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HABITAT SUITABILITY INDEX MODEL FOR NILGIRI TAHR IN ERAVIKULAM NATIONAL PARK

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(REPORT OF THE PROJECT KFRI/354/2000)

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ABSTRACT

A field survey of the endangered Western Ghats endemic, Nilgiri tahr, was conducted in all the known locations in Kerala. The number of animals sighted along with classification of the individuals, the latitude and longitude with GPS were recorded. The food species were identified and their quantitative assessment made. The extent of the habitat and the abundance of indirect evidences were also recorded. The threats to the animals and the habitats were assessed.

The population of tahr in Kerala occurs as fragmented and the total is about 1,000 in eleven populations, the largest being about 700 in Eravikulam National Park. The other promising populations are in Varayattu Mala in Neyyar, Kochupamba in Goodrikkal Range, the Nelliampathy Hills and Meesappuli Mala.

Population of Nilgiri tahr in Eravikulam National Park was estimated using Bounded Count technique in the identified blocks. An area map was digitized with all relevant details of various locations and blocks were demarcated. The area under each block was then calculated and the population and density were estimated in each block. The food species of Nilgiri tahr in Eravikulam National Park were identified through direct observations and quantified in different blocks through clip and weigh method. The nutritive values of food species were also quantified.

Factors like density, block size, cliff, altitude and percentage availability of principal food species were utilized to develop a Habitat Suitability Index Model for Nilgiri tahr. The altitude, extent of cliff and the food species were the important parameters that affect the number and distribution of tahr population. The Habitat Suitability Index Model was found to be satisfactory from the results of the regression analysis. However, further studies are suggested to improve the precision of the model.

ABSTRACT OF THE PROJECT PROPOSAL

Code	KFRI/354/2000
Title	Habitat Suitability Index Model for Nilgiri tahr in Eravikulam National Park
Objectives	To study the following parameters of tahr habitat in Eravikulam National Park for devoloping HSI for Nilgiri tahr Plant species available in the habitat and the composition Availability of food species quantified in terms of g/m^2 Calorific value of food species Quality of the forage (stage of development) consumed Utilisation of habitats The model developed will be applied in two other tahr habitats (eg. Shettivara hills in Parambikulam) for habitat assesment To identify the different habitats and estimate the population of Nilgiri tahr in the state and prepare a distribution map. To identify the degradation factors in tahr habitats and suggest management measures for improvement.
Expected Outcome	Distribution and status of Nilgiri tahr in the State Identification of the parameters of importance for assessing the status of tahr in the State
Date of Commencement	April, 2000
Scheduled date of completion	March, 2002
Funding Agency	Kerala Forest Department (Under World Bank aided Kerala Forestry Project).
Principal Investigator	P.S. Easa
Associate	M. Sivaram
Research Fellow	Saju K. Abraham

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Abstract

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INTRODUCTION

The Nilgiri tahr *Hemitragus hylocrius* Ogilby, 1838 is restricted to the hills of Southern India. It is the congener of the Himalayan tahr *Hemitragus jemlahicus*, found from Kashmir to Bhutan (Schaller, 1973) and the Arabian tahr *Hemitragus jayakari*, which is confined to the mountain districts of Arabia (Harrison and Gallagher, 1974; 1976). The Nilgiri Tahr is with short gray-brown or dark coat. There are facial markings, particularly distinct in mature males, consisting of a dark brown muzzle separated from a dark cheek by a white stripe running down from the base of horns.

The Nilgiri tahr was first named as *Kemas hylocrius.* Later Blyth included the tahr in the genus *Hemitragus* under the subfamily Caprinae. The Nilgiri tahr is an endangered species listed in schedule I of the Indian Wildlife (Protection) Act 1972 and categorized as vulnerable by the IUCN. Uncontrolled hunting and conversion of tahr habitat to plantations and other human related pressure resulted in the decline of the population (Schaller, 1977, Davidar, 1978). Its habitat has been reduced to less than one tenth of the total range of the species in the past (Schaller, 1977). The largest population of Nilgiri tahr is found in Eravikulam National Park in the High Ranges of Kerala.

Review of Literature

The genus *Hemitragus* appears in the fossil records of the beginning of the major glaciations in Europe (Geist, 1987). During the Pleistocene, it ranged as far west as Europe, from where it disappeared about 17,000 to 10,000 years ago (Schaller, 1977). At present, the genus is represented by three widely separated species. *Information* on the habits and biology of Nigiri tahr is mostly confined to hunting accounts and description of encounters with the animals. Systematic observation has been limited to Schaller's study in 1971. Rice (1984) was the first to make an extensive study on the ecology and behaviour of tahr. Several papers on the biology and management of Nilgiri tahr in captivity have also been published (Pillai, 1963; Potti, 1966; Chandran, 1980; Wilson, 1980; Swengel and Pichner, 1987). Murugan (1997) discussed the population dynamics and habitat requirements with reference to food, water and shelter of Nilgiri tahr in the Nilgiris in Tamil Nadu. Sumitran (1993) studied the ecology of Nilgiri tahr in the Nilgiris. Mishra and Johnsingh (1994) compared the habitat and population of Nilgiri tahr in Anamalai and Parambikulam wildlife sanctuaries.

Habitat Suitability Index (HSI) Model - An Overview

Selection of appropriate sites for reintroduction of tahr requires some basis for determining suitability. It is also essential to monitor the habitat in Protected Areas (PAs) where tahr population is observed in order to prevent habitat degradation. Thus, there is a need for an index of habitat suitability that can be used either as a parameter to monitor the existing population and habitats or to prioritize possible areas for reintroduction. Such an effort has not so far been attempted on Nilgiri tahr. The HSI modeling procedure is elaborated under the Methods Section.

A series of HSI models developed by the United States Fish and Wildlife Services for various species are formalized synthesis of biological and habitat information published in scientific literature and based on the opinions of identified experts (Short, 1986; Rogers and Allen, 1987). The assumptions necessary for organizing and synthesizing the species-habitat information into the model have also been discussed. Some of such models have been tested and modified based on field data (Neil *et al*., 1988; Loukmas and Halbrook, 2001). The HSI models have also been published based on the field data for the animal species such as *Nemorhaedus goral*, white tailed deer, Cape Mountain Zebras (Roy *et al*., 1995; Novellie and Winkler, 1993; Roseberry and Wolf, 1998). It may be noted that although there are several habitat models on the abundance and distribution of wildlife species, they lack field application due to complexity (Loyn *et al.*, 2000; Khaemba and Stein, 2001).

OBJECTIVES

The present programme was formulated to identify the habitats of Nilgiri tahr in Kerala, to estimate the population, to identify the degradation factors in tahr habitats and to develop a Habitat Suitability Index Model based on different parameters.

STUDY AREA

Eravikulam National Park, situated in the High Ranges of the Western Ghats in Idukki district covers an area of about 97 km^2. The park is of undulating terrain comprising a high rolling plateau area with a base elevation of about 2000 m (Fig. 1). Most of the peaks rise 100-300 m above this plateau. The main plateau is split from northwest to southeast by the Turner's Valley. Anamudi, with an elevation of 2695 m is the highest point south of the Himalayas,

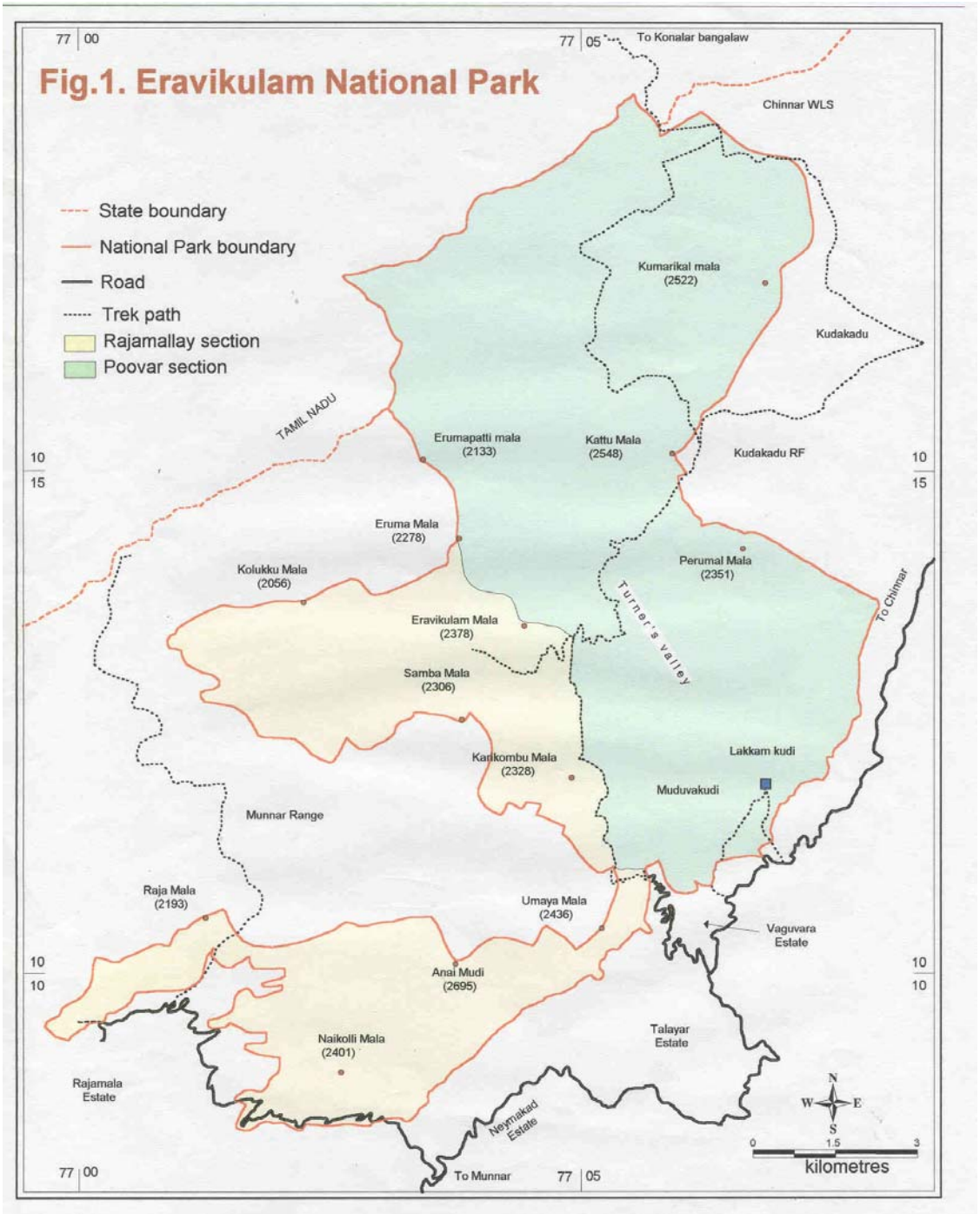


Fig.1. Eravikulam National Park
77 | 00
77 | 05
To Konalar bangalaw
Chinnar WLS
State boundary
National Park boundary
Road
Trek path
Rajamallay section
Poovar section
Kumarikal mala
(2522)
Kudakadu
TAMIL NADU
Erumapatti mala
(2133)
Kattu Mala
(2548)
Kudakadu RF
10
15
Eruma Mala
(2278)
Kolukku Mala
(2056)
Perumal Mala
(2351)
Turner's valley
To Chinnar
Eravikulam Mala
(2378)
Samba Mala
(2306)
Lakkam kudi
Karikombu Mala
(2328)
Muduvakudi
Munnar Range
Raja Mala
(2193)
Umaya Mala
(2436)
Vaguvara
Estate
Anai Mudi
(2695)
Naikolli Mala
(2401)
Talayar
Estate
Rajamala
Estate
Neymakad
Estate
N
W
E
S
0
1.5
3
kilometres
To Munnar

falls in the southern part of the Park. The Eravikulam National Park is contiguous with Grass Hills of Tamil Nadu, which is of similar terrain and vegetation. The horizontally and vertically rounded cliffs are the characteristic features of Eravikulam. Rice (1984) has described the Park in detail.

The mammals reported from Eravikulam National Park include Nilgiri tahr (*Hemitragus hylocrius*), gaur (*Bos gaurus*), elephant (*Elephas maximus*), barking deer (*Muntiacus muntjak*), mouse deer (*Tragulus meminna*), Nilgiri langur (*Trachypithecus johni*), Malabar giant squirrel (*Ratufa indica*), tiger (*Panthera tigris*), panther (*Panthera pardus*), wild dog (*Cuon alpinus*), jackal (*Canis aureus*), jungle cat (*Felis bengalensis*), stripe necked mongoose (*Herpestes vitticollis*), Ruddy mongoose (*H. smithi*) and Nilgiri marten (*Martes gwatkinsi*).

Weather conditions of the area are predominantly influenced by the southwest monsoon. The average annual rainfall is 4050 mm. The area has an annual temperature ranging from 8^0 C to 23^0 C. The hottest months of the year are April and May (Seshadri, 1986). The vegetation could be subdivided into grassland, shrub and forests. The terrain above 2000 m is covered primarily by the grasslands with small patches of forest in gullies and hollows. Shrub lands are found along the bases of cliffs and intersperse in rocky areas. The shola forests, classified as Southern Montane Wet Temperate Forest, are located mostly in the valleys (Chandrasekharan, 1962). Shetty and Vivekanandan (1971) have described the flora of the area. Karunakaran (1997) studied the ecology of grasslands in Eravikulam National Park.

There are dense human settlement along the southern and eastern boundaries (Rice, 1986), tribal settlements at Edamalakudy, Parrappayar and Lukham Kudy and also tribal populations on the Tamil Nadu side of the border (Anon., 1993). Tea estates are contiguous to the park (Rice, 1984 and 1986). The only tribal settlement within the sanctuary is Luckham Kudy near the eastern boundary.

METHODS

Population distribution in Kerala

The population of tahr in its ranges has been reported to be fragmented (Davidar, 1978). The published literature was referred for the available information on locations of hitherto reported populations and personnel involved in tahr conservation were consulted to get more recent

information on the distribution and status in such areas. These areas were thoroughly searched for tahr. The number of animals sighted was recorded along with information on the herd composition and population structure. The latitude and longitude of the locations were recorded with a GPS. The altitude, extent of the area and number of cliffs were recorded. A qualitative assessment of the food species in the area was also made. Information on the adjacent areas and sources of disturbances was also documented.

Population estimation by Bounded Count Technique

Bounded count technique proposed by Regier and Robson (1966) was followed for estimating the population of Nilgiri tahr. In this technique, repeated independent efforts are made to census the population. In any census, the observers are not likely to detect all the individuals in the area. The construction of an estimate of population size is based solely on the numbers observed in repeated incomplete counts.

Twelve blocks based on the home range, as suggested by Rice (1984), were taken as the basic unit for population estimation. The blocks were repeatedly covered on foot for a fixed period recording the animals sighted for five days. Population estimation of Nilgiri tahr was normally conducted during April – May. However, since a seasonal comparison was thought to be helpful for developing HSI, population estimation of Nilgiri tahr was conducted in April and October 2000 and in December 2001 in Eravikulam National Park. Logistic problems did not allow a continuous monitoring.

The unknown population size N is estimated by

$$\hat{N} = X_{(m)} + [X_{(m)} - X_{(m-1)}],$$

where $X_{(1)} \leq X_{(2)} \ldots \leq X_{(m-1)} \leq X_{(m)}$ represent the numbers observed in consecutive days, arranged in increasing order.

The lower and upper confidence limits of N are

$$N_L = X_{(m)}$$

$$N_U = X_{(m)} + [X_{(m)} - X_{(m-1)}] \quad [1-\alpha/\alpha]$$

Where $X_{(m)}$ and $X_{(m-1)}$ are the largest and second largest counts obtained respectively, α is the type-I error. In this study, α is fixed as 20 per cent. The useful descriptions on this technique are found in Seber (1973) and Routledge (1982).

The details collected include the herd size and the various age-sex classification within the herd such as adult male, adult female, sub adults and yearlings. The classification by Rice (1984) as given below, was followed.

Young (0-1 years)	Light brown coat
Yearling (1-2 years)	Grey brown coat
Adult Female (2+ years)	Grey brown coat, Shoulder height above 70 cm
Light brown male`	Grey brown coat
(2-4 years)	Horns thick facial markings distinct
Dark brown male	Grey brown coat- dark brown
(5 years)	Larger than Adult female
Saddle back male	Dark brown, Shoulder height 110 cm
(6+ years)	Saddle on the back, white knee patch

Habitat type, activity and environmental factors were also recorded.

The Park boundary and the block boundary were visited and the latitude and longitude of various locations were recorded using a GPS receiver. A digital map of Eravikulam National Park was prepared using the GPS data with the help of the computer program, MapInfo Professional and topo sheets (Fig. 2). The area of each block was calculated.

A three dimensional map was generated with information on the contour (Fig. 3). The altitude of peaks and the areas utilized by tahr were measured using altimeter. The extent of cliff was calculated using planimeter from the three dimensional maps.

Figure 2.

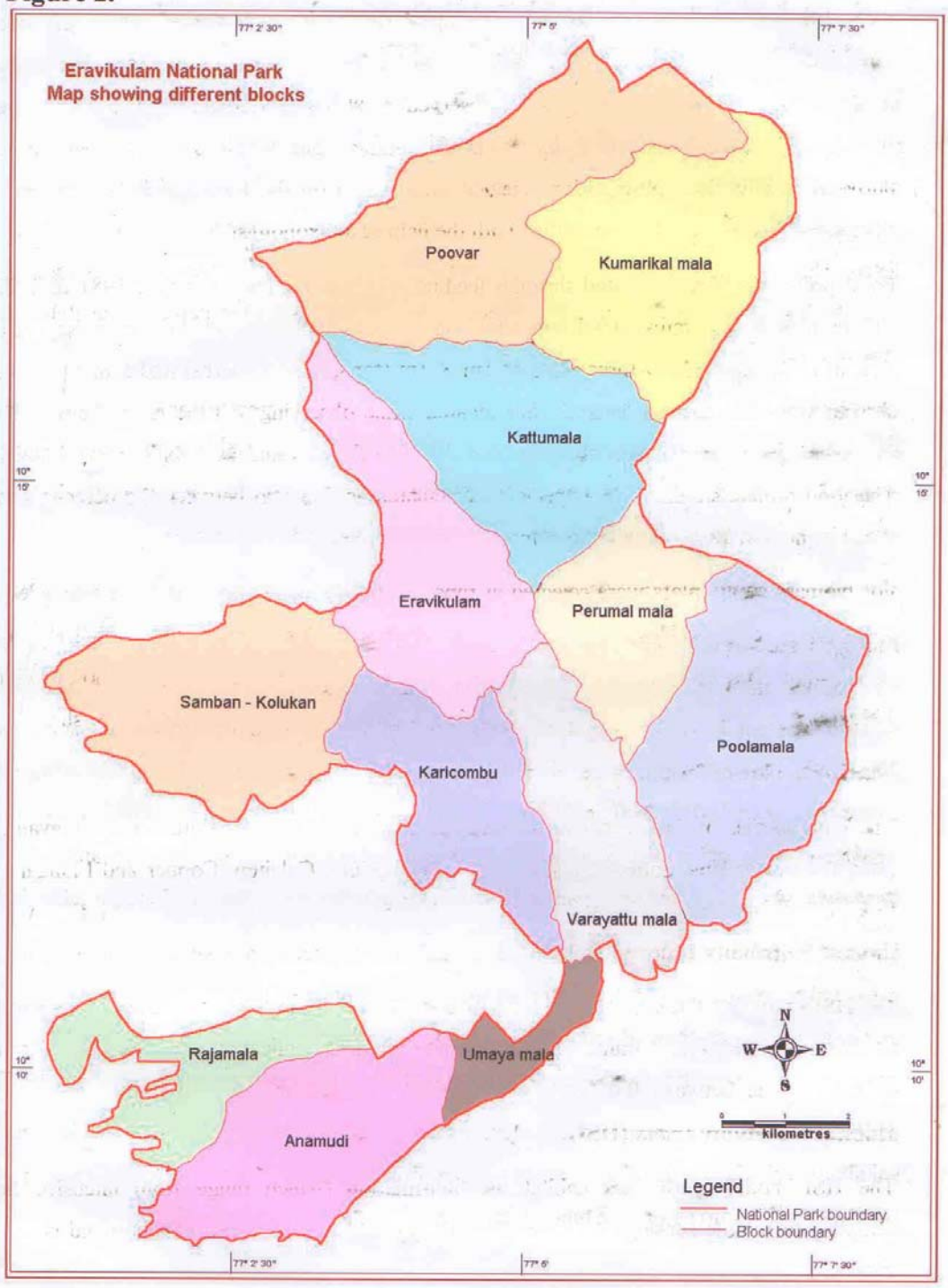
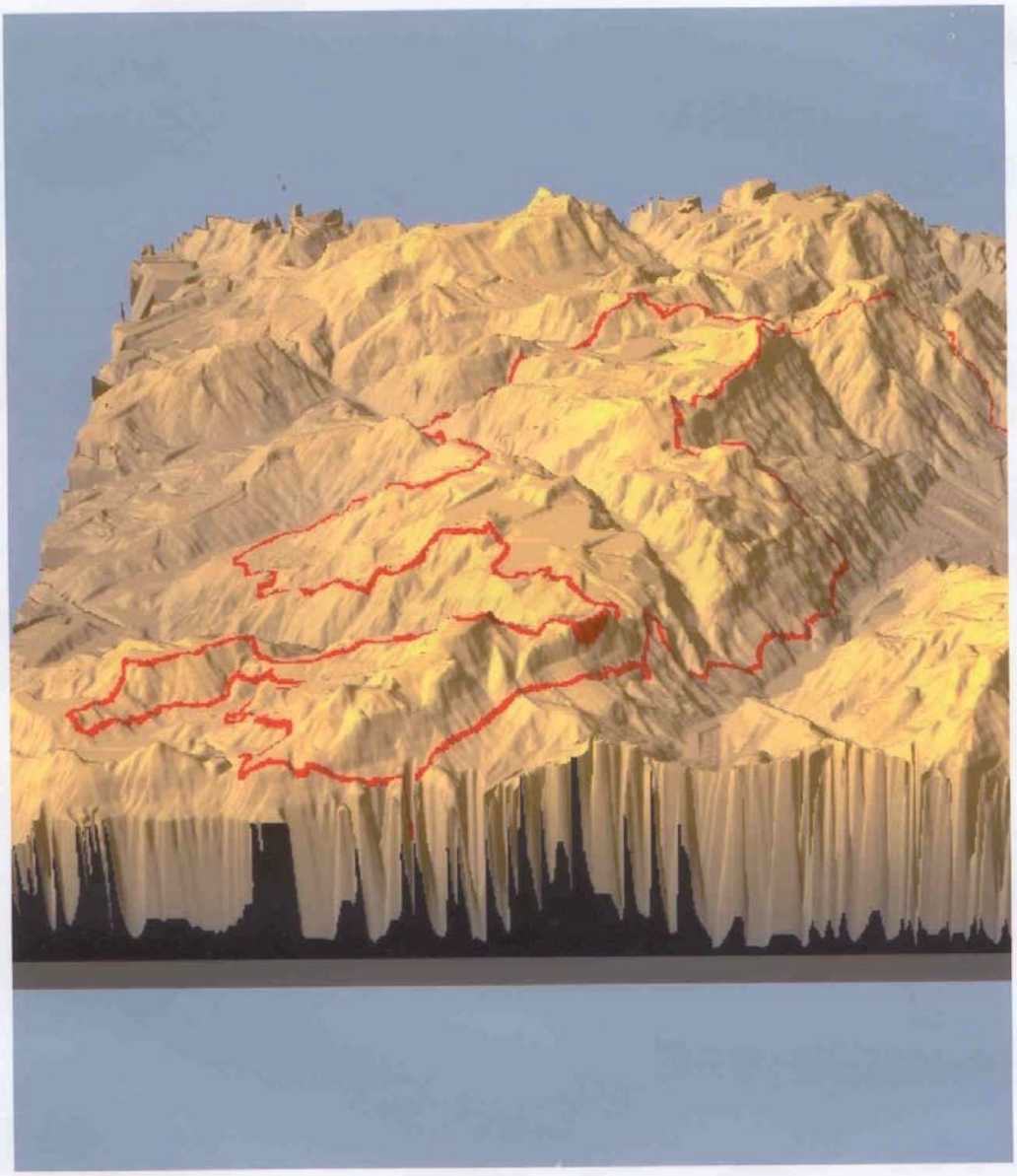

Eravikulam National Park
Map showing different blocks
77° 2' 30"
77° 5'
77° 7' 30"
10° 15'
Poovar
Kumarikal mala
Kattumala
Eravikulam
Perumal mala
Samban - Kolukan
Karicombu
Poolamala
Varayattu mala
Rajamala
Umaya mala
Anamudi
N
W
E
S
0 1 2
kilometres
Legend
National Park boundary
Block boundary

Figure 3. 3D view of Eravikulam National Park



Principal and preferred food species

Rice (1984) has recorded the food species of tahr in the area. However, since there was a time lapse of about 16 years, it was decided to go for identification of food species from direct observation. Selected herds were observed in almost all the areas in the Park and the food species were identified from the fresh feeding signs in quadrats selected for the purpose. Several such observations yielded information on the food species of tahr in the area. These plants were later identified with the help of a taxonomist.

Food preference was estimated through feeding quadrat method (Grobler, 1981 and 1983). The number of quadrats varied depending on the size of the area used by the animal at the time of observation. Fifty-three plots of 1 m x 1 m (for grass and herbs) and 5 m x 5 m (for shrubs) were laid at fresh feeding sites located while observing. All the food plant species within the plots were listed. The percentage of species fed and availability were assessed. The food preference index of a species was calculated as the ratio between what was fed to and what was available in the environment.

For biomass study, plots were selected at random and the number of quadrats was selected taking the size of the block into account. The plant species available in the habitat and their composition were studied. Biomass was calculated by using Clip and weigh method (Weigert, 1962) in plots of 1 m x 1 m plots for grass; 2 m x 2 m for herbs and 5 m x 5m for shrubs.

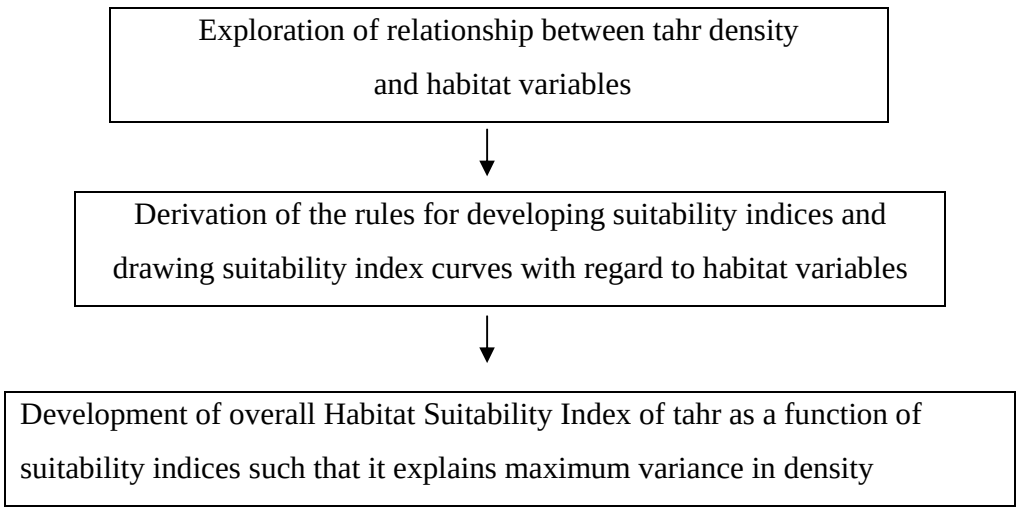
Nutritive value of food species

The food species of Nilgiri thar in the study area were analysed for total nitrogen, available phosphorus, available potassium, zinc, iron, magnesium, calcium, copper and manganese. Since it was not possible to analyse all the food species, only those species of plants, which formed the major component of food, were selected for chemical analyses. The food plants collected were dried at 100 ^{0}C in an oven, powdered in a Wiley mill, sieved and stored in desiccator over calcium chloride. The powdered materials were used for analyses. The micronutrients were measured against standard solutions by atomic absorption (Vogel, 1975).

Habitat Suitability Index (HSI) Model

The HSI model synthesizes habitat use information (which ranges from intensive field sampling to remote sensing) into a framework appropriate for field application and is scaled between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). In order to formulate HSI model, suitability index curves are developed presenting species-habitat suitability criteria. There are three categories of suitability index curves. Category I curves are based on professional judgment, with little or no empirical data. Both category II (utilization criteria) and category III (preference criteria) curves depend on source data collected at various locations where target species are observed or collected. Once the suitability indices are developed for the important habitat variables of the species, various combinations of these can be tried to best fit the regression equation. Based on the methodology used in the literature, the procedure for developing HSI model for Nilgiri tahr was conceived into three steps as presented below.

Procedure for developing HSI Model



RESULTS

Status and distribution of Nilgiri tahr population in Kerala

Nilgiri tahr is strictly confined to the highland plateau of the Western Ghats. The largest population of Nilgiri tahr in its ranges is confined to Eravikulam National Park in Kerala and Mukurthi National Park in Tamil Nadu. Fragmented population of this endangered, endemic has been reported by Davidar (1978), who surveyed the Nilgiri tahr populations in the Western Ghats. There had also been observations and reports of such populations from other parts (Fletcher 1911; Davidar, 1976; 1978; Daniel, 1987). Schaller (1971), Daniel (1971) and Davidar (1963, 1971, 1975, 1976 and 1978) have given the locations and the size of tahr population in its range. Eravikulam National Park in the High Ranges of Kerala is abode of the largest population of tahr.

The locations of tahr sightings during the present survey are plotted in Figure 4. The details of animals sighted in different locations with fragmented populations are given in Table 1.

Table 1: Group composition of fragmented population of Nilgiri Tahr

No.	Location	AM	AF	SAM	SAF	Y1	Y	Total*
1	Elival mala	2	5	1	3	-	-	11
2	Parambikulam	2	7	2	4	2	-	17
3	Mangaladevi		6	2	4	-	-	12
4	Kochupampa	4	7	2	5	4	-	22
5	Nelliampathy hills	4	14	6	8	5		38
6	Chinnar	-	3	-	-	-	-	3
7	Varayattu Mala	6		-	-	-	-	58
8	Ponmudi hills	-	-	-	-	-	-	18
9	Meesappuli Mala	-	-	-	-	-	-	64
10	Gundumala		-	-	-	-	-	60
	Total							303

* Total need not tally across rows because of the unknown age group composition

AM-Adult male, AF-Adult female, SAM-Sub adult male, SAF-Sub adult female, Y1-Yearling, Y-Young


Fig. 4. Distribution of Nilgiri tahr in Kerala
KARNATAKA
TAMIL NADU
Kannur
Aralam WLS
Wayanad North
Wayanad WLS
Wayanad South
Calicut
Silent Valley NP
Nilambur North
Nilambur South
Mannarkad
Elival mala
Palakkad
Nelliampathy
Nemmara
Pandaravara
Trichur
Chimmony WLS
Peechi WLS
Parambikulam WLS
Vengoli mala
Eravikulam NP
Mankulam
Chinnar WLS
Chalakudy
Vazhachal
Thattekad WLS
Munnar
Malayattur
Kothamangalam
Gundumala
Idukki WLS
Periyar Tiger Reserve
Kottayam
Mangaladevi
Ranni
Kochupamba
Konni
Achenkovil
Thenmala
Punalur
Shendurney WLS
Pomudi
Trivandrum
Peppara WLS
Agasthya-vanam BP
Neyyar WLS
Varayattumotta
Tahr areas
N
W
E
S
Division boundary
Range boundary
Forest boundary
River
Forest area

Siruvani-Muthikulam Hills

The Siruvani hills are contiguous with Attappady. This range is to the south of Nilgiri hills and north of Palghat gap (10^o 55' N and 76^o 45 E ^{o}). It is one of the smallest hill ranges in the Western Ghats. The peaks- Vellingirimala, Kunjaramala, Peria Kunjaramala, Ayyappanmudi and Elivalmala rise sharply from the basin reaching heights between 1500 and 2100 m. Smaller grass-covered hills are found in this area.

Elivalmala (which means rat's tail mountain) lies to the north and west of the Palghat gap and south of Muthikulam (between 10^0 56.206' and 10^0 56. 103' N and between 76^0 38.267' and 76^0 38 05' E). The extent of the grassland area is about 10 ha and is bordered by evergreen forests on the northeast and south and rocky cliff on the western side.

A total of 11 animals were seen during the visit. One was a lone saddleback, about 6 year old. A group was sighted very near to the cliff and had 6 adult females, 2 sub adult males and 2 sub adult females. They moved away in two groups comprising of 6 and 4. One group moved towards the right side and the other group to the left of the cliff. The forest officials of the Singappara Forest station told that they had observed a herd of 30 in December 2000.

The abundance of tahr pellets clearly indicates that this area is used by more than one herd.

Another tahr habitat is the Kuncharmala, which borders the Kerala-Tamil Nadu in the south end of the Siruvani dam. It is contiguous with the Ayyappanmudi and is about 1 km^2 in extent. The middle land grassland extends to over 2 ha area. Major part of the area is steep cliffs. Stunted evergreen forests border the top portion of the hill. No animal was sighted during our visit. But the fresh droppings indicate that the animal is using this area. The grasslands are quite good.

Degradation factors: The Elival area is under heavy pressure due to various factors. The adjacent human habitation is really a threat to the population. The tribes depend on the shola forests nearby for the NWFP resources. The population is also subject to poaching, as per the information from the tribes.

Parambikulam Wildlife Sanctuary

The forests in Parambikulam, well known for its rich wildlife, were worked heavily during the last century. The Parambikulam-Aliyar river valley project and its associated series of dams and other structures came up during the 1960's followed by extensive teak plantations. The sanctuary area ranges in altitude from 459 to 1439 m above sea level. The tahr was seen in Pandaravara, Shettivara Hills and Karimalagopuram. Davidar (1978) and Mishra and Johnsingh (1994) surveyed tahr population in this area.

Pandaravara

Pandaravara (between 10^0 29.4' and 10^0 29.566' N and between 76^0 49.417' and 76^0 49.520' E) is a prominent ridge running north to south and could be seen from the Top slip forest rest houses. The ridge is in three sections, Pandaravara in the middle, which is the highest point (1300 m), Naduva and Kattadi mala on either side. The inter-state boundary cuts through the centre of the peak, leaving only a third of the peak in Tamil Nadu. The route is through Karian shola, an unspoiled semi-evergreen and evergreen forests. The grassland and cliffs occupy about 6 to 8 km^2. The presence of date palm (*Phoenix humilis*) indicates low altitude grasslands.

Four tahr resting on the rocky cliff on the north side of the Pandaravara was observed. The herd included two adult females and two yearlings. There are sufficient indirect evidences to prove that this area was intensively used by tahr in the past. Davidar (1978) conducted a survey and observed 22 tahr in Pandaravara and adjacent areas. This area is utilized by gaur and tahr.

Degradation factors: The extent of grassland is on the decrease and is highly eroded with frequent fire. The food species were also very low in abundance.

Shettivara hills

The Kerala part of the Vengoli hills, known as Shettivara hills, faces the forest settlements in Thunakadavu across the lake. The hill ranges between 10^0 25.330' and 10^0 25.378' N and between 76^0 46.384' and 76^0 48.035'E with 903 m maximum altitude. During our visit to this area, we observed only one saddle back in the lower base of the hill at about 600 m altitude. The abundance of pellets indicates a small group of tahr in the area. Davidar (1978) surveyed

the entire stretch up to Tamil Nadu and estimated a population of 20-25 animals. The animals are said to be moving to the Valparai area.

Degradation factors: The area has changed drastically in the recent past. The food species is almost lacking and the area is already with shrubby vegetation.

Karimalagopuram

Karimalagopuram consists of two peaks, the Karimala (1445 m) and Kalyanathy mala (1418 m) on the southern part of Parambikulam Wildlife Sanctuary. Karimalagopuram is an ideal habitat for Nilgiri tahr with sheer cliffs on one side and undulating grasslands extending to 3 to 4 km^2. The area lies between 10^0 21.534' and 10^0 22.3'N and between 76^0 45' and 76^0 44.35 E. Nine animals were seen during the visit in the Kalyanathy mala, five adult females and four sub adults. No tahr was seen in Karimala. But the presence of pellets indicates that this area is highly utilized by tahr. Davidar (1978) reported about 120 tahr in this area. *Themeda tremula*, *Arundinella mesophylla* and *Heteropogon contortus* are abundant in this area.

Degradation factors: The lemon grass, *Cympopogon flexuosus* covers almost all parts. The area is vast but the observations indicate lack of food species in the area.

Kuchi Mudi

Kuchi mudi is located in the northern part of Parambikulam Wildlife Sanctuary. The area is dominated by dry deciduous forest intermixed with bamboo thickets. The hills rise abruptly in the north with an altitude of 1290 m. Thick undergrowth of *Cympopogon flexuosus* and hill date palm is dominant in this area. During the present study, no animals were seen but the indirect evidences indicate that more than two tahr are using this area. Mishra and Johnsingh (1994) reported seven animals in this area. The area is contiguous with Nelliampathy hills. The labourers in the nearby estate reported sightings of tahr numbering about 15 at the time of forest fire in the grasslands.

Degradation factors: The estate nearby is a source of disturbance due to human pressure and the area is subjected to fire every year. The population moves to other areas in Nelliampathy and hence escapes from much of the anthropogenic pressures.

Mangala Devi in Periyar Tiger Reserve

The Periyar Tiger Reserve ranges in altitude from 900 m to 2019 m above sea level and the average annual rainfall is between 2000 mm and 5000 mm. The eastern part of the Periyar

Tiger Reserve is bordered by the High Wavy mountains and Cumbum valley. The Mangala Devi lies between 9^0 36'4. 2" and 9^0 36'0.0" N and between 77^0 13; 13.1" and 77^0 12; 52.2' E. The area is accessible from Karadikavala forest station. Low altitude grasslands with rocky patches is the major vegetation type. Twelve animals were seen going down to the lower dry deciduous forest in Tamil Nadu side.

Degradation factors: The area has abundant food species but is frequented with fire.

Kochupamba

This area falls under the Goodrickal Reserved Forests of Ranni Forest Division. The tahr habitat is a fragmented area of about 10 km long and about 1 km wide. The area lies between 9^0 22.450' and 9^0 22.250' N and between 77^0 08.40.6' and 77^0 08.443' E. The maximum altitude is 1180-1200 m. A total of 22 animals were sighted during the visit. This included four saddlebacks seen on the southern extremity of the area. The number of cliffs is more on the western side of the ridge. There was reliable count of about 42 by James Zacharias (per. comm.). However, the recent observations by others confirm the present survey result of 22. A detailed survey on the plant species and the food species of tahr in the area was also carried out.

Table 2 shows the grass species present in Kochupamba. The percentage fed and preference index of food species selected for the feeding quadrats are shown in Table 3. Nearly eight species are dominant in this area. The dominant species is the Lemongrass, *Cymbopogon flexuosus*. It is not fed by tahr mainly because of high tannin content. Other dominant species are *Arundinella ciliata*, *A. purpurea*, *Heteropogon contortus*, *Ischaeum indicum*, *Panicum notatum* , *Themeda triandra* and *Tripogon bromoides*. As many as eight species are found to be fed by tahr in this area. *Ischaeumum indicum* was the most preferred and abundant species. The other major food species are *Arundinella ciliata*, *A. purpurea*, *Heteropogon contortus*, *Themeda triandra* and *Tripogon bromoides*.

Table 2. Grasses of Kochupamba

1	***Alloteropsis cimicina***
2	*Arthraxon lancifolius*
3	*A. quartinianus*

20	*Ischaemum indicum*
21	*I. zeylanicolum*
22	*I. timorense*

4	*Arundinella ciliata*
5	*Arundinella purpurea*
6	*Chrysopogon hackelii*
7	*Brachiaria ramose*
8	*Chionachne koenigii*
9	*Cymbopogon flexuosus*
10	*Digitaria longiflora*
11	*D. ciliaris*
12	*Dimeria thwaitesii*
13	*Eragrostis unioloides*
14	*E. bifaria*
15	*Garnotia tenella*
16	*Heteropogon contortus*
17	*Jansenella griffithiana*
18	*Isachne setosa*
19	*Isachne miliacea*

23	*Panicum gardneri*
24	*Panicum notatum*
25	*Paspalum scrobiculatum*
26	*P. compactum*
27	*Paspalidium flavidum*
28	*Rottboellia exaltata*
29	*Sorghum nitidum*
30	*Sporobolus indicus*
31	*Pseudanthistiria umbellate*
32	*Pseudosorghum fasciculare*
33	*Setaria intermedia*
34	*Eulalia trispicata*
35	*Themeda cymbaria*
36	*Themeda triandra*
37	*Tripogon bromoides*

Table 3. Specieswise availability, percentage fed and preference index of grasses in Kochupamba

No	Species name	Percentage availability	Percentage Fed	Preference index
1	***Arundinella ciliata***	24.00	7.00	0.28
2	*Arundinella purpurea*	22.00	7.40	0.34
3	*Brachieria ramosa*	10.00	0.00	0.00
4	*Chrysopogon hackelii*	15.00	3.00	0.28
5	*Curculigo arachiodes*	5.00	0.00	0.00
6	*Cymbopogon flexuosus*	27.86	0.00	0.00
7	*Digitaria longiflora*	30.00	0.00	0.00
8	*Eulalia tripiscata*	10.00	0.00	0.00
9	*Heteropogon contortus*	25.00	7.50	0.29

10	*Isachne setosa*	10.00	2.00	0.20
11	*Ischaemum indicum*	17.50	7.00	0.41
12	*Panicum notatum*	17.50	.00	0.00
13	*Sorghum nitidum*	22.50	.00	0.00
14	*Themeda cymbaria*	20.00	4.00	0.23
15	*Themeda triandra*	12.50	3.75	0.32
16	*Tripogon bromoides*	14.00	4.60	0.36

Degradation factors: The area is good in terms of extent, abundance of food species and the number of cliffs. It is not much disturbed but for cattle grazing in some portions and the fire in summer.

Ponmudi Hills

Ponmudi hills lie between 8^0 43.509' and 8^0 43.951' N and betweeen 77^0 6.127' and 77 6.057' E and is a continuation of the Agasthyamala region. The major vegetation types are evergreen, semi-evergreen, moist and dry deciduous forests. The valleys are interspersed with evergreen forests. Grasslands are found on the top of the hills dominated by date palm. The highest peak is the Ponmudi peak with an altitude of 1080 m. There are private plantations of tea and rubber in the outer areas of this mountainous region. Tahr was seen in two peaks, Sarkar Motta and Ponmudi peak. Eighteen tahr were seen during the present survey. The animals could not be classified as they were sighted from a distance.

GREENS (2000), a voluntary organization, sighted two groups of tahr consisting of 13 and 18 individuals with five yearlings in 2000.

Degradation factors: The area, though rich in food species is highly disturbed due to human interference from the adjoining plantations. It is also subjected to frequent fire.

Varayattu Mala

The Varayattu Mala is located on the top of Neyyar Wildlife Sanctuary with the crestline height of the ghats not exceeding 1500 m. This forest is a known type locality for a large number of plant species with extremely restricted distribution. Two visits were made to document the tahr habitat in the region. Extensive grasslands are spread along the rim of the valley starting from Kodayar Reserved Forest to Agasthyar Peak. Fifty eight animals were observed in the area. Only six could be classified. The grasslands are dominated by *Imperata* sp., date palm and *Themeda* sp. This area is adjacent to Kalakkad–Mundanthurai Tiger Reserve of Tamil Nadu.

Degradation factors: The area is rich in food species and is extensive with cliffs. Human pressure, mostly from Tamil Nadu is reported in this area. Poaching has also been reported to be a problem, especially from Tamil Nadu.

Nelliampathy Hills

Two surveys were conducted in Nelliampathy Reserved Forests of Nenmara Forest Division. A total 38 animals were sighted in Kurisumala - Hilltop (37) and Mampara (1). The workers of the estates nearby reported sightings of about 80 animals at Kurisumala – Hilltop area. The sighting of five yearlings in the herd during the present survey also indicates recruitment to the population.

Degradation factors: The grasslands at Hilltop is extensive with cliffs and abundant food species. But the area is highly disturbed due to various human activities, which lead to fire in summer. Poaching is also reported from the area. Cattle grazing is the major degradation factor.

Meesappuli Mala

The area in Silent Valley plateau in Munnar is one of the best ideal habitats of tahr in terms of food species, extent and the lack of disturbance. The count in the area has shown that there are at least 64 animals in the area.

Degradation factors: There are actually no factors observed as degrading the habitat. However, there had been serious doubts on the safety of animals from the southern part.

Gundumala

The area is near the Tertian plateau in Munnar with a population of about 60 tahr. Food is abundant and the area is extensive with not much human pressure.

New Amarambalam - Anginda areas above Silent Valley National Park and New Amarambalam Reserve Forests of Nilambur South Division is known to have a population of tahr. However, it cannot be treated as a fragmented population because of the contiguity with the adjacent tahr habitat of Mukurthi National Park.

Chinnar

Three animals were sighted in Chinnar Wildlife Sanctuary during the present survey. The tahr habitat is a small hill called Jamba Mala (Kasi Mala) near Mangappara settlement. The grassland is approximately 2 km^2. James Zacharias (per. comm.) sighted 18 animals in this area in 1988.

Degradation factors: Food species are less due to fire.

POPULATION ESTIMATION

Population estimation of Nilgiri tahr was conducted in April and October 2000 and in December 2001 in Eravikulam National Park. The estimated population and the density are presented in Table 4. The estimated population of tahr in the area during the three seasons varied and the difference could be attributed to the change in weather affecting the direct sightings of animals. It was not possible to draw conclusions on age-sex distribution, as nearly 50 per cent of the population was unidentified.

Table 4. Estimated total population and density (individuals/km^2) in Eravikulam

	April 2000		October 2000		December 2001	
Number	696		559		444	
	LCL	UCL	LCL	UCL	LCL	UCL
	626	906	487	847	431	503
Density	6.27		5.03		4.0	
	LCL	UCL	LCL	UCL	LCL	UCL
	5.63	8.16	4.38	7.63	3.88	4.53

LCL -Lower Confidence Limit; UCL-Upper Confidence Limit

The block-wise density of Nilgiri tahr for three seasons are shown in Tables 5, 6 and 7 and also depicted in Figure 5. In December 2001, the Umayamala block was clubbed with the Anamudi block. The density estimates show that Umayamala, Anamudi and Rajamala blocks had consistently more number of tahr during the census periods. The lowest number was observed in Kolukkan, Samban and Poovar areas.

Table 5. Density (individuals/km^2) of Nilgiri tahr during April 2000

Block	Estimate	(LCL - UCL)
Anamudi	12.9	(10.3 – 20.9)
Rajamala	26.8	(24.4 – 34.2)
Umayamala	34.3	(19.3 – 79.5)
Poolamala	9.0	(8.7 – 9.6)
Varayattumudi	17.7	(13.1 – 31.6)
Karikombu	9.1	(7.9 – 13.0)
Samban Kolukkan	2.3	(1.4 – 5.1)
Erumapetty	9.6	(9.5 – 10.0)
Kattumala	6.0	(3.7 – 13.0)
Perumal mala	3.1	(2.1 – 6.3)
Kumarickal	4.1	(3.9 – 4.6)
Poovar	2.4	(1.6 – 4.9)

Table 6. Density (individuals/km^2) during October 2000

Block	Estimate	(LCL - UCL)
Anamudi	10.6	(9.7 – 13.1)
Rajamala	23.0	(19.5 – 33.5)
Umayamala	24.0	(16.7 – 46.0)
Poolamala	8.2	(7.6 – 10.0)
Varayattumudi	9.1	(6.8 – 15.9)
Karikombu	5.3	(3.3 – 11.1)
Samban Kolukkan	1.8	(1.3 – 3.2)
Erumapetty	10.3	(9.0 – 14.0)
Kattumala	7.6	(4.9 – 15.9)
Perumal mala	4.4	(2.2 – 4.7)
Kumarickal	-	-
Poovar	0.6	(0.3 – 1.4)

Table 7. Density (individuals/km^2) in December 2001

Block	Estimate	(LCL – UCL)
Anamudi	24.82	18.61 – 39.89
Rajamala and Umayamala	25.86	13.93 – 30.17
Poolamala	6.00	04.00 – 16.16
Varayattumudi	15.06	12.15 – 26.70
Karikombu	5.30	-
Samban Kolukkan	-	-
Erumapetty	15.44	11.66 – 43.43
Kattumala	3.48	3.2 – 4.2
Perumal mala	4.4	-
Kumarickal	0.7	0.41 – 1.6
Poovar	0.5	0.27 – 1.2

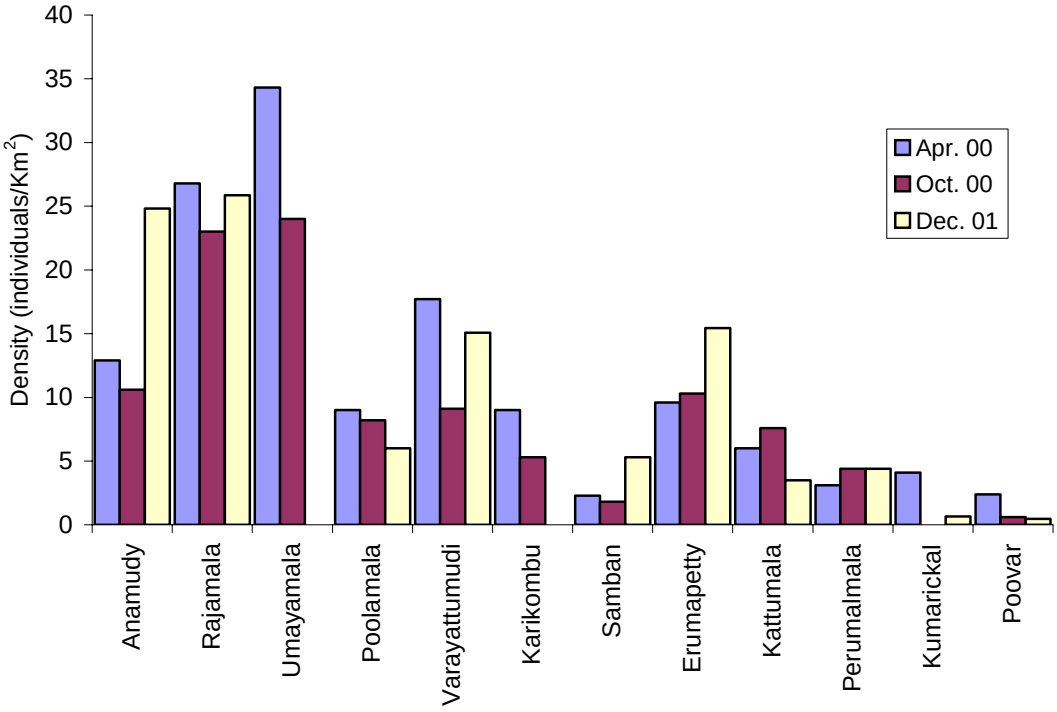


Fig.5. Block wise density of tahr in different seasons in Eravikulam National Park

FOOD AND FEEDING

Food species

Tables 8 and 9 show the list of grass and herb species recorded in the selected plots in Eravikulam National Park during the study. Rice (1984) reported 37 food species of Nilgiri tahr in Eravikulam National Park. During the present study, tahr was observed to feed on 19 species of grasses, 12 species of herbs and three shrubs. Tahr licked one species of lichen, *Parmotrema grayanum*. The fresh shoots of the dwarf bamboo, *Sinarundinara densifolia* and *S. walkariana* were also eaten. The major component of the food is grass.

Table 8. Grasses and sedges available in the selected plots in Eravikulam National Park

No	***Name of the plant species***
1	*Ischaemum indicum* var. *indicum*
2	*Ischaemum tadulingami*
3	***Arundinella ciliata***
4	*Arundinella mesophylla*
5	***Arundinella purpurea***
6	*Anthraxon villosum*
7	*Eulalia phaeothrix*
8	*Eulalia thwaitessi*
9	*Andropogon lividus*
10	*Themida tremula*
11	*Helictotrichon virescens*
12	*Chrysopogon ceylanicus*
13	*Heteropogon contortus*
14	*Isachne setosa*
15	*Isachne fischeri*
16	*Isachne borneorum*
17	*Dichanthium polyptychum*
18	*Sehima nervosum*
19	*Tripogon ananthaswamianus*
20	*Tripogon bromoides*
21	*Tripogon narayani*
22	*Curculio arachioides*
23	*Clorophytum malabaricum*
24	*Ancilima* sp.

Table 9. List of herb and shrub species available in the selected plots in Eravikulam National Park

No	Name of the herb species
1	*Swertia corymbosa*
2	*Pedicularis zeylanica*
6	*Justicia sp*
3	*Leucas ternifolia*
4	*Neanotis monosperma*
5	*Anemone rivularis*
21	*Osbeckia aspera*

7	*Cyanotis arachnoidea*
8	*Gentiana quadrifaria var. zeylanica*
9	*Ageratina adenophora*
10	*Plectranthus nilgherricus*
11	*Cyanotis pilosa*
12	*Anaphalis subdecurrens*
13	*Anaphalis meeboldii*
14	*Anaphalis bournei*
15	*Anaphalis sp*
16	*Spilanthes calva*
17	*Wahlenbergia marginata*
18	*Hydrocotyle javanica*
19	*Sopubia trifida*
20	*Strobilanthes kunthianus*

22	*Ranunculus wallichianus*
23	*Parnassia wightiana*
24	*Smithia hirsuta*
25	*Bupleurum distichophyllum*
26	*Glochidion sp*
27	*Impatiens sp*
28	*Crotalaria sp*
29	*Crotalaria clarkei*
30	*Atylosia rugosa*
31	*Pouzobia wightii*
32	*Hedyotis anamalayana*
33	*Hedyotis swertioides*
34	*Drosera peltata*

Principal food

Grass

Table 10 shows the distribution of grass species in the feeding sites. The percentage fed and preference index of grass species are shown in Table 11. Nineteen species of grass formed the diet of Nilgiri tahr in Eravikulam National Park with about six species contributing more (Table 8). *Chrysopogon zeylanicus* forms the major food species (13.78%) followed by *Eulalia phaeothrix* (10.8%), *Arundinella ciliata* (10%), *Sehima nervosum* (9.1%) and *Ischaemum indicum indicum* (6.9%).

Table 10. Species-wise distribution of grasses in the feeding sites

No	Species name	Frequency	Percentage cover
1	*Arundinella ciliata*	4	2.20
2	*Arundinella fuscata*	2	1.10
3	*Andropogon lividus*	4	2.20
4	*Arundinella mesophylla*	8	4.40
5	*Andropogon polyptychus*	1	0.60

6	*Arundinella.purpurea*	2	1.10
7	*Andropogon xilosum*	1	0.60
8	*Curculigo arachiodes*	3	1.70
9	*Chrysopogon zeylanicus*	40	22.2
10	*Cympopogon sp*	1	0.60
11	*Dicanthium polypticum*	2	1.10
12	*Eulalia phaeothrix*	40	22.20
13	*Heteropogon contortus*	5	2.80
14	*Heteropogon virescens*	1	0.60
15	*Isachne bourneorum*	3	1.70
16	*Isachne fisheri*	1	0.60
17	*Ischaeum .indicum*	4	2.20
18	*Ischaemum indicum indicum*	8	4.40
19	*Isachne setosa*	1	1.10
20	*Ischaeum tadulingami*	1	0.60
21	*Sehima nervosum*	23	12.80
22	*Tripogon ananthaswamianus*	4	2.20
23	*Tripogon bromoides*	14	7.80
24	*Tripogon narayani*	1	0.60
25	*Themeda trandra*	1	0.60
26	*Themeda tremula*	4	2.20

Table 11. Percenatge of grasses fed and preference index

No	Species name	Percentage fed	Preference index
1	*Arundinella fuscata*	4.25	0.13
2	*Arundinella ciliata*	10.00	0.35
3	*Andropogon lividus*	5.25	0.27
4	*Arundinella mesophylla*	6.25	0.26
5	*Andropogon polyptychus*	1.00	0.33
6	*Arundinella purpurea*	3.00	0.75
7	*Curculigo arachiodes*	2.33	0.28
8	*Chrysopogon zeylanicus*	13.76	0.30
9	*Dicanthium polypticum*	1.00	0.10
10	*Eulalia phaeothrix*	10.82	0.27
11	*Heteropogon contortus*	2.80	0.30
12	*Ischaeum bourneorum*	0.66	0.03
13	*Ischaeum indicum*	0.50	0.26
14	*Ischaemum indicum indicum*	6.87	0.28
15	*Sehima nervosum*	9.13	0.28
16	*Tripogon bromoides*	5.25	0.27
17	*Tripogon ananthaswamianus*	3.14	0.27
18	*Tripogon narayani*	1.00	0.10
19	*Themeda tremula*	2.75	0.21

Herb

Tahr feeds on 11 species of herbs. The species-wise distribution of herb species in the feeding quadrats is given in Table 12. The percentage of each herb species fed and their preference index are given in Table 13. *Cyanotis arachioides, C. pylosa, Hedyotis anamalayana* and *H.swotiodes* are the major herb species fed by tahr. However, there was seasonal variation in the composition of the species in the diet.

Table 12. Species-wise distribution of herbs in the feeding sites

No	Name of the species	Frequency	Percent cover
1	*Anaphalis mioboldii*	6	5.8
2	*Anaphalis bournii*	11	10.7
3	*Anaphalis subdericus*	2	1.9
4	*Anaphalis* sp.	1	1.0
5	*Cyanotis arachiodes*	11	10.7
6	*Crotalaria clarkii*	1	1.0
7	*Cyanotis pilosa*	2	1.9
8	*Hedyotis anamalayana*	7	6.8
9	*Hedyotis swotiodes*	1	1.0
10	*Impatians* sp	1	1.0
11	*Leucas ternifolis*	15	14.6
12	*Neonotis monosperma*	1	1.0
13	*Osbeckia aspera*	6	5.8
14	*Posobia wrightii*	1	1.0
15	*Pedicularis zeylanica*	7	6.8
16	*Spilanthus calva*	1	1.0
17	*Swortia corimbosa*	4	3.9
18	*Sopubia trifida*	1	1.0
19	*Wolenbergia marginata*	1	1.0

Table 13. Percentage of herb species fed and preference index

No	Species	Percentage fed	Preference index
1	*Anaphalis mioboldii*	0.33	0.07
2	*Anaphalis bournii*	0.20	0.02
3	*Cyanotis arachiodes*	2.09	0.48
4	*Cyanotis pilosa*	1.50	0.45

5	*Hedyotis anamalayana*	2.43	0.44
6	*Hedyotis swortiodes*	1.00	1.00
7	*Neonotis monosperma*	2.00	0.40
8	*Osbeckia aspera*	2.17	0.35
9	*Posobia wrightii*	1.00	1.00
10	*Spilanthus calva*	1.00	1.00
11	*Swortia corimbosa*	1.75	0.75
12	*Wolenbergia marginata*	1.00	1.00

Shrub

Two shrub species were found fed by tahr (Table 14). The *S. kunthianus* is a gregarious species found in almost all blocks in Eravikulam. The tahr prefers the fresh leaves of this species. *Ageratina adenophor*a is an exotic weed spread all over the National Park along the ridges of the sholas.

Table 14. Percentage of shrub species fed and preference ind**ex**

Species name	**Percentage fed**	**Preference index**
Ageratina .adenophora	0.25	0.04
Strobilanthus kunthianus	3.63	0.39

According to Rice (1984), tahr in Eravikulam prefers the inflorescence of certain species like *Hypericum mysorense, Pedicularis perrotettii, Crotalaria clarkii, Anaphalis bournii, A. lawii* and *Eriocaulon brownianum.* Rice (1984) observed that two uncommon plants, *Lactuca hastate* and *Impatians tomentosa* were liked by tahr. There was also some seasonal preference for certain species of food species.

Biomass

The block-wise distribution of cover and biomass of plant species estimated from the plot data are given in Table 15. Rajamala, Kattumala, Anamudi and Kolukkumala have more availability and biomass. The availability of biomass presented here is irrespective of seasons.

Species wise plant biomass is given in Table 16. It shows that *Chrysopogon zeylanicus* and *Eulalia phaeothrix* are the major species in the study area. The percent availability and biomass of herb and shrub species were less in the quadrats studied.

Table 15. Block-wise distribution of percentage cover and biomass (g/m^2**)**

Block Name	Percentage cover	Biomass
Rajamala	25.00	97.29
Anamudi	23.53	151.26
Karikombu	21.79	66.65
Varayattumudi	17.98	56.89
Kolukkumala	24.18	80.25
Eravikulam	20.08	64.35
Poolamala	20.00	89.41
Kattumala	25.58	87.36
Kumarickal mala	15.25	48.16
Poovar	20.00	74.41

Table 16. Species-wise distribution of percentage cover and biomass of grasses (g/m^2)

SI. No	Food species	Percentage cover	Biomass
1	*Andropogon lividus*	11.00	42.82
2	*Andropogon* sp	3.50	8.00
3	*Arundinella ciliata*	10.00	9.50
4	*Arundinella mesophylla*	20.00	13.50
5	*Arundinella purpurea*	30.00	17.00
6	*Chrysopogon zeylanicus*	29.10	115.75
7	*Curculigo arachiodes*	4.00	4.67
8	*Dicanthium polypticum*	10.00	27.52

9	*Eulalia phaeothrix*	21.98	83.43
10	*Helictrotrichon virescence*	10.00	10.00
11	*Heteropogon contortus*	25.00	77.64
12	*Isachne setosa*	7.50	6.50
13	*Ischaemum indicum indicum*	19.78	80.36
14	*Ischaemun indicum*	22.00	57.49
15	*Leucas ternifolis*	11.00	10.57
16	*Osbeckia aspera*	2.50	2.50
17	*Sehima nervosum*	20.50	69.43
18	*Themeda tremula*	25.00	56.09
19	*Tripogon ananthaswamianus*	12.50	15.50
20	*Tripogon bromoides*	11.31	14.36
21	*Tripogon narayani*	30.00	151.80

NUTRITIVE VALUE OF THE FOOD SPECIES

Nutritional factors play vital roles in various physiological events in animal growth. The results of the chemical analyses of food plants are shown in Tables 17, 18 and 19. There was species-wise and seasonal variation in the quantity of nutrients. The relationship between percentage fed and preference index of the species with their respective nutritive values in different seasons are given in Tables 20, 21 and 22. The zinc and iron were found to be positively related with the increase in the quantity fed (%) of the species. This indicates that animal preferred the food species, which are rich in zinc and iron. However, such relationship was seen only in dry season. Otherwise there was no significant pattern with regard to other nutritional parameters.

Table 17. Chemical nature of major food species during dry season

Name of plant species	N (%)	Available Ph (%)	K (%)	Zn (ppm)	Fe (ppm)	Cu (ppm)	
Ischaemum indicum indicum	0.78	0.14	0.86	39.5	455	55	1
Arundinella purpurea	0.74	0.21	0.80	57	470	30	1
Arundinella mesophylla	0.59	0.21	0.47	64.0	670	5	2
Pteridium aquilinum	0.85	0.14	0.76	37.5	110	10	1
Phlybophyllum kunthianus	0.85	0.14	1.14	95	175	15	8
Sehima nervosum	0.95	0.14	0.73	61.5	675	15	1
Osbeckia aspera	1.05	0.14	0.49	49.5	155	10	9
Ageratina adenophora	1.48	0.35	1.32	91.0	240	10	3
Andropogon lividus	1.18	0.14	0.62	44.5	420	10	1
Tripogon bromoides	0.81	0.21	0.75	57.5	705	5	9
Ischaeum tadulingami	0.89	0.34	0.93	22.5	205	52	6
Eulalia phaeothrix	0.48	0.14	0.71	45.5	240	15	5
Heteropogon contortus	0.70	0.28	0.68	35.5	585	70	7
Chrysopogon zeylanicus	0.55	0.21	0.63	87.5	1805	50	2

Table 18. Chemical nature of major food species during wet season

Name of plant species	N (%)	Available Ph (%)	K (%)	Zn (ppm)	Fe (ppm)	Cu (ppm)	(
Ischaemum indicum indicum	0.74	0.21	0.78	61	2040	30	13
Arundinella ciliata	0.81	0.21	0.58	54.5	2400	1090	14
Phlybophyllum kunthianus	0.89	0.21	1.26	73.5	130	20	80
Sehima nervosum	0.55	0.14	0.51	27	550	45	88
Andropogon lividus	0.59	0.21	0.83	27.0	155	35	10
Tripogon bromoides	0.96	0.14	0.44	34	925	95	12
Eulalia phaeothrix	0.96	0.14	0.65	54	1165	140	16
Heteropogon contortus	0.59	0.21	0.83	27.0	155	35	10
Chrysopogon zeylanicus	0.70	0.14	0.49	26.5	1000	95	11
Themeda tremula	0.52	0.14	0.62	46	1305	40	82
Hedyotis swortioides	0.66	0.14	0.76	26.5	280	20	94

Table 19. Chemical nature of major food species during post monsoon season

Name of plant species	N (%)	Available Ph (%)	K (%)	Zn (ppm)	Fe (ppm)	Cu (ppm)	I
Ischaemum indicum indicum	0.62	0.21	0.62	42	1990	50	
Arundinella mesophylla	0.92	0.21	0.79	90	2530	50	
Phlybophyllum kunthianus	1.55	0.14	1.02	99.0	655	30	
Sehima nervosum	0.74	0.21	0.8	63.5	1420	10	
Andropogon lividus	0.77	0.14	0.55	45.5	1645	20	
Tripogon bromoides	0.55	0.14	0.43	39	1260	20	
Eulalia phaeothrix	0.89	0.21	0.61	57.5	2110	20	
Heteropogon contortus	1.1	0.28	0.78	105	1305	15	
Chrysopogon zeylanicus	0.4	0.14	0.71	52.5	915	20	

Table 20. Relationship between quantity fed (%) and preference index of major species with their respective nutritional values (Dry season)

Nutritional parameters	Correlation coefficient	
	%Fed	Preference index
Nitrogen (%)	-0.39	-0.04
Available Phosphorus (%)	-0.41	0.21
Potassium (%)	-0.17	0.37
Zinc (ppm)	0.57*	0.05
Iron (ppm)	0 .56*	-0.12
Copper (ppm)	0.02	0.09
Manganese (ppm)	0.21	0.27
Calcium (%)	-0.20	0-.12
Magnesium (ppm)	0.25	0.57

* P< 0.12

Table 21. Relationship between quantity fed (%) and preference index of major species with their respective nutritional variables (Wet Season)

Nutritional parameters	Correlation coefficient	
	% Fed	Preference index
Nitrogen (%)	0.16	-0.09
Available Phosphorus (%)	-0.42	-0.19
Potassium (%)	-0.29	0.18
Zinc (ppm)	-0.08	-0.49
Iron (ppm)	0.01	-0.67
Copper (pp,)	-0.16	-0.87
Manganese (ppm)	0.29	-0.21
Calcium (%)	0.49	-0.14
Magnesium (ppm)	-0.37	-0.45

Table 22. Relationship between quantity fed (%) and preference index with nutritional variables (Post-monsoon season)

Nutritional parameters	Correlation coefficient	
	%Fed	Preference index
Nitrogen (%)	-0.45	-0.11
Available Phosphorus (%)	-0.26	0.21
Available Potash (%)	0.26	0.25
Iron (ppm)	-0.25	0.18
Zinc (ppm)	-0.10	-0.79
Copper (ppm)	-0.09	-0.42
Manganese (ppm)	-0.07	-0.14
Calcium (%)	-0.01	-0.47
Magnesium (ppm)	0.41	0.17

DEVELOPMENT OF HABITAT SUITABILITY INDEX (HSI) MODEL

Description of the variables used in the model

The block-wise information on the following variables were used in the model.

Density (No./km^2): It is expressed as the ratio between the number of animals to the total area surveyed.

Extent of cliff (km/km^2): It is computed as the ratio between the total length of cliff to the total area.

Altitude (m): The minimum altitude recorded in the area surveyed.

Percentage availability of food species: The percentage availability of food species was assessed in the field by laying quadrats. The percentage availability of *Chrysopogon zeylanicus* and *Eulalia phaeothrix* alone was considered here, as they were the most fed by the animal and also abundantly available throughout the blocks during the survey showing significant relationship with the density estimates.

Density as an index of abundance for developing HSI

The estimated population of Nilgiri tahr was 696 with the density of 6.3 individuals /km^2 in April 2000. The population was 559 with the density of 5 individuals /km^2 in October 2000.

However, in December 2001, the estimated population was only 444 with the density of 4 individuals/km^2 (Table 4). The reduction in the population in December 2001 was due to the adverse climate and mist. Therefore, the census figures of December 2001 were excluded for further analysis. The block-wise estimates of density presented in Tables 5 to 7 show the variation in block-wise abundance and density between the seasons. However, the density estimates by and large indicate the concentration of animals. The correlation analysis of block-wise density estimates between April 2000 and October 2000 also reflects this trend (Fig. 6). This means that these abundance estimates are useful for further analysis to relate with block-wise habitat variables.

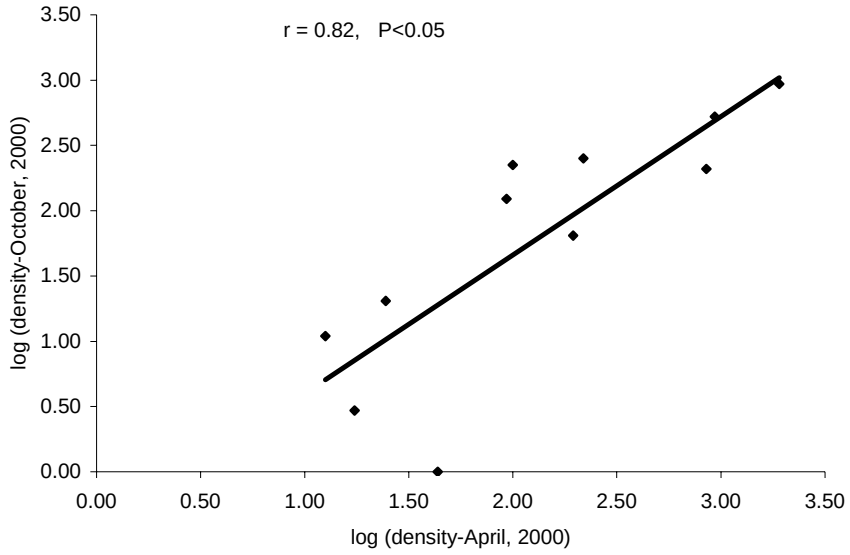


Fig.6. Correlation between population density estimates of different seasons

Density - Habitat Relationship

The density of tahr was found to decrease with an increase in the extent of block (Fig. 7 and 8). This indicates that the extent of area may be less important. The importance lies in the combination of features that are present in the area.

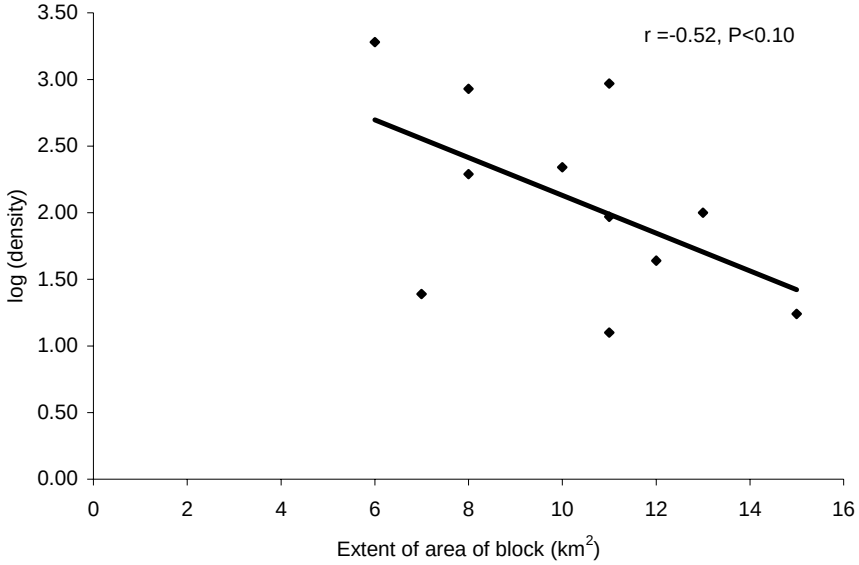


Fig. 7. Relationship between density and extent of block (April 2000)

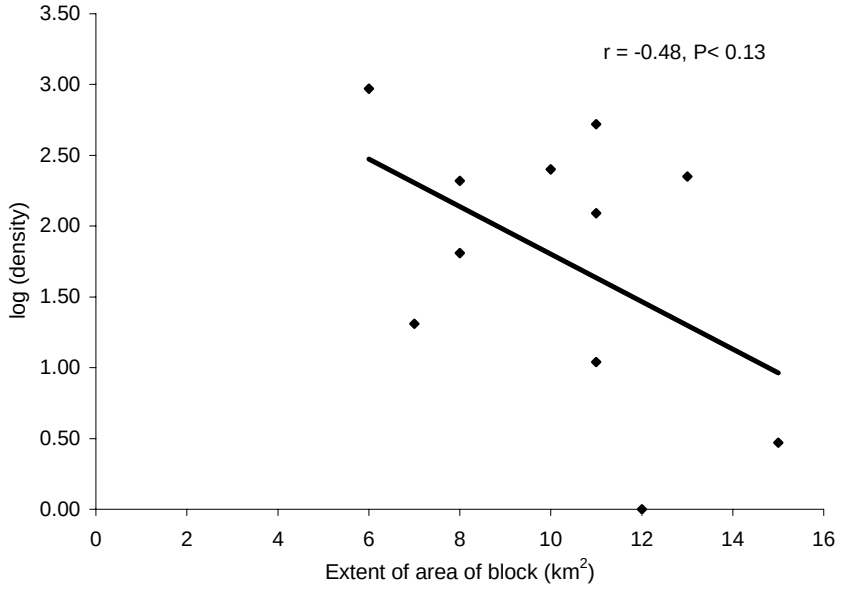


Fig.8. Relationship between density and extent of block (October 2000)

The altitude here refers to the minimum altitude recorded in a given block. Figures 9 and 10 depict the altitude-habitat relationship for the census periods April 2000 and October 2000.

The density was found to increase with the increase in the altitude. However, such relationship was found to be significant only in April 2000.

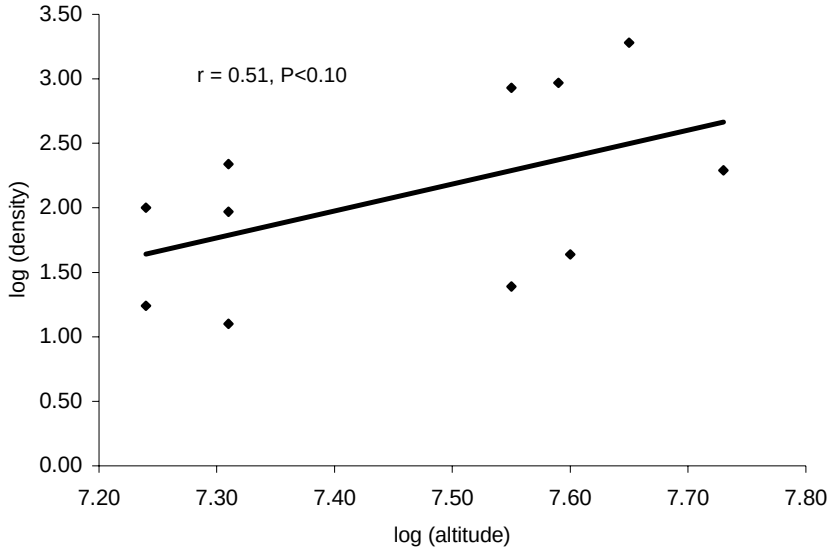


Fig.9. Relationship between density and altitude (April 2000)

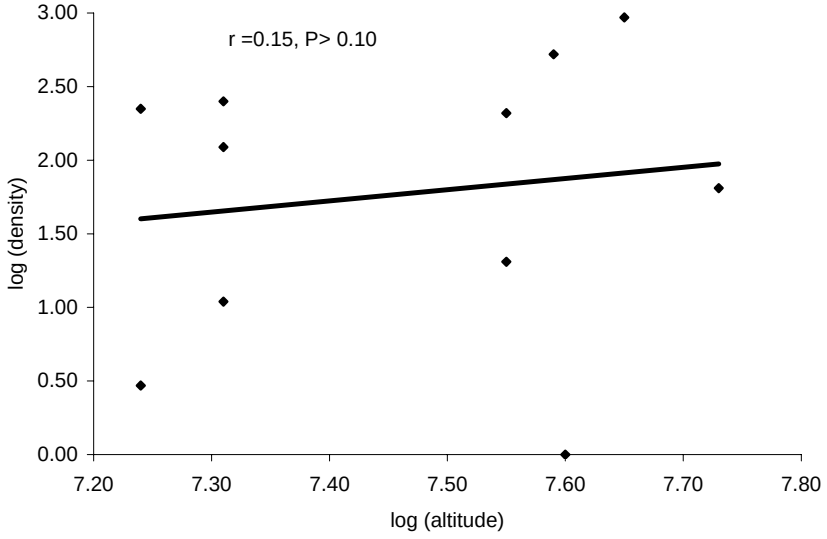


Fig. 10. Relationship between density and altitude (October 2000)

The density of animal was found to be significantly higher in the blocks where the extent of cliff was more (Fig. 11 and 12). This clearly indicates that tahr prefers habitat with sufficient extent of cliff for protecting themselves from the predators.

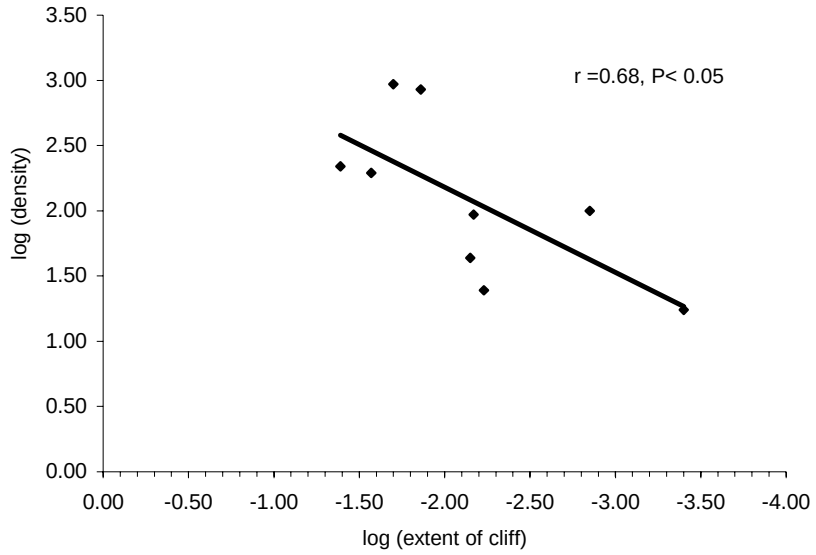


Fig. 11. Relationship between density and extent of cliff (April 2000)

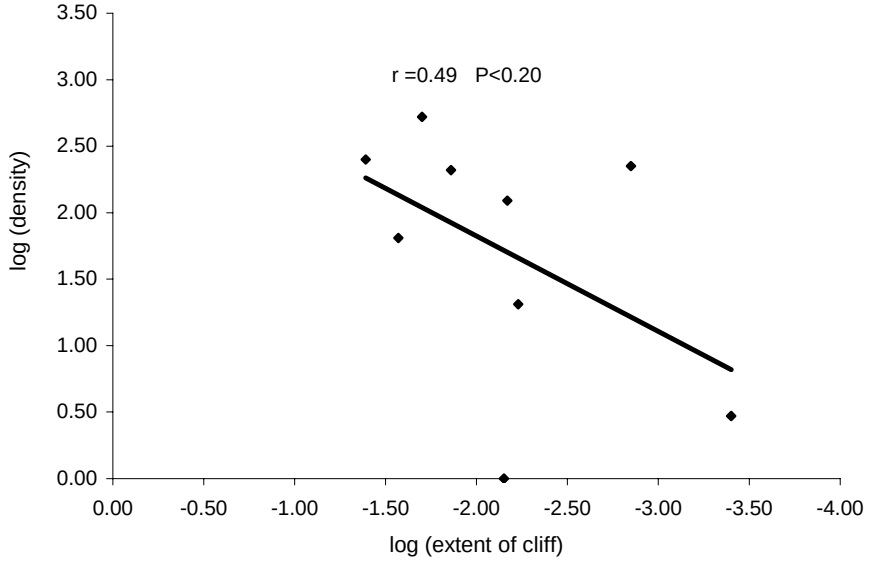


Fig. 12. Relationship between density and extent of cliff (October 2000)

Among the food species, the increase in the availability of *Chrysopogon zeylanicus* and *Eulalia phaeothrix* was positively related with the density estimates. However, the relationship with regard to *Eulalia phaeothrix* was not significant in April 2000. The percentage availability of

Ischaemum indicum indicum was negatively related with the density estimates (Table 23). The correlation between the percentage availability and the density was not significant with regard to other food species. The scatter diagrams indicating the relationship between the availability of food species and the density are presented in Figures 13 to 16, for the percentage availability of *Chrysopogon zeylanicus* and *Eulalia phaeothrix.*

Table 23. Correlation between density and percentage availability of food species

Species	Correlation coefficient	
	Density (April 2000)	Density (October 2000)
Chrysopogon zeylanicus	0.51*	0.43*
Eulalia phaeothrix	0.37	0.67***
Ischaemum indicum indicum	-0.47*	-0.60**
Sehima nervosum	-0.25	-0.21
Tripogon bromoides	-0.08	-0.24

***- P< 0.05; **-P< 0.10; *- P< 0.20

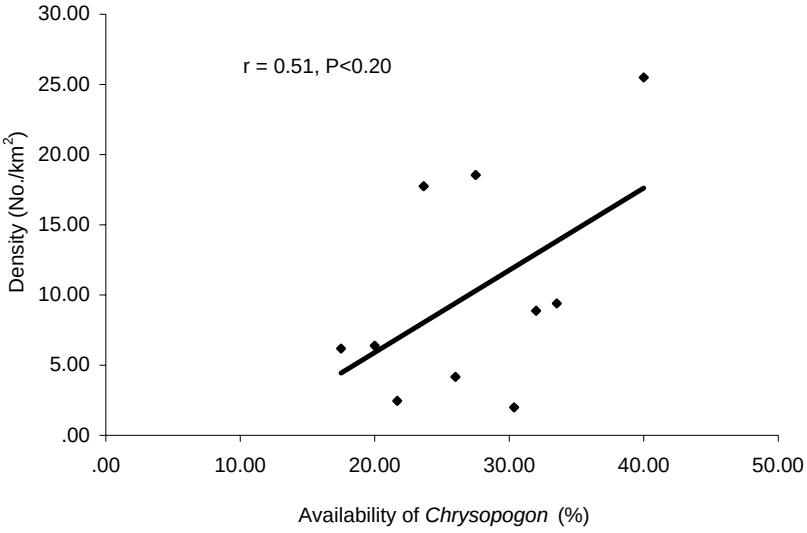


Fig. 13. Relationship between density and percentage availability of *Chrysopogon* (April 2000)

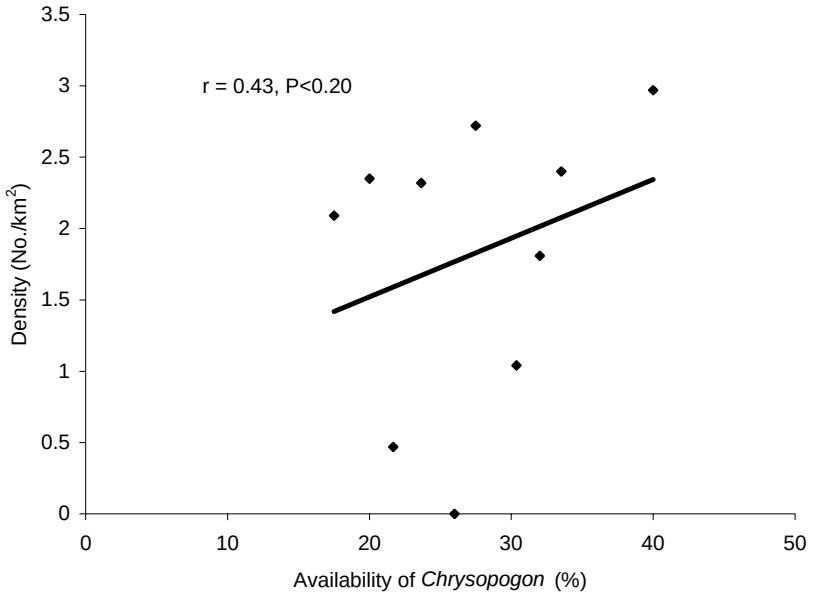


Fig. 14. Relationship between density and percentage availability of *Chrysopogon* (October 2000)

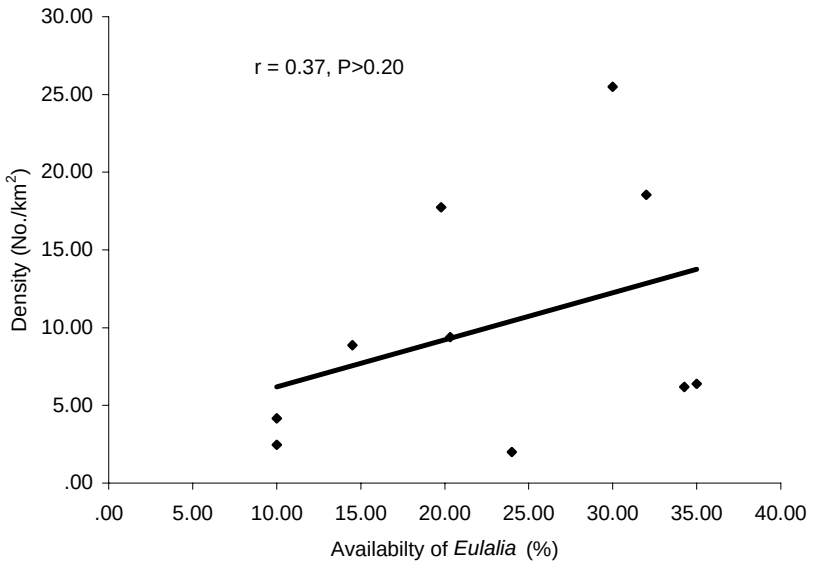


Fig. 15. Relationship between density and percentage availability of *Eulalia* (April 2000)

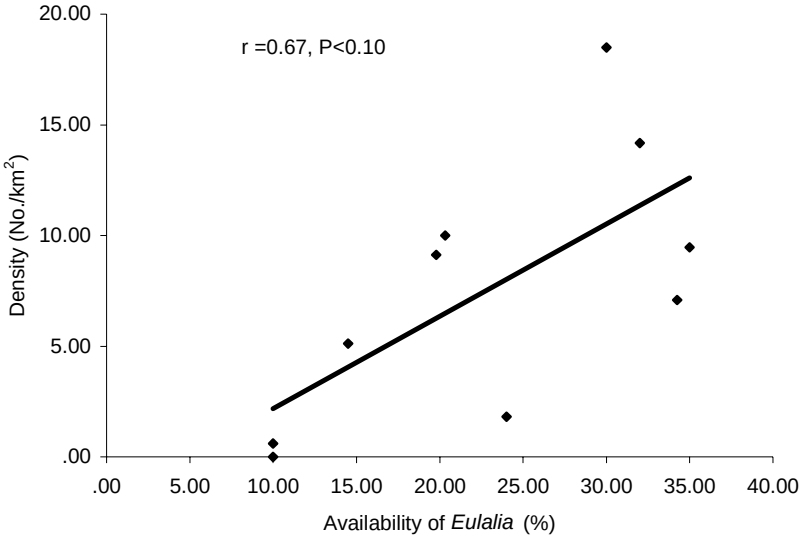


Fig. 16. Relationship between density and percentage availability of *Eulalia* (October 2000)

Among the biomass variables, only the biomass of *Chrysopogon zeyalanicus* was found to be significantly related with the density estimates. The increased availability of biomass of *Chrysopogon zeyalanicus* was found to be related with the increased density estimates of both the census periods considered (Table 24).

Table 24. Correlation between density and biomass of food species

Food species	Correlation coefficient	
	Density (April 2000)	Density (October 2000)
Chrysopogon zeylanicus	0.64*	0.61*
Eulalia phaeothrix	-0.17	0.03
Ischaemum indicum	-0.26	-0.35
Sehima nervosum	0.05	0.04
Tripogon bromoides	-0.14	-0.27

* P<0.05

Habitat Suitability Index (HSI) Model

Based on the observed relationships between density and habitat variables, as discussed earlier, the suitability criteria were formulated and they are presented as Suitability Index (SI) curves from Figures 17 to 19 for the variables extent of cliff, altitude and availability of food species respectively. If the extent of cliff (ratio between the total length of cliff to total area) is 0.2 km/km^2 or more then it is considered to be optimum with the suitability index 1.0. The extent of cliff less than 0.2 km/km^2 has diminishing index value as shown in Figure 17. The altitude of 2000 m or above from the sea level was considered to be optimum with the suitability index of 1.0. The suitability index diminishes as the altitude decreases from 2000 m (Fig. 18). If the percentage availability of food species, either C*hrysopogon zeylanicus* or *Eulalia phaeothrix* is 35 per cent or more then it is considered to be optimum with the suitability index of 1.0. The suitability index decreases as the percentage availability of food species decreases from 35 per cent as shown in Figure 19.

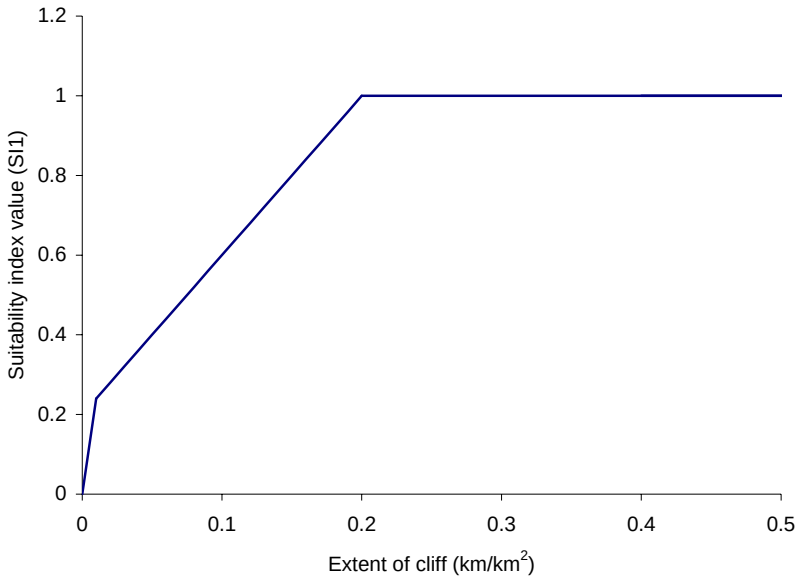


Fig. 17. Suitability index curve for extent of cliff

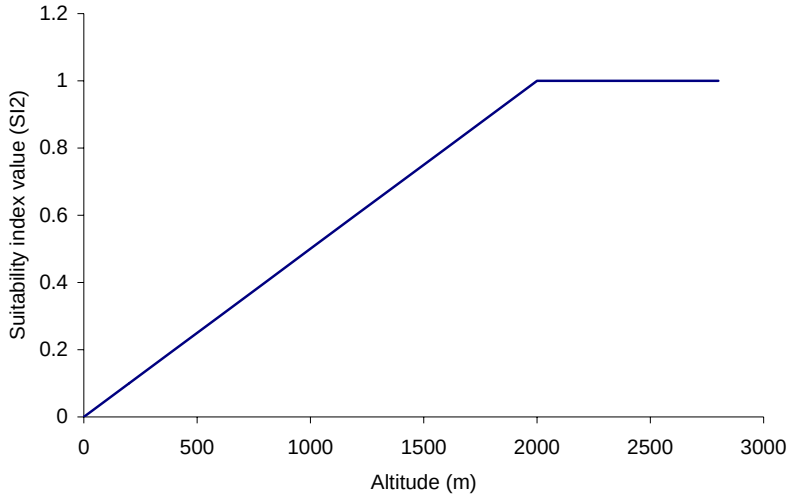


Fig. 18. Suitability index curve for altitude

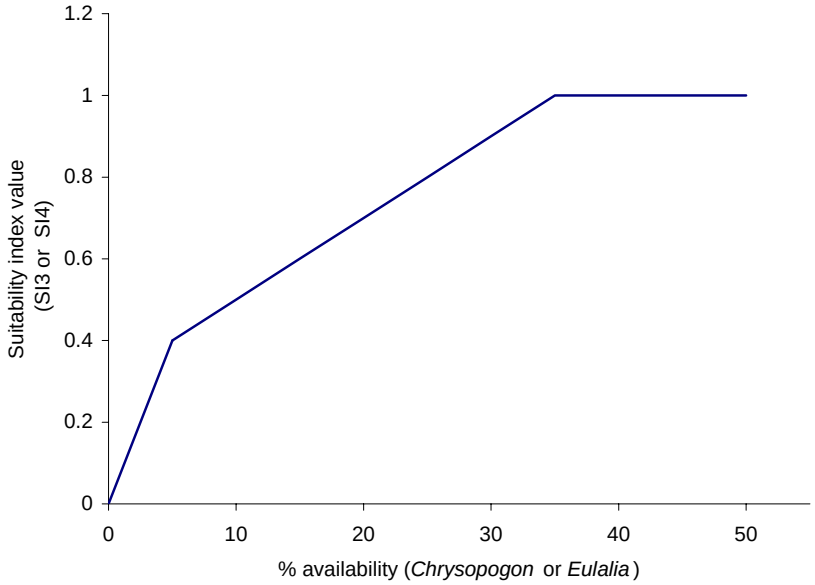


Fig. 19. Suitability index curve for availability of food species

The two habitat suitability indices were developed from the above suitability index curves. One is HSI1 reflecting physiographic characteristics and the second is HSI2 reflecting the availability of food species. The overall HSI is the product of HSI1 and HSI2. The respective equations are as follows.

$$HSI1 = \sqrt{SI1 \times SI2} \quad (1)$$

$$HSI2 = \sqrt{SI3 \times SI4} \quad (2)$$

$$HSI = HSI1 \times HSI2 \quad (3)$$

The suitability indices considered were not assigned differential weightages. The habitat suitability indices HSI1 and HSI2 were worked out as the geometric mean of SI1 and SI2, and SI3 and SI4 respectively. The overall HSI was assumed to be the multiplicative effect of HSI1 and HSI2 because the factors considered both in HSI1 and HSI2 are required for the survival of tahr.

Regression analysis of density and habitat suitability indices

In order to test the reliability of the habitat suitability indices developed here, they were related to the density of tahr in April 2000 and October 2000 using regression analysis. First, regression equation was developed by entering HSI1 and HSI2 together in the regression analysis. Secondly, the regression equation was developed by considering the overall HSI. The results are presented in Table 25.

Table 25. Regression equations relating density and habitat suitability indices

Sl. No.	Regression equation	R^2 (%)	Adj. R^2 (%)
I	April-2000		
1	Log (density)= -1.47+ 1.77 HSI 1 (1.02) (0.72) +2.96 HSI2 (1.38)	76.4	67.0**
2	Log (density)= 0.47+ 2.82 HSI (0.42) (0.67)	74.5	70.2***
II	October- 2000		
3	Log (density)= -5.19+ 0.16 HSI 1 (1.42) (1.00) +8.95* HSI 2 (1.93)	83.4	76.8***
4	Log (density) =-0.32 + 3.47 HSI (1.07) (1.72)	40.6	30.7*

*- P<0.10; **- P< 0.05; ***- P< 0.01

Standard errors are in the parentheses

As regards the density estimates of April 2000, HSI1 and HSI2 together and HSI explained nearly 70 per cent variance in density. As far as October 2000 is concerned, while HSI1 and HSI2 together explained 77 per cent variance in density estimates, the overall HSI explained only 31 per cent. The correlation between HSI and observed density estimates of April 2000 and October 2000 is presented in Figures 20 to 21. In general, the analysis indicates the extent of reliability of the habitat suitability indices as satisfactory. Nonetheless, the index model can be improved by including more number of parameters. The model can also be tested in other areas and while doing so the HSI models developed here may require modifications.

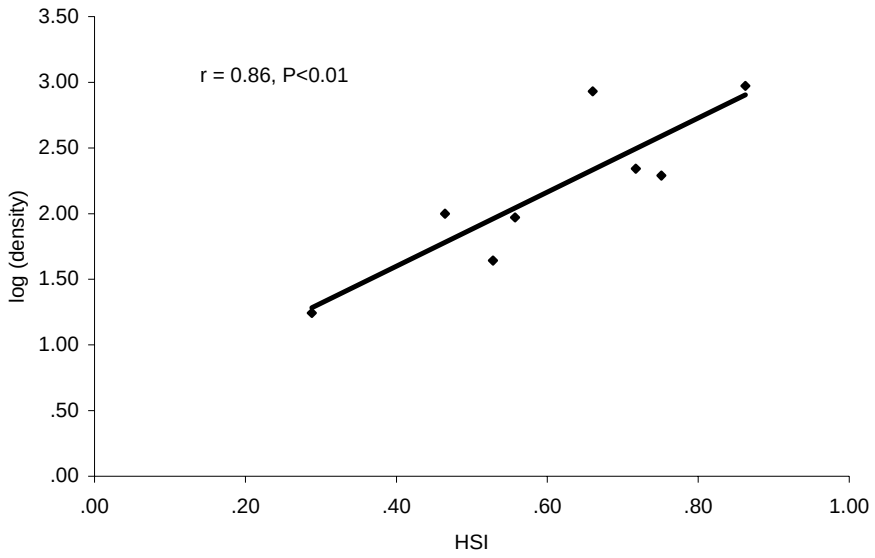


Fig. 20. Correlation between observed density and HSI (April 2000)

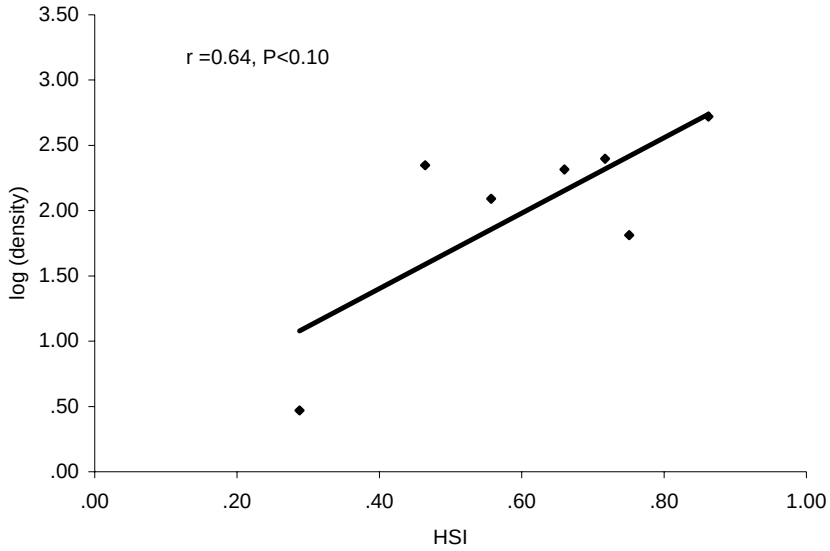


Fig. 21. Correlation between observed density and HSI (October 2000)

APPLICATION OF HSI MODEL IN FRAGMENTED TAHR AREAS

Table 26 shows the density of fragmented tahr habitats and their physiographical features. The density of tahr ranges from 2 individuals /km^2 in Parambikulam to 11 individuals /km^2 in Gundumala. The minimum altitude ranges from 730 m in Ponmudi hills to 2200 m in Meesappuli Mala. The extent of cliff (ratio of total length to total area) varied from 0.16 km/km^2 in Mangaladevi and Karimala to 0.66 km/km^2 in Elival Mala. Using the suitability index curves (Fig. 17 to 19) and equation (1), the suitability index values for different fragmented tahr habitats were worked out for physiographic characters (Table 27).

With these index values, HSI1 was related with the density of tahr. HSI1 was positively correlated with the density explaining 20 per cent of variance at P<0.20 (Fig. 22). We could not work out HSI2 relating availability of food species. It is necessary that the overall HSI, which is the product of HSI1 and HSI2 be computed and the suitability of the sites be examined. An assessment based only on the HSI1 and the density of the animal indicates that Meesappuli Mala, Gundu Mala, Elival Mala and Nelliampathy Hills may be areas worth considering for conservation.

Table 26. Density and physiographic features of fragmented tahr habitats

No	Name of the place	Area (km^2)	Density ($No./km^2$)	Altitude (m)		Extent of cliff (km/km^2)
				Minimum	Maximum	
1	Mangaladevi	3	4	1160	1322	0.16
2	Karimala	5	2	1246	1445	0.16
3	Elival mala	2	7	1800	2065	0.66
4	Nelliampathy	5	7	1320	1540	0.20
5	Chinnar	1	3	1510	1750	0.50
6	Varayattumala	10	6	887	1460	0.30
7	Ponmudy hills	4	5	729	1255	0.22
8	Meesappuli mala	12	5	2200	2534	0.37
9	Gundumala	6	11	1900	2405	0.21
10	Kochupamba	5	4	1060	1189	0.26

Table 27. Suitability index values for different tahr habitats

No	Name of the place	SI1	SI2	HSI1
1	Mangaladevi	0.84	0.58	0.70
2	Karimala	0.84	0.62	0.74
3	Elival mala	1.00	0.90	0.95
4	Nelliampathy	1.00	0.66	0.81
5	Chinnar	1.00	0.76	0.87
6	Varayattumala	1.00	0.44	0.67
7	Ponmudy hills	1.00	0.36	0.60
8	Meesappuli mala	1.00	1.00	1.00
9	Gundumala	1.00	0.95	0.97
10	Kochupamba	1.00	0.53	0.73

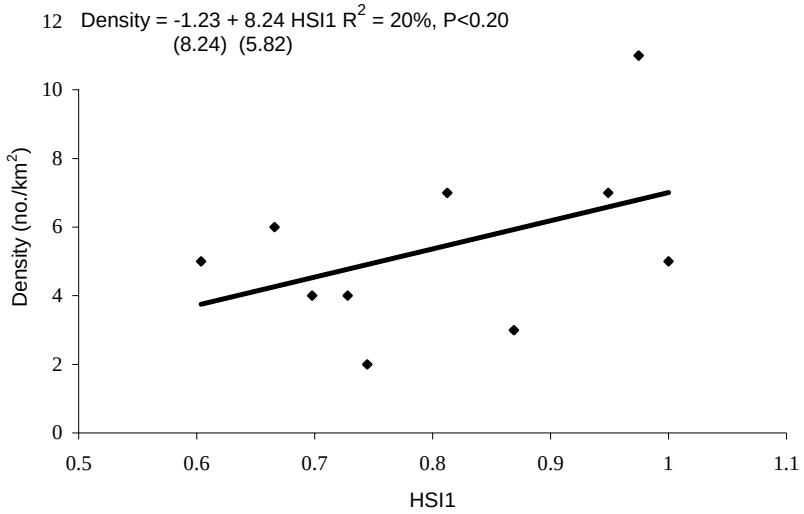


Fig.22. Correlation between HSI1 and density in fragmented tahr habitats

DISCUSSION

The study reveals that the population of tahr in the State of Kerala is highly fragmented and the total of 998 were in 11 populations with the largest population of 696 in Eravikulam National Park. The area in Varayattu Mala in Neyyar is extensive and rich in food species. However, the number sighted was comparatively fewer. But this is also a reflection of the season and it is possible that the area will have more number of animals. Kochu Pamba area in the fringes of Periyar Tiger Reserve is a promising location in terms of vastness and lack of disturbance, though the number sighted was not much. The areas in Nelliampathy Hills are rich in terms of food abundance and extent of grasslands. However, the human disturbance poses the major threat to the population.

The population estimation in different seasons shows that there is a seasonal variation in the density of tahr. For developing the HSI model, various parameters were taken and related with the density estimates of April 2000 and October 2000. The density estimates of December 2001 were less and thus excluded for further analyses. The density of tahr was found to increase with the increase in the altitude. The extent of cliff has an important role in the distribution of tahr. The relationship between density and extent of cliff indicates that the

density increases with the increase in the extent of cliff. Among the food species, availability of *Chrysopogon zeylanicus* and *Eulalia phaeothrix* has a positive relation with the density.

Based on these relationships, the Habitat Suitability Indices were developed. The potential of the Habitat Suitability Indices in capturing variation in tahr density was in general found to be satisfactory from the results of the regression analysis. The analysis indicates that HSI1 and HSI2 can be adopted independently for the evaluation of the suitability of the sites. It is however suggested to work out the composite index HSI also because it does not need further effort. The HSI model developed here can be improved by incorporating more number of variables that affect tahr density.

RECOMMENDATIONS

The areas that would contribute to the maintenance of a viable population include the Varayattu Mala area in Neyyar, the Nelliampathi Hills, Kochu Pamba and Meesappuli Mala other than the Eravikulam National Park and the New Amarambalam-Anginda population. These areas have to be strictly protected to avoid human pressure. The application of the Habitat Suitability Index Model in these areas will give a proper direction as to the development of the area.

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