Impact of biotic disturbances on Nilgiri langur habitat, demography and group dynamics

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Impact of biotic disturbances on the Nilgiri langur (*Trachypithecus johnii*) habitat, demography and group dynamics was investigated from 1985 to 1988. Wood cutting, dynamiting and pilgrimage were the disturbances. Based on the intensity of disturbances the Nilgiri langur habitat was subjectively differentiated into highly disturbed (HD), moderately disturbed (MD) and least disturbed (LD) areas. Ten groups of langur were selected: four in the HD areas and three each in the MD and LD areas. These groups were monitored to collect data on group size, composition and birth and death rates. There was loss of trees, poles and canopy cover due to firewood cutting and pilgrimage to Sorimuthayanar temple. Most of the trees cut were Nilgiri langur food plants. Dynamiting near Servalar reservoir destroyed 103 trees belonging to 10 species in a sample area of 1.2 ha. All ten species were Nilgiri langur food plants. Disturbances decreased birth rate and increased death rate. Increase in mean group size seen in the LD area was not seen in other two areas. Several conservation problems are identified and management recommendations for protection, restoration and education are given.

ALTHOUGH several studies have focused on the problem of loss of undisturbed forests and its threats to the survival of rainforest primates[1], very little research has been done in this context in India, where habitat loss is considerable[2]. A study by Sugiyama and Parthasarathy[3] indicates that the relationship between habitat loss and decline in primate populations can be considerable. They report a 54.5% decline in the population of common langurs due to deforestation between 1961 and 1976.

Elsewhere, some studies have quantitatively documented how disturbances to forests are detrimental to primates[4,5]. Human disturbance of habitat has important consequences for the demography, morbidity, behaviour and ultimately the survival of non-human primates[6]. One form of disturbance in rainforests that has drawn the attention of primatologists is logging, which may selectively remove valuable timber tree species from the forest. Changes in the distribution and abundance of food sources occurring as a result of selective logging were interpreted to cause changes in the 'cost-efficiency' of feeding on certain foods[5]. Reduction of food resources has also been shown to decrease the population density of primates[7].

Traditionally, food availability and predation pressures have been considered the most important factors limiting the growth of a population. The first can act directly through birth and death rate to determine population growth rate, whereas predation can only act on death rate. Food availability is usually considered to be a more important factor than predation in influencing primate demography[8].

Forest areas in India are under various forms of increasing biotic pressures. One such pressure is due to local people, collecting what is often termed 'minor forest produce' such as firewood and poles. Human disturbances gradually change the forest structure and composition and can have a deleterious effect on arboreal mammals.

This study examines the impact of biotic disturbances in the Kalakad–Mundanthurai Tiger Reserve (KMTR) on the habitat, demography and group dynamics of Nilgiri langurs (*Trachypithecus johnii*, Sterndale 1884), an endangered colobine leaf-monkey endemic to the Western Ghats mountains of India. In certain parts of the riverine forest on Mundanthurai plateau, the presence of stumps of numerous trees indicated woodcutting by local people for firewood and poles. Woodcutting has effects that are somewhat similar to selective logging. Dynamiting to deepen the Servalar river bed close to the outlet of the Servalar reservoir and use of riverine area by pilgrims also cause disturbances to the Nilgiri langur habitat. An account of these disturbances and an evaluation of their impact on the Nilgiri langurs and their habitat is presented here.

Study area

The intensive study site was the Mundanthurai plateau (8°23′–9°0′N and 77°8′–77°33′E) in the KMTR (Figure 1). It is the only plateau in KMTR varying in altitude from 180 m (lower Papanasam) to 220 m (upper Papanasam).

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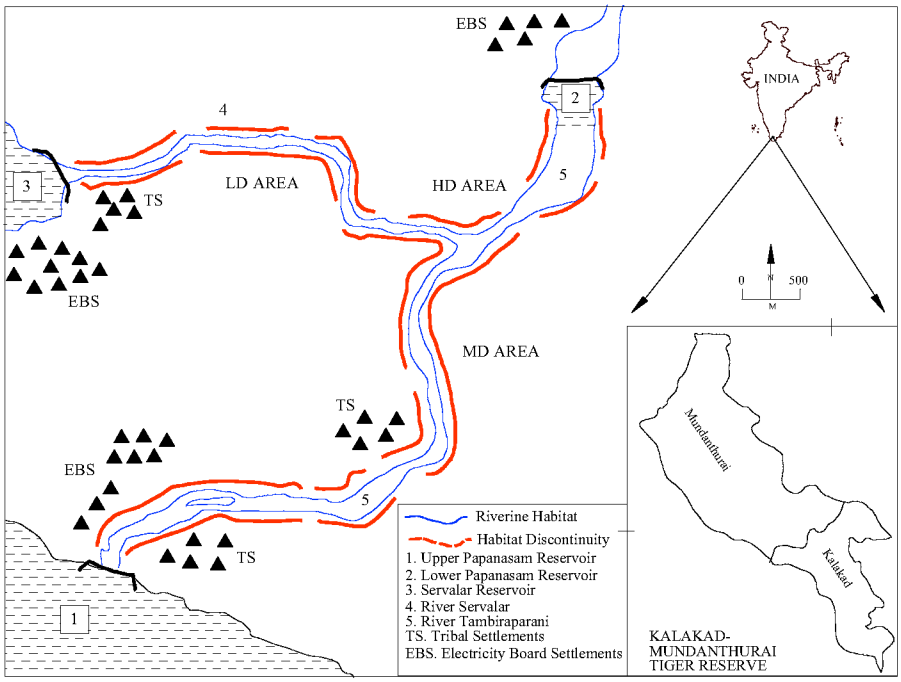


Figure 1. Location of Mundanthurai plateau, the main study area, showing distribution of riverine forests.

The river Tambiraparani, the major river of Tirunelveli District, and its tributary, Servalar, flow through the plateau. The average annual rainfall (1980–1987) was 805 mm at lower Papanasam and 1098 mm at upper Papanasam, both during the south-west and north-east monsoons. The climate is hot and dry, with temperatures reaching 38°C in summer (March–May). Three major vegetation types occur on the plateau: (i) riverine forest, (ii) tropical dry deciduous forest, and (iii) plantations (teak, *Eucalyptus*, etc.). More details on vegetation are given elsewhere[9–11].

Study species

The endangered Nilgiri langur is endemic to the Western Ghats, being distributed from the Kanyakumari hills (8°N) at the southern tip of the Indian peninsula to the Coorg hills in Karnataka (12°N). It is usually found in tropical evergreen forests at altitudes above 500 m asl. However, in the Tirunelveli hills in Tamil Nadu, the Nilgiri langur is found even in the foothills where the riverine forests are continuous with the forests of upper slopes[12]. A typical example of this habitat type was once found on the Mundanthurai plateau. Here, prior to the construction of upper Papanasam dam during 1938–1943 and Servalar dam during 1974–1988, the riverine forests of perennial Tambiraparani and Servalar were continuous with the evergreen vegetation of the higher altitudes.

Nilgiri langurs are predominantly folivorous, with young leaves being the dominant food item. Leaves, seeds, fruits, flowers and flower buds are consumed from over 90 plant species. They live in uni-male, bisexual or all-male groups, varying in size from 2 to 29 individuals (mean = 10). Home ranges of troops vary between 2.2 and 6.4 ha[11].

The Nilgiri langur is presently categorized as an endangered species[13]. It has suffered population decline mainly due to habitat destruction and poaching for the supposedly medicinal properties of its meat[14–18]. Recent surveys in Tamil Nadu[19] have indicated further decline from the earlier estimates[20], again mainly due to habitat destruction and poaching.

Methods

Quantifying habitat disturbances

Wood cutting: This was more common on the banks of river Tambiraparani between its confluence with Servalar and the lower dam. This stretch of 3000 m (1500 m on each bank) was divided into five 300 m blocks. Block one was close to the periphery of the sanctuary and block five 1.5 km inside. Within each 300 m block, at every 50 m interval, one 10 m × 25 m quadrat was laid. Thus, 60 quadrats were laid, 30 on each bank. In each quadrat, all trees (> 20 cm girth at breast height – GBH) were identified, enumerated and their locations mapped. For each tree, basal area was measured and the height and canopy cover index were estimated. These quadrats were checked for new cutting signs once every 15 days. This monitoring continued from January 1987 to June 1988.

Dynamiting: A 500 m × 15 m belt transect was laid on each bank of the river Servalar close to the outlet of the Servalar reservoir. All the trees in these transects were identified and their locations were recorded under five categories based on the distance from the river edge (< 3 m, 3–6 m, 6–9 m, 9–12 m, 12–15 m). Height and GBH of each tree were measured and canopy cover index estimated. Tree deaths due to dynamiting were counted. The area covered by dumping of stones along the riverbed was measured.

Other disturbances: The number of persons entering the Reserve for cutting wood and worshippers coming to Sorimuthayanar temple on the plateau was counted. Between January 1987 and June 1988, one or two days in a month, sitting near one of the wood cutters' paths close to the sanctuary entrance, the number of men and women entering and those leaving the Reserve with grass and wood was counted. In addition to this, the number of persons coming to the riverine forest for cutting wood was recorded, while making behavioural observations (dawn to dusk for 10 days each month) on langurs. The number of persons visiting the temple during the festival and the number of sheds built by them around the temple were counted. An estimate of the total number of poles used in shed construction was made. The area of understorey cleared by the pilgrims to set wood-stove ovens was quantified.

Based on the above, the Nilgiri langur habitat was classified into highly disturbed (HD; lower Papanasam reservoir to the confluence), moderately disturbed (MD; from the confluence to Sorimuthayanar koil) and least disturbed (LD; from the confluence to the end of dynamiting on the Servalar river).

Demography and group dynamics

Ten groups of Nilgiri langur were selected: four in the HD areas, and three each in the MD and LD areas. These groups were monitored between May 1985 and April 1988 to collect data on group size, composition, and birth and death rates. Major demographic parameters were calculated as follows[21,22].

Birth rate, $b = I_t/F_t$,

where I_t is total number of infants born in one year and F_t is total number of females observed in one year.

Death rate, $q_n = d_n/I_n$,

where d_n is the number of animals dying in year n, and I_n is the total number of animals observed in the group in that year.

Age-specific death rate, $q_x = d_x/I_x$,

where d_x is the number of animals dying in age-class x, and I_x is the total number of animals belonging to that age class in the group.

Rate of increase, $r = (\ln N_t - \ln N_0)/t$,

where N_0 is the population size at the start of the time interval t, N_t is the population at time t, and ln refers to natural logarithm.

Results

Biotic disturbances on riverine habitat

Loss of trees: In January 1987, the area (1.5 ha) marked for monitoring wood cutting on the banks of river Tambiraparani had in total 552 trees belonging to 64 species. Of these, 127 trees (or 23% of the total) belonging to 31 species were cut for fire wood and poles (Table 1). All the 31 species cut by wood cutters were Nilgiri langur food plants. Wood cutters preferred species such as *Aglaia roxburghiana*, *Pongamia pinnata*, *Albizzia amara*, *Bauhinia racemosa* and *Diospyros peregrina* which formed 52% of the total trees cut. These five species are among the first 15 species by rank of abundance among the 45 food tree species recorded in the range of the Tambiraparani Nilgiri langur troop. There was no significant difference in tree cutting between the top five ranking species with the other 26 species ($\chi^2 = 2.04$, $df = 2$, $P > 0.05$). The difference in cutting frequency among the top five ranking species, however, was highly significant ($\chi^2 = 37.30$, $df = 4$, $P < 0.001$). This shows that some species are cut preferentially.

Rate of tree cutting: Tree cutting and the number of persons coming for wood cutting were relatively steady throughout the year. From January 1987 to June 1987, in the 1.5 ha area, 40 (31%) trees were cut from July to December 1987, 50 (39%) trees were cut and 37 (29%) trees were cut from January 1988 to June 1988. The total number of wood cutters recorded in the above-mentioned periods was 888, 978, and 828, respectively.

Table 1. Rank order of tree species cut by wood cutters on Tambiraparani riverbank from January 1987 to June 1988

Tree species	No. of trees available	No. of trees cut (% of total)
Aglaia roxburghiana	39	22 (17.3)
Pongamia pinnata	100	16 (12.6)
Albizzia amara	21	13 (10.2)
Bauhinia racemosa	17	9 (7.2)
Diospyros peregrina	32	6 (4.7)
Alphonsea sclerocarpa	20	5 (3.9)
Erythroxylon monogynum	12	5 (3.9)
Hopea parviflora	19	5 (3.9)
Syzygium cumini	29	5 (3.9)
Tectona grandis	23	5 (3.9)
Others	240 (54 species)	36 (28.3) (21 species)

There was no significant difference in tree cutting during the periods ($\chi^2 = 2.19$, $df = 2$, $P > 0.05$). The overall rate of tree cutting was 56.4 trees/ha/year. As expected, more trees were cut near the periphery of the sanctuary than in the interior. Seventy-four trees (58%) of the total (127) were cut in the first block.

The number and percentage of trees cut in other blocks, from periphery to interior, were 21 (16%), 12 (9.1%), 13 (10%), and 7 (5%), respectively. In the Tambiraparani study area, during 120 days of scan on Nilgiri langurs (1440 h of observation), 129 wood cutters were seen in different hours of the day. Use of the area by wood cutters was significantly greater between 1000 and 1400 h than during other periods. Over 60% of the wood cutters were seen between 1000 and 1400 h.

Loss of canopy cover: As a result of tree cutting, there was considerable loss of canopy cover. Mean canopy cover available in the 1.5 ha area was 7882 m^2. Of this, 1082 m^2 (14%) was lost due to cutting of 127 trees. About 55% of the loss of canopy cover was due to the cutting of 65 trees of five species – *P. pinnata*, *A. lebbeck*, *A. roxburghiana*, *B. racemosa* and *Syzygium cumini*.

In general, smaller trees (90% of trees with canopy cover < 151 m^2, 98% of trees with height < 10.6 m in height and 92% of trees with basal girth < 175 cm) were cut. The changes in habitat components due to wood cutting during the 18-month period were significant (summarized in Table 2).

Pole and tree cutting during festival: During the five-day long festival in July 1987, approximately 50,000 persons visited the temple, i.e. an average of 10,000/day. For building 100 sheds, 581 poles were used. These were classified into five categories based on circumference and length: (i) 244 poles of 15–20 cm circumference and up to 2 m length; (ii) 161 poles of 21–25 cm and 2–2.5 m, (iii) 75 poles of 26–30 cm and 3 m; (iv) 59 poles of 31–35 cm and 3.5 m; and (v) 42 poles of > 35 cm and > 3.5 m. The first two categories of poles formed 70% of the total cut. Based on length and girth of all categories, it was estimated that a total of 75.4 m^3 of wood would have been collected from the riverine and plantation forests during the 5 days of the festival. Poles used for the sheds were from 13 tree species. Excluding *Eucalyptus* sp. all others were food plants of Nilgiri langur (Table 3). Of the 581 poles cut, 220 (37.8%) were langur food tree species.

During the festival, 538 wood-stove ovens were set on the ground for cooking. Around each oven an area of approximately 4 m^2 was cleared. Two hundred and forty six ovens were set along the Tambiraparani riverbanks. As a result, 0.22 ha of shrub cover had been cleared for setting the ovens of which 0.10 ha was in the riverine habitat.

Changes in the habitat due to dynamiting: Before dynamiting, the sample area (1.2 ha) on the Servalar bank had 264 trees representing 17 species. Of these, 103 (39%) trees belonging to ten species died due to dynamiting. All ten species were Nilgiri langur food plants. Mortality was greatest in *Calophyllum decipens*, *Hopea parviflora*, *Mesua ferrea* and *Syzygium cumini*.

The number of individuals dying was correlated with the number of individuals of that species on the site prior to the disturbance (Spearman's rank correlation, $r_s = 0.82$, $df = 9$, $P < 0.05$). This suggested that there were no differential deaths of species than would be expected from their abundance. This was confirmed by a contingency table analysis of the top nine tree species pooled into 7 classes ($\chi^2 = 6.32$, $df = 6$, $P > 0.05$) and also of the top four ranking tree species separately ($\chi^2 = 3.56$, $df = 3$, $P > 0.05$).

The total canopy cover available in the 1.2 ha area was 68,460 m^2 and of this 27,379 m^2 (40%) was lost due to the death of 103 trees. The death of individuals of the top four species (*H. parviflora*, *C. decipens*, *M. ferrea* and *S. cumini*) accounted for 94% of the loss of canopy cover.

More trees died within 3 m from the edge of the water. Between 0 and 15 m from the river, the number of trees that died in each 3 m distance interval was 40, 28, 15, 11

Table 2. Changes in habitat components due to wood cutting in the sample area of 1.5 ha between January 1987 and June 1988

Component	Beginning of study (A)	End of study (B)	Net change (A – B)
Total no. of trees	552	425	127
Mean no. of trees/quadrat	9.20	7.10	2.10
Mean canopy index (m^2)	7882	6801	1081
Tree density (trees/ha)	368	283	85
Tree species diversity	1.11	1.07	0.04

Table 3. Percentage frequency of tree species used for building 100 sheds

Tree species	Parts used by langur as food	Frequency of use (%)
Calophyllum decipens	YL YFR SD	46 (18.54)
Diospyros peregrina	YL RFR	28 (11.29)
Eucalyptus sp.		28 (11.29)
Pongamia pinnata	YL FLB FLR SD	27 (10.89)
Tectona grandis	YL PTL FLB YFR SD	25 (10.08)
Mangifera indica	FLB PTL RFR SD	24 (9.68)
Aglaia roxburghiana	YL FLB YFR SD	21 (8.47)
Syzygium cumini	YL FLB FLR YFR RFR SD	14 (5.65)
Alphonsea sclerocarpa	YL FLB RFR SD	10 (4.03)
Albizzia amara	YL ML FLB YFR SD BR	9 (3.63)
Lepisanthes tetraphylla	FLB YFR	7 (2.82)
Hopea parviflora	YL FLB YFR	5 (2.02)
Terminalia bellerica	YL YFR SD PTL PH	4 (1.61)

YL, Young leaf; ML, Mature leaf; PTL, Petiole; FLB, Flower bud; FLR, Flower; YFR, Young fruit; RFR, Ripe fruit; SD, Seed; BR, Bark; PH, Pith.

and 8. This clearly indicates that the number of tree deaths fell sharply with increasing distance from the river.

In the home range of the two langur groups using the dynamited area, shrubs covered an area of 15.6 ha. Dumping of stones from the riverbed resulted in the loss of nearly half (7.5 ha) of the shrub cover. A summary of changes in the habitat caused by these disturbances is given in Table 4.

Impact of disturbance on Nilgiri langur demography and group dynamics

The sex ratio seen in different age classes and the female: young ratios in the different disturbed-area categories are given in Table 5. In the HD area, there was a decline in the proportion of adult males, but no significant difference could be observed in female : young ratio.

Birth rate was calculated for eight bisexual groups in three areas. Mean birth rate in the less disturbed LD area (0.66 infant/female/year) was greater than the other two areas (0.45 infant/female/year in the MD area, and 0.42 infant/female/year in the HD area). The overall birth rate between LD and HD areas was significantly different ($\chi^2 = 4.31$, $df = 1$, $P < 0.05$).

The difference in birth rate of each group compared against the mean birth rate (0.52) of the Mundanthurai plateau population is given in Figure 2. The mean death rate in the HD area was greater (0.71/year) than other areas, 0.37/year in MD area and 0.23/year in LD area. The difference in death rate of each group compared against the mean death rate (0.47) of Mundanthurai plateau population is given in Figure 3. The differences in death rate between LD and HD areas ($\chi^2 = 21.75$, $df = 1$, $P < 0.001$), MD and HD areas ($\chi^2 = 21.75$, $df = 1$, $P < 0.001$) and MD and HD areas ($\chi^2 = 28.52$, $df = 1$, $P < 0.01$) were significant.

Age-specific death rate varied between areas and between sexes with age (Table 6). In LD area, the juvenile males showed high death rate (0.49/year) than any other age/sex category. In MD area, sub-adult males showed higher death rate (0.57/year) than any other age/sex category. In HD area, there was a higher death rate in sub-adult males (0.99/year) than in any other age/sex category.

Population growth rate for the three areas is presented in Figure 4. In the LD area, in 1985–1986, the growth rate was 0.14/year. It decreased to 0.05/year in 1986–1987 (when there was dynamiting), and then increased again to 0.13/year in 1988. Groups in MD and HD areas showed a continuous decreasing trend. This trend in growth rate was more in HD area than in MD area.

The mean group size among the three disturbance categories, regardless of year, showed significant variation (Kruskal–Wallis One-way ANOVA, $df = 2$, $P < 0.05$). Comparison between years in different areas showed that there was an increase in the mean group size in LD area from 13 in 1985 to 17.2 in 1988. Such significant variation was not seen in MD and HD areas (Table 7).

Table 4. Changes in habitat components after dynamiting on Servalar river bank (sample area 1.2 ha)

Component	Before dynamiting (*A*)	After dynamiting (*B*)	Net change *A* – *B* (%)
Tree density (trees/ha)	220	134	86 (39.1)
Tree species diversity	2.10	1.50	0.6
Mean height (m)	117.1	116.0	1.2 (0.01)
Total basal area (m^2)	11427.7	9387.3	2040.4 (17.9)
Total canopy cover (m^2)	68460	41081	27379 (40.0)
Total shrub cover (ha)	15.60	8.10	7.5 (48.1)

Discussion

Marsh *et al.*[1], while discussing the effects of disturbances on rainforest primates, hypothesize that the disturbance categories are not exclusive and different kinds of disturbances often follow one another. In the Nilgiri langur habitat in Mundanthurai plateau, the major forms of disturbances seen were pole/fire wood cutting, dynamiting and loss of understorey vegetation. As the construction of the Servalar reservoir has been completed, dynamiting has ceased but pole/fire wood cutting and clearance of understorey vegetation around the temple during the festival continue.

These disturbances have serious impacts on the habitat and will eventually affect the Nilgiri langurs in

Table 5. Age/sex composition in different categories of disturbed areas on the plateau at the beginning (1985) and end of the study (1988)

	Beginning of study			End of study		
Age/sex class	LD	MD	HD	LD	MD	HD
Ad female : Ad male	100 : 21 (14 : 3)	100 : 56 (9 : 5)	100 : 67 (9 : 6)	100 : 25 (20 : 5)	100 : 45 (11 : 5)	100 : 38 (13 : 5)
SA female : SA male	100 : 100 (9 : 9)	100 : 86 (8 : 7)	100 : 100 (5 : 5)	100 : 150 (4 : 6)	100 : 125 (4 : 5)	100 : 150 (2 : 3)
J female : J male	100 : 167 (3 : 5)	100 : 100 (3 : 3)	100 : 60 (5 : 3)	100 : 114 (7 : 8)	100 : 50 (6 : 3)	100 : 175 (4 : 7)
Ad female : Inf	100 : 36 (14 : 5)	100 : 33 (9 : 3)	100 : 56 (9 : 5)	100 : 80 (20 : 16)	100 : 73 (11 : 8)	100 : 62 (13 : 8)

Table values are proportions and actual numbers are in parentheses. LD, MD and HD represent least, moderately and highly disturbed areas, respectively. Ad, Adult; SA, Sub-adult; J, Juvenile; Inf, Infant.

many ways. Habitat alteration occurring on the banks of river Tambiraparani and around the temple may slowly lead to denudation of the area. On the river bank, 74 of the 127 trees were cut within 18 months and this rate of loss can never be compensated by natural regeneration. Eventually, this area would cease to be a langur habitat. Once the trees are removed from this area, wood cutting would intensify in other areas. Wood cutting which initially started as 'selective logging' of smaller trees would end up as 'clear felling'. Pole cutting is a problem all along the riverine belt in Mundanthurai and, as observed by Johnsingh and Joshua[9], even the most common trees such as *Mangifera indica*, *P. pinnata* and *S. cumini* have very few individuals in the 30 cm–2 m, 2.1–4 m and 4.1–6 m categories all of which are pole size and easy to cut illegally. Hall and Rodgers[23] recorded such high intensity of pole cutting in accessible areas in coastal forests in Tanzania. They have also suggested that cutters are obliged to advance progressively into the hitherto less-severely affected core areas of the forests, auguring further deterioration of forest status.

The overall impact of these disturbances on the riverine vegetation would be seen in the loss of understorey, lack of regeneration and disappearance of evergreen species confined to the riverine areas such as *Aglaia roxburghiana*, *Diospyros peregrina* and *Calophyllum decipens*. Loss of such trees would result in reduction in canopy continuity, greater exposure of langurs to aerial predators and loss of food. More wood cutters were seen between 1000 and 1400 h when langurs usually rest and such disturbances could lead to stress. Similar negative effects of habitat alteration on primates as a result of logging have been reported (A. D. Johns, unpublished report).

Discontinuity seen along the riverine vegetation on the plateau is shown in Figure 1. With increasing wood cutting this discontinuity would only increase. In logged forests, primates lose their canopy pathways, resulting in changes in the ranging behaviour[1]. Although presently Nilgiri langurs are able to cross these discontinuities, it may become difficult in the future. Groups may get isolated and, if they move across patches, may become vulnerable to village dogs, which sometimes accompany wood cutters. For example, during the study, there were 38 sightings of domestic dogs and a dog once killed a juvenile langur.

It has been speculated (J. P. Skorupa in ref. 24) that fragmentation of the forest canopy following selective logging may increase the vulnerability of certain African monkeys to predation. In west Malaysia, both diurnal and nocturnal raptorial predators occurred at exceptionally high densities in the vicinity of logging roads and cleared areas[5]. Four observations made of Brahminy kite (*Haliastur indus*) attempting to prey upon Nilgiri langur infants while the group was moving through the tree canopy in HD area support this possibility. It is unlikely that any single factor continuously limits the density of an animal population[25]. Very little is known of the demographic

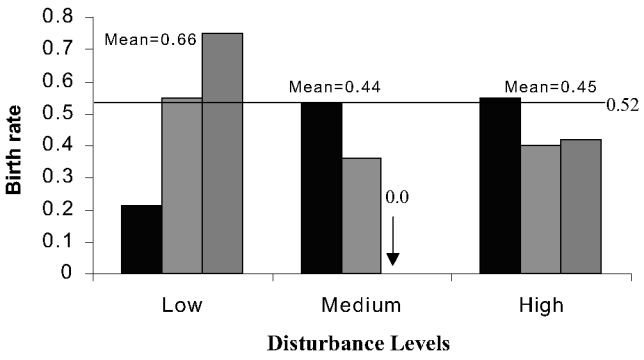


Figure 2. Birth rate of different Nilgiri langur troops in areas under different human disturbance levels.

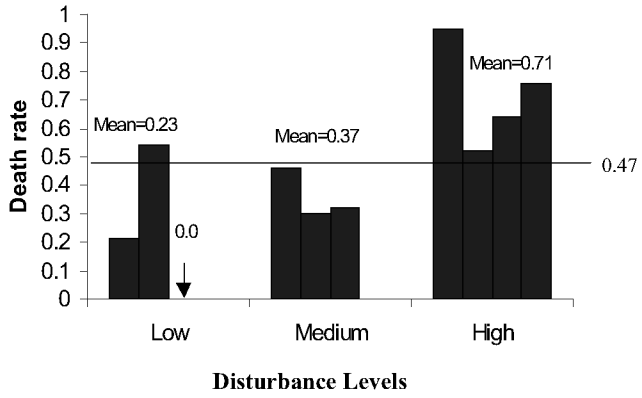


Figure 3. Death rate of Nilgiri langur troops in areas under different human disturbance levels.

Table 6. Age sex-specific death rates in LD, MD and HD areas

	Total animal years			Death recorded			Death rate		
Age/sex	LD	MD	HD	LD	MD	HD	LD	MD	HD
Adult male	3.98	5.42	5.19	0	1	1	0.00	0.18	0.19
Adult female	17.52	8.92	10.39	4	3	4	0.23	0.34	0.38
Sub-adult male	10.38	5.27	9.07	0	3	9	0.00	0.57	0.99
Sub-adult female	8.46	4.66	6.31	0	2	2	0.00	0.45	0.31
Juvenile male	6.17	3.95	6.41	3	2	3	0.49	0.51	0.00
Juvenile female	8.14	3.43	4.53	2	0	1	0.25	0.00	0.00
Infant	14.95	6.92	9.58	4	3	7	0.27	0.43	0.73

Table 7. Mean size of Nilgiri langur groups among areas of different disturbance categories

Area	Group*	Year				Mean group size
		1985	1986	1987	1988	
LD	SRV I	–	21	26	29	25.3
	SRV II	–	17	10	12	13.0
	SRV III	12	17	25	25	19.8
	SRV IV	11	13	11	13	12.0
	CCP	16	10	13	7	11.5
	Mean	13.0	15.6	17.0	17.2	
MD	KAN I	21	10	12	22	16.3
	KAN II	3	3	4	3	3.3
	MDR III	14	10	12	16	16.0
	ST	13	8	10	8	8.0
	CNP	7	6	8	6	6.0
	Q (N)	–	6	4	–	5.0
	Mean	11.6	7.2	8.3	11.0	
HD	MDR I	15	6	10	10	10.3
	MDR II	8	8	10	13	9.8
	LDM I	12	17	14	13	14.0
	LDM II	3	1	2	4	2.5
	KTS (J)	7	5	4	8	6.0
	KTS (K)	7	3	3	2	4.0
	PAT	7	4	3	3	4.3
	E	13	10	7	11	10.3
	Mean	9.0	6.8	6.6	8.0	

*Although information on 19 groups is presented, this paper uses information only from 10 groups.

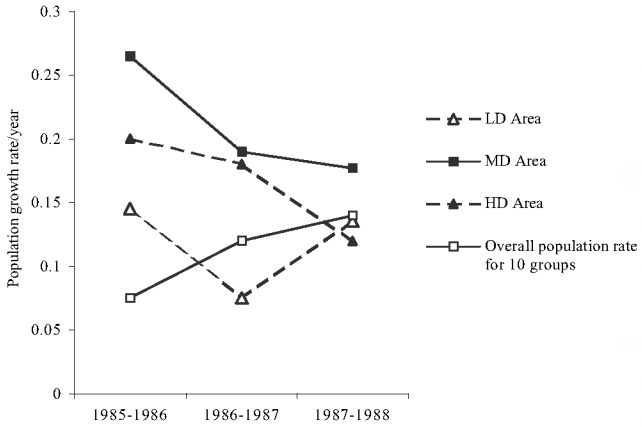
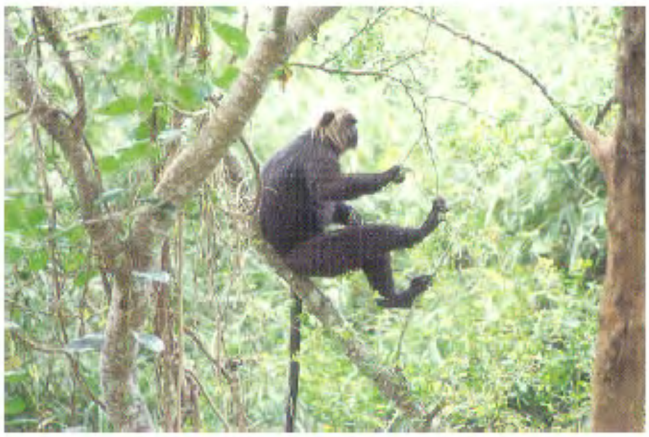


Figure 4. Area-specific and overall population growth rates of Nilgiri langurs from 1985 to 1988.



The Nilgiri langur in Mundanthurai plateau—an indicator of the detrimental effects that human disturbances can have on animal populations. (Photo: A. J. T. Johnsingh)

mechanisms, causing population decline following logging[1]. Densities can drop through the disappearance of social groups[26] or by reduction in the group size[27]. Reduction in group size is probably affected mainly by increased mortality among infants and juveniles related to food shortages and dominance rank[28]. Johns[29] reported a high level of infant mortality in all species following logging, although the causes of death were not known. MacKinnon[26] found that following logging operations 15–30 km away, orangutan densities in his study area increased by immigration, but the number of infants per female was lower, indicating less breeding. Groups living in HD area in general had smaller group size, lower birth rate and higher death rate.

If hunting follows severe habitat disturbance, it could lead to the total elimination of the species in an area[29]. Management action on the Mundanthurai plateau should aim towards reducing disturbances and keeping the area free from poaching. Johnsingh and Joshua[9]

have given guidelines for protecting and managing the plateau.

Conclusions

It is clearly evident that the biotic disturbances have serious impact on the habitat and these will eventually, affect the Nilgiri langurs in many ways. The rate of wood cutting and loss of trees cannot be compensated by natural regeneration. Once the trees are removed from this area, the pressure would intensify in other areas. Overall impact of these disturbances on the riverine vegetation along the river banks would be seen in the loss of understorey, lack of regeneration, disappearance of evergreen species confined to the riverine areas, reduction in food plants, etc. In the sampled areas, these impacts changed the habitat components in the form of reduction in density, diversity, height and basal area in the sample area.

Ultimately, significant difference in demographic patterns was observed in groups living in the three areas of different disturbance magnitude categories. High death rate and low birth rate and a resulting continuous decreasing trend in population growth is evident in the HD area. The continuation of this situation will result in population decline and change in population composition.

Conservation problems

Six major conservation problems have been identified on the plateau:

1. The langur habitat is under severe biotic pressure in the form of wood cutting for fire wood. This pressure affects the habitat in terms of reduction in food plants, loss of canopy continuity, lack of regeneration and recruitment of important food plants and overall change in habitat quality.
2. Occasional poaching has been recorded in the plateau. Two incidents were recorded during the four-year study. In total 15 Nilgiri langurs from two groups were poached.
3. The demographic pattern of Nilgiri langur showed unhealthy trend like the overall low population growth rate, high death rate in HD area, and overall high mortality rate in male recruitment age class (juveniles and subadults).
4. Nilgiri langur groups are isolated due to natural discontinuity in the habitat. This has been further intensified due to wood cutting.
5. The habitat is under threat due to monthly (1000 pilgrims visit during the last Friday of each Tamil month) and annual (50,000 pilgrims) visits of pilgrims. They cut trees (poles) and remove ground cover.
6. Massive habitat loss took place due to a flash flood in October 1992. The habitat loss was on either bank of Servalar and part of Tambiraparani river after the confluence of both the rivers. Death rate of Nilgiri langur was very high (71 of 155 animals in 13 troops died)[30].

Management recommendations

Considering the severe habitat disturbances caused by local people, pilgrims, poaching and unexpected loss of habitat due to flash flood, the langurs and their habitat need immediate conservation and management actions.

Protection

1. Cutting pressure and other disturbances such as cooking and camping in the riverine habitat by pilgrims should be immediately stopped. Strict and regular patrolling of riverine habitat should be done.
2. Domestic dogs seen inside the forest, which kill not only langur but chital (*Axis axis*) and sambar (*Cervus unicolor*), should be shot dead.
3. There must be a continous monitoring of the number of pilgrims visiting every month. Attempts should be made to minimize and control their impact on the natural habitat. The entry of special vans, vehicles and government bus services should also be regulated through enforcement of visiting hours and issue of permits.
4. Pilgrims should be persuaded to bring cooked food and not be allowed to cut trees for camping and cooking.
5. A special protection team should be arranged on a rotational basis with all the department staff, for monthly visits to the temple area to keep check on pilgrims so that they do not cut wood.
6. Extra protection force should be brought from the other ranges of the Reserve during the time of the annual festival to control the mass gathering of pilgrims.

Restoration

1. Wherever biotic pressures have decimated the habitat, planting of Nilgiri langur food trees should be done. The following tree species, from the top-ten ranking food tree species are suggested: *P. pinnata*, *T. bellerica*, *A. amara*, *A. lebbeck*, *S. cumini*, *L. coromandelica* and *T. indica*.
2. In addition, the same species should be planted along the banks of bigger streams which are tributaries of these two major rivers.
3. Wherever possible plantation should be raised adjacent to the riverine habitat using *A. amara*, *A. lebbeck* and *S. cumini*. Activities 2 and 3 can provide extra habitat for langurs to move freely and feed and provide escape cover from the poachers.
4. Massive restoration plan should be taken up on both banks of Servalar river with planting of a few more pure

riverine species like *Hopea parviflora*, *Calophyllum decipens* and *Mangifera indica* (wild variety).

Education

1. An intensive education programme for the pilgrims visiting the temple and the local people who are involved in wood cutting should be launched at an early date. Creating awareness among the pilgrims and the public at large can be achieved by displaying information boards in chosen places on the way to the temple about the conservation significance of the habitat and uniqueness of the endangered Nilgiri langur and other arboreal mammals, with a request not to cause any disturbance to the habitat.
2. Periodically, the same message can be flashed in local newspapers and television programmes.
3. Education and training programmes for the students of adjacent schools and colleges should be arranged to spread the message of the importance of this Reserve and especially the highly endangered Nilgiri langur and its habitat.
4. Local naturalists and NGOs, including the recently formed Village Forest Committees, should be encouraged to take up the education programme.

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