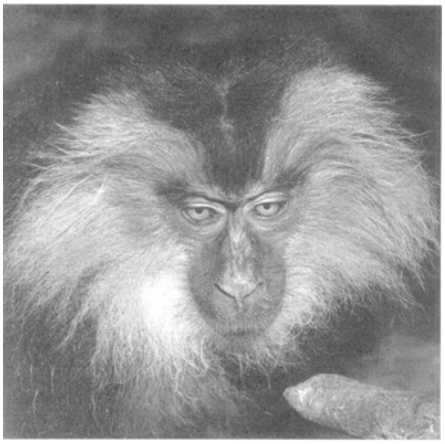
CONSERVATION OF ENDANGERED FAUNA in SHARAVATHI RIVER BASIN, CENTRAL WESTERN GHATS



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CONSERVATION OF ENDANGERED FAUNA IN SHARAVATHI RIVER BASIN, CENTRAL WESTERN GHATS

SUMMARY

The rare lion tailed macaque (Macaca silenus) is an endangered species endemic to Western Ghats of South India in the tropical evergreen and semi evergreen forests. It is is a taxonomically distinctive species. Special reasons for conserving this unusual monkey relate to its singular role as the only exclusively arboreal forest –dwelling macaque. The fragmentation of habitat is one of the threats to Lion tailed macaque (LTM) in Western Ghats. Other threats are clear felling, selective-felling, habitation and access roads, hunting (for eating and mistaken identity by hunters as Niligiri langurs), legal and unauthorised collection of minor forest produce like Artocarpus, Ficus fruits which are its most important foods. The Lion tailed Macaque is on the verge of extinction due to extensive and widespread destruction of its habitat, even though it is secondary to its hunting. A study has been carried out in the Sharavathi river basin for a period of four months to explore the status of LTM's threats and conservation. Loss of habitat due to increasing anthropogenic activities is the primary threat to these animals. Fragmentation of habitats due to encroachments and unplanned developmental activities are converting the contiguous habitat into remnants which are unsuitable for LTM's as they are exposed to predation, hunting and also to inbreeding. During the field survey, a troop of LTM was spotted at the north bank of the Sharavathi River below Jog Falls. The region is fragmented by Honavar-Belgaum road along which forest encroachment for agriculture and horticulture is extensive. A severe decline in numbers of monkeys is reported since selective-felling operation began in early 60's. High forests lie between 200 to 500 m elevation and are transitional between semi-evergreens and evergreens. Since, this is now probably the north most limit of M.silenus, and also the habitat differs markedly from *Cullenia*-dominant and *Dipterocarpus*-dominant forests in south Western Ghats. Careful protection and management has to be adopted through restoration of forests to conserve the endangered endemic species.

CONTENTS

SUMMARY

CONTENTS

1.0 **INTRODUCTION**

"*Hot-spots*" are the regions of exceptionally rich species diversity and include 3.5% of the remaining primary forests in the world, containing about 34,000 endemic plant and 700,000 endemic animal species. Among the world's 34 "hot-spots", are the *evergreen* forests of Western Ghats of south India. The *Western Ghats* comprise a total area of 160,000km^2 containing eight national parks and 39 wildlife sanctuaries in six states: Goa, Gujarat, Kerala, Maharashtra, Tamil Nadu and *Karnataka*. This region possesses rich species diversity and is one of the *most* threatened regions of south Asia. Two-thirds of the species found in the Western Ghats are *endemic* to this region, including the *endangered* **Lion Tailed Macaque**, Macaca silenus.

The Macaque monkeys, a genus of dozen or so species is important to humans as their contributions to laboratory medical sciences are well known. Contributions to evolution and biological regulation of animal societies have been dramatically enhanced by studies of wild macaques. Investigations of the relationship between structure and regulation of social groups of primates and the habitat in which they live have increasing relevance to the fate of man as we attempt to delineate the factors modulating our own social behaviours. Among such important macaques only the Lion tailed macaque is an obligate *rainforest* dweller. It has been uniquely classified as the only truly arboreal macaque, thus offering the opportunity to examine the behavioural correlates of arboreal living and a forest canopy habitat and thereby measure and contrast the effects of hereditary and environmental influences on behaviour.

Among many primate species living in the Western Ghats of Karnataka, Lion Tailed Macaque can be considered as an indicator species. This species is mainly arboreal and is an obligate evergreen forest species, feeding predominantly on fruits and insects. In Karnataka, habitat of this primate is threatened by *human*-caused disturbances and forest *fragmentation* (Krishnamurthy and Kiester, 1998).

All regions, where Lion Tailed monkeys have been reported, contain the lofty dense evergreen forests characterised by a large number of tree species reaching ~30 to 50m or more in height and forming a dense canopy. The vast majority of trees have large simple leaves. Giant climbers, epiphytic ferns, mosses and orchids are numerous at all levels from the canopy to the forest floor. The woody under storeys include saplings, smaller species of trees, shrubs and often a tangle of cane or bamboo-like reeds. Except in the ravines, the undergrowth is relatively free of herbaceous plants. The plant communities favoured by Macaca silenus have a very large, slightly buttressed tree occurring at elevations from 600 to 1400 m in areas over 3000 mm rainfall. The typical dominant canopy tree associations are Cullenia-Palaquium, Cullenia-Calophyllum, Poeciloneuron-

Cullenia, and Palaquium-Mangifera (Champion and Seth, 1968). Lianas present are also a conspicuous feature; these are woody climbers with flexible stems, which may be a foot thickness in diameter, forming big disorderly curls. They have cauliflower-like canopies, in which both flowers and fruits sprout from the trunks or branches of trees and lianas. Trees and Lianas- and their seedlings – dominate the forest, where more than a half of the plant species are woody and herbs like orchids and ferns occur high up in the trees as epiphytes on the branches. The necessary conditions for its growth are:

1. A tropical temperature almost throughout the year: found between 23°30'N and 23°30'S latitude. The land surfaces are within 1000 m altitude.
2. High rainfall: at least 1800 mm per year (when evenly distributed). Such "ever-wet tropical" climate prevails, indicating that the earth was covered with this type of forest very long ago. It is hard to delineate precise boundaries for these forests (rainforest).

Peculiarities of rainforest: They contain large numbers of species of flora and fauna in an ecosystem. Their potential for utilisation is greatest in terms of quality, but smallest in terms of quantity. They are usually *fragile* and once damaged severely, do *not* recover, or recover *very slowly*.

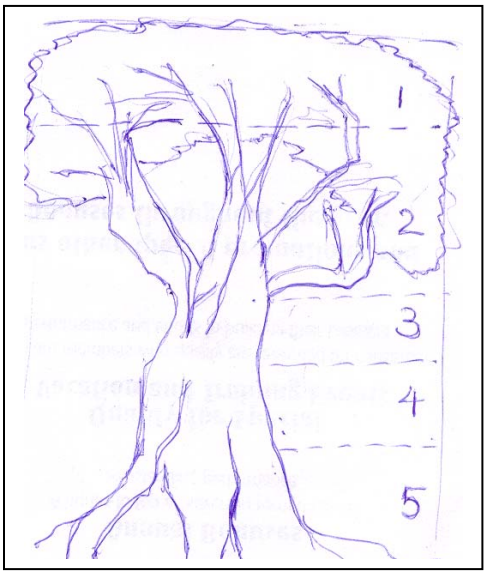
Climate: The existence of this type of vegetation is mainly conditioned by climate. At the equator, the mean temperature at sea level is about 26°C and 12 hour-day length shows *little* seasonal variation. The tropical region is usually hot but it *never* becomes *excessively* hot. There is a close relationship between heat and moisture and the typical structure of a tropical rainforest with its giant trees and buttresses. In the humid tropics, the diurnal *temperature fluctuation* is around 7 to 12°C near the tropics of Cancer and Capricorn. The maximum temperature seldom exceeds 34°C. A mean temperature of 20°C in the coolest months of the year marks the boundary of the tropical rainforest. Temperature is related to latitude and altitude: temperature decreases by 0.61°C per 100 m increase in elevation.

Precipitation: Second limiting factor is precipitation. Tropical rainforest can grow only in the presence of sufficient moisture but this is not the case all the time. In the tropics the extremes of wet and dry seasons are *more pronounced* than temperature variation between seasons.

Microclimate: Every vegetation creates its own microclimate. The taller and more closed the canopy is, the greater the relative protection it provides. The outside climate does eventually determine the climate inside. Since, the forest canopy is high and generally fairly dense, the protection inside a tropical rainforest is large, yet between the outside

climate and the microclimate inside, one can identify a series of microclimates by examining the epiphyte growth on the trees. A forest tree with 5 microclimates (Longman & Jenik, 1974) is shown in Figure 1.

Figure 1



Top of the crown is exposed to weather with micro Epiphytes.

The protected part of crown and it is dominant zone of Epiphytes.

Driest upper part of the crown, with flat crust forming lichens.

Moist lower part of the trunk with best growth of lichens and mosses.

Trunk base with buttresses with moist shadowy holes with abundant moss growth.

Temperature inside and outside the forest:

A temperature fluctuation inside the tropical rainforest is diurnal. The temperature in the forest is usually ~7 to 10°C less than that of outside. In plants, biochemical reactions at various heights, oxidation of humus through nitrate concentration varies due to temperature variations. Inside the forest, the temperature at depths between 5~40 cm is rarely lower than 23°C (Schulz, 1960). Therefore, all reactions in the soil, like root function, decomposition of organic matter or activities of the soil fauna, will be disturbed if normal conditions are altered such as opening of forest cover (Jacobs, 1981).

1.1 **Lion Tailed Macaques (LTM):**

Lion tailed macaques belong to the Order-Primate (Gray, 1821), Family- Cercopithecidae (Gray, 1821) and Genus- Macaca (Linnaeus, 1758).

Genus	**Species**	**Family**	**Diploid Chromosome no.**
M. silenus	Macaca silenus (Linnaeus)	Cecopithecidae	42(Bender & Chu, 1963; Napier & Napier, 1967)

LTM belong to the Family Cercopithecidae, Subfamily Cercopithecinae. They are usually sexually dimorphic animals inhabiting a variety of habitats with an equal variety in diet. The monkey live in multimale, multifemale troops of usually ~10 to 20 animals, although troop size may vary from ~4 to 30 individuals (Roonwal and Mohnot, 1977). The dominant or largest male leads the group yet remains apart from it (Sugiiyama, 1968)(G.Mitchell & J.Erwin, 1986). They are handsome animals with full, almost white lion-like facial ruff or mane, may be called "Lion monkey"- the translation of the Sanskrit name Singalika. The tuft on the tail is found consistently only in adult males, developing with sexual maturation. Few female adults' tails are tufted. The ruff characterises all members of this species, first appearing on youngsters of 5 to 6 month's of age. Infants look like other macaque species, a dark dingy gray-brown. Adult males are larger than females, but are still among the smaller macaques, averaging about 55 cm in body length and 8 kg in weight.

It is considered as an *indicator* species. It is arboreal and obligate evergreen forest species, which feed on fruits and insects. (Krishnamurthy and Kioster, 1998). Lion Tailed Macaque (Macaca silenus) lives only in the Western Ghats Mountains of South India, in the tropical rainforest called Shola. Although sometimes mislabelled with a Sinhalese-name for Langur, "Waterloo", the Lion Tailed Macaque has never occurred in Sri Lanka except as introduced commercially. It is one of India's most endangered species. Their numbers have been so reduced by habitat fragmentation, human population pressures and hunting (legal and illegal) that extinction is imminent. The immediate measures to preserve them are to protect and preserve their natural habitats and to protect the monkeys.

In the IUCN Mammal Red Data Book - 76E (endangered) Macaca silenus, common name is Lion tailed macaque. It is endangered (E) taxa, which is in danger of extinction, i.e., whose survival is unlikely if the causal factors continue to operate. Included are taxa whose numbers have been so drastically reduced that they are deemed to be in immediate danger of extinction. It has also been listed in Appendix 1 of CITES (Convention on International Trade in Endangered Species of wild fauna and flora) which is exactly the same list of July 29,1983 CITES list. (G.Miechell & J.Erwin, 1986). It is protected under Indian Wildlife protection act 1972 (SCHEDULE – I: Rare and endangered species which are totally protected).

The LTM is a seriously endangered species and its total world population in nature has been variously estimated from 405(Green and Minkowki, 1977), to over 1200. Ali (1985) estimates its current minimum population at 915. Recent studies indicate population of 3,000 (Karanth 1985). The LTM are endemic lives only in the evergreen monsoon forests. It is highly susceptible to logging, disturbances and the conversion of natural

forests to teak plantations. First of all, the primatological community has drawn both national and international attention to the plight of Lion tails, and this has resulted in definite conservation measures. The late prime minister of India, Smt. Indira Gandhi, acutely aware of its precarious status, enlarged Anamallai Wildlife sanctuary and relocated several villages to provide more security for groups in that area and also stopped a large-scale hydroelectric scheme at Silent Valley, a primary forest area in Kerala Border a prime habitat of LTM. One of the major problems in the conservation of this species has been the *low rate* of reproduction in natural and captive populations (Green and Minkowki, 1977; Lindberg, 1980a, b). The genetic and behavioural suitability of captive-born individuals for reintroduction scheme is also another major concern if these individuals are to contribute to the maintenance of wild populations (Kurt Benirschke, 1986). Long time study (local people) or continuous studies of two identifiable troops of Lion tailed macaques for a 19 month-period concede that the survival of this species depends on its access to a very large and continuous expanse of undisturbed rainforest. (Steven and Karen, 1977). The reason for its present endangered condition is due to the loss of habitats, due to deforestation, forest fragmentation (primary threat) and human-caused disturbance (encroachment and hunting, etc)

1.1.1 **Habitat and distribution:**

Lion tailed macaques have been sighted in the Anshighat, Jog Falls, Siddapur, Hulekal, Gerusoppa forest ranges and Mastimane Ghat of North-western Karnataka. They range mainly through mature forests. In Western Ghats, over 50% of the population is distributed in habitat fragments within <20 km^2. In Karnataka, the habitat of Lion tailed macaque (including most of the study areas) is now within the reserved forests; providing habitat protection,– where still attempts have to be made to include more areas under reserved forest (Krishnamurthy and Kioster, 1998). Another habitat is Agastyamalai (Southern most part of Western Ghats). They are found only in fragmented patches within its former range.

The Ashambu hill is located between latitude of 8º32' to 8º 38' (N) where these animals are found. Other localities like Nilgiris, and Anamalais hills (11º30') have similar requirements for their survival. Further north in Karnataka, the rainforest structure differs floristically. The canopy, here, is generally abundant with Dipterocarpus i.e., Lion tailed macaques are in less density.

Remnant patches of shola forest found in sheltered sites along watercourses among hills, generally used to connote any of the wet broad-leaved evergreen forest formation in Western Ghats. Annual rainfall of the areas is >175cm and < 250cm. Luxurious growth is at the altitude of 500 to1500 m. <300 to 600 m rainforests grade into low-lying moist deciduous types. Above 1500 to1800 m in altitude, it is Stunted Montane forest. Lion

tailed macaques stay in lofty dense evergreen forests, which have a large number of tree species of heights 30 to less than 50m forming dense canopies. Majority of the trees have large simple leaves, giant climbers, epiphytic ferns, mosses and orchids, which are numerous at all levels of forest from canopy to floor. Woody under storeys have saplings, smaller species of trees, shrubs, cane or bamboo-like reeds. Except ravines, there is an undergrowth-free of herbaceous plants.

The diet for Macaques in general: LTM's diet varies from month to month but the tree species *Cullenia exarillata* and *Artocarpus heterophylus* (Jack fruit) are important year-round food. Recent field studies on other Macaques have showed that they are prominently fruitivorous (M.silenus, Green & Minkowski, 1977). Soil ingestion by Macaques was noted by Eudey (1978) and Lidberg (1977), which possibly provide nutritious elements to the diet and influence digestion (Donald G. Lindberg, 1980). They obtain their food from diverse undisturbed mature rainforest trees. They eat fruits of the top and the second storey of trees. They use every stratum of the forest and they consume flowers, fruits of climbers, small trees, and shrubs, leaves of reeds, grass and sedges. They also eat insects of specific life stages like adults, pupae and larvae, lizards and tree frogs; fungi are gleaned from foliage, exposed and snatched from inside dead wood, plucked underneath bark and rotting log falls.

Scattered aggregation of LTM's along tree species during various months are:

March and April: Syzigium species, which grows on ridges and higher slopes.

May: Litsea wighitiata, which grows on steep valleys and reeds, breaks along stream banks.

June: Shallow wet soil at the base of precipitous cliffs, where later, ripening aggregation of Litsea sp. occurs.

July and August: LTM cover another area where there are gentle slopes and wide valleys with numerous trees like the fruiting Artocarpus are found. One of the most important things is that LTM's diet varies in composition throughout the year.

1.1.2 **Home range:**

It ranges for over 5 km^2 (Minkowski, 1977) of continuous rainforest in a year (in 1974 and 1975, the monkeys' home range extended still further (O. Michael and J.F. Cates)). Each troop's range includes perennial water resources. (Steven and Karen, 1977), moreover, they spend less than 1% of their time on the ground. Some arboreal forest animals have greater home range sizes. Grein & Minkowski (1977) give a figure of about 5 km^2 for Macaca silenus.

Macaques are housed in pairs or in family groups (Crandall, 1964; Yadav, 1971), unimale groups (Kitchener, 1975~1976; Sargerson, 1977; Vreesvijik & Koning, 1978, Klos, 1981), and multimale/multifemale groups (Chance, 1956;Dumond, 1967;Gledhill, 1972; Desai and Malhotra, 1976; Deag, 1977; Vreeswijk and Koning, 1978; Kleiman, 1980; Klos, 1981), Though infants have been produced in groups of different sizes, both Gledhillm 1972; Kleiman, 1980, report that more than one male is needed in a group to stimulate breeding.

Competition: Food competitors for these animals are mainly arboreal mammals, namely, Nilgiri langur (presbytis johinii) and Malabar giant squerrel(Ratufa indicca).

Predation: Its terrestrial predators are Leopard, Dhole (Wild dog) including humans.

Disease: an introduction of disease causing viruses, bacteria and parasites may lead to the death of the animal.

1.1.3 **Evolution**

Male and female genital morphology seen in the silenus-sylvanus group of macaque species is ancestor for the genus. Considering this evidence along the date of early entry of macaques into Europe, it is apparent that they are related to M.sylvanus, however, it seems that this species is more *distinct*. It is linked to M.silenus and its relatives (Fooden, 1975) essentially by retention of similar ancestral conditions, and not by any shared or derived states, which would uphold its placement within the same species group. It may thus be tentatively recognised as a separate group.

After its origin in northern Africa, early macaques spread into Eurasia. One group entered southern Europe, where they are recognised as a succession of temporal sub species of *Macaca sylvanus*. A second group of macaques moved eastward, reaching India by the later Pliocene epoch. This group, like early M. sylvanus, would have been *long-tailed*, with *silenus*-type reproductive organs. The ancestral species probably spread from southern India, along the coast towards inland to Burma and into Malaya. As in Europe, climatic fluctuations affected Southern Asia and "Sundaland" (a collective term for Indonesia and the neighbouring margins of the Sunda shelf, see Medway, 1970). Brandon –Jones and Heiiemae (unpublished one) suggested that cool or arid phases (linked to drops in sea-level and thus to island connections, permitted migration of suitably adapted species) have led to restriction of forest in relict areas within this region (Eudy). Such phases would have altered several times during the past 2 million years and more rapidly after 0.5 million years with episodes of warmer and moist climate during which islands and their species were isolated from one another. The timing of this oscillation is quite unclear, but the relative sequence of evolutionary events postulated for macaca is

estimated to be in best agreement with the underlying philosophy of known fossils and rare biogeographic evidence (suggested by Brandon-Jones and Hiiemae in the past). With alarming climatic amelioration and decay, several Asian macaque groups came into contact and competition. Long tailed early sinica group populations moved toward south and went into peninsular India, perhaps strongly competing with indigenous M.silenus. The sinica group was also moved toward China where they would have become larger or shorter-tailed. Later, M.silenus may have been restricted to its present south West Indian relict distribution, while the northern and southern members of the sinica group may have become partly and generally isolated.

Dispersal of species in Asia

Silenus-sylvanus group: The distinct distribution of extant species extends from the Atlas Mountains of North Africa eastward to Sulawesi, suggesting that the silenus-sylvanus group of macaques experienced the earliest dispersal throughout Asia (Fooden, 1975).

Fooden (1975) infers primarily for tail length and secondarily from skull morphology that Macaca silenus is morphologically most similar to the ancestral population of the Asian sector of the silenus-sylvanus group. Today M. silenus is reduced to a relic population with perhaps no more than 800 individuals in south Indian higher ranges (Mohnotr, 1976). Fooden considers that the M. silenus subgroup originated in peninsular India from where it dispersed northward to reach continental and subsequently insular Southeast Asia. According to Fooden (1975), the initial dispersal northward may have provided the impetus for tail reduction that expresses itself in a west to east gradient in the subgroup. At present, a gap of about 2000 km separates M.silenus in peninsular India from M.nemestrina leonina in Assam and Burma. M.silanus may have been driven to refugium in south India from which it did not recover due to the subsequent expansion of M. radiata in Peninsular India. The dispersal of the silenus group to the major islands of Indonasia, the Mentawai Islands and Sulawesi appears to be intimately associated with the glacial phenomena on Sundaland. The Sunda shelf or Sundaland is that area of the present sea floor in the western part of the East Indian archipelago, which emerged from the sea during the Pleistocene glacial maxima (Donald G. Lindberg, 1980).

1.1.4 **Threats:**

Analysis showed various patterns of habitat fragments like linear strips, semi circular and irregular polygons. For example, forest fragmentation concentrated around areas where previously disturbance had occurred, like, the presence of several human habitations within lion tailed macaque's habitat, and the expansion of human population (Krishnamurthy and Kiester, 1998). Activities of these animals are limited in hillsides, and they may less extensively invade the habitats within Shola on a seasonal basis, seeking fruits of gregarious palm (Bentinckia coddapanna), which grows on the narrow

edges of rocky precipices in the southern most Ghats. They also make brief seasonal excursions into the low-lying semi-evergreen areas. The lowest zone is the heaviest hunting zone, thus, they need to be protected. One troop on the Sharavati river north bank (Uttara Kannada district, Karnataka) is most frequently observable.

Hunting: This animal is being hunted for

1. food
2. as a source of medicinal products; this use of primates is closely related to hunting for food (and may be nothing more than a by-product of such hunting), which involves the use of certain body parts for their supposed medicinal value. For example, in South India, the meat of LTM is said to have an aphrodisiac value with other medicinal properties.
3. LTM occurs in less diverse primate faunal areas and require special conservation measures of their own (G. Mitchell &. Erwin, 1986), which is seldom considered, making them more viable to be hunted.

The conversion of forest into another land use or the long-term reduction of the tree canopy cover (below 10% threshold) results in the loss of vegetation cover. Deforestation implies to the long-term or permanent loss of forest cover transforming it into another land use. Such a loss can only be caused and maintained by a continued human-induced or natural perturbation. Deforestation includes areas of forest converted to agriculture, pasture, water reservoirs and urban areas. The term specifically excludes areas where the trees have been removed as a result of harvesting or logging, and where the forest is expected to regenerate naturally or with the aid of silvi-cultural measures. Unless logging is followed by the clearing of the remaining logged-over forest for the introduction of alternative land uses, or the maintenance of the clearings through continued disturbance, forests commonly regenerate, although often to a different, secondary condition. In areas of shifting agriculture, forest, forest fallow and agricultural lands appear in a dynamic pattern where deforestation and the return of forest occur frequently in small patches. To simplify reporting of such areas, the net change over a larger area is typically used. Deforestation also includes areas where, for example, the impact of disturbance, over utilisation or changing environmental conditions affect the forest to an extent that it cannot sustain a tree cover above the 10 percent threshold.

1.2 **Fragmentation**

Fragmentation is the breaking up of a habitat or land type into smaller parcels (Forman, 1995). It is implicit that the pieces are somewhat widely and usually unevenly separated. Carving up or subdividing an area with equal width lines is dissection. Dissection could be considered as a special case of fragmentation. Alternatively, the fragmentation concept has been used in a narrower sense, of being essentially the combination of '*habitat* loss'

and *'isolation'*. However, both habitat loss and isolation increase with all these fragmentation processes. Furthermore, habitat loss can take place with or without fragmentation and likewise it can happen in isolation too. In essence, habitat loss and isolation are both useful concepts but different and broader in meaning than fragmentation. Many additional spatial and ecological characteristics result from or are correlated with fragmentation. (Forman, 1997)

Fragmentation is caused by natural processes as well as human activities. For example, herbivore population explosions could break a continuous habitat into small patches just as effectively as logging and suburbanisation. Some human activities cause fragmentation, whereas others, such as the spread of irrigation or severe degradation due to overgrazing typically change the land *without* fragmentation.

Furthermore, each mechanism operates at a range of scales. Thus, a nesting of fragment sizes over a range of scales is probably a normal result of land fragmentation. The finer scale pattern of habitat fragments is suggested to be especially detrimental to small organisms, specialist species, and ecosystem functions. Finally, it warrants emphasis that scattered patches result from several mechanisms.

- fragmentation of *previously continuous* habitat.
- a patchy substrate of different soils and slopes.

Alternatively, scattered patches may be due to colonisation into new separate locations. Thus, climate in short, fragmentation is one of several important spatial processes in land transformation. Space, species, and other parameters introduced below result from this process.

Two types of spatial processes are categorised in one category are roads, railroads, power lines wind breaks, etc. and in the other category are logged clearings, cultivated fields, hosing tracts, pastures, and the alike. The ecological effects of dissection and fragmentation may be similar, or highly dissimilar, depending on whether the dissecting corridor is a barrier to movement of the species or otherwise a different process is involved.

Fragmentation affects either the whole area or a patch within it. Patch number or density in the landscape increases with fragmentation, average patch size decreases with it and the total amount of interior habitat normally drops with it. Connectivity across the area in continuous corridors or matrix typically decreases with fragmentation.

Other spatial processes include *Perforation*, which means the process of making holes in an object such as a habitat or land type. An extensive forest is perforated by logged or blow down clearings, and a desert-grassland is perforated by scattered or clustered

houses. *Shrinkage* means the decrease in size of objects, such as patches. For instance, remnant woodlots shrink as portions are removed for farming or building houses. *Attrition* means the disappearance of objects like patches and corridors. Usually, small patches disappear, although the occasional disappearance of large patches is apt to be especially ecologically significant (Forman, 1997).

Fragmentation is considered to have two components:

1) Reduction of the total extent of habitat type, or perhaps of all natural habitats in a landscape; and
2) Apportionment of the remaining habitat into smaller and more isolated patches.

Habitat fragmentation occurs when human development or some other force eliminates large areas of contiguous natural habitat, leaving habitat "*islands*" thereby conforming that the remaining species of plants and animals are left in a limited space, *isolated* from other similar communities and habitats. Examples of this condition are natural spaces (parks or undeveloped lots) that are surrounded by urban infrastructure, remnant patches of wilderness that are left when a forest is cleared for farming, or elevated terrestrial habitats that suddenly become scattered islands when a landscape is flooded. While some plant and animal species initially remain on the habitat fragments, the long-term stability of the isolated ecosystems is in question. Habitat fragmentation is a pervasive problem that has generally been recognised as the *primary cause* of the loss of biodiversity. Understanding fragmentation processes and its effects has a vast practical importance with respect to sustainable use of forest ecosystems and sustaining wildlife populations.

A decrease in the overall area of habitat is quite serious, but when combined with fragmentation, it can undermine the integrity of all ecosystems. Roads, urbanisation and agriculture are among the main human activities, which break up natural areas, often with disastrous implications for flora and fauna. The frequency of occurrence and its long lasting effects are also difficult to reverse. The results of this include inadequate forest interior for edge sensitive species, inadequate size of contiguous forest for area sensitive species, inability of some forest species populations to receive and provide genetic material to other isolated populations. This affects animals as it leads to changes in behaviour of animals, decrease in reproductive fitness (inbreeding), and possibility of extinction of keystone species, which could be fatal on the environment. Also fragmentation affects plants, as they are susceptible to extinction through biomass loss, and decimation of tree communities and disruption of species distribution, i.e., their interdependence, disruption of symbiotic relationships. Fragmentation specifically causes an increase in emission levels of greenhouse gases as it has been shown that certain types of man made fragmentations in central America are more detrimental to the environment because they show a greater increase in greenhouse gas emissions (Radzicki, 2002).

1.2.1 **Species most vulnerable to habitat fragmentation**

a. Rare species
b. Species with a large home range
c. Species with limited dispersal
d. Species with low reproductive potential
e. Species with short life cycles
f. Species depending on resources that are unpredictable in time or space
g. Ground nesting birds
h. Species of interior habitats
i. Species exploited or persecuted by people

1.2.2 **Consequences of habitat fragmentation:**

Biotic: isolation, edge effects
Abiotic: sunlight, temperature, wind and water flux

Biotic

i) Isolation has the following elements

· time since isolation;
· distance from other remnants (MacArthur and Wilson 1963);
· size (MacArthur and Wilson 1963);
· connectivity;
· surrounding landscape;
· changes in dispersion;
· shifts in abundance patterns to favour weedy species;
· changes in species composition:
· extinction of native species,
· colonisation by invaders;
· changes in gene frequencies (heterogozygosity decrease).

ii) Edge effects are characterised by:

· ecological trap;
· nest predation;
· increased species diversity;
· elimination of interior species;
· shape.

Abiotic

i) Sunlight increase

· shade tolerant species move to interior;

· pioneer species invade edges;
· changes in temperature and water regimes;

ii) temperature fluctuations increase

· daytime temperature is higher => increased transpiration
· night temperature is lower => behavioural changes

iii) impact of wind increases

· higher evapotranspiration => changes in nutrient status in soil (add biomass)
· damage to existing vegetation => creation of gaps (pioneer species invade)

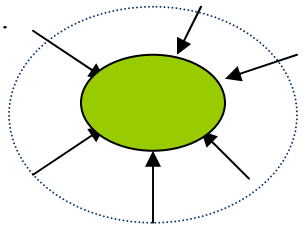
iv) changes in water flux

· rainfall interception; evapotranspiration; increased surface and ground water flows

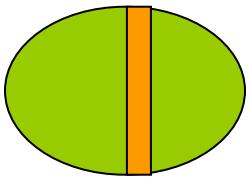
Habitat fragmentation, or the subdivision of a continuous habitat into smaller patches, has three components, viz., direct removal of suitable habitat, reduction in patch size, and increasing isolation of the remaining patches (Andren, 1994).

There are three types of habitat fragmentations: regressive type, divisive type and intrusive type.

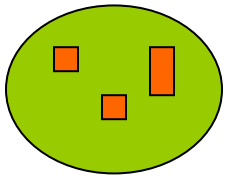
1. Regressive type: an area of a land is decreased due to the reduction of the size of the area.
2. Divisive type: an area of a land is divided into two halves (could be due to a road passing through the area).
3. Intrusive type: a few patches of fragme nted areas inside the land.

1. 

Regressive type

2. 

Divisive type

3. 

Intrusive type

A range of techniques could be adopted to increase the connectivity in fragmented landscapes. These include creating corridors, buffers and stepping-stones to aid the movement of different organisms. Stepping-stones are patches of habitat, which ease movement through the landscape without necessarily creating direct links. Buffer zones around woodlands may help to reduce the edge effect, and protect the interior of the woods from disturbances caused by activities such as agrochemical applications on an adjacent land. Additional solutions include creating a matrix of other semi-natural habitats such as scrubland, which may still be favourable to some woodland fauna. Species-specific links, such as badger tunnels and *aerial runways* for squirrels, are also

used to help these animals to negotiate roads. There is a "Time lag" in the effects of fragmentation since some of such effects may not come apparent for decades or centuries, like certain ecological processes (nutrient cycling, soil formation, etc.), and the ability of species in isolated fragments to track changes in habitat conditions related to changing climate.

2.0 **OBJECTIVES:** Objectives of this investigation are

i. Mapping the distribution of Lion Tailed Macaque in Sharavathi River Basin.
ii. To identify the habitats preferred by LTM.
iii. To identify its foraging plants within the habitat.
iv. Analysis of habitat status in relation to the survival of LTM.
v. To evolve strategy for conserving endangered endemic Sharavathi River Basin Fauna.

3.0 **STUDY AREA:**

Sharavathi river basin, Central Western Ghats was chosen to study the status of native tree species, habitat of endemic Lion tailed macaque (LTM) and for evolving strategies to conserve threatened species of flora and fauna. Energy and Wetlands Research Group (EWRG) at Centre for Ecological Sciences (CES), Indian Institute of Sciences (IISc) with research facilities has been carrying out conservation research in the Sharavathi river basin (Figure 2 and 3). This study focuses mainly on LTM's, habitat condition and conservation and management aspects of the fragile ecosystems in Sharavathi river basin.

3.1 **The Sharavathi River Basin:** Sharavathi River is one of the important west flowing rivers of Karnataka. The river originates near Ambutirtha village, Tirthahalli Taluk of Shimoga district at an elevation of about 730 m and runs through the districts of Shimoga and Uttara Kannada (Figure 3). At Jog, the river drops precipitously from a height of 253 m into a deep gorge creating, one of the most spectacular scenes of the Western Ghats. The major tributaries of the river are, Nandiholé, Haridravathi, Sharmanavathi, Hilkunjiholé, Nagodiholé, Hurliholé, Yenneholé, Mavinaholé, Gundabalaholé, Kalkatteholé and Kandodiholé. The total catchment area of the river up to Honnavar is 3600 km^2 where it joins the Arabian Sea. The entire catchment is very steep and thickly wooded.

The river basin has been harnessed for hydroelectric power projects to its fullest potential. The Mahatma Gandhi Hydroelectric Project was commissioned in 1948. This was followed by Sharavathi Generating Station commissioned in 1964-65, Linganamakki

Dam Power House and the Sharavathi Tail Race Project at Gersusoppa in 2002. These account for about 45% of the total installed capacity of hydroelectric power in the state. Sharavathi River alone, in its fullest potential, accounts for an estimated electricity generation of about 6,000 million units (kWh) per annum (Ramachandra et al., 2007).

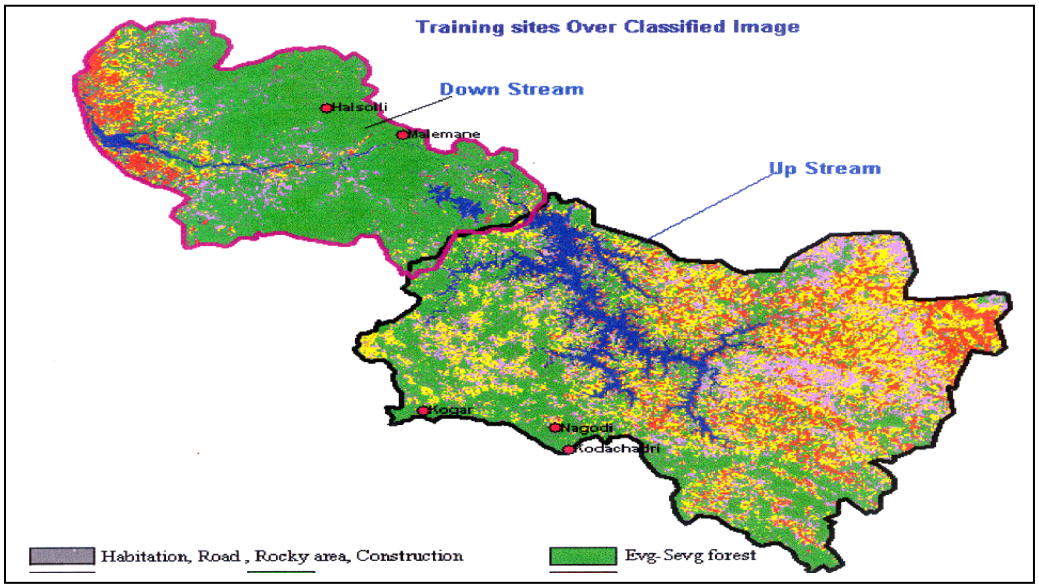


Figure 2: Sharavathi river basin (with sampling points)

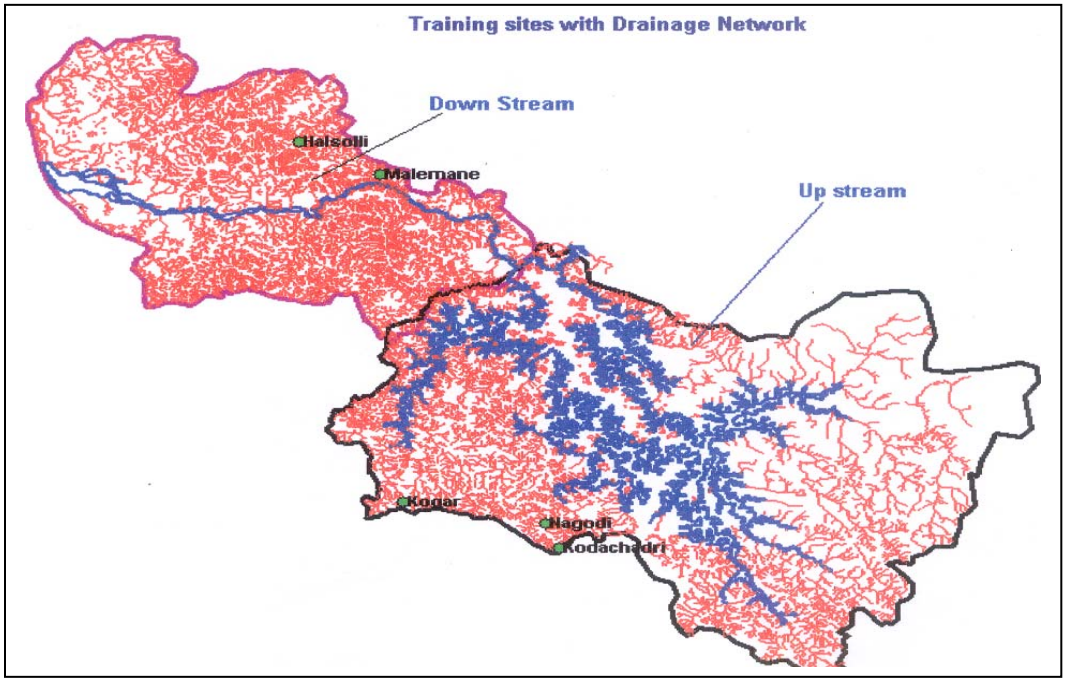


Figure 3: Drainage network (Sharavathi river basin)

The river water is stored in three major reservoirs, at Linganamakki (14º10'24" N, 74º50'54" E), Talakalale (14º11'10" N, 74º46'55" E) and Gerusoppa (14º15'N, 74º39' E). The areas submerged for these reservoirs are 326.34, 7.77 and 5.96 km^2 respectively. The Linganamakki reservoir resulted in the full or partial submergence of 99 villages in the Sagar and 76 villages in the Hosanagar Taluk of Shimoga district, also causing the displacement of 12,000 people. The Talakalale reservoir resulted in the full or partial submergence of 3 villages in the Sagar Taluk. Gerusoppa reservoir lead to the submergence of 5.96 km^2 of tropical evergreen to semi-evergreen forests. Additionally, for the Sharavathi Tail Race Project, 4.72 km^2 of forest and 0.08 km^2 of other lands were also acquired for township, roads, etc. (Ramachandra and Subash Chandran, 2003) The entire Sharavathi river basin along its upstream and downstream comprises of the Linganamakki Dam/ Reservoir and Gerusoppa Dam/Reservoir respectively.

Hydro meteorological characteristics of Sharavathi River Basin:

Temperature and Humidity: Relative humidity is generally high at around 75% during southwest monsoon season and moderate during the rest of the year. Humidity during summer afternoons is relatively lower. Average minimum and maximum temperature is about 15 to 38ºC.

Wind: Wind is generally moderate with some increase in strength in monsoon months. From May to September, winds are mainly southwesterly or westerly and on some afternoons, northwesterly. Northeasterly and easterly winds appear in October and predominate till the end of January. There is a gradual shift of winds in a clock-wise direction from February. By April, the wind is mainly southwesterly in the mornings and partially northeasterly and southeasterly in the afternoons.

Linganamakki Dam: The Linganamakki reservoir has a catchment area of nearly 1991 km^2. It receives water mainly from rainfall and also from the Chakra and Savahaklu reservoirs, which are linked to Linganamakki through a canal. The water from the reservoir flows to Talakalale, balancing the reservoir through a trapezoidal canal with a discharge capacity of 175.56 m^3. The length of this channel is about 4318.40 m with a submergence of 7.77 km^2. It has a catchment area of about 46.60 km^2. The gross capacity of the reservoir is 129.60 m^3 (Ramachandra and Subash Chandran, 2003).

Gerusoppa Dam: Sharavathi River with tailrace water of Mahatma Gandhi Hydel Station is carried by Sharavathi river to Gerusoppa Dam, which is built on this river. The dam is 58 m high, 423 m long, made of concrete with gross storage of 150 M.cum. The Gerusoppa Dam (in Honnavara Taluk of Uttara Kannada district) lies between Latitude 14º14'30"(N) and Longitude 74º37'15"(E). For a better understanding of the details of Shimoga and Uttara Kannada districts are included in the Annexure (annexure 1) as Sharavathi River Basin falls in these two districts.

4.0 METHOD

This involved the following tasks:

i. *Exploratory survey:* It was carried out throughout the river basin to find out the habitats preferred by Lion Tailed Macaque (LTM) and the catchment status.
ii. Consultation with the experts and local people.
iii. Mapping its distribution with the help of GPS in the field
iv. Analyses of entire catchment using already classified remote sensing data (supervised classification)

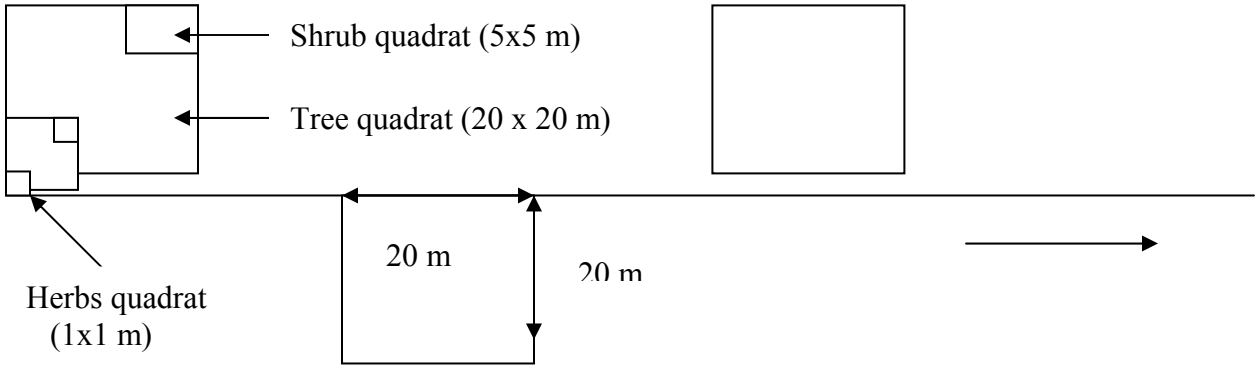
General forest types and classification:

Plant identification using standard keys from published literature on flora

Survey	**Method**
Mapping of LTM distribution in the Sharavathi River Basin	Transect based sampling - using binoculars, GPS and maps
Habitat Identification	Field visits – reconnaissance survey
Vegetation Sampling	Transect based Quadrat method
Vegetation Identification ✓ Phenological, Morphological ✓ Physiological, Anatomical.	Fieldwork, Literature, Consultation with the experts and Local people.
General information about LTM	Literature
Identification of the Animal	Field visits
Conservation of the animal	Literature, fieldwork, data analyses in consultation with experts

Vegetation sampling in the Sharavathi river basin: The methodology used for sampling the vegetation is a combination of transects (line laid from a point considering all elevation) with quadrats (for recording ground vegetation) as shown in the Figure 4. Transect has to be flexible so that one does not leave the course of the stream. It may even be sinuous. Along the transect, quadrats of 20x20 m^2 are laid to enumerate all the trees (which are 30 cm or more in GBH). The girth was measured at 130 cms. For each tree, the approximate height is estimated visually in metres (m). The climbers associated with the trees were noted although there was further survey to identify some of them. The inter-quadrat distance kept was normally 20 m. Larger area was sampled using more number of quadrats (5 quadrats were laid on the right and left hand side, alternatively) maintaining inter-quadrat distance of approx. 20 m.

Figure 4: Transect based quadrats



i. ***Ground vegetation***: The ground layer of plants, the plants of 1m or more in height but having GBH <30 cm, were sampled using 2 sub-quadrats of 5x5 m^2 each, located within the tree quadrat as shown in the Figure 4. Within the 5x5 m^2 quadrats, 2 sub-quadrats of 1x1 m^2 were placed, as shown in the Figure, for sampling the diversity of herb layer of plants less than 1m in height.

ii. ***The herb layer:*** The herb layer of plants (<1m in ht.) within each of these 5x5 m^2 sub-samples were enumerated in 2 sub-quadrats of 1x1 m^2 each, also placed diagonally towards two of the corners of the 5x5 m^2 quadrat as shown in the Figure. All plants within the herb layer quadrats, including Pteridophytes and seedlings of trees were enumerated and identified as far as possible.

iii. ***Estimation of Canopy Cover:*** The nature of canopy cover within each quadrat of 20x20 m^2 has been noted at different points, one point being in the centre of the quadrat. The canopy cover is ranked as 0, 1, 2 and 3.

iv. ***Estimating Community Parameters:*** Species diversity is one of the most obvious and characteristic features of a community. From the earliest observations of rich diversity of tropical communities in comparison with impoverished polar communities, ecologists have tried to quantify the diversity concept.

Species Diversity*:* Diversity consists of two components—variety and relative abundance of species (species richness).

i) ***The diversity measurement:*** Species richness is used because it may only be one component of diversity but it is relatively simple to measure, and it has been successful in many studies. Moreover, species diversity measurement is more informative than species alone. (Anne E. Magurran, 1988). Diversity of tree

species has been estimated using Shannon-Weiner's and Simpson's methods (Krebs, 1985).

a) **Species richness:** This is the oldest and the simplest concept of species diversity—the number of species in the community. The basic measurement problem is that it is often not possible to enumerate the entire species in a natural community.

b) **Heterogeneity:** Simpson (1949), who proposed the second concept of diversity, combines two separate ideas, species richness and evenness. In a forest with 10 equally abundant tree species, two trees picked at random are likely to be different species. But in a forest with 10 species, one of which is dominant and contains 99% of all the individuals, two trees picked at random are unlikely to be different species (Krebs, 1989). The term heterogeneity was first applied to this concept by Good (1953) and for many ecologists this concept is synonymous with diversity (Hurlbert, 1971).

c) **Shannon-Wiener's Index, H:** A measure of a community's diversity is simply the number of species it contains; say s. this is, however, an unweighed measure analogous to the range of a qualitative variety. To arrive at a weighed measure, i.e., one takes an account of the relative quantities of the species. The appropriate functions of Pi (i = 1…s), where Pi is the proportion of the community belonging to the i^{th} species. The desirable proportion for H is as follows:

   For a given s, H* should have its greatest value when Pi=1/s for all i. Such community will be called completely even.

   Given the two completely even community s, one with s species and other with s+1, the latter should have greater H*. Proportion '1' ensures that an 'even' community shall have a greater index of diversity than one in which, though the number of species is the same, the community is dominated by one or a few of them in which case its diversity in the intuitive sense would be less. The function of Pi, which satisfy this property is given by (Bhat, Prasad, Hedge, Saldanha, 1986)

$$H^* = \Sigma Pi \log Pi$$

   It assumes that individuals are randomly sampled from an "indefinitely large" (i.e., an effectively infinite) population (Pielou, 1975). In practice, error is significant (Peet, 1974). The value of index falls between 1.5 and 3.5 and rarely surpasses 4.5 (Margalef, 1972).

d) **Species Dominance**: This is a measure of concentration and is given by

$$\sum Pi^2 = \lambda$$

λ is the probability that any two individuals picked independently and at random from the community will belong to the same species. This measure is the property, which is the opposite of diversity. Thus, lower the λ, higher the diversity. This suggests the use of some function that increases with decreasing λ as an index. Negative of dominance or concentration =1- λ or 1/λ. This *Simpson's* index (1- λ) ranges form zero (low diversity) to almost 1 (Krebs, 1989).

ii) ***Importance value index (IVI):*** It is a statistical quantity, which gives an overall picture of the importance of the species in the community. It considers the relative values of the density, frequency and basal area in a given sample (Subash, Divakar and Naik, 1999). IVI is given by

IVI = Relative Density + Relative Frequency + Relative Basal Area

The measurement of diversity requires knowledge of taxonomic classification. Diversity measures require an estimate of species importance in the community.

5.0 **RESULTS AND DISCUSSION**

Two locations namely Malemane and Kanoor, were chosen for the following reasons:

i. Representative sampling sites based on preliminary results of exploratory survey.
ii. Both the locations have similar conditions, i.e., both have secondary and disturbed evergreen to semi-evergreen forests.
iii. Spotted Lion Tailed Macaques at Malemane.

Line transects method was adopted for sampling the flora. The species diversity indices for flora such as Shannon-Weiner, Simpson's indices were computed for each sampling site. The indices calculated were for trees of >10 cm in circumference at a height of 130 cms from ground level. The samples in the 20 m x 20 m quadrats were again subjected to computation of diversity indices, and are listed in Table 1. Malemane with H' = 3.25 and Kanoor H' = 3.06 indicates higher diversity. Simpson's index also confirms this result as it ranged from 0.95017 (Malemane) and 0.93413 (Kanoor).

Table 1: Diversity indices and other details for Malemane and Kanoor forest samples.

Locality	**totwg**	**tot.evg**	**tot.ind**	**tot.spp**	**tot.ba**	**Sps.richness**	**Shannon**	**sim-dom**	**sim-div**	**Pielou**
Malemane	17	37	169	38	9.784	7.213	3.259	0.050	0.950	0.896
Kanoor	13	24	94	32	8.145	6.823	3.064	0.066	0.934	0.884

Important Value Index is computed for both the locations. Malemane (Table 2) and Kanoor (Table 3) show the following results: At Malemane, IVI ranges from 1.412(the lowest) to 25.425 (the highest) and this data depicts that almost all the tree species such as *Knema attenuata*, *Aglaia species1*, *Dipterocarpus indicus*, *Callophyllum tomemtosum*, *Myristica dactiloids*, *Syzygium gardineri*, *Drypeles elata*, *Holigarna grahmii*, *Aglaia species2*, *Litsea species1*, *Olea dioica*, *Litsea species2*, *Palaquium ellipticum*, *Hopea ponga*, *Garcinia morella*, *Myristica malabarica*, *Holigarna ferruginea*, *Garcinia cambogea*, *Beilschmedia fagifolia*, *Aglaia anamallayana*, *Elaeocarpus tuberculatus*, *Nothopegia colebrookeana*, *Diospyros saldanhae*, *Unidentified species*(*UI*), *Syzygium species1*, *Dimocarpus longan*, *Holigarna arnottiana*, *Cassine glauca*, *Elaeocarpus serratus*, *Actinodaphne hookeri*, *UI3*, *Syzygium species2*, *Mangifera indica*, *Aglaia species3*, *Macaranga peltata*, *Microtropis wallichiana*, *Syzygium species3 and Vepris bilocularis* are evenly distributed.

Table 3 lists IVI for Kanoor, which ranges from 2.830 to 37.043 and the forest is mainly dominated by a few species like *Bischopia javanica*, *Lagerstroemia microcarpa* and *Olea dioica*. From this, it is evident that forests of Malemane have more endemic species than that of Kanoor. Both these sites seem to be quite similar having well-established forests and spotting of LTM at Malemane confirming the need for conservation of forest habitats with rich diversity, which would conserve endangered endemic species such as the lion tailed macaque.

Table 2: IVI for different tree species of Malemane			
Sl. No.	**Name**	**Family**	**IVI**
1	*Knema attenuata**	Myristicaceae	25.425
2	Agl sp1	Meliaceae	19.431
3	*Dipterocarpus indicus**	Dipterocarpaceae	19.220
4	*Callophyllum tomentosum*	Clusiaceae	18.220
5	*Myraistica dactyloides*	Myristicaceae	16.269
6	*Syzygium gardneri**	Myrtaceae	15.574
7	*Drypetes elata**	Euphorbiaceae	14.749
8	*Holigarna grahamii**	Anacardiaceae	14.127
9	Agl sp2	Meliaceae	13.172
10	Litsea sp1	Lauraceae	12.884
11	*Olea dioica*	Oleaceae	11.944
12	Litsea sp2	Lauraceae	11.065
13	*Palaquium ellipticum**	Saspotaceae	10.467
14	*Hopea ponga**	Dipterocarpaceae	8.707
15	*Garcinia morella*	Clusiaceae	8.691
16	*Myristica malabarica**	Myristicaceae	7.070
17	*Holigarna ferruginea**	Anacardiaceae	6.868
18	*Garcinia cambogea*	Clusiaceae	6.797
19	*Beilschmedia fagifolia*	Lauraceae	6.776
20	*Aglaia anamallayana**	Meliaceae	5.933
21	*Elaeocarpus tuberculatus*	Elaeocarpaceae	4.401
22	*Nothopegia colebrookeana**	Anacardiaceae	4.035
23	*Diospyros saldanhae**	Ebenaceae	3.996
24	UI1		3.437
25	*Syzygium sp1*	Myrtaceae	2.875
26	*Dimocarpus longan*	Sapindaceae	2.840
27	*Holigarna arnottiana**	Anacardiaceae	2.640
28	*Cassine glauca*	Celastraceae	2.267
29	*Elaeocarpus serratus*	Elaeocarpaceae	2.256
30	*Actinodaphne hookeri**	Lauraceae	2.213
31	UI3		2.212
32	*Syzygium sp2*	Myrtaceae	2.034
33	*Mangifera indica**	Anacardiaceae	2.014
34	Aglaia sp3	Meliaceae	2.008
35	*Macaranga peltata*	Euphorbiaceae	2.008
36	*Microtropis wallichiana**	Celastraceae	1.984
37	Syzygium sp3	Myrtaceae	1.979
38	*Vepris bilocularis**	Rutaceae	1.412
	* Western Ghats endemics		

Table 3: IVI for different tree species at Kanoor		
Name	**Family**	**IVI**
Bischopia javanica	Euphorbiaceae	37.04
Lagerstroemia microcarpa	Lythraceae	32.09
*Knema attenuata**	Myristicaceae	26.98
Olea dioica	Oleaceae	26.78
Aglaia sp1	Meliaceae	16.16
*Diospyros assimilis**	Ebenaceae	15.37
*Hopea ponga**	Dipterocarpaceae	12.81
Syzygium cumini	Myrtaceae	11.59
Garcinia morella	Clusiaceae	11.35
Aglaia sp2	Meliaceae	10.70
*Diospyros bourdilloni**	Ebenaceae	10.15
*Aglaia anamallayana**	Meliaceae	8.97
*Careyota urens**	Aracaceae	7.18
Syzygium sp1	Myrtaceae	7.14
Syzygium sp2	Myrtaceae	6.83
*Artocarpus hirsuitus**	Urticaceae	6.35
Litsea sp1	Lauraceae	4.75
Aporosa lindleyana	Euphorbiaceae	4.32
*Holigarna grahamii**	Anacardiaceae	4.07
Pterosperimum diversifolium	Sterculaceae	3.57
*Diospyros candolleana**	Ebenaceae	3.18
Cinnamomum zeylanicum	Lauraceae	3.13
Elaeocarpus serratus	Elaeocarpaceae	3.13
*Nothopegia colebrookeana**	Anacardiaceae	3.03
Vitex altissima	Verbanaceae	3.02
Myristica dactyloides	Myristicaceae	2.95
Persea macrantha	Lauraceae	2.96
*Holigarna ferruginea**	Anacardiaceae	2.91
*Antidesma menasu**	Euphorbiaceae	2.86
Capparidaceae member	Capparidaceae	2.85
*Dimorphocalyx beddomei**	Euphorbiaceae	2.83
Mimusops elangi	Sapotaceae	2.83
* Western Ghats endemics		

5.1 **Causes and Consequences of Fragmentation**

Human intervention in the ecosystem has resulted in erosion of biodiversity in the recent past in the river basin. The loss in biodiversity could be attributed to the habitat loss and *fragmentation* of the natural landscape. The analysis revealed extensive fragmentation in the river basin as consequences of damming the river, which include large-scale

migration, population increase, encroachment of forestlands and conversion of forestlands to agricultural lands, etc. Fragmentation has resulted in the remnant areas of native vegetation to be surrounded by matrices of agricultural, horticultural and other human impacted lands. These in turn, have important influences on the biota within the remnant patches, especially along the edges of the remnant patches as well as in the surrounding matrices. The fragmentation is fuelled by anthropogenic activities, which are degrading the forest habitat of the critical watershed areas. Such human pressures have caused the fragmentation of large, unbroken tracts of forest into, smaller isolated patches. This process has lessened the value of the forest as a habitat for many of the plant and animal species native or original to the Sharavathi River basin, from where, it is feared that many will be lost forever. These consequences vary with the distance and connectivity between the neighbouring patches. The physical distances and influences modify the size, shape and the position of the individual patches and their constituents. The characteristics of the patch along with the spatial and temporal changes in the landscape were done to quantify the extent of damages. The remote sensing data in conjunction with GIS and GPS helped in landscape characterisation. Land use changes, landscape dynamics and landscape characterisation have been analysed from patch to river basin level to understand the temporal changes due to developmental activities in the river basin. Landscape analysis, showed that the indices of shape, richness and diversity provided an additional evaluation of land cover spatial distribution within the complex mountain landscape. The landscape analysis has provided an outline of the degree of propagation of the disturbance from the non-biotic source and fragmentation. It is revealed that fragmentation has caused loss of connectivity, ecotones, corridors and the meta-population structure. A spate of construction activities in the lower catchment of Sharavathi River and ongoing and threatened fragmentation from the burgeoning human population are perilous to the habitats of several animals also(Ramachandra et al., 2007).

5.2 **Threats and Mitigation**

Mitigation measures that are to be undertaken in order to overcome devastating effects of fragmentation for conservation of biodiversity in the Sharavathi river basin include the following (Ramachandra et al., 2007):

Fragmentation caused by the submersion of vast areas and also due to biotic pressures [increasing settlement, agricultural fields, quarrying, fuel wood, fodder and NTFP (Non timber forest product) collection, encroachment, roads in reserve forests, etc.]. Land uses in the catchment were monitored for changes using temporal satellite imageries (IRS 1C data) and ground surveys. A centralised planning is necessary to maintain landscape in a desirable state.

Lopping of branches for fuel wood and collection of leaves for fodder deprives animals of their food. Joint Forest Management (JFM) committees involving local people are to be formed in the catchment area and they should be associated with future management of forest in respective village territories.

Overgrazing in the region has resulted in scarcity of resources for wild animals. Village fodder farms are to be initiated and managed to meet the needs of soil and water conservation and for other ecosystem needs.

Conversion of forests into monoculture in vast areas for commercial purposes has affected the free movement of wild animals and deprived them of food and habitat. Monoculture plantations only serve either small mammals or agricultural pests as hiding places. An action plan needs to be prepared urgently for reducing area under monoculture by introducing forest species. Moreover, conversion of plantation into natural forests is necessary for meeting other ecological requirements including enhancement of watershed value.

Fire, within limits, has an ecological role to play in the Western Ghats. But unregulated and frequent forest fires, accidental as well as intentional, have detrimental effects on the flora and fauna, and ecosystems as such. This necessitates appropriate management strategies such as creation of fire lines, restoration of evergreens, which provide greater fire immunity to the forests, adoption of a village centred fire management strategy, etc.

Theft of forest products and poaching of animals have also affected the faunal diversity. Strengthening of JFMs, creation of nature clubs in the villages, and spread of awareness can go a lopping way in controlling hunting menace. The nature club helps in the ecological and nature conservation/ awareness movements. The village based nature clubs may be associated with animal census activities and other conservation centred activities.

Regressive and intrusive fragmentation processes occurring in the region is to be controlled by removing all encroachments surrounding the interior forests and within core areas.

Threats due to divisive type of fragmentation due to roads (which are inevitable) could be overcome by planting trees, which are likely to have wide canopy on either side of the road, and by providing ladders for animals to cross from one side of the habitat to another side (bifurcated due to a road).

6.0 CONCLUSION

Endemic fauna in Western Ghats require *contiguous* habitat for survival. Study of LTM's in the Sharavathi river basin indicates that population increase and consequent anthropogenic activities, including unplanned developmental activities, are the major reasons for degradation of habitats, deforestation and consequent decline in biodiversity. The study suggests that shrinkage of habitat due to regressive, divisive and intrusive fragmentation processes in the river basin needs to be checked through appropriate restoration and management measures.

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9.0 GLOSSARY

- **Adapt (adaptation)** - to adjust to new conditions or surroundings in an effort to survive
  when our family moved to Minnesota we had to **adapt** to the cold winters.
- **Biodiversity** - the variety of plants and animals, their genetic variability, and their interrelationships and ecological processes, and the communities and landscapes in which they exist.
- **Biogeography:** the study of the geographic distributions of organisms, both past and present (Brown and Gibson 1983:557).
- **Connectivity:** a parameter of landscape function that measures the processes by which a set of populations is interconnected into a metapopulation (adapted from Baudry and Merriam 1988:23).
- **Corridor:** a spatial linkage that facilitates movements of organisms among habitat patches in a landscape (adapted from Merriam 1988:16).
- **Deciduous forest:** type of forest made up of trees that lose their leaves in the winter.

- **Deciduous/semi-deciduous broadleaf forest:** Natural forests with > 30% canopy cover, below 1200 m altitude in which between 50-100% of the canopy is deciduous and broadleaves predominate (> 75% of canopy cover)
- **Deforestation:** destruction of forested habitats for conversion to other uses.
- **Degraded forest:** A degraded forest is a secondary forest that has lost, through human activities, the structure, function, species composition or productivity normally associated with a natural forest type expected on that site. Hence, a degraded forest delivers a reduced supply of goods and services from the given site and maintains only limited biological diversity. Biological diversity of degraded forests include many non-tree components, which may dominate in the undercanopy vegetation.
- **Diversity:** typically used in relation to species, a single index that incorporates the number of species and relative abundances of species (evenness). For example, a collection is said to have high diversity if it has many species and their abundances are relatively even. There are many types of diversity indices (Pielou 1977:292; Wiens 1989a:123):
- **Ecological communities:** a group of interacting plants and animals living in a defined area.
- **Ecosystem:** a group of plants and animals occurring together, along with the physical environment with which they interact.
- **Ecological Processes:** The relationships between living organisms, and their environment. Among these processes are natural disturbances such as periodic fire, flooding, or beaver activity; natural stresses such as disease or insects; catastrophic weather related events such as severe storms or lightning strikes, or more subtle ongoing processes such as succession and hydrology.
- **Ecosystem Management:** The careful and skillful use of ecological, economic, social, and managerial principles in managing ecosystems to produce, restore, or sustain ecosystem integrity uses, products, and services over a long-term.
- **Ecotone:** a habitat created by the juxtaposition of distinctly different habitats; an edge habitat; a zone of transition between habitat types (Ricklefs 1979:869) or adjacent ecological systems having a set of characteristics uniquely defined by space and time scales and by the strength of the interactions (Hansen and diCastri 1992:6) (see Boundary).
- **Edge effect:** (1) changes in a community due to the rapid creation of abrupt edges in large units of previously undisturbed habitat (Reese and Ratti 1988:127); (2) tendency for increased variety and density of organisms at community or habitat junctions (Odum 1971:157).
- **Edge species:** species preferring the habitat created by the abutment of distinctive vegetation types (Ricklefs 1979:869).

- **Endemic species:** An endemic species is a native species restricted to a particular geographic region owing to factors such as isolation or response to soil or climatic conditions.
- **Evergreen forest:** a forest made up of trees that do not lose their leaves or needles in the winter.
- **Forest biological diversity:** Forest biological diversity means the variability among forest living organisms and the ecological processes of which they are a part; this includes diversity in forests within species, between species and of ecosystems and landscapes.
- **Forest biome:** This reflects the ecological and physiognomic characteristics of the vegetation and broadly corresponds to climatic regions of the Earth. In this document, it is used in reference to boreal, temperate and tropical forest biomes.
- **Forest degradation:** Changes within the forest that negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and/or services.
- **Forest ecosystem:** A forest ecosystem can be defined at a range of scales. It is a dynamic complex of plant, animal and microorganism communities and their abiotic environment interacting as a functional unit, where trees are a key component of the system. Humans, with their cultural, economic and environmental needs are an integral part of many forest ecosystems.
- **Forest fragmentation:** patchwork conversion and development of forest sites (usually the most accessible or most productive ones) that leave the remaining forest in stands of varying sizes and degrees of isolation (Harris 1984:4
- **Forest improvement:** Changes within the forest that positively affect the structure or function of the stand or site, and thereby increase the capacity to supply products and/or services.
- **Forest plantation:** A forest established by planting or/and seeding in the process of afforestation or reforestation. It consists of introduced species or, in some cases, indigenous species.
- **Forest species:** A forest species is a species that forms a part of a forest ecosystems or is dependent on a forest for part or all of its day-to-day living requirements or for its reproductive requirements. Therefore, an animal species may be considered a forest species even if it does not live most of its life in a forest.
- **Forest:** The FAO definition of a forest is considered as the basic one (FAO, 1998; FRA 2000), but many other useful definitions of "forest" exist in published form. The fact that "forest" has been defined in many ways is a reflection of the diversity of forests and forest ecosystems in the world and of the diversity of human approaches to forests. In this document, a forest is a land area of more than 0.5 ha, with a tree canopy cover of more than 10%, which is not primarily under agricultural or other specific non-forest land use. In the case of young forests or regions where

tree growth is climatically suppressed, the trees should be capable of reaching a height of 5 m *in situ*, and of meeting the canopy cover requirement.

- **Forest type:** Within biomes, a forest type is a group of forest ecosystems of generally similar composition that can be readily differentiated from other such groups by their tree and under canopy species composition, productivity and/or crown closure.
- **Gap formation:** the creation of a habitat patch of different characteristics within a larger patch (Wiens 1989b:201).
- **Genetic drift:** the change in allele frequency due to random variations in fecundity and mortality in a population (Ricklefs 1979:871).
- **Habitat:** the place where a particular type of plant or animal lives. An organism's habitat must provide all of the basic requirements for life and should be free of harmful contaminants.
- **Habitat edge:** region where one type of habitat (for example: forest) borders on another type of habitat (for example: grassland or cropland).
- **Habitat fragmentation:** breaking up large areas of continuous natural habitats into smaller patches of natural habitats isolated from each other by human-altered habitats. The area that is too small may not provide enough space to maintain a breeding population of the species.
- **Habitat loss:** Habitat loss, used with reference to an individual species, is the permanent conversion of former (forest) habitat to an area where that species can no longer exist, be it still forested or not.
- **Habitat patches:** areas distinguished from their surroundings by environmental discontinuities. Patches are organism-defined (i.e., the edges or discontinuities have biological significance to an organism) (adapted from Wiens 1976:83).
- **Heterogeneity:** the variety of qualities found in an environment (habitat patches) or a population (genotypic variation) (Ricklefs 1979:872).
- **Home range:** an area, from which intruders may or may not be excluded, to which an individual restricts most of its usual activities (Ricklefs 1979:872) (cf Territory).
- **Index method:** a counting method involving sampling that yields measures of relative abundance rather than density values (Ralph 1981:578).
- **Index:** (1) the proportional relation of counts of objects or signs associated with a given species to counts of that species on a given area; (2) counts of individuals (e.g., at a feeding station) reflecting changes in relative abundance on a specified or local area (Ralph 1981:578).
- **Keystone species:** a species whose abundance dramatically alters the structure and dynamics of ecological systems (Brown and Heske 1990:1705).
- **Landscape:** the traits, patterns and structure of a specific geographic area, including its biological composition, its physical environment, and its anthropogenic or social

patterns. An area where interacting ecosystems are grouped and repeated in similar form.

- **Landscape change:** alteration in the structure and function of the ecological mosaic of a landscape through time (Turner 1989:173).
- **Landscape composition:** the relative amounts of habitat types contained within a landscape (Dunning et al. 1992:170).
- **Landscape ecology:** field of study that considers the development and dynamics of spatial heterogeneity, interactions and exchanges across heterogeneous landscapes, the influences of spatial heterogeneity on biotic and abiotic processes, and the management of spatial heterogeneity (Turner 1989:172).
- **Landscape function:** the interactions among the spatial elements, that is, the flow of energy, materials, and organisms among the component ecosystems (Turner 1989:173).
- **Landscape:** the landforms of a region in the aggregate; the land surface and its associated habitats at scales of hectares to many square kilometres (for most vertebrates); a spatially heterogeneous area (Turner 1989:173); mosaic of habitat types occupying a spatial scale intermediate between an organism's normal home-range size and its regional distribution (Dunning et al. 1992:169).
- **Line transect:** a sampling route, through a surveyed area, that is followed by an observer counting contacts over a measured distance (Ralph 1981:578).
- **Lower montane forest:** Natural forests with > 30% canopy cover, between 1200-1800 m altitude, with any seasonality regime and leaf type mixture.
- **Lowland evergreen broadleaf rain forest:** Natural forests with > 30% canopy cover, below 1200 m altitude that display little or no seasonality, the canopy being >75% evergreen broadleaf.
- **Metapopulation:** a collection or set of local populations living where discrete patches of the area are habitable and the intervening regions are not habitable (Gilpin 1987:127); basic demographic unit composed of a set of populations in different habitat patches linked by movement of individuals (Merriam and Wegner 1992:151).
- **Microhabitat:** the particular parts of a habitat that an individual encounters in the course of its activities (Ricklefs 1979:874).
- **Migration:** regular, extensive, seasonal movements of birds between their breeding regions and their "wintering" regions (Welty 1975:463).
- **Monitoring:** measuring population trends using any of the various counting methods (Ralph et al.) in press.
- **Native species:** A native species is one that naturally exists at a given location or in a particular ecosystem, i.e. it has not been moved there by humans.
- **Native species plantation:** Intensively managed forests with > 30% canopy cover, which have been planted by people with species that occur naturally in that country.

- **Natural expansion of forest:** Expansion of forests through natural succession on land that, until then, was under another land use (e.g. forest succession on land previously used for agriculture). Implies a transformation from non-forest to forest.
- **Natural forest:** A forest composed of indigenous trees and not classified as forest plantation.
- **Natural regeneration on forest lands:** Natural succession of forest on temporarily unstocked lands that are considered as forest.
- **Old growth forest:** Old growth forest stands are stands in primary or secondary forests that have developed the structures and species normally associated with relic primary forests distinct from any younger age class.
- **Primary forest:** A primary forest is a forest that has never been logged and has developed following natural disturbances and natural processes, regardless of its age. "Direct human disturbance" is referred to as the intentional clearing of forest by any means (including fire) to manage or alter them for human use. Also included as primary forests, are forests that are used inconsequentially by indigenous and local communities living in traditional lifestyles relevant for the conservation and sustainable use of biological diversity.
- **Quadrat:** a small sample plot, usually square or rectangular (Ralph 1981:578).
- **Reforestation:** It is the re-growth of forests after a temporary (<10 years.) condition with less than 10% canopy cover due to human-induced or natural perturbations (FAO, FRA 2000).
- **Remote sensing:** the imaging of earth features from suborbital and orbital altitudes, using various wavelengths of the visible and invisible spectrum (Richason 1978:xi).
- **Restoration:** any action taken to repair, maintain, protect, and enhance the ecological integrity of a Basin. .

  Secondary forest: A secondary forest is a forest that has been logged and has recovered naturally or artificially.
- **Semi-evergreen moist broadleaf forest:** Natural forests with > 30% canopy cover, below 1200 m altitude in which between 50-75% of the canopy is evergreen, > 75% are broadleaves, and the trees display seasonality of flowering and fruiting.
- **Species richness:** the number of species in a given area (Ralph 1981:578).
- **Transect:** a cross section of an area along which the observer moves in a given direction (Ralph 1981:578) (see Line transect, Point transect, Strip transect method).

10.0 **ANNEXURE**

SHIMOGA DISTRICT

General: Shimoga, one of the 19 districts of the Karnataka state, is situated in the mid-southwestern part of the State. It is bestowed with abundant natural resources. The western part is replete with fascinating natural beauty, being clothed with dense tropical forests stimulated by heavy rainfall. The eastern area consists of an open country with some fine lakes and stony hills making this part also attractive to the eye.

Location: The district is situated between 13°27' and 14°39' (N) latitude and between 74°38' and 76°4' (E) longitude. It is located about the mid- southwestern part of the State. Its greatest length from east to west is 152.9 km and from north to south it is 128.8km.

Topography: The raise towards the crest of the Ghats is very rapid, a height of 1, 343 m being attained at Kodachadri, a mountain on whose summit meet the two boundaries of Shimoga and South Kanara districts. Kodachadri is a fine peak situated at about 16.1 km, northeast of Nagar.

Water Resources: One of the important rivers that flow through the Shimoga district is Sharavathi. Ground water is present in the voids of rocks and soil. It is an important source of irrigation in several parts of the State. The average rainfall of the place is 1, 526 mm per annum, yielding about 15, 751.37 million m^3 of water. The major portion of this water goes underground. The water table has been gauged in the district and it varies from 2 m to 15 m and the fluctuation of water table is 7.88 m. The surveys conducted have revealed that there is good scope for tapping groundwater for irrigational and other purposes like making additional wells feasible.

Mineral Resources:

Geology: Geologically, the Shimoga district consists of the most ancient rock formations of Archaean complex, which are chiefly composed of 2 systems; the Dharwar system (or Dharwar Schist) and the Gneissic system. Nearly the Dharwar Schist, the Shimoga band forming a prominent belt from West to East and Occupying a larger area, covers two-thirds area of the district. This belt is made up of various types of Schist, chiefly chloritic and in places micaceous or hornblondic, associated with volcanic rocks of different types. Along with them are found some highly altered sedimentary rocks such as quartzites, conglomerates, limestones, shales and banded ironstones (ferruginous quartzites). The Shimoga Schist belt is split up into several small bands by intrusion of the Granites.

Climate: The cold season is from December to February, which is one of generally clear light weather. It is followed by the hot season from March to May. The Southwest monsoon season is from June to September. October and November constitute the post monsoon or retreating monsoon season.

Temperature: After January, there is rapid increase of temperatures. April is usually the hottest month with the mean daily maximum temperature at 35.8°C and the mean daily

minimum temperature 22.2°C. Nights during May are slightly warmer than that during April. With the onset of the Southwest monsoon in the district early in June, there is applicable drop in the day temperature but the nights still continue to be nearly as warm as during the summer season. Day temperature increases slightly from September and a secondary maximum in day temperature is reached in October, but the nights become cooler with the progress of the season. After October, both the day and night temperature decrease steadily till about January and later begin to increase. In December, the mean daily maximum temperature is 29.2°C and the mean daily minimum temperature is 14.9°C. (Karnataka State Gazetteer-Shimoga District, 1975)

Vegetation Cover: The Shimoga district comprises 10558 km^2 (46.60%of the forest area) of the Western Ghats. Western Ghats of India, because of its geographical location, stable geological history, equitable climate, heavy rainfall and good soil condition supports a variety of tropical forest ecosystems (Champion & Seth, 1968). Phyto-geographically, these forests are rich, not only with high species diversity but also with several palaeoendemic species which are botanically a "relict" of an ancient and unique vegetation (Champion & Seth, 1968). The ecosystem diversity, here, ranges from Evergreen/Semi-evergreen forest to moist and dry deciduous types, scrubland savanna and grass-Shola complexes of higher altitudes. *Most peninsular Indian rivers have their catchment in the forest ecosystem of the Western Ghats* (Ahmedullah & Nayar, 1986; Daniels, 1997). The study area also comprises some of the forest types of Western Ghats. Ranging from high elevation grassland to evergreen forest.

Evergreen and semi-evergreen are found only in the Sharavathi Wildlife sanctuary and southern and Southwestern part of the study area that comprises Kavaledurga, Netuvasae, Nigalvni, Nagara, Nagodi (Lion-Tailed Macaque's habitat) and Kodachadri range (LTM's habitat) but these forests are also disturbed due to forest fire, tourism, lopping and logging. The southern part too comprises of Shola forests having evergreen and semi-evergreen types of vegetation. The southern and Southwestern side have pockets of very good forest patches of *primary forest* (old, climax one) dominated by *Dipterocarpus indicus, Poeciloneuron indicum, Mesua ferrea and Palaquium ellipticum.*

The moist deciduous forests and bamboo mixed jungle is found throughout the study area and dominated by 4 species of *Terminalia* (*T. tomentosa, T.chebula* & *T. bellerica*), *Lagerstroemia lanceolata*, *Xylia xylocarpa* and a very small number of *Pterocarpus marsupium* and *Dalbergia latifolia*. In highly disturbed areas, bamboo growth is luxuriant.

The scrublands are found on the slopes of hill tracks and plain lands where fire incidents occurred. In some cases, this type of vegetation found on the top of a hill. *Carya arborea*,

Dilema pentagyna, *Phoenyx sylvestris*, *Emblica officinalis* and *Randia domentorum* dominate this type of vegetation.

The grasslands are found in the plain lands on the edges of the reservoir and also on top of the hills. Tall grass (Masse) and *Phoenyx sylvestris* dominated the grasslands on top of the hills. Nearly 122 islands are there in the study area. Number of Islands is more due to submersion of the vast area during the dam construction. These Islands comprising forests ranges from grasslands to evergreen forests. Acacia plantation (*A.auriculiformis* and *A.emgium*) is seen everywhere in the catchment area from plain lands to hilltops. Areca, rubber, Eucalyptus, Pine, Cashew and Casuarina plantations are also found in the area. In most of the cases, Areca plantations involve in forest encroachments and cover almost all the areas where water sources are found. The Southeastern and a part of Southwestern side involve extensive agricultural activities, comprising major crops like paddy, sugarcane, and pulses and now Keralite farmers have introduced ginger.

UTTARA KANNADA DISTRICT:

General: The Uttara Kannada (formerly North Kanara) is the north most coastal district of Karnataka. It has a geographical area of 10,291 km^2(The district is divided into 11 Taluks and the entire forest area of the district is divide into 34 forest ranges). In Western Ghats stretching through the western peninsular of India in the North-South direction covers a substantial portion of the district. Topographically, the district may be divided into three district zones, viz., the flat and narrow coast, the abruptly rising hills and the flatter elevated Eastern zone that joins the Deccan plateau. Wide river mouths, small creeks and low hills projecting into the sea interrupt the continuity of the coastal line. Within few kilometres to the East, there are sudden rising hills, clad in forests. The hills of Western Ghats run in North-South direction. Parallel to the coast. In Uttara Kannada, the hills are steep towards the west with deep winding valleys. There are several great waterfalls in the district and the chief among all of them is Jog. The coastal tract has the finest estuaries of Karnataka (Daniels, 1989).

Location: The district is located in the mid-western part of the state. It lies between 74° 9' to 75° 10' (E) longitude and 13°55' to 15°31'(N) latitude and extends over an area of 10,327 km^2 , which is 5.37 % of the total area of the state. It extends to about 328 km north to south and about 160 km east to west. The district that is a long and narrow strip of territory is surrounded by Belgaum district and Goa territory in the north, Dharwad district in the east, Dakshina Kannada and Shimoga districts in the south and the Arabian Sea in the west. There is an extent of only 10 m of plain land in the south and it is here that the southern boundary of this district and the northern boundary of the Dakshina Kannada district meet.

Topography: The district is hilly and thickly wooded in most of the parts. Its major part is essentially highland, the lowland being restricted to pockets along the courses of rivers. The coastal lands are the best-developed areas with a high degree of development and a high density of population. It is in this region, the Taluks of Karwar, Ankola, Kumta, Honavar and Bhatkal, are situated. The eastern margin is an undulating land, partly under forest and partly cleared up for agriculture (Suryanath U. Kamath, Karnataka State Gazetteer Uttara Kannada District, 1985).

Geology: The district consists of rock formations of Archaean complexes; the oldest rock of the earth crust. Rocks of the Archaezoic era occur over the whole of the district. The district is characterised by a system of ridges and a plateau on the west descending rapidly to a rather narrow strip of low land covered by alluvium, which with the abundant annual rainfall supports cultivation. The low land appears to be the creation of a later period than the upghat regions. It emerged from the sea during the glacial and inter-glacial period due to the change in sea level when water from continental ice cap was removed. Sea has transgressed up to the level of the edges of the Ghats, submerging land up to an elevation of about 200 m. When the sea level retreated after a long time, it did not only erode the height of the present coastal region but formed many sediment platforms.

The Archaean formations are divisible into an older group of sediments and igulous viatrusives, all very highly metamorphosed, which are classified as the Dharwar System and a younger group of plutonic intrusive termed as the Peninsula Gneiss. A capping of laterite, which is locally the source of iron and manganese ores and ocher, frequently overlies both.

In the western part of the district, nearly parallel to the coastline, there is a range of hills with several peaks over 700 m high descending westwards gradually towards the coast. This consists of a varied assemblage of granites and schist. Eastwards in the interior, the district is almost entirely hilly and consists of both the Dharwar and the Peninsular Gneiss, the latter frequently occupying the low ground. In this district, the Dharwars are typically represented by Chlorite-schist. Other rock formations belonging to this system are Quartzite, Magnetic-quartzite, Limonite-quartzite, Senicite-quartz-schist, and Phyllite fine-grained gray limestone. Dolamite, Epidiorite and other basic igneous rocks. The Dharwar rocks are highly placated. Their folding is clearly seen in the Limestones, which are thought to be the youngest in the Dharwar sequences. Dolamite bands are known to occur in the western parts of the district.

The Peninsular Gneiss consists mostly of fine-grained Granite- gneisses out cropping in the lower levels of the central and southern parts of the district. The best exposures of this Gneiss are near southern boundary of the district where the Sharavathi River plunges down a vertical precipice in the magnificent Jog Falls. They generally show a lower degree of metamorphism than the Dharwars, as they have been emplaced subsequent to the Dharwar folding.

Pegmatites and Quartz veins are also known to occur in this area. The Archaean Granites and Gneiss with their sparse bonds of Dharwars are capped by laterite at many places in the district. They are typical tropical rocks resulting from the alteration under tropical conditions of the basement rocks. They are capping flat-topped ridges and bluffs all along the coast of a hundred feet in thickness and occasionally show local enrichment of iron and manganese ores.

Groundwater: Groundwater in the district occurs under water table conditions in the weathered mantle and jointed and fissured in bedrocks. Along the coastal belt, groundwater occurs in the sandy alluvium. A thick capping of laterite mantle on Granites, Schistose rocks and Sandstones, covers major part of Uttara Kannada district. These laterites are highly porous and hold and transmit sufficient quantity of groundwater. The average rainfall in the district is 2,741.7 mm. The groundwater recharge is mainly a result of infiltration of this rainwater and little extent through seepage from streams, tanks, reservoirs and water applied for irrigation. It is discharged artificially by abstraction of water from dug wells. The fluctuation of water table varies in the district from 312 m for hard rock area and alluvium.

Climate: Uttara Kannada has a tropical climate with a well-defined annual rainy season. The remaining 6 months have practically no rainfall. Isolated showers may occur in December and May. During March to May, it is at the most dry and hot. The temperature reaches at its maximum of 38ºC. It is not so cold in winter.

Soils: The soils of the district are basically derivatives of the Dharwad system - ancient metamorphic rocks in India; rich in iron and Mg. Exposed lateritic rocks along the coastal hills are very infertile and almost barren. During the last 15years, most of these hills have been brought under forest plantation dominated by Acacia auriculoformis. (M.D. Subashchandran, Divakar K. Mesta, Manjunath B. Naik, 1999)

Land Utilisation: About 80% of Uttara Kannada district's land is under the legal control of the Forest Department but actual forest cover is somewhat lower. The details are given in the table.

Vegetation of Uttara Kannada: In the slopes of the Western Ghats form north to south of the Uttara Kannada district, there is beautiful cover of dense forests of magnificent timber. The forests, stimulated by heavy rainfall, start growing within a few kilometres from the coast. They are generally lofty, dense and evergreen, characterised by a large number of trees. They occur together with fine canopies of tree crowns and shrub growth.

The maps by Pascal (1982, 1984) depict the details of vegetation. The broad vegetation zones of the district from the west to the east are coastal, evergreen, and semi-evergreen, moist and dry deciduous. These zones are broadly overlapped with the rainfall zones. The first two fall within the 200 to 40 cm rainfall zone. The moist deciduous forests occur within 200 to 125 cm rainfall zone and dry deciduous in the Northeastern parts have more than 125 cm rainfall. Human influences over the millennia have considerably altered the vegetation in every zone, so much of the coastal hills are rocky with mere scrub. Within

the evergreen zone, especially along the banks of rivers occur secondary deciduous forests. Grassy banks are found even among higher hills. Together with the southern hill ranges of Goa and Belgaum, Uttara Kannada has geographical uniqueness, being the northern limits for distribution of endemic plant species like *Arenga wightii*, *Dipterocarpus indicus*, *Pinanga dicksonii*, *Polyalthia fragrans*, *Myristica fatua*, Var. magnifica, *Gymnacranthara canaria*, etc. (Ramesh & Pascal, 1997). Among the vertebrate animals, and endemic mammals- Lion-Tailed Macaque has its northern limit in the district. (M.D. Subashchandran, Divakar K. Mesta, Manjunath B. Naik, 1999)

SL No	**CATEGORY**	**AREA (km^2)**	**%**
1	**Forest**	8164	79.7
2	Land under non-agricultural use	277	2.7
3	Barren & uncultivable land	204	2.0
4	Cultivable waste	78	0.8
5	Pastures & other grazing land	198	1.9
6	Under miscellaneous tree crops & groves	52	0.5
7	Current fallows	66	0.6
8	Other fallow land	87	0.8
9	Net area sown	1121	10.9
10	Total cropped area	1280	12.5
11	Area sown more than once	159	1.6

Source: District statistical office, Karwar. (M.D. Subashchandran, Divakar K. Mesta, Manjunath B. Naik, 1999)

Annexure II

Feeding Seasonality of One Troop of *Macaca silenus* for 12 Continuous Months, 1974-1975

Species	*March-April*	*May-june*	*July-August*	*September-October*	*November-December*	*January-Feburary*
Cullenia exarillata,	*xxxx*	*xxx*	*xxx*	*xxx*	*xxx*	*xxxx*
Artocarpus heterophyllus,	*xx*	*xxx*	*xxxx*	*xxxx*	*xx*	*xx*
Elaeocarpus munroii	*x*	*x*	*x*	*xxx*	*x*	*xx*
Miliusa wightiana,	*xx*	*x*		*x*	*xxx*	*xxx*
Eugenia species,	*x*	*xx*	*xx*	*x*	*x*	*x*
Vepris bilocularis,	*xx*	*xx*	*xxx*	*xxx*	*x*	
Toddalia asiatica,	*xx*	*x*		*x*	*xx*	*xx*
Palaquium ellipticum,	*xx*	*xx*	*x*	*x*	*x*	
Holigarna nigra,	*x*	*x*	*x*	*x*		
Myristica beddomei,	*x*	*x*	*x*			*x*
Jambosa mundangam,	*xxxx*	*x*				*x*
Symplocos sessilis,	*x*	*xx*		*x*		
Litsea wightiana,	*xxxx*	*xxxx*				
Litsea beddomei,	*xx*	*x*				
Elaeocarpus tuberculatus,	*x*	*xx*				
Ficus retusa,	*xx*					
Calophyllum trapezifolium,	*x*					
Aglaia bourdilloni,	*x*					
Antidesma menasu,		*x*		*x*	*xx*	
Ochlandra scriptoria,	*xx*	*x*	*x*	*x*		*xx*
Viburnum acuminatum,	*xx*	*xx*	*x*	*x*	*x*	
Oplismenus compositus,	*x*	*xx*	*x*	*x*	*x*	
Tetrastigma sulcatum,	*x*	*x*		*xxx*	*xxx*	
Sclera cochinensis,	*xx*	*xx*			*x*	*x*
Randia rugulosa,	*x*	*xx*			*x*	*x*
Isachne gardneri,	*xx*	*xx*				*x*
Gordonia obtuse,	*xx*				*x*	*xx*
Embelia adnata,	*x*	*xxx*		*x*		
Ormosia travancorica,	*xx*	*x*		*x*		
Octotropis travancorica,	*x*				*xx*	*xx*
Psychotria congesta,	*x*	*xx*			*x*	
Chloranthus brachystachys,	*x*			*x*	*x*	
Canthium diococcum,	*x*	*x*				
Symphyllia mallotiformis,	*x*					*x*

Drypetes oblongofolia,	*x*					
Luisia tenuifolia,	*x*					
Litsea oleoides,		*xx*	*xxx*			
Diospyros peregrina,		*xxx*				*x*
Actinodaphne tadulingami,		*x*	*xx*			
Litsea insignus,		*x*				
Elaeocarpus venustus,		*x*				
Loranthus elasticus,			*xx*	*xxxx*		
Bentinckia coddapanna,			*x*	*x*		*x*
Ardisia pausiflora,			*x*		*x*	*x*
Cinnamomum sulphuratum,			*x*			
Gomphandra coriacea,			*x*			
Psychotria octosulcata,				*xx*	*xx*	
Loranthus obtusatus,				*xxx*	*x*	
Ficus tsiela,					*xx*	
Hemicyclia elata,				*xx*		
Rapanea daphnoides,				*x*		
Diospyros nilagarica,					*xx*	*xx*
Macaranga roxburghii,					*xxx*	
Calamus travancorica,					*xx*	
Lasianthus cinereus,					*x*	
Saprosma corymbosum,					*x*	
Scolopia crenata,					*x*	
Viscum ramosissimum,					*x*	
Dioscorea belophylla,					*x*	
Aristolochia tagala,					*x*	
Ficus talboti,						*x*
Canthium umbellatum.						*x*

Source: Steven and Karen, 1975. The Lion tailed Monkey and its South Indian Rain Forest Habitat. In Primate Conservation, Ed.Prince Rainier III of Monaco / Bourne, Academic Press, New York.

Plant species eaten by LTM (Source:Umapathy and Kumar, 2000, Habitat Fragmentation and Feeding Ecology- Primate Report 58)

Oroxylum indicum, *Bombax malabaricum, Cassia* sp., *Vateria indica, Diospyros sylvatica, Elaeagnus kologa, Elaeocarpus ferrugineus*, *E. conferta, Bischofia javanica*, *Glochidion bourdillonii*, *Mallotus tetracoccus* , *Macaranga peltata*, *Mesua ferrea*, *L.deccanensis* , *L. oleoides, Loranthus tomentosus*, *A. hirsutus Ficus glomerata, F. hispida, F. macrocarpa*, *F. nervosa, F. travancorica*, *F. infectoria, F. integrifolia*, *Knema attenuata* , *Maesa indica*