



The Lion-tailed Macaque *Macaca silenus* (Primates: Cercopithecidae): conservation history and status of a flagship species of the tropical rainforests of the Western Ghats, India

Mewa Singh¹, Werner Kaumanns², Mridula Singh³, H.S. Sushma⁴ & Sanjay Molur⁵

¹ Biopsychology Laboratory, University of Mysore, Manasagangotri, Mysuru, Karnataka 570006, India

² LTM-Research and Conservation, Eschenweg 5, 37130 Gleichen, Germany

³ Maharaja's College, University of Mysore, Mysuru, Karnataka 570005, India

⁴ c/o Karthik Vasudevan, Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand 248001, India

⁵ Zoo Outreach Organization, PB 1683, 9A, Lal Bahadur Colony, Peelamedu, Coimbatore, Tamil Nadu 641004, India

Email: ¹ mewasingh@bsnl.in

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Author Details: MEWA SINGH has been working on primates for three decades and has spent considerable time in the Annamalais studying LTMs. He is involved in primate behavior, and is currently studying the status of mammals in Karnataka.

WERNER KAUMANNNS has worked on LTMs in captivity for over two and a half decades. He is also interested in the management of LTMs in fragmented habitats.

MRIDULA SINGH worked on mode of parental investment patterns by the female LTMs, and is also interested in the behavior of LTMs.

H.S. SUSHMA did her Ph.D. work on sympatric LTM, Nilgiri Langur, Giant Squirrel and Bonnet Macaque. She is interested in the ecology and behavior of LTMs.

SANJAY MOLUR has been involved in conservation status assessments of fauna and flora in South Asia for over 12 years and is currently working on the status of small mammals of the Western Ghats.

Author Contributions: Mewa Singh and Werner Kaumanns have been working on the ex situ and in situ aspects of LTM conservation. Along with Mridula Singh and Sushma they developed the concept and worked on the initial draft of the manuscript, which was further worked on by Sanjay Molur.

Abstract: The Lion-tailed Macaque (*Macaca silenus*) is a threatened species inhabiting the rainforests of the Western Ghats mountain range in southern India. Once assessed to be less than a thousand individuals remaining in the wild habitats, the population is now estimated to be between 3000 and 3500 individuals. However, the rainforest habitats of the species are highly fragmented. During the past three decades or less, the population of this species has severely declined due to habitat degradation and illegal hunting in several areas of its occurrence. *In situ* conservation programs included notification of certain areas as Lion-tailed Macaque conservation regions. Several captive breeding programs have been initiated in order to have a viable captive population of the species. However, the analysis reveals that both *in situ* and *ex situ* conservation programs have not achieved the desired success and the species is even more endangered than it was a few decades ago. In this article, we discuss these conservation programs and suggest further measures for effective conservation of Lion-tailed Macaques.

Keywords: Lion-tailed Macaque, Western Ghats, conservation, captive breeding, illegal hunting, adaptive management

The Lion-tailed Macaque (LTM) (*Macaca silenus*) is endemic to the tropical rainforests of the Western Ghats mountain range in the three southern Indian states of Kerala, Tamil Nadu and Karnataka (Kumar 1987). It belongs to the most primitive *sylvanus-silenus* of the macaque lineages (Thierry et al. 2004). At present, the species ranges over about 20,000 km² but actually occupies an area less than 2,500 km² (Molur et al. 2003). For its endemism, low reproductive turnover (Singh et al. 2006) and small number in the wild habitats (Molur et al. 2003), the species has attracted special conservation concerns. It was classified as Schedule-I (highly protected) species in the Indian Wildlife (Protection) Act 1972 and as an Endangered species by IUCN (IUCN 2007; Kumar et al. 2008). Since the Western Ghats are a home to a wide variety of flora and fauna including many endemic species, the Lion-tailed Macaque is considered a flagship species for the rainforests of the Ghats. For the past four decades, several measures have been initiated for the conservation of the species. These include conservation and management steps in the wild habitats of this species as well as captive breeding for maintaining viable reserves. However, it appears that most of these programs so far have not achieved the success that was expected. At present, the species appears to be in the same threatened condition, if not worse, as it was a few decades ago. In this article, we discuss the various *in situ* and *ex situ* conservation initiatives, reassess the conservation status of the species, and outline an action plan on the basis of lessons learnt from the past few decades.

STATUS AND CONSERVATION IN NATURAL HABITATS

Status

Table 1 summarizes, in a chronological order, the major field studies on ecology, and behavior and population estimates of the Lion-tailed Macaques in the Western Ghats. Some of these studies provide information on the status of the species. In the initial study, Green & Minkowski (1977) estimated the total wild population to be around 600 individuals and feared that the species may be close to extinction. They based their conclusions on the small area of occupancy and small population size. However, further studies (Table 1) revealed that the LTMs were present in many more areas than those reported by Green & Minkowski. Many of these studies reported population estimates only for small regions of occurrence of LTMs. Later, Karanth (1985) surveyed the entire

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Table 1. Landmark field studies on Lion-tailed Macaques

Reference	Main topics
Sugiyama (1968)	A pilot study on the ecology of lion-tailed macaques
Green & Minkowski (1977)	Ecology and population estimated to be about 600 individuals in total
Kurup (1978)	Distribution and status survey
Bhat (1982)	Additional information on lion-tailed macaques in Karnataka
Ali (1985)	Estimated the total population to be about 915 individuals
Karanth (1985)	Surveyed the entire state of Karnataka and estimated the number to be about 3,000 individuals in the state
Kumar (1987)	Ecology and population dynamics in Anaimalai Hills
Kumar <i>et al.</i> (1995)	Effects of fragmentation
Menon & Poirier (1996)	Behavioral responses to habitat alterations
Singh <i>et al.</i> (1997)	Distribution and primate associations in Anaimalai Hills
Singh <i>et al.</i> (2000)	Lion-tailed macaques in Sringeri forests
Singh <i>et al.</i> (2001)	Behavioral responses to habitat alterations
Krishnamani & Kumar (2000)	Phytoecology of lion-tailed macaque habitats
Ramachandran & Joseph (2000)	Status in Silent Valley and adjacent areas
Singh <i>et al.</i> (2002)	Lion-tailed macaques in fragments and large tracts in Anaimalai Hills
Kumara & Singh (2004)	32 groups in Sirsi-Honnava region – a potentially viable population
Krishna <i>et al.</i> (2006)	Population dynamics in a forest fragment
Sushma & Singh (2006)	Sympatricity with other primates and niche separation

rainforest region in the whole state of Karnataka and reported that a sizable population existed there. He perceived a good prospect for conservation of LTMs in Karnataka. Further studies revealed that the total population of LTMs was larger than that estimated earlier. However, it was realized that most of the subpopulations of LTMs inhabited forest fragments that were largely isolated and ranged in size from less than 1km² to about 20km² (Kumar *et al.* 1998). At present, there are three types of LTM habitats: (i) There are areas with relatively large forest tracts without any fragmentation and thus providing contiguous habitats (e.g. Silent Valley National Park and Kalakad-Mundanthurai Tiger Reserve), (ii) Forest fragments surrounded by tea gardens or monocultures of commercial plantations where the LTM groups are virtually isolated as they are unable to use their surroundings for movement between fragments (e.g. Valparai plateau of the Anaimalai Hills and Indira Gandhi Wildlife Sanctuary (Singh *et al.* 2002), and (iii) Fragmentation caused by scattered villages with pockets of croplands interspersed inside a large stretch of rainforests where the remaining narrow alleys of rainforests still connect remaining patches of forests. These alleys still make the local population of LTMs contiguous (e.g. Sirsi-Honnava region of Karnataka (Kumara & Singh 2004)). There appear to be four regions with potentially viable populations of LTMs in their natural habitats. Silent Valley in the state of Kerala harbours 14 groups with about 275 individuals (Ramachandran & Joseph 2000). In 2004, there were 32 groups of LTMs with an estimated population of about 790 individuals inhabiting the forests of Sirsi-Honnava between Sharavathy and Aghnashini rivers in the state of Karnataka (Kumara & Singh 2004). A recent survey revealed a sizable population of LTMs in the Kudremukh National Park and its adjoining regions (Kumara & Singh *in press*). The Kalakad-Mundanthurai Tiger Reserve in the state of Tamil Nadu with about 440km² of rainforests is a potentially viable habitat of LTMs (Molur *et al.* 2003). Although a number of groups have been sighted in this region (Johnson 1985), no recent quantitative population estimates are available. At present, the total wild population comprises 3000-3500 individuals fragmented into 49 subpopulations (Molur *et al.* 2003) (Figure 1). The 31 well known groups in the Anaimalai Hills (Singh *et al.* 2002) are distributed in seven unconnected subpopulations, and this

pattern is more or less the same for more than half of the wild population of LTMs. Recent studies show a severe decline in the number of groups and individuals of LTMs from various regions. Once 10 groups of LTMs in the Brahmagiri-Makut region of Karnataka (Karanth 1985) have now declined to only one group and a single adult male (Kumara & Singh 2004). Likewise, 62 groups of LTMs observed in Kudremukh-Someshwara-Mukambika wildlife sanctuaries in 1985 (Karanth 1985) have now been reduced to only nine groups (Vasudevan *et al.* 2006). Kumara & Sinha (*in press*) have reported a 69% decline in the population in other regions of the state of Karnataka during the past about 25 years (Image 1). Though the number of groups in the Sirsi-Honnava region of Karnataka is the same as in 2004 (Kumara & Singh 2004), the total number of individuals that was estimated to be 790 is now about 600 (H.N. Kumara *pers. comm.* April 2008). Systematic data on such population trends from other states are not available. One reason that LTMs have declining habitat is that the lower elevation forests which are their prime habitat areas, have been clear cut for the logging industry. However, Kumara & Sinha (*in press*) have concluded that since the rainforest habitats in Karnataka have not changed much during the past 25 years or so, the drastic decline in numbers of LTMs is primarily due to illegal hunting. In addition to habitat fragmentation, illegal hunting now also appears to be a major threat for the survival of Lion-tailed Macaques.

Conservation

It was already in the 1970s that the Lion-tailed Macaque was realized as endangered, requiring urgent measures for *in situ* conservation for the remaining populations. Forest and Wildlife Departments in the range states in southern India identified some areas with contiguous rainforests and notified them as special areas for LTM conservation. Kalakad-Mundanthurai in the state of Tamil Nadu, Silent Valley in the state of Kerala, and Brahmagiri-Makut in the state of Karnataka were three such areas. However, the population status and population trends in the subsequent years were not assessed in Kalakad-Mundanthurai. The LTM number in Silent Valley appears to have remained stable over the years. In Brahmagiri, the 10 groups of LTMs known to exist in 1984 have now declined to only one group and the population has



Image 1. Current broad distribution of Lion-tailed Macaque in the Western Ghats. Although LTMs are severely fragmented, the polygons depicted here are broad groupings of the fragments. The break between the bottom two polygons is due to the Palghat gap dividing the Annamalai hills fragments from Silent Valley National Park subpopulation. The break between the middle and northern polygons is in Coorg district of Karnataka where LTM does not occur due to hunting although the habitat is suitable. Map created using Google Earth.

reached a point of non-viability (see Kumar et al. 1994; Kumara & Singh 2004). Illegal hunting goes on unabated in many regions.

During informal meetings of conservation biologists and forest officials, several measures for population management were discussed such as restocking in depleted habitats, male transfer between isolated forest fragments, and managing unnatural demographics. However, no such steps were taken up. Discussions during meetings also revealed that the situation did not yet warrant reintroduction of captive bred LTMs into their wild habitats. 'Experimental reintroduction' as proposed by Lindburg (2001) in some confined forest patch in order to learn the know-how of procedures of reintroduction was not even given a serious consideration. The few conservation

measures as described above were not put into effect and hence did not contribute to the improvement of the status. Even in several 'protected areas' and reserved forests with contiguous LTM habitats, illegal hunting has become a serious threat. The forest fragments inhabited by LTMs continue to shrink in size and the habitat quality deteriorate in terms of food resources especially since many of these fragments are on private lands and the forest departments have no 'jurisdiction' in such properties. The species appears to be in a worse situation than it was some 30 years ago.

BREEDING PROGRAMS IN ZOOS

The North American zoo community recognized the seriously threatened status of the LTM in its natural habitats

quite early. It was therefore intended to establish a viable population of the species in captivity that might serve as a reserve. Such initiatives were also taken up in Europe, Japan and India.

Captive breeding under Species Survival Plan in North America

The history of captive LTMs in North America has been described by Lindburg (2001). Although the LTMs have been in American zoos since the later part of the 19th century, it was only in 1981 that the species was brought under a Species Survival Plan (SSP) of the then American Association of Zoological Parks and Aquariums (AAZPA), currently Association of Zoos and Aquariums (AZA) with a goal to establish a viable captive population. Gledhill (1988) started an international studbook for the species and coordinated the program. Much scientific input was provided by Donald Lindburg, the then head of major conservation programs for endangered species at San Diego Zoo and currently Director Emeritus of San Diego Zoo's office of Giant Panda Conservation. A science based management approach with emphasis on genetic and reproductive biology resulted in a successfully growing captive population of about 200 individuals. Since it was felt that space limitations required a smaller population size without losing genetic diversity, 'hedge breeding' was propagated in 1991 (Lindburg 2001). The principle was to allow breeding only to a small number of genetically valuable individuals. Many males were vasectomised, a number of females were neutered, and the birth interval in breeding females was extended to increase the generation time. About 15 years later, it was found that the number of infants not only was reduced but it was even below the number required for the survival of the population. It seems that the management schedule was not compatible with the biological needs of the species. This practice also ignored the fact that in the past, the LTM females in captivity did not reproduce in a predictable way, and about 30% did not reproduce successfully at all (Lindburg et al. 1981). There seems to be a risk of disturbances in the hormonal cycles of females when kept with vasectomised males (Harvey & Lindburg 2001). It could also be possible that the resulting altered demographic and social structures contributed to breeding problems. The status of the population may also have been negatively affected by loss of interest in the species due to a perceived 'safe population size' in wild habitats. Furthermore, the LTMs were considered as carriers of dangerous viruses. The situation now has reached a point that there are only a few females of breeding age left in the SSP population (Scott Carter pers. comm., March 2008).

Captive breeding under European Endangered Species Program

Following the North American SSP, the LTM in European zoos was brought under EEP (European Endangered Species Breeding Programs) in 1989. Between 1989 and 2006, Werner Kaumanns coordinated the program. Referring to the Annual Reports and continuous analysis of the populations, Kaumanns & Rohrer (1995), Kaumanns et al. (2001) and Krebs & Kaumanns (2003) have described the development of the European population. During the first 10 years, the population more than doubled due to some imports from other captive

situations into the population, relatively successful breeding, and increase in the number of participating institutions from 12 to 33. At present, the metapopulation in Europe comprises of more than 250 individuals but is required to be about 400 to be viable (Kaumanns et al. 2005). However, Kaumanns et al. (2001) also reported several problems with the population. As in the SSP population, more than 30% of the females of the historical population did not reproduce at all. Further, among the successfully breeding females, there was a large variance in reproductive output with few females contributing most infants. Birth rates increased over the decades but remained lower than expected and the infant mortality remained high for unknown reasons despite improvement in living conditions.

Captive breeding initiatives in India

It has been repeatedly propagated that India, the range country of the LTMs, must have a viable captive population of the species. A few Indian zoos were maintaining some confiscated individuals few of which bred occasionally. In the past, there was no attempt to establish a viable population by coordinated breeding programs. The first master plan for captive breeding of LTMs in India was drawn in 1996 (Gledhill 1996), in order 'to establish a secure population with genetic diversity to support a future reintroduction program, if needed'. Eight zoos were identified for captive breeding and an elaborate schedule of animal transfer, keeping and breeding was outlined. However, no elaborate action was taken up in the subsequent years. It was finally realized that the existing population of about 60 individuals comprising small groups with unbalanced sex ratios was not appropriate to achieve the goal. In 2001, another initiative was taken up by the Central Zoo Authority of India for a "Coordinated Breeding Program" for LTMs. Three zoos viz. Aaranyak Zoological Park, Vandalur, Shri Chamarajendra Zoological Gardens, Mysuru and Thiruvananthapuram Zoo were identified for this purpose. A committee consisting of the Directors of respective zoos and a few field biologists was constituted to implement and oversee the program. It was planned to shift scattered LTMs in other zoos in India (20 females, 32 males, in 16 zoos) to the above three zoos for establishing new breeding groups. However, the Indian zoos holding individual or two to three animals either did not respond or refused to send their animals for the program. It was also decided to add the study group of LTMs at Wild Animal Park of San Diego Zoo to the Indian population. However, eventually the SSP decided that they had to retain the San Diego group for re-establishing their own dwindling population of LTMs. The studbook for LTMs by the Wildlife Institute of India attests to the fact that little breeding success has been achieved in the captive populations of LTMs in India over these years. Comprising a few dozen individuals with occasional births in a few zoos, the present population in India does not appear to have much scope for development into a viable stock. By 2005 the captive LTM numbers in 19 Indian zoos were 29 males, 28 females, and 8 unsexed.

Authors Mewa Singh and Werner Kaumanns have taken up a recent plan to support Indian LTM populations as part of the Planned Conservation Breeding Programs initiated by the Central Zoo Authority. The plan called for the LTM group of Cologne Zoo, one of the most successful breeding groups of EEP, to be shifted to Mysore Zoo, India for conservation breeding and research. However, till now the above plan has

not materialized due to bureaucratic hurdles in India.

COLLATING AND ORGANIZING CONSERVATION ACTIVITIES

Because of the threatened status and the general interest in the species, five international meetings have been held to plan for the conservation of LTMs four of which were organized by Zoos (Baltimore Zoo, 1982; Woodland Park Zoological Gardens, Seattle, 1986; San Diego Zoo, 1990; The Zoo Outreach Organization and Arignar Anna Zoological Park, Vandalur, 1993) and the fifth one by the University of Mysore (Mysore, 1999). During each meeting, the latest status of the population in natural habitats and in captivity was presented and plans were envisaged for conservation. Topics including husbandry, maintaining viable captive populations, reintroduction of surplus individuals, need for further field surveys, and filling of gaps of research on biology were discussed. A major achievement of these meetings was collation and presentation of knowledge on status and biology of the species (Heltne 1985; Kumar et al. 1995; Schwibbe et al. 2000, 2001). Other achievements of the meetings included the passing of several resolutions, preparation of management plans for *in situ* and *ex situ* populations, and formation of international consortia to oversee LTM conservation and management. Whereas these plans influenced the *ex situ* breeding programs to a significant extent, they were rarely put into practice *in situ*.

PERSPECTIVES FOR LION-TAILED MACAQUE CONSERVATION

It may be inferred from the foregoing discussion that both *in situ* and *ex situ* conservation programs for the LTMs may have contributed to slow down the process of extinction. However, these programs were not efficient enough to prevent further shrinking of both the wild and the captive populations. Since time is running out, there is further need of readjustment of conservation activities that should be based on critical evaluation of the shortcomings of the past activities. Singh & Kaumanns (2005) have provided a general perspective for research and conservation of LTMs.

By now, it is fairly well known why the LTM is a threatened species. The possible steps for conservation have been repeatedly spelled out during the past few years. Still, why considerable progress has not been made is probably due to the lack of a competent and responsible working unit that could take care of the problems and efficiently implement the conservation measures. Conserving species like the LTM requires protection of habitats and populations. However, this has to be based on the biology of the species. Since the execution of most management activities requires governmental authority, they would have to be carried out by forest and wildlife departments of the concerned states. As only the field biologists who have worked on this species have the necessary special expertise, the working unit should consist of authorities and biologists for management even on a day-to-day basis. A few selected officers in the Forest Departments should be trained in LTM biology and conservation, and they should remain actively involved independent of their actual places of posting. Some non-governmental conservation organizations and international *ex situ* expertise on LTMs should also be a part of this working unit to help implement the conservation steps.

The first and the foremost requirement is an updated reassessment of the remaining wild populations. However, this assessment has to be more than the occasional static counts

of groups and individuals as in the past. A subpopulation (a single group as in a small forest fragment, or all groups with overlapping home ranges as in a large forest tract) should be the unit of assessment. It is recommended that the assessments are done biannually so that changes in demography e.g. births, deaths and dispersal, are recorded on a regular basis and *population dynamics* are analyzed locally. In addition, each habitat should also be monitored along certain parameters so that the changes in habitat quality are analyzed. The assessments should be done state-wise and all data should be deposited with a single institution. The recommended institutions for this purpose are Kerala Forest Research Institute, Peechi for Kerala, University of Mysore for Karnataka, and Zoo Outreach Organization for Tamil Nadu. Further, one of these institutions should collate the data for the entire Western Ghats. The analyses should refer to questions of small population biology such as question of Effective Population Size. Possible reasons for changes in demography should be identified. The quality of the analysis should be such that it allows predictions not only for future population trends but also for the effect of unexpected biological events such as random genetic drift. Management practices should be decided locally for each subpopulation on the basis of trends in population and habitat quality. The model of 'adaptive management' should be adopted for these practices where the results of failure or success of the previous attempt are incorporated into the next step of management (Walters 1978).

During the past one decade or so, several measures were suggested to manage LTM populations and habitats in forest fragments (Kumar et al. 1998; Singh et al. 2002). These measures included enhancing the resource quality in degraded fragments, linking fragments with narrow corridors to facilitate at least male migration, and to exchange males among fragments. None of these suggestions have been implemented. The working unit should seriously try the implementation of these steps. Biologists could collect systematic data on the outcome which could be used to develop a model for management practices. Activities like transfer of males between groups could be based on the concept of 'experimental reintroduction' suggested by Lindburg (2001). For enhancing resource quality inside fragments and for linking fragments, trees species that could provide large amount of fruits, grow fast and provide good shade for coffee are required as many fragments are in private lands and the interests of the farmers cannot be overlooked. Help should be sought for identification of such tree species from field biologists such as those from Nature Conservation Foundation, Mysore, and Rainforest Research Station, Valparai, who have been working on such issues for a long time.

The type of habitats like Sirsi-Honnava harbouring potentially viable LTM populations in contiguous forest tracts that are being encroached from within (Kumara & Singh 2004) should be legally designated as LTM conservation areas. As the latest surveys in Karnataka have shown, a large proportion of the LTM population has disappeared during a short period due to illegal hunting (Kumara & Sinha in press). Since the LTM has a very low population turnover due to delayed sexual maturity and long inter-birth intervals (Singh et al. 2006), highly reduced numbers in hunting affected areas can cause rapid local extinctions. Nongovernmental organizations involved in education and awareness building should be

encouraged to work with locals in LTM areas to help reduce or prevent hunting. It is, therefore, necessary that the authorities find the ways and do their level best to control hunting of LTM.

Lion-tailed Macaques have been maintained in captivity for several decades as a species of special conservation concern (e.g. SSP and EEP for this species). Experience has shown that it is a very difficult species to breed in the long run. At present, there are about 500 individuals in the zoos worldwide. Although several males have been vasectomised and females neutered, there are at least about 300 individuals, most of them under EEP in Europe, who can breed. This captive population accounts for about 8% of the total global population and therefore, it must be protected and propagated. The captive population has not only proved to be of value for research and conservation education, it can also be maintained as a reserve. For example, even if full scale reintroduction programs are not yet warranted, surplus but breeding males could be used to infuse new genes in forest fragments where natural dispersal is not possible or the resident male(s) dies. The captive breeding program under EEP has been doing comparatively well and it must continue heading for a much larger population as has been recommended for a number of years in the EEP (Kaumanns et al. 2006). The SSP must rejuvenate the LTM breeding program in order to improve the population status. India still has to build up its population of LTM in zoos. Before an elaborate population management there can be realized, LTM holding institutions must improve the basic infrastructure for primate husbandry. The LTMs under human care in India should be looked after by the working unit mentioned earlier. As recommended in the case of forest officials, a few zoo curators and veterinarians must get special training in LTM husbandry and they should be involved in the LTM programs on regular basis despite their frequent transfers to other places. Recently, a major project has been undertaken by National Institute for Research in Reproductive Health, Mumbai to establish a National Center for Primate Breeding and Research (Puri & Ganguly 2005). We strongly recommend that this center take up LTM breeding not to procure animals for biomedical research but for facilitating conservation. If successful, the center should share the know-how with zoos maintaining LTMs. In order to improve LTM husbandry and population management, it is proposed to refer to husbandry guidelines developed by the two authors MS and WK (Kaumanns et al. 2005). These guidelines are based on almost 20 years of work with European population and intensive analyses of its development.

Because of its restricted range, endemism to a small region, threatened status, the LTM has attracted special conservation concerns. These concerns also stimulated biological research and the species today is one of the most well studied macaque species in wild and in captivity. However, despite these activities, the LTM is still threatened and the species might even become 'Critically Endangered' if the present declining trend in population continues. *In situ* and *ex situ* conservation measures need to be intensified. The most urgent need is the establishment of a responsible working unit including forest officers, biologists and zoo professionals. The management practices must incorporate the results of biological research. There are still several gaps in our knowledge about the LTM biology that need to be filled up. For example, the effects of fragmentation on such factors as genetic status, hormonal cycles,

parasitic status, demographic dynamics, and nutritional status, have not yet been satisfactorily investigated. The LTM is a flagship species for the Western Ghats, but it should also become a flagship species for the development of management models for other species that are not so well studied but are also threatened by small population size and habitat fragmentation.

REFERENCES

- Ali, R. (1985). An overview of the status and distribution of the Lion-tailed Macaque, pp.13-25. In: Heltne, P.G. (ed). *The Lion-Tailed Macaque: Status and Conservation*. Allan R. Liss, New York.
- Bhat, H.R. (1982). Additional information on the status of Lion-tailed Macaque (*Macaca silenus*) in Karnataka. Paper presented at the International Symposium on Lion-Tailed Macaques, Baltimore, May 19-22.
- Gledhill, L. (1988). Lion-tailed Macaque, (*Macaca silenus*), International Studbook. Woodland Park Zoological Gardens, Seattle.
- Gledhill, L. (1996). A masterplan for the Indian *ex-situ* population of Lion-tailed Macaques, *Macaca silenus*. *OWM TAG* (Old World Monkeys Taxon Advisory Group) 3(2):8-9.
- Green, S.M. & K. Minkowski (1977). The Lion-tailed Macaque and its southern Indian rainforest habitat, pp. 289-337. In: G.H. Bourne & H.S.H. Rainier (eds.). *Primate Conservation*. Academic Press, New York.
- Harvey, N.C. & D.G. Lindburg (2001). A long term decline in swelling of the sexual skin in captive Lion-tailed Macaques. *Primate Report* 59: 43-50.
- Heltne, P.G. (ed.) (1985). *The Lion-tailed Macaque: Status and Conservation*. Alan R. Liss, New York.
- IUCN (2007). 2007 IUCN Red List of Threatened Species. <www.iucnredlist.org>. Downloaded on 08 March 2008.
- Johnson, T.J.M. (1985). Lion-tailed Macaque behavior in the wild pp. 41-63. In: Heltne, P.G. (ed). *The Lion-Tailed Macaque: Status and Conservation*. Allan R.Liss, New York.
- Karanth, K.U. (1985). Ecological status of the Lion-tailed Macaque and its rainforest habitats in Karnataka, India. *Primate Conservation* 6: 73-84.
- Kaumanns, W., E. Krebs & M. Singh (2005). An endangered species in captivity: Husbandry and management of the Lion-tailed Macaque (*Macaca silenus*). *My Science* 1:43-71.
- Kaumanns, W., E. Krebs, C. Schwitzer & M. Singh (2005). Primates in Europe. *Zeitschrift Des Kolner Zoo* 48: 85-96.
- Kaumanns, W. & B. Rohrerhuber (1995). Captive propagation in lion-tailed macaques: The status of the European population and research implications, pp. 296-309. In: Ganslosser, U., J.K. Hodges & W. Kaumanns (eds.). *Research and Captive Propagation*. Filander Verlag, Furth.
- Kaumanns, W., C. Schwitzer, P. Schmidt, A. Husung & C. Knogge (2001). The European Lion-tailed Macaque population: An overview. *Primate Report* 2001: 65-76.
- Kaumanns, W., M. Singh, W. Beisenherz, C. Schwitzer & C. Knogge (2000). Bartaffen und ihr Lebensraum. *Zeitschrift Des Kolner Zoo* 43:147-168.
- Krebs, E. & W. Kaumanns (2003). *European Studbook for the Lion-tailed Macaque*. Cologne Zoo, Cologne.
- Krishna, B.A., M. Singh & M. Singh (2006). Population dynamics in a group of Lion-tailed Macaques (*Macaca silenus*) inhabiting a rainforest fragment in the Western Ghats, India. *Folia Primatologica* 77: 377-386.
- Krishnamani, R. & A. Kumar (2000). Phyto-ecology of the Lion-tailed Macaque (*Macaca silenus*) habitats in Karnataka, India: Floristic structure and density of food trees. *Primate Report* 58: 27-56.
- Kumar, A. (1987). The ecology and population dynamics of Lion-tailed Monkeys (*Macaca silenus*) in southern India. Ph.D. Thesis, Cambridge University. Zoo Zen, Zoo Outreach Organization, Coimbatore.
- Kumar, A., S. Molur & S. Walker (eds.) (1995). *The Lion-tailed Macaque: Population and Habitat Viability Assessment Workshop*. Zoo Outreach Organization, Coimbatore.
- Kumar, A., M. Singh & S. Molur (2008). *Macaca silenus*. In: IUCN 2008. 2008 IUCN Red List of Threatened Species. <www.iucnredlist.org>.

Downloaded on 12 March 2009.

- Kumar, A., N. Sivaganesan, G. Umopathy & A. Prabhakar (1998).** *A Study on the Management of Fragmented Rainforests of Western Ghats for the Conservation of Fauna with Special Emphasis on Small Mammals*. Salim Ali Centre for Ornithology and Natural History, Coimbatore.
- Kumara, H.N. & M. Singh (2004).** Distribution and abundance of primates in the rainforests of the Western Ghats, Karnataka, India and the conservation of *Macaca silenus*. *International Journal of Primatology* 25: 1001-1018.
- Kumara, H.N. & V.R. Singh (in press).** Estimation of lion-tailed macaque *Macaca silenus* population in Kudremukh Forest Division, Karnataka. *International Journal of Primatology*.
- Kumara, H.N. & A. Sinha (in press).** Decline of Lion-tailed Macaque populations in the Western Ghats, India: Identification of a viable population and its conservation in Karnataka state. *Oryx*.
- Kurup, G.U. (1978).** Distribution, habitat and status survey of Lion-tailed Macaques, *Macaca silenus*. *Journal of Bombay Natural History Society* 75: 321-340.
- Lindburg, D.G. (2001).** A century of involvement with Lion-tailed Macaques in North America. *Primate Report* 59: 51-64.
- Lindburg, D.G., A.M. Lyles & N.M. Czekala (1989).** Status and reproductive potential of Lion-tailed Macaques in captivity. *Zoo Biology Supplement* 1: 5-16.
- Menon, S. & F.E. Poirier (1996).** Lion-tailed Macaque (*Macaca silenus*) in a disturbed forest fragment: Activity patterns and time budgets. *International Journal of Primatology* 17: 969-985.
- Molur, S., D. Brandon-Jones, W. Dittus, A. Eudey, A. Kumar, M. Singh, M.M. Feeroz, M. Chalise, P. Priya & S. Walker (2003).** *Status of South Asian Primates: Conservation Assessment and Management Plan (C.A.M.P) Workshop Report, 2003*. Zoo Outreach Organization/CBSG-South Asia, Coimbatore.
- Puri, C.P. & N.K. Ganguly (eds.). (2005).** *National Center for Primate Breeding and Research: Vision, Challenges and Opportunities*. National Institute for Research in Reproductive Health, Mumbai.
- Ramachandran, K.K. & G.K. Joseph (2000).** Habitat utilization of lion-tailed macaque (*Macaca silenus*) in Silent Valley National Park, Kerala, India. *Primate Report* 58:17-26.
- Schwibbe, M., M. Singh, W. Kaumanns & C. Knogge (eds.) (2000).** *Primate Report* 58.
- Schwibbe, M., M. Singh, W. Kaumanns & C. Knogge (eds.) (2001).** *Primate Report* 59.
- Singh, M. & W. Kaumanns (2005).** *In situ and ex situ research and conservation perspective for the Lion-tailed Macaque (Macaca silenus): A model for planning conservations strategies for other endangered primates*, pp. 127-139. In: Puri, C.P. & N.K. Ganguly (eds.). *National Center for Primate Breeding and Research: Vision, Challenges and Opportunities*. National Institute for Research In Reproductive Health, Mumbai.
- Singh, M. & W. Kaumanns (2005).** Behavioural studies: A necessity for wildlife management. *Current Science* 89: 1230-1236.
- Singh, M., H.N. Kumara, M. Ananda Kumar & A.K. Sharma (2001).** Behavioral responses of Lion-tailed Macaques to a changing habitat in a rainforest fragment in Western Ghats, India. *Folia Primatologica* 72: 278-291.
- Singh, M., H.N. Kumara, M.A. Kumar, A.K. Sharma & K. DeFalco (2000).** Status and conservation of Lion-tailed Macaques and other arboreal mammals in tropical rainforests of Sringeri Forest Range, Western Ghats, Karnataka, India. *Primate Report* 58: 5-16.
- Singh, M., A.K. Sharma, E. Krebs & W. Kaumanns (2006).** Reproductive biology of Lion-tailed Macaque (*Macaca silenus*): An important key to the conservation of an endangered species. *Current Science* 90: 804-811.
- Singh, M., M. Singh, M.A. Kumar, H.N. Kumara, A.K. Sharma & W. Kaumanns (2002).** Distribution, Population Structure and Conservation of Lion-tailed Macaques (*Macaca silenus*) in the Anaimalai Hills, Western Ghats, India. *American Journal of Primatology* 57: 91-102.
- Singh, M., M. Singh, H.N. Kumara, M.A. Kumar & L. D'Souza (1997).** Inter- and intra-specific associations of nonhuman primates in Anaimalai Hills, South India. *Mammalia* t.61: 17-28.
- Sugiyama, Y. (1968).** The ecology of the Lion-tailed Macaque (*Macaca silenus*): A pilot study. *Journal of the Bombay Natural History Society* 65: 283-292.
- Sushma, H.S. & M. Singh (2006).** Resource partitioning and interspecific interactions among sympatric arboreal mammals of the Western Ghats, India. *Behavioral Ecology* 17: 479-490.
- Thierry, B., M. Singh & W. Kaumanns (2004).** Why macaque societies?, pp. 3-10. In: Thierry, B., M. Singh & W. Kaumanns (eds.) *Macaque Societies: A Model for the Study of Social Organization*. Cambridge University, Cambridge.
- Vasudevan, K., M. Singh, V.R. Singh, M.A. Chaitra, R.S. Naniwadekar, R.S., V. Deepak & N. Swapna (2006).** *Survey of Biological Diversity in Kudremukh Wildlife Complex, Karnataka*. Survey Report of Kudremukh Wildlife Division, Karnataka Forest Department, Bangalore, India.
- Walters, C.J. (1978).** Ecological optimization and adaptive management. *Annual Review of Ecology and Systematics* 9: 157-188.

