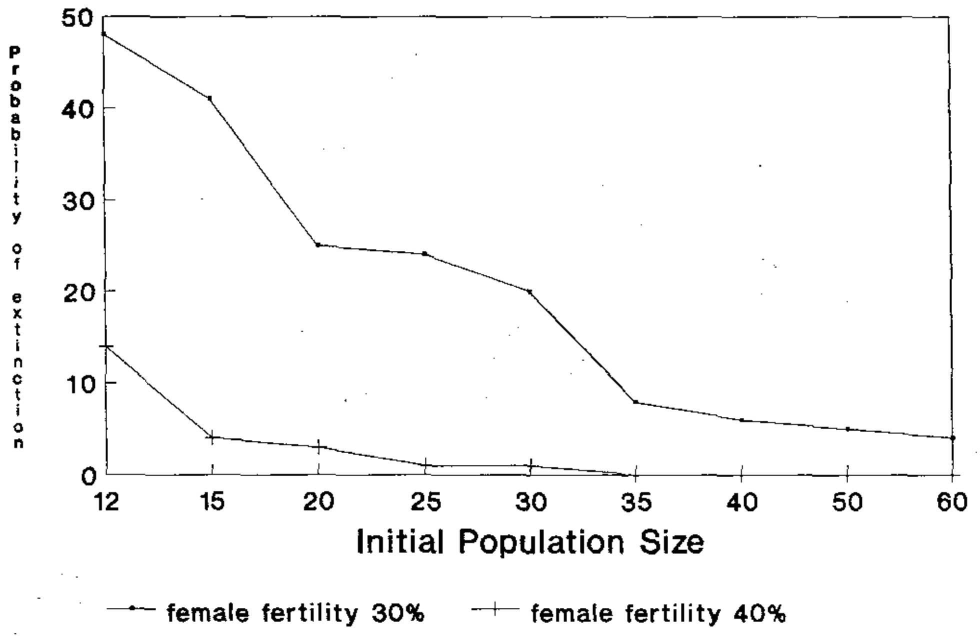


Fig. 4
PROBABILITY OF EXTINCTION
Ic = 0.3; % Female Breeding = 40 & 30

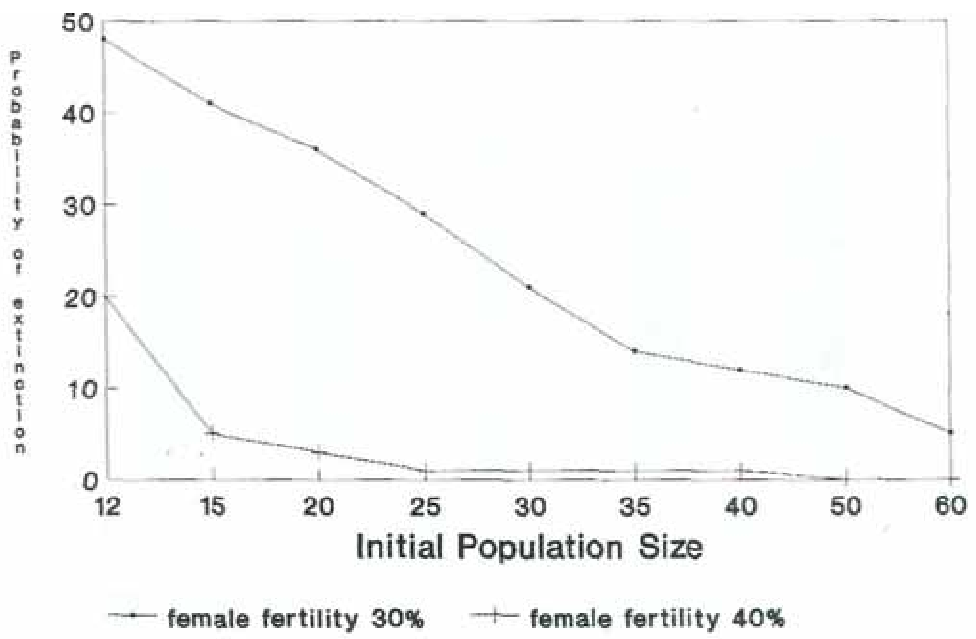


Fig. 5
PROBABILITY OF EXTINCTION
1c =1.7; % Female Breeding = 40 & 30

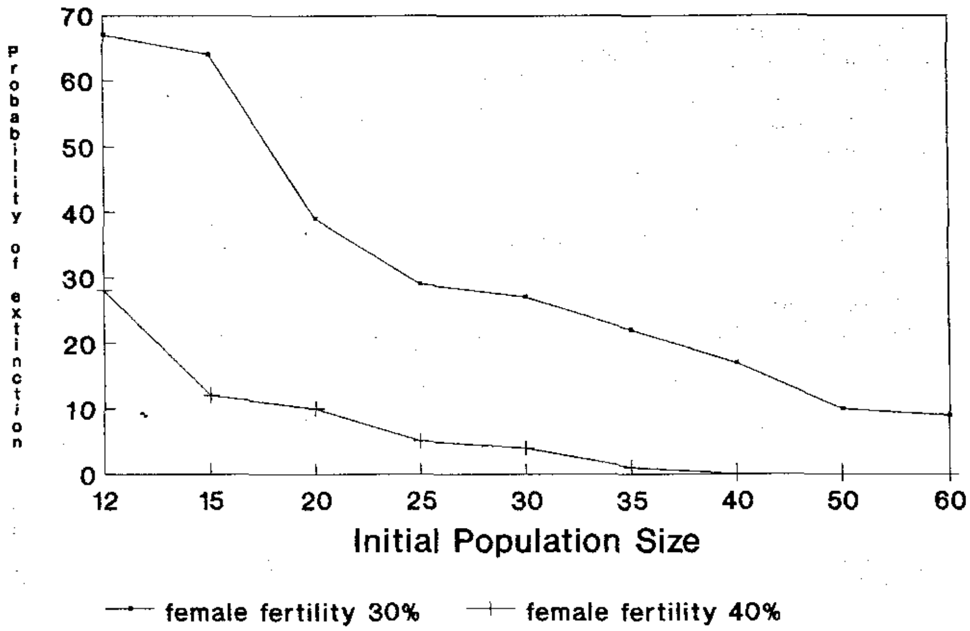


Fig. 6
PROBABILITY OF EXTINCTION
lc = 3.14; % Female Breeding = 40 & 30

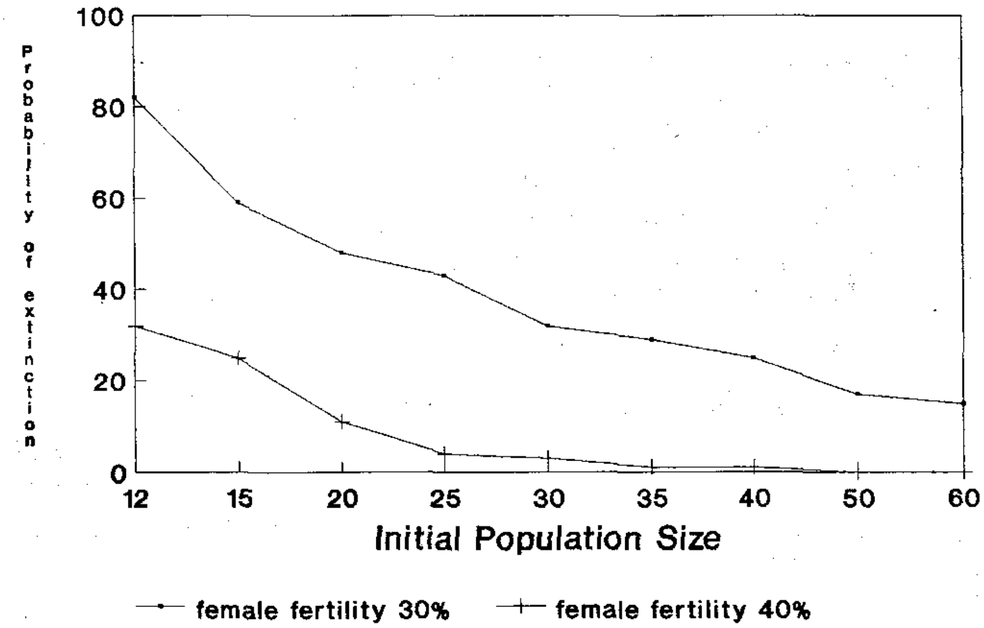


Fig. 7
PROBABILITY OF EXTINCTION
lc = 5.7; % Female Breeding = 40 & 30

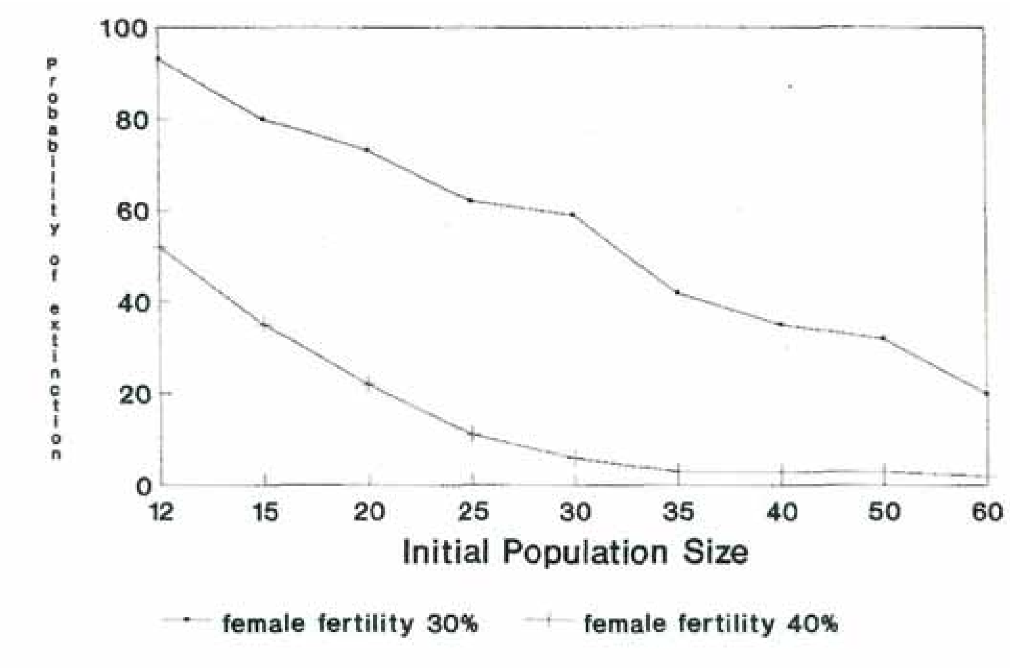
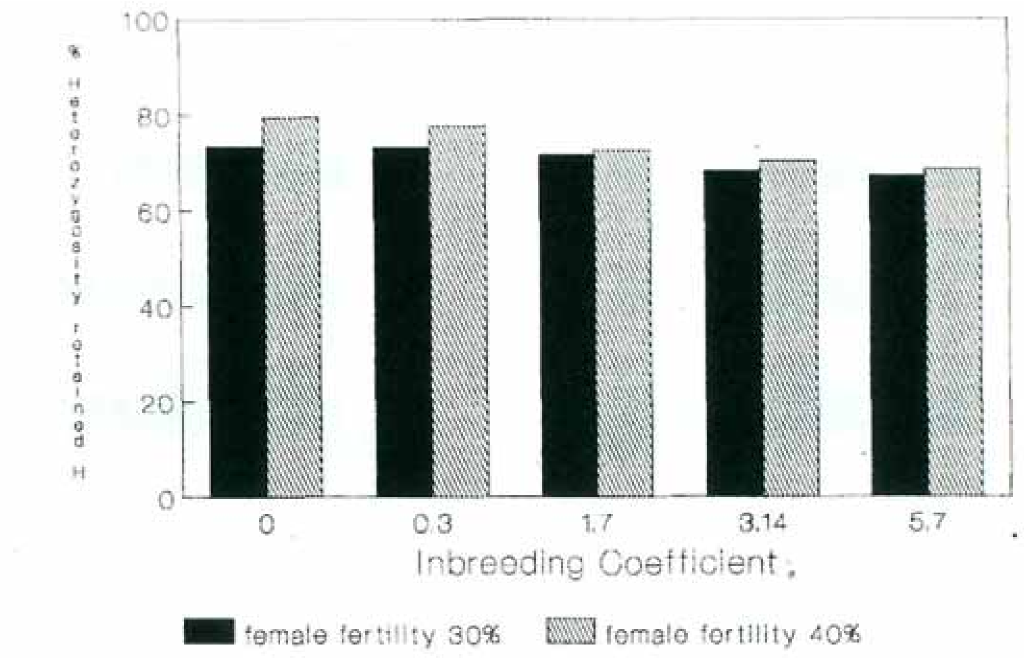


Fig. 8 Heterozygosity retained

n = 12; female fertility = 40 % & 30%



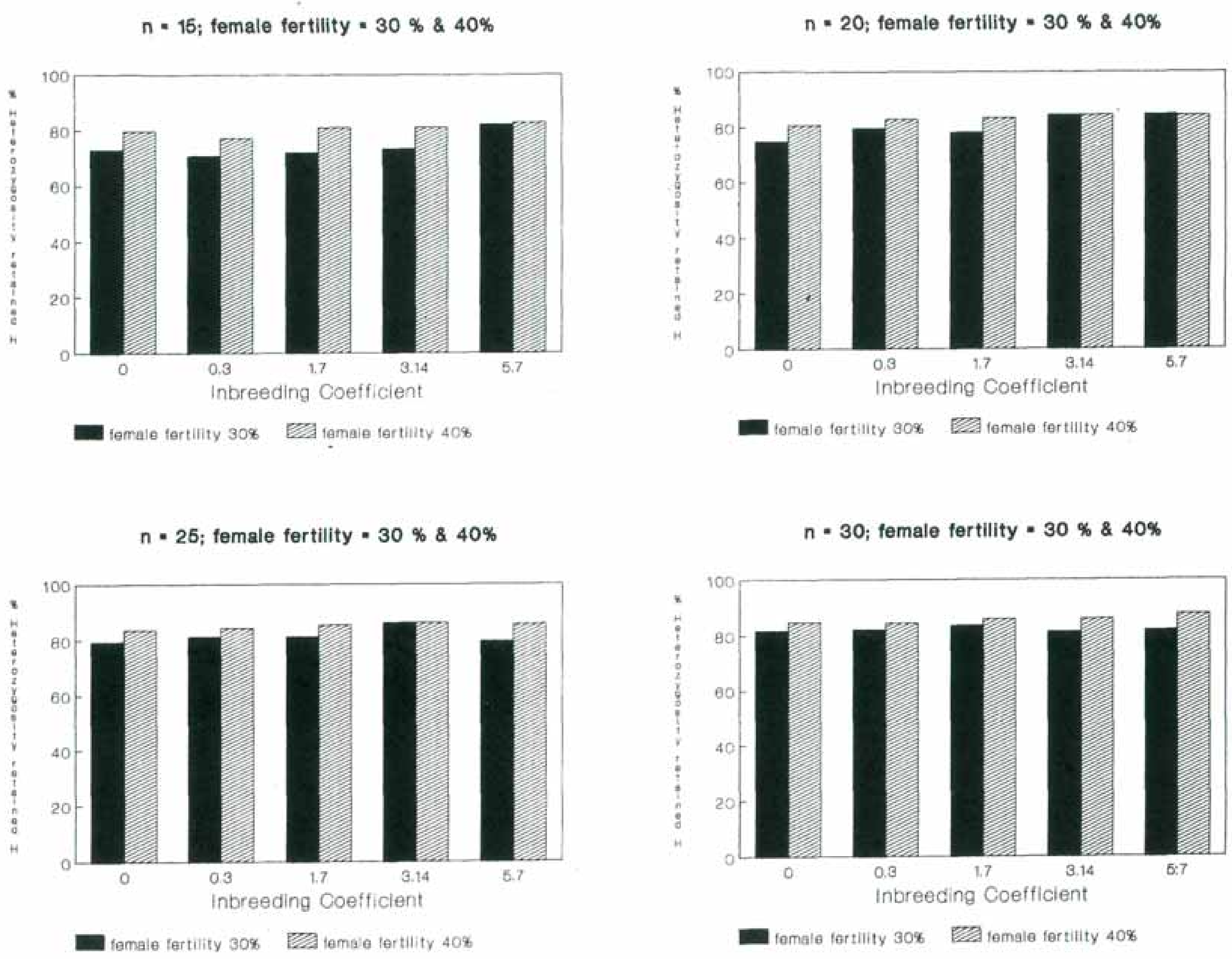


Fig. 9 Heterozygosity retained

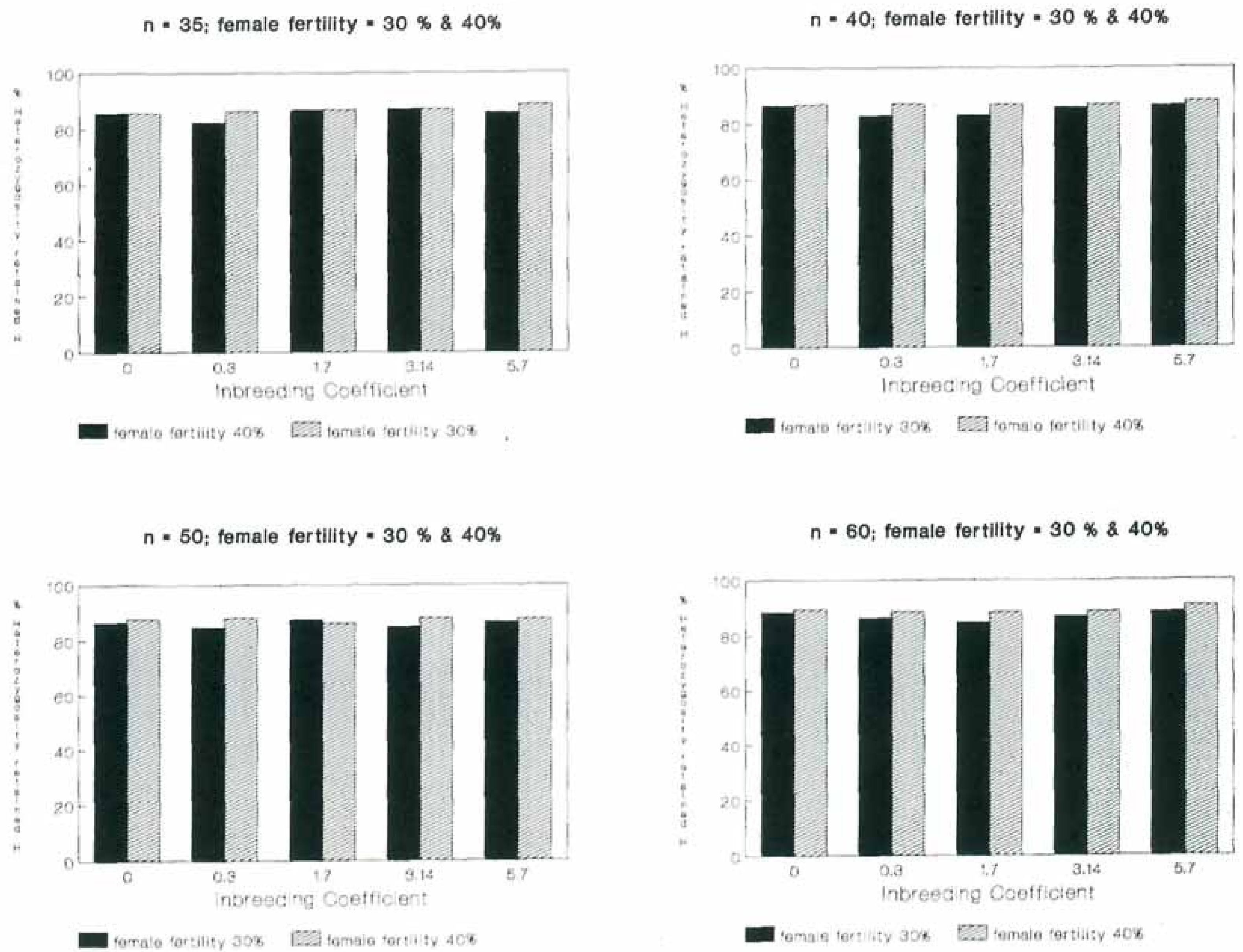


Fig. 10 Heterozygosity retained

between 30% and 40% of breeding females.

According to field research at Topslip, the percentage of females which successfully breed every year is around 30%. Such populations, therefore, do not stand a good chance of survival. Reintroduction from the captive stock or translocating into these groups are necessary to keep the populations healthy. This will not only increase the number of successfully breeding females but also infuse fresh genetic material into the group.

Poaching is one of the important factors that need to be considered in Lion-tailed macaque management. An estimated loss of one individual per group per year as modelled, reduces the population dramatically to numbers which cannot increase or be sustained in decades to come.

There are many isolated, small single groups of less than 30 individuals. As the scenarios tell, these groups have no chance of survival without intensive management intervention. Such groups need to be translocated to areas having a sizeable population of Lion-tailed macaques with a high carrying capacity and no hinderance to movement between groups. Very small groups with less than seven individuals also may be captured to strengthen the captive population and for use in genetic manipulation of the wild population.

The basic models assume two catastrophes of 2 percent and 5 percent frequency of occurence per year with a multiplicative effect on survival only. This means that up to 25% of the individuals may be killed. The two catastrophes modelled were drought and disease. No data is available on these and other environmental perturbationss. Hence these values were modelled for all scenarios irrespective of the kind of catastrophe that occurs. The lack of such information makes it difficult to predict effect on reproduction and survival.   More research on this aspect is urgently required.

Similarly, juvenile mortality of 5% was was assumed since not enough data was available. (Some biologists felt this value should have been made higher.) Further research and monitoring are needed for a more reliable estimate of this factor.

Likewise, migration between populations and the sexes involved was assumed and needs further observation and research to suggest realistic values.

Additional recommendations:

1. Protection from poachers. This should be given high priority in the management of Lion-tailed macaques as it has been demonstrated that the loss of an individual every year to poachers can dramatically affect the stability of small populations.

2. Habitat management. Populations of less than 12 Lion-tailed macaques are almost certain to go extinct in one decade or less. Lion-tailed macaques are very sensitive to loss of vegetation, especially tall trees where they spend most of their time. Forest patches need to be continguous with canopy cover to encourage migration.

3. Maintaining a healthy stock of Lion-tailed macaques in captivity is crucial for intensive metapopulation management. The captive population can provide a good source of

genetic material for the wild population either by reintroduction of living animals or of germ plasm.

4. Small populations of less than 7 individuals of Lion-tailed macaques are almost certainly doomed to extinction. These may be taken into captivity and used for strengthening the existing captive population and other wild populations.

5. Research and monitoring of basic biology such as fertility, mortality, migration rates, and evironmental influence such as catastrophes need to be pursued. For successful management and for saving this species from extinction, this is crucial.

TRANSLOCATION AND REINTRODUCTION

Options for the re-introduction of the LTM into their original habitat were considered by the Translocation and Reinroduction Group. Many of the LTM populations are small and may not survive unless supplemented from other groups or even by captive bom animals. If found necessary, reintroduction and translocation may be taken up as a concurrent measure for conservation of the LTM populations and habitats which are under threat. The Translocation and Reintroduction Group examined factors which are responsible for the declining population as well as conditions prevailing and in potential reintroduction sites. The problem of fragmented populations was also considered. The carrying capacity of me habitats available for the LTM in the three States in which it occurs must be determined on priority basis. Involving local people is essential.

The Working Group first considered Translocation and Reintroduction seperately with considerations and reasons for each activity:

Translocations

Considerations and Justifications: the following points were discussed in detail by the Working Group in trying to determine the factors necessary for translocation.

The need for identification and resolution of factors leading to the decline or disappearance of LTMs from the target habitat was stressed by the Group. The Working Group also emphasized the importance of determining demographic factors: carrying capacity, density, group size, range and distribution, in areas of optimum LTM populations and apply them to targeted areas.

Genetic viability of fragmented populations and their habitats must be ascertained and used to determine how healthy populations should be maintained.

Appropriate target sites should be identified and animals studied to determine the amount of " survival skill sharpening" necessary for the LTMs to be successfully translocated. Intermediate steps may be necessary depending on the origin of the animals to be translocated.

It is crucial to reduce the possibility of disease transmission by effective veterinary screening. The Guidelines of the IUCN SSC Reintroduction Specialist Group for translocation and reintroduction of captive bred animals give detailed instructions in this regard.

The importance of educating the local people was stressed. They should be frilly briefed about the background and goals and logistics of the projects, including collection of animals, group establishment, maintenance and follow-up of programs and made "owners" of the programme in some fashion.

The Working Group also highlighted the necessity to develop a plan to maintain genetic diversity and prevent inbreeding.

The important reasons or "justification" for Translocations are:

1. Translocation / reintroduction will augment genetic variability in fragmented populations.

2. Translocation / reintroduction activities can be used to remove animals which are in conflict with local human activities to more secure areas where they will not be harassed or hunted.

3. Translocation/ reintroduction of animals can be done to re-populate areas of prime habitat previously utilized by LTMs.

Reintroduction

Considerations and justifications

The same considerations as were given for translocation were presented for reintroduction. In addition reintroduction attempts, if done with captive born animals, will need additional support personnel, administration, infrastructure, training both of animals as well as people, intensive monitoring of the LTMs and additional follow-up programs.

Justification for Reintroductions:

1. As in translocation, reintroduction will augment genetic variability in fragmented populations and re-populate areas of prime habitat previously utilized by LTMs, provided the original causes of destruction have been removed

2. Reintroduction can be used for experimental programmes, to reintroduce captive born LTMs in fragmented areas vacated by translocated animals.

3. Reintroduction is a goal of all captive breeding programs.

4. Reintroduction of LTMs, even experimental activities, will be useful in gaining knowledge of the reintroduction process for LTMs in time of absolute necessity, of other macaques and similar primate species.

5. A reintroduction programme will call attention to the LTM as the flagship species representing the conservation effort in Western Ghats region and to the role of zoos in the conservation effort.

6. Reintroduction activities of LTM will result in the training field biologists, captive breeding specialists and other wildlife workers in reintroduction biology and processes.

The Working Group in Translocation / Reintroduction developed a Guidelines or Process for translocation / reintroduction which is given below:

Process for Translocation / Reintroduction

Participating Organizations: Government of India: Department of Environment and Forest, Central Zoo Authority, Department of Forestry, Tamil Nadu, Kerala and Karnataka.

1. Feasibility Study
    a. conducted by private organizations in association with state government.
    b. assess species biology and habitat
    c. carrying capacity and ecosystem dynamics

2. Formulation of Project Proposal
    a. conducted at the State or National level Forest Department
    b. project implementation and administration are at state level.
    c. should involve long-term funding and technical advise.
    d. Establish project goals and objectives
    e. protocol for translocation or reintroduction.
        1. selection of appropriate site in a protected area
        2. selection of animals for project
            i. genetic representation
            ii. sex ratio
            iii. ages
            iv. group size

3. Implementation of Guidelines of IUCN SSC Reintroduction Specialist Group and other relevant recommendations for translocation or reintroduction of captive born animals.

4. Monitoring and population management

    a. pre and post release public education programs
    b. consideration of local economics and traditional practices and provision of alternatives

Recommendations

1. Animals that are currently in fragmented populations of private estates or monoculture plantations, which have a very low probability of long term survival, should be considered for translocation into suitable viable habitats.

2. Determine which fragments are non-viable based on ecology, group size, etc. and consider them for translocation.

3. Determine which fragments can be utilized by LTMs with the introduction of additional genetic material.

4. Develop a multi-faceted education program using the LTM as a flagship species, pre & post release.

5. Set up a supplemented, free-ranging program for captive bred LTMs in India that would provide training for animals and wildlife personnel. This should be done in a suitable forest area that is not currently occupied by LTMs.

6. All reintroducted animals should be screened for diseases using recognised veterinary protocols.

7. Any translocation / reintroduction program should involve the local villages Irving inside the forest areas as well as in the peripheral areas. These people need to be compensated for their loss of traditional rights.

8. All translocations / reintroductions should preferably take place in protected areas.

9. All translocation / reintroduction programs should be taken up and monitored under the aegis of the Central and State governments, Central Zoo Authority, in collaboration with the Wildlife Institute of India, SACON and KFRI.

GENETICS

The Genetics Group analyzed the problems of genetic origin arising in populations of LTM The wild population, being fully of isolated and fragmented small groups, may have problems of inbreeding, for lack of opportunities for transmigration. The captive metapopulation in North America, Europe and Japan has been managed according to the AZA Species Survival Plan and therefore has an acceptable level of inbreeding. The Indian captive metapopulation, however, has not been managed and there may be some instances of inbreeding.

The objective of the Genetics Group was to identify and implement management strategies for the maintenance of genetic variability in long-term breeding populations of LTM. They have been done for the captive and wild population, including intervention strategies.

A. Captive Population Analysis.

All records that are available at Indian zoos on their captive LTM or through the Central Zoo Authority should be collated and data obtained should be as follows:

1. Date Of Birth (for captive-born animals), capture location (if available) and estimated age (for wild-born animals), breeding records (including known or suspected infertility or abnormal breeding behavior), pedigrees, and medical history (such as vaccines, surgery, etc.).

Animals must be permanently tattooed or otherwise marked to facilitate accurate individual identification, and to ensure the maintenance of correct pedigree data. These data need to be analyzed to devise a recommended breeding plan to minimize inbreeding.

2. As the LTM SSP has no source information about some of the captive LTMs, e.g. whether they were captive-or wild-born. All the zoos that have LTMs should be contacted to determine if they have additional records which may help to identify unknown animals as wild or of captive origin.

3. As there is no genetic data available on the 70 LTM s currently maintained in Indian zoos, the Central Zoo Authority should coordinate the collection of whole blood samples from captive Indian LTM, to be used for the laboratory genetics study (Section III, below). All precautions should be taken to ensure that the health, safety, and well-being of LTM be maintained during sampling.

4. The Central Zoo Authority of India will coordinate the collection of existing captive LTMs in India into larger groups maintained in eight zoos, viz., Vandalur, Hyderabad, Trivandrum, Chandigarh, Delhi, Kanpur, Mysore and Bhubaneshwar which are identified by the Indian Species Coordinators Committee and the Global Animal Survival Plan Committee.

Dr. Don Lindburg has commented that this will not be easy as females introduced into established groups are apt to be killed and males cannot be grouped. Some zoos have to settle for keeping single males in their facilities.

B. Wild Population Analysis

1. The collection of biological samples (blood, tissue, semen or hair) on 12-15 individuals sampled from the two extremes of the geographical range of the LTM be organized. According to the Census Group, these populations are found in northern water shed of Sharavathi in Kar-nataka (northern-most) and Kalakkad, Tamil Nadu (southern-most). Given the lack of precise geographical origins of most of the captive LTM population, collection of these samples for analysis is crucial to the preservation of the species.

C. Genetic Comparison of Captive and Wild Populations

1. An inter-institutional group (including representatives from the Primate Specialist Group) should be formed. This will have the responsibility of identifying the laboratories, equipment, and personnel necessary to conduct the genetic typing here in India.

2. This inter-institutional group should also recruit a molecular geneticist who has the necessary laboratory and analytical skills needed to conduct the typing and analyze the resulting data. (Institutions such as CCMB in Hyderbad, IISc in Bangalore and the IBMS in Madras should be involved).

3. The inter-institutional group should assist in organizing the training of Indian veterinarians, zoo personnel, and scientists, and other aspects of technology transfer, including research opportunities for undergraduate and graduate students. This will facilitate the dissemination of laboratory skills for genetic typing for use in this and related projects in India.

4. The genetic typing data must be subjected to a population genetic analysis. These data should be used to compare the populations by estimating the genetic distance between populations, and by estimating the degree to which the wild population has broken down into genetically distinct, non-interbreeding subpopulations.

Mr. Sharma commented that the observations as written in the above paras were not accepted by the group. The LTM is an endangered species and it would not be appropriate to allow free-for-all research with this species, either in the wild or in captivity. Only professionals from selected research institutions, who have adequate expertise in carrying out genetic typing work should be involved in research on LTM.

D. Intervention Strategies

1. The results of the typing data and the population genetic analysis will indicate two crucial features of LTM populations. First, it will tell how genetically different wild populations from the north and the south are from each other. Secondly, it will indicate how much of the genetic variation typical of wild populations is already represented in the captive Indian population. This knowledge will suggest in general terms what needs to be done to preserve a genetically healthy LTM population. Consultation with the varous other specialist groups will be necessary for providing more specific recommendations for practical advice concerning implementation.

Dr. DonLindburg commented that it is not productive to move individuals between zoos considering only the genetic criteria and ignoring the social and xenophobic traits.

2. The Protected Areas Group will identify viable populations which should be protected.

3. The Translocation and Reintroduction Group and the Disease Group will suggest the feasibility and practical details of "artificial migration" between small protected groups using captured males, and on the capture of whole, small groups and their relocation into zoos or other protected areas.

4. The Assisted Reproduction Group will be consulted on the feasibility of collecting sperm samples from males in small populations that cannot be protected, for use in artificial insemination or *in vitro* fertilization.

ASSISTED REPRODUCTION

The Assisted Reproduction Group discussed management strategies to help maintain genetic diversity in small populations and save the species by aiding with fester population growth using methods of assisted reproduction such as artificial insemination and embryo transfer.

The Group defined Assisted Reproduction as any human intervention to enhance the potential reproductive success of individuals or populations.

The Working Group listed the objectives of Assisted Reproduction as:

a. To help maintain genetic diversity in small populations, particularity saving genetic material from non-breeding under-represented individuals.
b. To aid with fester population growth
c. To develop and maintain a bank of frozen genetic material.
d. Increase the reproductive knowledge of the species and therefore management potential
e. Transport gametes instead of animals to:
    1. reduce risk of disease
    2. reduce transportation stress;
    3. reduce introduction trauma;
    4. reduce possible political problems

In assessing the need for Assisted Reproduction, the Working Group discussed the LTM meta-populations as divided into three groups

A. Captive World population
B. Captive Indian population
C. Wild Indian population

Recommendations

1. It was noted by the working group that rapid population growth did not seem to be a priority at this time.

2. After assessing the metapopulation, captive (world), captive (Indian) and wild, the Working Group felt that management techniques utilizing natural breeding could maintain genetic diversity in all three groups at this time

3. It is recommended that the wild population be further studied to give insight into the level of inbreeding, reproductive parameters and reproductive efficiency

4. It is recommended that captive population reproduction records should be reviewed to earmark the problem animals in need of assisted reproduction.

5. It is recommended that all non-invasive animal management and behavioural enhancement techniques should be utilized to correct the situation before invasive techniques are applied. *(A*

list of priorities is given after Recommendations)

6. All personnel performing the procedures should be trained in the techniques utilizing non-endangered species as surrogates (Bonnet and Rhesus macaques) before working on the LTM

7. It is recommended that the following research activities are taken up as preparatory measures in the eventuality that Assisted Reproduction for the survival of LTM should become a necessity.

a. creation and fostering of partnerships between areas of expertise, i.e. zoos wild life biologists and research institutions

b. create areas within each zoo for basic research with minimal equipment, such as refrigerator and freezer

c. identify regional research institutions to coordinate and carry out the more technical work

d. establish a field center near a wild population to
   i. acclimatize the animals for observation and possible future capture
   ii. monitor non-invasively the menstrual cycles, interbirth intervals, etc.
   iii. possible future short term housing for males and medium term housing for females for possible collection & distribution of gametes

(Editor's comments: The results of the Modelling exercise were not complete at the end of the Workshop. Following the Workshop a very large amount of modelling was done by Sanjay Molur as part of a Training Course at Chicago and afterward. These results were not available to the Working Groups at the LTM PHVA Also, since the PHVA, the Central Zoo Authority has undertaken a collaborative project with the Centre for Cellular and Molecular Biology to address a number of conservation problems of endangered species of Indian wildlife with bio-technological methods.)

8. While the Working Group has taken a somewhat conservative view with regard to Assisted Reproduction, considering the implications of the computer modelling exercise with respect to inbreeding of LTM, the need for supplementation of populations with 1.2 adults, the need for additional adult female LTMs, and the vulnerability of the species in general, it may be considered a recommendation of this PHVA Workshop that techniques in Assisted Reproduction nonetheless be developed as a contingency against future requirement. As the Central Zoo Authority has taken a project with the Centre for Cellular and Molecular Biology, it is suggested that a project to develop Assisted Reproduction in LTM be undertaken using first more common surrogates on priority basis.

Priorities for Assisted Reproduction

Basic assessment of the problems animals with existing technology

Males — i. physical examination;
ii. hormonal assessment;
iii. multiple electroejaculation

Females ~ i. sex skin breakdown;
ii. urine and serum hormone assessment;
iii. physical exam with rectal palpation

Advanced techniques available

Males: Semen collection — Freezing and Artificial Insemination

Females: Artificial Insemination — Embryo Flushing, Embryo Freezing, possible *In vitro* Fertilization

Necessities

1 .Viable offspring from frozen sperm
2. Repeatable stimulation

CAPTIVE HUSBANDRY REPORT AND GLOBAL ANIMAL SURVIVAL PLAN

The Captive Husbandry Working Group reviewed the status and management of Lion-tailed macaque in captivity in Indian zoos, using information and articles supplied in the Briefing Book as well as personal experience of long-term zoo personnel. It was noted that in the absence of a systematic plan for breeding, many zoos had overbred and inbred their animals while others had been stuck with just one animal or with more than one of a single sex, or with a non-breeding group for some years. However, a national meeting of Species Coordinators' was held under the auspices of the Central Zoo Authority immediately preceeding the PHVA and eight zoos were identified as breeding centres for Lion-tailed Macaque. The Species Coordinator with the help of CZA will now make a plan for existing animals in Indian collections.

The following eight zoos were identified as Breeding Centres for the country

a. Arignar Anna Zoological Park, Madras
b. Nehru Zoological Park, Hyderabad
c. Trivandrum Zoological Gardens, Trivandrum
d. M. C. Chhatbir Zoo, Chandigarh
e. National Zoological Park, New Delhi
f Allen Forest Zoo, Kanpur
g Chamarajendra Zoological Gardens, Mysore
h. Nandankanan Biological Park, Bhubaneswar

These Centres are to maintain and breed the animals to be kept for conservation purpose, therefore attention to genetic and demographic factors is essential. The origin or lineage and age of each animal in the 24 zoos in India (39:42:1) will be ascertained and a national plan made before any animal is shifted to the Breeding Centres.

It was also observed that the standard of enclosure design, diet, medical care, etc. varied quite a lot between zoos, but it was felt that the formation of Central Zoo Authority and the Recognition of Zoo Rules would go a long way in directing the zoos towards better management.

Recommendations:

1. All breeding programmes are to be conducted under the recommendations of an elected Regional Species Co-ordinator who will be responsible for liaisoning with the International Studbook Keeper.

2. In order that conservation goals be achieved, each animal is to be individually marked by a tattoo or transponder and each animal is to have an individual record card and veterinary history. A copy of this should accompany any animal being translocated.

3. Specimens not fit for breeding may not be retained or transferred to Breeding Centres. Every effort should be made to avoid inbreeding and overbreeding.

4. These eight Breeding Centres shall manage animals according to the National Coordinated Breeding Programme and cooperate with international efforts.

5. Male migration should occur on the recommendation of Regional Species Co-ordinator.

6. Understanding that in the wild the LTM is a predominantly arboreal species, zoological collections should endeavour to manage their LTMs realising the species' natural behaviors and requirements. Group size should be dictated by enclosure design and availability of space. A minimum group size should be 1:2 animals of breeding age. Enclosure design must allow for the natural expansion of group.

7. The diet should ensure that all animals receive optimal nutritional requirements. It was noted that in the wild 37.3% of the diet consists of vertebrates and invertebrates.

8. All animals should be subjected to regular veterinary screening, and personnel handling the animals should be medically checked.

9. Enclosures should take into account the animal's need for privacy and night quarters must allow sufficient space for the numbers of animals within the group. If it is a large group, space requirements will be considerable if the animals are locked in.

10. Environmental enrichment should be regarded as a necessary measure to encourage natural behavioral pattern.

11. Personnel connected with breeding of LTMs at Breeding Centers should be exposed to modern methods of husbandry and breeding. People (keepers) directly managing this species should be properly trained and their knowledge put to better use.

12. Hand rearing should not be encouraged but fostering may in some cases be an option.

13. Regular exchange of information and knowledge between the facilities holding the species should be done.

Global Animal Survival Plan (G.A.S.P.)

Another objective of the P. H. V. A was to create a Global Animal Survival Plan for management of all LTMs in zoos around the world as a single viable population.

1. To develop a long-term captive plan for LTMs which will provide assistance for the survival of the species as a free-ranging population.

2. Provide assistance to LTM conservation by:

a. developing and maintaining a captive propagation program which will provide a reserve with sustainable genetic and demographic viability for possible future revitalisation of the wild population if the need and opportunity occurs,

b. conducting research that will contribute to the management of LTMs both in captivity and in the wild; collaboration should be established where appropriate with field researchers with the results being communicated to the species managers

Objectives:

Global Captive Propagation Programmme

1. Establish minimum target population goals for global captive population sufficient to provide for a maximum of genetic diversity for a minimum of 100 years

2. Assign responsibility for a portion of the minimum target population to each of the various regional management programs according to the collective resources and space

3. Distribute founder representation throughout the regional programmes to provide maximum genetic viability within all regions,

4. Establish genome resource banks for LTMs which should be within the range state. These banking programs will include the collection, storage, use, exchange and research into the use of genetic material from founders and selected captive and/or wild individuals.

5. Form a LTM GASP committee consisting of a. Regional Coordinators; b. International and Regional Studbook Keepers; c. Addl. I.G., Wildlife, Ministry of Environment and Forests, Government of India

6. Compile and distribute a husbandry manual to all institutions holding LTMs, emphasizing the maintenance of behavioral, social, genetic and demographic stability.

7. Develop an educational programme involving the general populace emphasising the benefit to be derived from the preservation of this species and its habitat

8. Develop and implement a Master Plan to achieve the goals, objectives of the LTM G A. S.P. ***In situ***

Programs:

1. Collaborate with PHVA Workshops in institutiing resulting recommendations.

2. Promote and encourage additional field research especially in the fields of behavior, repro duction, and ecology.

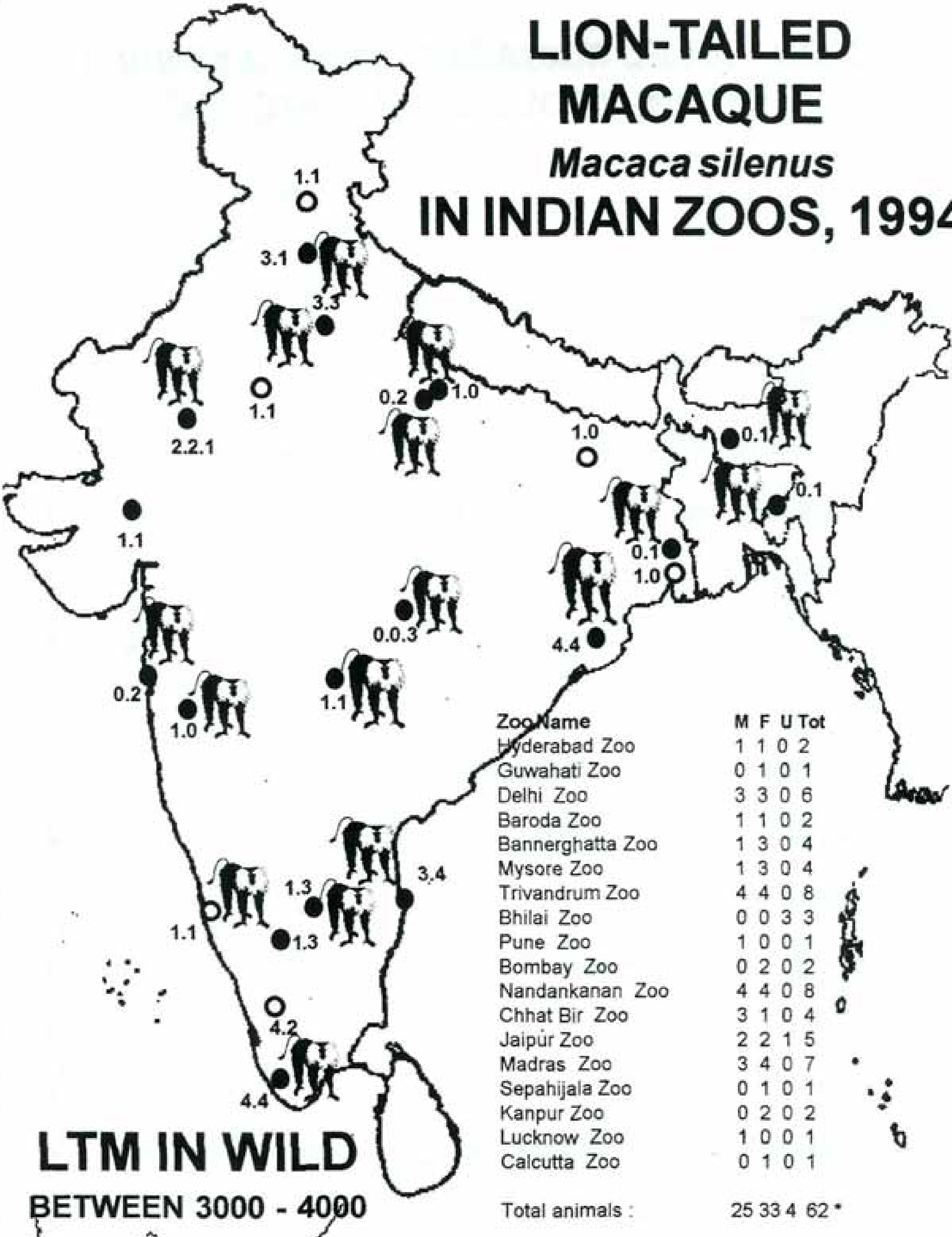
3. Promote additional *ex situ* programs which will provide support for *in situ* programs.

4. Assist in locating and providing financial assistance to carry out recommended programs.

LION-TAILED MACAQUE

Macaca silenus

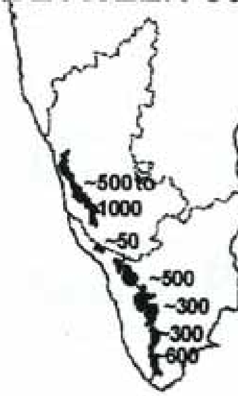
IN INDIAN ZOOS, 1994



Zoo Name	M	F	U	Tot
Hyderabad Zoo	1	1	0	2
Guwahati Zoo	0	1	0	1
Delhi Zoo	3	3	0	6
Baroda Zoo	1	1	0	2
Bannerghatta Zoo	1	3	0	4
Mysore Zoo	1	3	0	4
Trivandrum Zoo	4	4	0	8
Bhilai Zoo	0	0	3	3
Pune Zoo	1	0	0	1
Bombay Zoo	0	2	0	2
Nandankanan Zoo	4	4	0	8
Chhat Bir Zoo	3	1	0	4
Jaipur Zoo	2	2	1	5
Madras Zoo	3	4	0	7
Sepahijala Zoo	0	1	0	1
Kanpur Zoo	0	2	0	2
Lucknow Zoo	1	0	0	1
Calcutta Zoo	0	1	0	1
Total animals :	25	33	4	62 *
Tricur Zoo	4	2	0	6
Simla Zoo	1	1	0	2
Patna Zoo	1	0	0	1
M'ble Palace Zoo	1	0	0	1
Jodhpur Zoo	1	1	0	2
Mangalore Zoo	1	1	0	2 **

LTM IN WILD

BETWEEN 3000 - 4000



HOW MANY ARE ENOUGH?

* Courtesy of CZA List of 1994

** Additional institutions from Arignar Anna Zoo Census in 1993

LION-TAILED MACAQUE *(Macaca silenus)* IN INDIAN ZOOLOGICAL GARDENS *

	M	F	U	T
Nehru Zoological Park, Hyderabad, AP	1	1	0	2
Assam State Zoo, Guwahati, AS	0	1	0	1
National Zoological Park, DL	3	3	0	6
Sayaji Baug Zoo, Baroda, GJ	1	1	0	2
Bannerghatta National Park, Bangalore, KA	1	3	0	4
Sri Chamarejendra Zool. Garden, Mysore, KA	1	3	0	4
Thiruvananthapuram Zoo, Trivandrum, KL	4	4	0	8
Maitri Baag Zoo, Bhilai, MP	0	0	3	3
Peshwe Park Zoological Garden, Pune, MH	1	0	0	1
Veermata Jijabai Bhosle Udyan Zoo, Byculla, MH	0	2	0	2
Nandankanan Biol. Park, Bhubaneshwar, OR	4	4	0	8
M. C. Zoological Park, Chhat Bir, PN	3	1	0	4
Jaipur Zoo, Jaipur, RJ	2	2	1	5
Arignar Anna Zoological Park, Vandalur, TN	3	4	0	7
Sepahijala Zoological Park, Sepahijala, TR	0	1	0	1
KanpurZoological Park, Kanpur, UP	0	2	0	2
Prince of Wales Zool. Gardens, Lucknow, UP	1	0	0	1
Zoological Garden, Calcutta, WB	0	1	0	1
Total zoos: 18 Total animals :	25	33	4	62

* Information courtesy of the Central Zoo Authority

EDUCATION

The students of M. Sc. programme in Wildlife Biology of the A. V. C. College in Tamil Nadu made up the Education Working Group which was facilitated by Sri Kumaragurubaran and Ms. Jackie Ogden. The mandate given to the Education Working Group was to try and create innovative, practicable ideas that could immediately be put to use. They have included some practical methods for immediate implementation as well as their recommendations. This Working Group also did some practical projects, such as designing posters and slogans which could be utilised in the education programmes which should come about for this species.

The great weakness of many failed conservation programmes has been the lack of interaction with the local people who live in or near wild animal habitats. It has been demonstrated over and over that the indigenous people cannot be taken for granted. At the same time, particularly in India, there is a natural inclination among the people to protect all life and to take pride in the indigenous wild animals.

The LTM is a species which will surely not survive without the interest and support of the local human population. The LTM habitat and population surveys along with education programmes will support and focus the development of economic programmes for local people to compensate them for any loss of forest use as well as to clarify areas in nature needing protection.

A beginning has been made to provide educational materials for people in the local area since the PHVA. A sticker-brochure has been printed in all the three languages of Tamil Nadu, Karnataka and Kerala and distributed to zoos holding the species, NGO's working with local people, and forest departments. (See end of this section for example.)

Also a wallet calendar was made by British Airways Assisting Conservation which was used by BA agents all over the world as compliments for the year 1995. More than 1000 of these were distributed to zoos, policy makers and forest officers as a reminder to conserve LTM.

Recommendations

1. The Education Working Group recognizes that both formal and informal education are critical to the successful conservation of suitable habitat for the LTM. We recommend establishing the LTM as a flagship species for the conservation of the entire region of the Western Ghats.

2. NGOs and clubs need to be involved, and campaigns must be aimed at local people surrounding national parks and forests where LTMs are found, with forestry and local people cooperating to further the conservation of this species. They should create a link between the forestry establishment and the local people.

3. The difficulties of governmental agencies working with village and tribal people were recognized. NGOs can be utilised as communicators and facilitators to institute social welfare programmes, establish good faith and gain the confidence of these local people.

4. LTM "subcommittees" or special interest groups should be established in existing nature foundations and groups. This method could be used to promote cooperative education and information exchange and ecotourism between the three states where LTMs are found.

5. The name of the species should be used wherever possible. For example, roads into national parks and reserves could be named as "LTM road".

6. Whenever possible, local people should be provided with opportunities for employment that supports the conservation of LTMs so that they will feel a sense of ownership in its conservation

7. "Targeting" audiences for education and awareness about LTM is essential - e.g., landowners and developers, consumers of LTM products as well as the general public.

8. Funding may be obtained through government education department; Ministry of Environment and Forests, GOI, municipalities; industries; interested parties; ecodevelopment funds; landowners and developers in LTM habitat areas.

9. The Group recommends the organization of a conference on conservation education in southern India.

Some practical methods for immediate implementation

1. The use of endangered species' pictures on the covers of textbooks and other books

2. Establish prizes and scholarships for individuals involved in grassroots conservation, one for students, one for adults — both laymen and professional.

3. The name of the species should be used whenever possible. For example, roads into national parks and reserves could be named "Lion-tailed macaque Road".

4. The possibility of developing ecotourism focusing on LTMs should be investigated, bearing in mind the potential danger of disturbance.

5. As the NGO's and NGPs belonging to the surrounding area know the local people very well, they should be encouraged to work individually with them using appropriate events.

6. Official national and state and international "days" or "weeks" should be fully exploited for purpose of education on LTM, e.g. Wildlife Week, World Forestry Day, World Environment Day, etc.

7. Social welfare programmes (medical camp, adult education programme) may be utilised to gain the confidence of local people and establish good faith.

8. Employment opportunities supporting conservation of LTM for local people should be created — such as guides in tourist areas — so that they can participate and have ownership in the conservation of this flagship species.

9. Create a slogan and logo on LTMs to be used in all education/information.

10. Production of a nature programme featuring the LTM and its rainforest habitat for regular television viewing both in India and abroad, in schools, etc.

11. Production of greeting cards, wedding cards, and calendars with the picture of LTM.

12. Placing big boards / advertisements in important places, gateways, sports stadia, entertainment places.

13. Creative advertisments should be placed on public TV, radio, newspapers, and films. These advertisments should be in English as well as local languages.

14. Encourage the naming of new consumer products, or new varieties of products, such as seeds, to be called "LTM ______."

15. Work with zoos in the three states to establish interpretation focusing on LTMs

16. Take native children to see LTMs in the wild.

LION-TAILED MACAQUE *Macaca silenus*
POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

February 1995
Coimbatore, India

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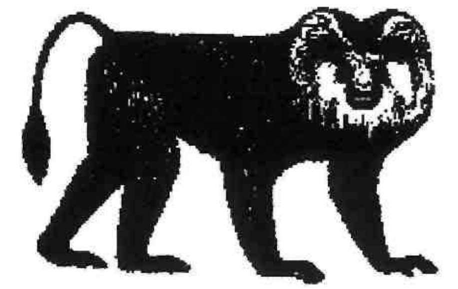

LION-TAILED MACAQUE
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LION-TAILED MACAQUE *Macaca silenus*
POPULATION AND HABITAT VIABILITY ASSESSMENT WORKSHOP

REPORT

February 1995
Coimbatore, India

Section V

Reference Material

Captive Breeding Specialist Group

Species Survival Commission
IUCN – The World Conservation Union
U. S. Seal, CBSG Chairman

POPULATION and HABITAT VIABILITY ANALYSIS WORKSHOPS

Objectives and Process

The PHVA workshop provides population viability assessments for each population of a species or subspecies as decided in arranging the workshop. The assessment for each species will undertake an in depth analysis of information on the life history, population dynamics, ecology, and population history of the individual populations. Information on the demography, genetics, and environmental factors pertinent to assessing the status of each population and its risk of extinction under current management scenarios and perceived threats will be assembled in preparation for the PHVA and for the individual populations before and during the workshop.

An important feature of the workshops is the elicitation of information from the experts that is not readily available in published form yet which may of decisive importance in understanding the behavior of the species in the wild. This information will provide the basis for constructing simulation models of each population which will in a single model evaluate the deterministic and stochastic effects and interactions of genetic, demographic, environmental, and catastrophic factors on the population dynamics and extinction risks. The process of formulating information to put into the models requires that assumptions and the data available to support the assumptions be made explicit. This process tends lead to consensus building on the biology of the species, as currently known, and usually leads to a basic simulation model for the species that can serve as for continuing discussion of management alternatives and adaptive management of the species or population as new information is obtained. It in effect provides a means for conducting management programs as scientific exercises with continuing evaluation of new information in a sufficiently timely manner to be of benefit to adjusting management practices.

These workshop exercises are able assist the formulation of management scenarios for the respective species and evaluate their possible effects on reducing the risks of extinction. It is also possible through sensitivity analyses to search for factors whose manipulation may have the greatest effect on the survival and growth of the population(s). One can in effect rapidly explore a wide range of values for the parameters in the model(s) to gain a picture of how the species might respond to changes in management. This approach may also be used to assist in evaluating the information contribution of proposed and ongoing research studies to the conservation management of the species.

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PHVA Workshop Preparation

Information and Expertise

Short reviews and summaries of new information on topics of importance for conservation management and recovery of the individual populations are also prepared during the workshop. Of particular interest are topics addressing:

(1) factors likely to have operated in the decline of the species or its failure to recover with management and whether they are still important,

(2) the need for molecular taxonomic, genetic heterozygosity, site specific adaptations, and the effects of seed banks on the rate of loss of heterozygosity,

(3) the role of disease, predation, and competition in the dynamics of the wild population, in potential reintroductions or translocations, and in the location and management of captive populations,

(4) the possible role of inbreeding in the dynamics and management of the captive and wild population(s),

(5) the potential uses of reproductive technology for the conservation of the species whether through genome banking or transfer of genetic material between subpopulations,

(6) techniques for monitoring the status of the population during the management manipulations to allow their evaluation and modification as new information is developed,

(7) the possible need for metapopulation management for long term survival of the species,

(8) formulation of quantitative genetic and demographic population goals for recovery of the species and what level of management will be needed to achieve and maintain those goals,

(9) cost estimates for each of the activities suggested for furthering conservation management of the species.

PHVA Workshop Preparation

Preparation and Documentation Needs

Information to be included in briefing book:

1. Bibliography - preferably complete as possible and either on disk or in clean copy that we can scan into a computer file.

2. Taxonomic description and most recent article(s) with information on systematic status including status as a species, possible subspecies, and any geographically isolated populations.

3. Molecular genetic articles and manuscripts including systematics, heterozygosity evaluation, parentage studies, and population structure.

4. Description of distribution with numbers (even crude estimates) with dates of information, maps (1:250,000 or better if needed) with latitude and longitude coordinates.

5. Protection status and protected areas with their population estimates. Location on maps. Description of present and projected threats and rates of change. For example, growth rate (demographic analysis) of local human populations and numerical estimates their use of resources (development plans) from the habitat.

6. Field studies - both published and unpublished agency and organization reports (with dates of the field work). Habitat requirements, habitat status, projected changes in habitat. Information on reproduction, mortality (from all causes), census, and distribution particularly valuable. Is the species subject to controlled or uncontrolled exploitation? Collecting?

7. Life history information - particularly that useful for the modelling. Includes: size - stage information, stage transitions, age of first reproduction, mean seed production and germination rates, occurrence and survival of seed banks, life expectancy, stage mortalities, adult mortality, dispersal, and seasonality of reproduction.

8. Published or draft Recovery Plans (National or regional) for the wild population(s). Special studies on habitat, reasons for decline, environmental fluctuations that affect reproduction and mortality, and possible catastrophic events.

9. Management masterplans for the captive population and any genome ban

10. Color pictures (slides okay) of species in wild - suitable for use as cover of briefing book and final PVA document.

PHVA Workshop Preparation

Plans for the Meeting:

1. Dates and location. Who will organize the meeting place and take care of local arrangements? Should provide living quarters and food for the 3 days in a location that minimizes outside distractions. Plan for meeting **and** working rooms to be available for the evening as well as the day. Three full days and evenings are needed for the workshop with arrival the day before and departure on the 4th day.

2. Average number of participants about 30 usually with a core group of about 15 responsible for making presentations. Observers (up to 20) welcome if facilities available but their arrangements should be their own responsibility. Essential that all with an interest in the species be informed of the meeting. Participants to include: (1) all of the biologists with information on the species in the wild should be invited and expected to present their data, (2) policy level managers in the agencies with management responsibility, (3) NGOs that have participated in conservation efforts, (4) education and PR people for local programs, (5) botanical garden or herbarium biologists with knowledge of the species, (6) experts in plant population biology and needed areas of biological expertise and (7) local scientists with an interest in the species.

3. Preparation of briefing document.

4. Funding (cost analysis available) - primarily for travel and per diem during the meeting, preparation of briefing document and the PVA report, and some personnel costs. CBSG costs are for preparation of the documents, completion of the modelling and report after the meeting, travel of 3-4 people, and their per diem. We estimate that each PHVA Workshop costs CBSG $10,000 to $15,000 depending upon the amount of work required in preparation and after the workshop to complete the report

5. Preparation of agenda and securing of commitments to participate, supply information, and make presentations needs to have one person responsible and to keep in close contact with CBSG office on preparations.

6. Meeting facilities need to include meeting room for group, break away areas, blackboard, slide projector, overhead projector, electrical outlets for 3+ computers, printer (parallel port IBM compatible), and photocopying to produce about 200-500 copies per day. Have food brought in for lunches. Allow for working groups to meet at night.

SSC MISSION

To preserve biological diversity by developing and executing programs to save, restore and, wisely manage species and their habitats.

PHVA WORKSHOPS

Guidelines

Every idea or plan or belief about the Species can be examined and discussed

Everyone participates & no one dominates

Set aside (temporarily) all special agendas except saving the Species

Assume good intent

Yes and ...

Stick to our schedule ... begin and end promptly

Primary work will be conducted in sub-groups

Facilitator can call 'timeout'

Agreements on recommendations by consensus

Plan to complete and review draft report by end of meeting

Adjust our process and schedule as needed to achieve our goals

POPULATION AND HABITAT VIABILTY ASSESSMENT

_ CBSG/SSC/IUCN thanks the 'Host Agency' for the invitation to participate in this Workshop on the conservation of the 'SPECIES'.

- SSC MISSION: To preserve biological diversity by developing and executing programs to save, restore and wisely manage species and their habitats.

- Captive Breeding Specialist Group (CBSG) works as a part of the IUCN Species Survival Commission (SSC) to assist rescue of species.

- CBSG has conducted **Population and Habitat Viability Assessment** (PHVA) workshops for >50 species in 22 countries at the request of host countries.

- **Values of the Workshops** are in:

    * bringing "together all groups responsible for the saving and management of the species to build a consensus on actions needed for the recovery of the species;

    * bringing together experts whose knowledge may assist rescue of the species;

    * assembling current information on status of the species and the threats to its survival;

    * providing an objective assessment of the risk of extinction of the species based upon current information;

    * using simulation models to test alternative management actions for rescue of the species and its recovery;

    * producing an objective report which can be used as a basis for the policy and implementation actions that are needed to save the species.

- These Workshops have helped chart a course for saving of many species; we hope that this Workshop will be a help to our colleagues in their work to save the 'Species'.

PHVA DATA NEEDS

MAP OF POPULATION(S) DISTRIBUTION AND FRAGMENTATION

CENSUS AND CHANGES DURING PAST 10-50 YEARS

AVERAGE AGE OF FIRST REPRODUCTION (FEMALE & MALE)

OLDEST AGE (SENESCENCE)

MONOGAMOUS OR POLYGYNOUS

INBREEDING

CATASTROPHES & THREATS

ALL MALES IN BREEDING POOL?

MAXIMUM YOUNG PRODUCED PER YEAR

PROPORTION OF ADULT FEMALES REPRODUCING PER YEAR

PROPORTION OF YOUNG (LITTER/CLUTCH SIZES)

MORTALITY: 0 - 1
JUVENILES
ADULT

FREQUENCY & SEVERITY OF CATASTROPHES

STARTING POPULATION SIZE (AGE DISTRIBUTION IF KNOWN)

CARRYING CAPACITY AND PROJECTED CHANGES

HARVESTS

SUPPLEMENTATION

ANNUAL RATES AND STANDARD DEVIATIONS IF POSSIBLE

VORTEX

Simulation model of stochastic population change

Written by Robert Lacy
Chicago Zoological Park
Brookfield, IL 60513

Version 5.1, 13 April 1991

Stochastic simulation of population extinction

Life table analyses yield average long-term projections of population growth (or decline), but do not reveal the fluctuations in population size that would result from variability in demographic processes. When a population is small and isolated from other populations of conspecifics, these random fluctuations can lead to extinction even of populations that have, on average, positive population growth. The VORTEX program (earlier versions called SIMPOP and VORTICES) is a Monte Carlo simulation of demographic events in the history of a population. Some of the algorithms in VORTEX were taken from a simulation program, SPGPC, written in BASIC by James Grier of North Dakota State University (Grier 1980a, 1980b, Grier and Barclay 1988). Fluctuations in population size can result from any or all of several levels of stochastic (random) effects. Demographic variation results from the probabilistic nature of birth and death processes. Thus, even if the probability of an animal reproducing or dying is always constant, we expect that the actual proportion reproducing or dying within any time interval to vary according to a binomial distribution with mean equal to the probability of the event (p) and variance given by $Vp = p * (1 - p) / N$. Demographic variation is thus intrinsic to the population and occurs in the simulation because birth and death events are determined by a random process (with appropriate probabilities).

Environmental variation (EV) is the variation in the probabilities of reproduction and mortality that occur because of changes in the environment on an annual basis (or other timescales). Thus, EV impacts all individuals in the population simultaneously — changing the probabilities (means of the above binomial distributions) of birth and death. The sources of EV are thus extrinsic to the population itself, due to weather, predator and prey populations, parasite loads, etc.

VORTEX models population processes as discrete, sequential events, with probabilistic outcomes determined by a pseudo-random number generator. VORTEX simulates birth and death processes and the transmission of genes through the generations by generating random numbers to determine whether each animal lives or dies, whether each adult female produces broods of size 0, or 1, or 2, or 3, or 4, or 5 during each year, and which of the two alleles at a genetic locus are transmitted from each parent to each offspring. Mortality and reproduction probabilities are sex-specific. Fecundity is assumed to be independent of age (after an animal reaches reproductive age). Mortality rates are specified for each pre-reproductive age class and for reproductive-age animals. The mating system can be specified to be either monogamous or polygynous. In either case, the user can specify that only a subset of the adult male population is in the breeding pool (the remainder being excluded perhaps by social factors). Those males in the breeding pool all have equal probability of siring offspring.

Each simulation is started with a specified number of males and females of each pre-reproductive age class, and a specified number of male and females of breeding age. Each animal in the initial population is assigned two unique alleles at some hypothetical genetic locus, and the user specifies the severity of inbreeding depression (expressed in the model as a loss of viability in inbred animals). The computer program simulates and tracks the fate of each population, and outputs summary statistics on the probability of population extinction over specified time intervals, the mean time to extinction of those simulated populations that went extinct, the mean size of populations not yet extinct, and the levels of genetic variation remaining in any extant populations.

Extinction of a population (or meta-population) is defined in VORTEX as the absence of either sex. (In some earlier versions of VORTEX, extinction was defined as the absence of both sexes.) Recolonization occurs when a formerly extinct population once again has both sexes. Thus, a population would go "extinct" if all females died, and would be recolonized if a female subsequently migrated into that population of males. Populations lacking both sexes are not considered to be recolonized until at least one male and at least one female have moved in.

A population carrying capacity is imposed by a probabilistic truncation of each age class if the population size after breeding exceeds the specified carrying capacity. The program allows the user to model trends in the carrying capacity, as linear increases or decreases across a specified numbers of years.

The user also has the option of modelling density dependence in reproductive rates. I.e., one can simulate a population that responds to low density with increased (or decreased) breeding, or that decreases breeding as the population approaches the carrying capacity of the habitat. To model density-dependent reproduction, the user must enter the parameters (A, B, C, D, and E) of the following polynomial equation describing the proportion of adult females breeding as a function of population size:

Proportion breeding = A + BN + CNN + DNNN + ENNNN,

in which N is total population size. Note that the parameter A is the proportion of adult females breeding at minimal population sizes. A positive value for B will cause increasing reproduction with increasing population sizes at the low end of the range. Parameters C, D, and E dominate the shape of the density dependence function at increasingly higher population sizes. Any of the values can be set to zero (e.g., to model density dependence as a quadratic equation, set D = E = 0). To determine the appropriate values for A through E, a user would estimate the parameters that provide the best fit of the polynomial function to an observed (or hypothetical) data set Most good statistical packages have the capability of doing this. Although the polynomial equation above may not match a desired density dependence function (e.g., Logistic, Beverton-Holt, or Ricker functions), almost any density dependence function can be closely approximated by a 4th-order polynomial. After specifying the proportion of adult females breeding, in the form of the polynomial, the user is prompted to input the percent of successfully breeding females that produce litter sizes of 1, 2, etc. It is important to note that with density dependence, percents of females producing each size litter are expressed as percents of those females breeding, and the user does not explicitly enter a percent of females producing no offspring in an average year.   (That value is given by the polynomial.)

In the absence of density dependence, the user must specify the percent of females failing to breed, and the percents producing each litter size are percents of all breeding age females (as in earlier versions of VORTEX). Read the prompts on the screen carefully as you enter data, and the distinction should become clear.   VORTEX models environmental variation simplistically (that is both the advantage and disadvantage of simulation modelling), by selecting at the beginning of each year the population age-specific birth rates, age-specific death rates, and carrying capacity from distributions with means and standard deviations specified by the user. EV in birth and death rates is simulated by sampling binomial distributions, with the standard deviations specifying the annual fluctuations in probabilities of reproduction and mortality. EV in carrying capacity is modelled by sampling a normal distribution.   EV in reproduction and EV in mortality can be specified to be acting independently or jointly (correlated in so far as is possible for discrete binomial distributions).

Unfortunately, rarely do we have sufficient field data to estimate the fluctuations in birth and death rates, and in carrying capacity, for a wild population.   (The population would have to be monitored for long enough to separate, statistically, sampling error, demographic variation in the number of breeders and deaths, and annual variation in the probabilities of these events.) Lacking any data on annual variation, a user can try various values, or simply set EV = 0 to model the fate of the population in the absence of any environmental variation.

VORTEX can model catastrophes, the extreme of environmental variation, as events that occur with some specified probability and reduce survival and reproduction for one year. A catastrophe is determined to occur if a randomly generated number between 0 and 1 is less than the probability of occurrence (i.e., a binomial process is simulated). If a catastrophe occurs, the probability of breeding is multiplied by a severity factor specified by the user. Similarly, the probability of surviving each age class is multiplied by a severity factor specified by the user.

VORTEX also allows the user to supplement or harvest the population for any number of years in each simulation. The numbers of immigrants and removals are specified by age and sex. VORTEX outputs the observed rate of population growth (mean of N[t]/N[t-l]) separately for the years of supplementation/harvest and for the years without such management, and allows for reporting of extinction probabilities and population sizes at whatever time interval is desired (e.g., summary statistics can be output at 5-year intervals in a 100-year simulation).

VORTEX can track multiple sub-populations, with user-specified migration among the units. (This version of the program has previously been called VORTICES.) The migration rates are entered for each pair of sub-populations as the proportion of animals in a sub-population that migrate to another sub- population (equivalently, the probability that an animal in one migrates to the other) each year. VORTEX outputs summary statistics on each subpopulation, and also on the meta-population. Because of migration (and, possibly, supplementation), there is the potential for population recolonization after local extinction. VORTEX tracks the time to first extinction, the time to recolonization, and the time to re-extinction.

Overall, VORTEX simulates many of the complex levels of stochasticity that can affect a population. Because it is a detailed model of population dynamics, it is not practical to examine all possible factors and all interactions that may affect a population, It is therefore incumbent upon the user to specify those parameters that can be estimated reasonably, to leave out of the model those that are believed not to have a substantial impact on the population of interest, and to explore a range of possible values for parameters that are potentially important but very imprecisely known. VORTEX is, however, a simplified model of the dynamics of populations. One of its artificialities is the lack of density dependence of death rates except when the population exceeds the carrying capacity. Another is that inbreeding depression is modelled as an effect on juvenile mortality only; inbreeding is optimistically assumed not to effect adult survival or reproduction.

VORTEX accepts input either from the keyboard or from a data file. Whenever VORTEX is run with keyboard entry of data, it creates a file called VORTEX.BAT that contains the input data, ready for resubmission as a batch file. Thus, the simulation can be instantly rerun by using VORTEX.BAT as the input file. By editing VORTEX.BAT, a few changes could easily be made to the input parameters before rerunning VORTEX. Note that the file VORTEX.BAT is over-written each time that VORTEX is run. Therefore, you should rename the batch file if you wish to save it for later use. By using data file input, multiple simulations can be run while the computer is unattended. (Depending on the computer used, the simulations can be relatively quick -- a few minutes for 100 runs — or very slow.) Output can be directed to the screen or to a file for later printing. I would recommend that VORTEX only be used on a 80386 (or faster) computer with a math co-processor. It should run on slower machines, but it might be hopelessly slow.

The program can make use of any extended memory available on the computer (note: only extended, not expanded, memory above 1MB will be used), and the extra memory will be necessary to run analyses with the Heterosis inbreeding depression option on populations of greater than about 450 animals. To use VORTEX with expanded memory, first run the program TUNE, which will customize the program EX286 (a Dos Extender) for your computer. If TUNE hangs up DOS, simply re-boot and run it again (as often as is necessary). This behavior of TUNE is normal and will not affect your computer. After TUNEing the Dos Extender, run EX286, and then finally run VORTEX. TUNE needs to be run only once on your computer, EX286 needs to be run (if VORTEX is to be used with extended memory) after each re-booting of the computer. Note that EX286 might take extended memory away from other programs (in fact it is better to disable any resident programs that use extended memory before running EX286); and it will release that memory only after a re-boot. If you have another extended memory manager on your system (e.g., HIMEM.SYS), you will have to disable it before using EX286.

VORTEX uses lots of files and lots of buffers. Therefore, you may need to modify the CONFIG.SYS file to include the lines

```
FILES=25
BUFFERS=25
```

in order to get the program to run.

VORTEX is not copy protected. Use it, distribute it, revise it, expand upon it. I would appreciate hearing of uses to which it is put, and of course I don't mind acknowledgement for my efforts. James Grier should also be acknowledged (for developing the program that was the base for VORTEX) any time that VORTEX is cited.

A final caution: VORTEX is continually under revision. I cannot guarantee that it has no bugs that could lead to erroneous results. It certainly does not model all aspects of population stochasticity, and some of its components are simply and crudely represented. It can be a very useful tool for exploring the effects of random variability on population persistence, but it should be used with due caution and an understanding of its limitations.

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ISSUE 1. MODELING

What Is A Model?

One method for understanding the factors affecting the population extinction process is to use population models. A model is a basic tool used to represent or describe, in a simplified and abstract form, a particular process of interest. In the case of the PHVA, modelling is a tool that mimics the processes by which populations propagate themselves from one year to the next.

Models can be very simple or extremely complex. Models may seem abstract, only academic, or even threatening. However, we make use of and encounter models in our normal day-to-day activities. Simple models that many of us encounter every day are symbols used in common signs. For example, the male/female diagrams on toilet doors are in fact simple models used to summarize and simplify important information. A more complicated day-to-day model is family financial planning. When we plan for financial savings or budgets, we: 1) define a financial objective; 2) collect data on our financial situation; 3) analyze the data under different scenarios using simplifying assumptions of real process; 4) evaluate different scenarios; and 5) make a decision. We may do all this in our minds, without the aid of a computer or calculator, but we nevertheless have preformed a modelling exercise to come to some conclusions. Population models are just an extension of this process of compilation and analysis of data using a simplified version of real processes. It is important to note that the purpose of the model is not intended to represent realistically and accurately all the processes involved, but to simplify the process sufficiently to gain a better understanding.

A very simple population model may look like this:

```
 -----------
 Population
 Size 1994
   = 100
 -----------
     |
     |
    \/
 + 10 Births
 + 3 Immigrants
 - 7 Deaths
 - 2 Emigrants
     |
     |
    \/
 -------------
 Population
 Size 1995
   = 104
 -------------
```

This simple process can be repeated year after year to give a basic idea of long term changes in population size. At a very basic level, all we need for a model of population projections are data on birth rates, mortality, immigration, and emigration. This very simple model may be sufficient for some purposes. However, more complex models that consider additional factors that affect population dynamics are more appropriate and useful for the PHVA process.

What Is A Simulation Model?

A stochastic population simulation model is a kind of model that attempts to incorporate the uncertainty, randomness or unpredictability of life-history and environmental events into the modeling process. Events whose occurrence is uncertain, unpredictable, and random are called stochastic. Most events in an animal's life have some level of uncertainty. For example, there usually is a 50/50 chance an individual is a male or female and a certain probability that individual will live through one year to the next, mate, reproduce, and produce an uncertain number of offspring. Although we cannot predict exactly what events an individual will experience during its life, we may have a general idea of the range of possibilities for these various events (e.g., on the average an individual may have a 90% chance of surviving from one year to the next, or that litter sizes vary from 1 to 4), but individuals vary within that range. Similarly, environmental factors, and their effect on the population process, are stochastic - they are not completely random, but their effects are predictable within certain limits.

Simulation solutions are usually needed for complex models including several stochastic parameters. A simulation model of an animal population mimics actual demographic and genetic events, such as deaths and births, in an explicit time dimension. Both time steps and individuals are usually simulated as discrete and finite. When stochasticity is included in a simulation model, each run may be a unique sequence of events, with different end results in all runs. So, to be able to present both a reliable expected average result, as well as an estimate of expected variations in the result, we need to run the simulation many times, often several thousand times..

Events that are stochastic need to be described in terms of both their average values (mean) and their variance, or standard deviation (a measure of the distribution which values can take around their mean). For example, if litter size ranges from 1 to 5, average of stochastic properties, both the average and variance need to be known.

The Vortex model incorporates factors with uncertain outcomes (stochastic factors) by randomly making a decision about what will happen within the limits as specified by the variance associated with that factor. For example, sex determination of a newborn is determined by the simple process of the computer "flipping a coin." Heads assigns one sex, tails the other. More complicated stochastic events, like the variation in survival rates associated with fluctuations in the environment (both the survival rates and the effect of environment have stochastic properties), are incorporated by the computer flipping multiple "biased" coins (those with probabilities for heads and tails are not 50/50). The coin flipping process is achieved by the computer using random number generators.

Because many of the processes in the population are stochastic, one run (simulation) of the model will result in a different outcome than a second run. One run is no more accurate than another - they simply reflect differences that might result from normal, expected variation in those stochastic factors that affect the population's dynamics. There are two levels of stochasticity incorporated throughout much of Vortex: reproduction and mortality are inherently stochastic (like a coin toss) and also the probabilities of reproduction and mortality vary over time (like a random selection of the coin to be tossed from a bag of variably biased coins). Thus the of stochastic processes modeled by VORTEX includes both individual survival and annual fluctuations in population survival rates (as distinct levels of stochasticity) and individual reproduction and variable reproductive rates. Also (in contrast to the above) dispersal but not dispersal rates (or probability) is stochastic in the VORTEX model. With respect to inbreeding, it is the individual mortality due to inbreeding that is stochastic (i.e., some inbred individuals live, others die, but all have a higher probability of mortality than do non-inbred individuals).

The same is true in real populations: two identical populations exposed to the same conditions will likely have different projections. That is the nature of stochastic effects. One of the purposes of running the stochastic model is to determine how much variation there might be around the average population projections. Therefore, multiple model simulations (perhaps as many as several hundred) are needed to show the range, or distribution, of possible outcomes that reflect the range of possible values affecting the population.

The processes in VORTEX that have stochastic, or random components are:

Sex determination
Individual survival
Survival rates or probability
Reproduction
Reproductive rates or probability
Number of offspring
Dispersal

Gene transmission
Inbreeding induced mortality
Mate selection
Occurrence of catastrophes
Mortality and loss of reproduction due to catastrophes

Why Model?

There are a host of reasons for why simulation modeling is valuable for the PHVA process. The primary advantage, of course, is to simulate scenarios and the impact of numerous variables on the potential of population extinction. Interestingly, not all advantages are related to generating useful management recommendations. The side-benefits are-substantial.

- Population modeling supports consensus and instills ownership and pride during the PHVA-process. As groups begin to appreciate the complexity of the problems, they have a tendency to take more ownership of the process and the ultimate recommendations to achieve solutions.

- Population modeling forces discussion on biological aspects and specification of assumptions, data, and goals. The lack of sufficient data of useable quality rapidly becomes apparent and identifies critical factors for further study (driving research), management, and monitoring. This not only influences assumptions, but also the group's goals.

- Population modeling generates credibility by using technology that non biologically oriented groups can use to relate to population biology and the "real" problems. The acceptance of the computer as a tool for performing repetitive tasks has led to a common ground for persons of diverse backgrounds.

- Population modeling explicitly incorporates what we know about dynamics by allowing the simultaneous examination of multiple factors and interactions - more than can be considered in analytical models. The ability to alter these parameters in a systematic fashion allows testing a multitude of scenarios that can guide adaptive management strategies.

- Population modeling can be a neutral computer "game" that focuses attention while providing persons of diverse agendas the opportunity to reach consensus on difficult issues.

- Population modeling outcome can be of political value for people in governmental agencies by providing support for perceived population trends and the need for action. It helps managers to justify resource allocation for a program to their superiors and budgetary agencies as well as identify areas for intensifying program efforts.

- The VORTEX model analyzes a population in a stochastic and probabilistic fashion. It also makes predictions that are testable in a scientific manner, lending more credibility to the process of using population modeling tools.

Why Use VORTEX (Rather Than Other Simulation Models)?

At the present time, our preferred model for use in the PHVA process is called VORTEX. This model, developed by Lacy et al., is designed specifically for use in the stochastic simulation of the small population/extinction process. It has been developed in collaboration and cooperation with the PHVA process. The model simulates deterministic forces as well as demographic, environmental, and genetic events in relation to their probabilities.

There are other commercial models, but presently they have some limitations such as failing to measure genetic effects, being difficult to use, or failing to model individuals. VORTEX has been successfully used in more than 70 PHVA workshops in guiding management decisions. VORTEX is general enough for use when dealing with a broad range of species, but specific enough to incorporate most of the important processes. VORTEX is in its sixth version and is continually evolving in conjunction with the PHVA process.

VORTEX has, as do all models, its limitations which may restrict its utility in some cases. If VORTEX is not considered appropriate, different models should be used. A "tool" kit of simulation models should be developed to enhance the overall process.

ISSUE 2. WHY UNDERTAKE SINGLE SPECIES CONSERVATION?

Management actions aimed at conserving Biodiversity take place at various levels of the biodiversity hierarchy, a nested hierarchy of spatially, taxonomically, and conceptually defined units with often ill-defined boundaries. Conservation problems are manifest at different levels of this hierarchy; for instance, a change in a flooding regime will require action at the ecosystem level, whereas a species-specific problem, (e.g. over harvesting or pathogens) will require action at the species level. Conservation activities focused on any one layer of the bio-spatial hierarchy must take into account linkages to other levels.

(1). The ECOSYSTEM and (2) COMMUNITIES are the most complex and least understood units of conservation management. It generally is acknowledged that extensive protected areas are an effective mechanism for retaining a large proportion of a region's biota. These approaches have been recommended as the foundation for effective conservation planning by the Biodiversity Convention and Agenda 21. The focus of management is ecological processes (e.g. nutrient flow, water systems, etc.) and composition (e.g., species).

(3). A SPECIES is a relatively discrete and readily recognizable unit of conservation management, and often the unit of national conservation legislation. The species is the traditional focus for the *ex situ* agencies (e.g., zoos and botanic gardens). The focus of management are the compositional elements of biodiversity: species and associated genetic diversity. Single species management can be undertaken both *in situ* and *ex situ,* taking into account the demographic and genetic status of the species.

The compositional elements of species are (4) POPULATIONS, (5) INDIVIDUALS, and (6) GENES, and they are increasingly becoming the focus of targeted management action. As populations of threatened species become increasingly isolated and fragmented, there is an increasing need to manipulate both demographic and genetic dynamics.

The majority of the world's species will be retained through the "coarse filter" approach of habitat conservation, which potentially could conserve all levels in the hierarchy. However, many protected areas will require management because of external influences impacting ecological processes and promoting the loss of species and changes in both community structure and composition. Protected area borders are permeable to disease, invasive species, poaching, civil unrest, and climate change. Accordingly, a "fine filter" approach is required to catch those species not secured through the priority action of habitat conservation.

Single species management for threatened species can take a variety of forms:

- Protection from invasive organisms and pathogens.
- Habitat modification and management (e.g., prescribed burning or provision of nest boxes).
- Reintroduction or translocation.
- Assisted reproduction.
- *Ex situ* breeding or propagation, either in-country or abroad.

Species as the compositional unit of a community or ecosystem are a convenient and discrete unit of management, particularly when that taxon is threatened and requires species-specific management. A PHVA provides focus on the species level of the hierarchy and provides a forum to bring all required expertise together to ensure a balanced integrated approach to species conservation. No one management body or mechanism will be sufficient to deal with the complexities of species conservation and the necessary links to other levels of biodiversity.

Protected areas have been established with the assumption that environmental conditions and community patterns/composition have been stable for long periods in the past and will continue to be stable into the future. There is increasing evidence that ecological communities are loosely organized collections of species whose coexistence depends on their individual limits and subsequent distribution along environmental gradients. On a geological scale, they could be viewed as relatively transient assemblages.

Species programs, dealing with single species issues, can be used effectively to promote habitat conservation. Species can be used as flagship (a symbol for conservation), or promoted as keystone (providing a key ecological function) and umbrella species (species requiring large areas of intact habitat) to help conserve of viable habitat reserves. *Ex situ* species displays, such as zoos and botanic gardens, can play a fundamental role in public education and fund raising. Species can provide a diagnostic tool for ecosystem monitoring. In some cases, the development of a single species program has lead subsequently to the development of habitat programs (Florida panther, red wolf, Costa Rican squirrel monkey, sangai, Sumatran rhino, golden lion tamarin).

However, poorly planned single species management can result in damaging changes in species abundance and can be interpreted as undermining the value of habitat conservation. For instance managing for dense concentrations of valued game or other high profile animals can profoundly degrade a habitat.

Single species management is sometimes accused of focusing on lost causes, however, an increasing number of species dismissed as facing inevitable extinction have survived through often intensive single species management. These include the Arabian oryx, Asiatic lion, Channel Island black robin, black-footed ferret, Mauritius kestrel, *Sophora toromiro* from Easter Island, and *Iliamna corei.*

There is a need to utilize the most efficient and most appropriate management responses to ensure species survival. The long term conservation of threatened species is dependent on the sustained collaboration between agencies responsible for habitat conservation and single species management, both *in situ* and *ex situ.*

ISSUE 3. INBREEDING DEPRESSION

A simple definition of inbreeding is the production of offspring by related Individuals. Inbred individuals have lower levels of heterozygosity, and correspondingly, higher levels of homozygosity.

Inbreeding depression is defined as the reduction of fitness (decreased survival, decreased fertility, less disease resistance, etc.) in inbred compared to non-inbred individuals.

There are two general categories in which observable changes of fitness can be correlated with measures of genetic variation:

A. Inbreeding coefficient (often designated as F value) known and correlated with fitness.

B. Heterozygosity has been measured and correlated with fitness.

There are two possible mechanisms for reduction in fitness when inbreeding increases and heterozygosity decreases:

A. Increased expression of specific recessive deleterious genes (i.e., genes that reduce survival or fertility) which are only expressed when homozygous;

B. the general loss of heterosis (i.e., the advantage of being heterozygous, which can occur even if there are no deleterious genes).

Which mechanism operates in a particular case of inbreeding depression is usually not known, However, the observed effect of inbreeding depression on fitness is what is relevant to assessment of risk to the population.

The smaller the population, the more likely potential mates will be related, resulting in inbreeding. Inbreeding may reduce survival and fertility which in turn, causes the population to become even smaller, increasing inbreeding even more. The result can be an extinction vortex.

There are numerous examples of inbreeding depression in domestic livestock, laboratory animals and zoo populations. There are no published cases of well studied vertebrate species that show a total lack of fitness depression when inbred. Inbreeding depression is less well documented in wild populations because of the difficulty in determining pedigrees for sufficiently long periods of time. However, examples include: Florida panther, Arabian or white oryx, Mississippi sandhill crane, golden lion tamarin, white tail deer, great tit, and lions isolated in the Ngorongoro Crater of Tanzania or the Gir Forest Sanctuary of India.

Although there is significant evidence of a detrimental effect of inbreeding depression, some small, known inbred populations survive. In general, about 95% of rapidly inbred laboratory mice lines go extinct and all efforts to produce inbred livestock lines have failed.

A common point is that populations (animal or plant) with a long history of inbreeding, small population size, or populations of island species do not necessarily suffer inbreeding depression. Theory suggests that inbred populations may be purged of deleterious genes and, therefore, will not show inbreeding depression when further inbred. Data to support this come primarily from highly inbred laboratory colonies of vertebrates and plants. However, this is not necessarily the case. There are a number of examples of populations that have been inbred, have a history of small population size, or have low levels of genetic diversity that still show inbreeding depression when further inbred. Inbreeding depression has occurred in the golden lion tamarin, cheetah, Przewalski's horse and Pere David's deer (all show low levels of genetic diversity). Furthermore, there have been several studies on species of plants that inbreed extensively in the wild (e.g., self-fertilize) but show inbreeding depression when further inbred.

One of the most profound examples of inbreeding in the wild is the Florida panther. The remaining 30-35 individuals show essentially no genetic variation using molecular technology and western pumas as controls. This monomorphic subspecies has documented male sterility, and males consistently produce more than 90% structurally abnormal sperm. In addition to 90% of the males being cryptorchid (one or both testes retained in the body cavity), both genders have a high incidence of cardiac defects and a high seroprevalence to infectious pathogens including feline infectious peritonitis, feline immunodeficiency virus, and rabies.

Another risk for small populations is loss of variation by genetic drift resulting in decreased adaptability to changing environments and increased risk of extinction. This effect is important for the long-term evolutionary viability of the population.

In general, management should avoid inbreeding when there are no other management conflicts. Situations in which management to minimize inbreeding depression should be considered include:

A. Establishment of new populations.

1. Selection of founders (non-related, short-term; adequate number and equalization representation, long-term).

2. Inadequate carrying capacity for a sufficiently large population to minimize genetic drift effects.

3. Growth rate of population so slow that it remains at low numbers over several generations resulting in rapid loss of genetic variation.

B. Management of existing small populations.

1. Population supplementation with unrelated stock, via translocation or from captivity.

2. Selective removal (harvest) of individuals from over-represented lineages (i.e., males that already have produced many offspring).

3. Habitat modification that will increase population size and decrease its variation (food supplementation, artificial nest-sites, etc.).

4. Optimal out-crossing (e.g. Peregrine falcon, Florida panther).

C. Management of metapopulations.

1. Gene flow through managed migration of individuals or their individuals.

The effect of inbreeding has considerable relevance to conservation. The numerous studies indicating inbreeding depression or correlating loss of fitness with decrease in heterozygosity suggest that there can be significant genetic risks associated with small population size. The risks of inbreeding must be weighed against other types of risks (demographic, catastrophic, etc.) The consequences of ignoring possible genetic risks may be severe. Managers must determine what level of risk they are willing to assume.

<u>Suggestions for facilitators</u>

Although it is difficult to assess level of knowledge of the audience, be prepared to elaborate on definitions of terms used in report and introductory lecture. Call upon population biologists for answers to difficult questions on population biology.

Commonly asked questions:

Q: "Inbreeding is not deleterious" or "It's not a problem for my species".
A: Refer to lecture and essays, reiterate level of risk and potential long-term effects from loss of heterozygosity. It may be helpful to use metaphors for risk: example: Some people have survived jumping without a parachute, but I wouldn't suggest it. Use the paper by Roelke et al. (inbreeding effects in the Florida panther) as an example.

Q: "Inbreeding is not a problem because I have adequate numbers in my population."
A: Look at effective number of individuals. What is the history of the population (i.e., unequal founder representation)? Is it known? The population may be structured in a way that inbreeding is a problem (i.e., subpopulation versus metapopulation size).

Q: If inbreeding is the only mating option, is there any point in continuing.
A: Even if inbreeding is inevitable, there are management actions to reduce risks (e.g. increasing population size as much and as fast as possible and equalizing founder representation). Because of the increased vulnerability of inbred populations, it may be necessary to reduce (even to unnaturally low levels) the threats and stresses placed on an inbred population, until such time that genetic variation is restored by immigration or mutation.

Slide Presentation/Lecture Content Suggestions for Inbreeding Discussion

(1) Include examples of inbreeding depression in wild: Florida panther, Arabian oryx, Mississippi sandhill crane, golden lion tamarin, white-tailed deer, great tit

(2) Include examples of small population that have survived with a discussion of what the insights they offer indicate about genetics risks of small population size. Pere David's deer, deer on grounds of presidential palace in Indonesia, whooping crane, and northern elephant seal. Many breeds of domestic dogs are moderately inbred. They survive when coddled, but show many genetic defects. Breeders out-cross them when these defects become life threatening.

(3) Stochasticity discussion: Development on luck of selection of initial individuals (i.e., some people have survived jumping without a parachute, but is isn't recommended). Discussion of responsibility for assuming risk.

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(4) Time scope of risks needs to be included. "All populations go extinct eventually." In the short term, only a few generations may be involved. No guarantees. Only a small % will survive. Will you accept the risk?

(5) Emphasize the fact that inbreeding depression is relevant to conservation. Relationship to extinction vortex. Inbreeding is not an alternative explanation for species decline, nor an independent threat, but rather a factor that interacts with demographic and environmental variation. Inbred populations have reduced demographic rates and experience greater susceptibility to demographic and environmental fluctuations.

(6) Include plant examples (particularly for outbreeding).

(7) Long term has two issues:
   (a) Whether you see inbreeding depression.
   (b) Whether loss of variability/adaptability causes extinction.

Issue 4. Lack Of Data

Information shortage is a theme that underlies the entire process and can and will arise at many points. This is both a valid concern, and also one approach to invalidate the entire process. Therefore, it is important to explicitly recognize this concern and continue to show the value of the totality of the information which is typically found and generated during the process.

The PHVA process assembles data uniquely and synergistically - the process of literature review, involvement of all identifiable expert and interested parties, group discussion of the analytical power of this aggregated information, contributions of unpublished data, field notes, etc., and administrator data combined with the audit like process of internal consistency checking validates information or helpfully detects problems. The entire review and modeling provide an objective assessment of the quality of data available from multiple sources. Data which are inadequate in isolation are often found critical and valuable when seen in the context of other data sets. Furthermore, the advance announcement and planning for the workshop stimulate the generation and assembly of additional information. At worst, information from analogous situations and taxa may be substituted for unavailable information and reviewed for its importance through sensitivity analysis.

This integrated and analytical review of data never before assembled, coming from many different sources, using knowledge of many individuals and groups on a common ground, has unique power to guide difficult management decisions. Much of the information which typically is mobilized has never before been available to managers in useful form. The process is a useful means to improve management to minimize extinction risk and minimize regrets while awaiting improved information.

The process generates priorities for information we most need to know, and may suggest that particular or sharper focus should be drawn to planned data collection and research, whereas other data collecting activities may be found less important and can be de-emphasized.

Thus far, on the basis of 75 exercises, there almost always has been enough information resulting from the entire process to provide better guidance to managers than existed before. If this is not the case, the process produces clear priorities for data collection so that they can be carried out systematically.

Because changes and disturbances to the habitat, human and otherwise, do not stop while we may delay analysis or action in pursuit of more information, the decision not to proceed must be recognized as a decision with considerable consequences of its own.