THE BEHAVIOR AND ECOLOGY OF NILGIRI TAHR

(*HEMITRAGUS HYLOCRIUS* OGILBY, 1838)

A Dissertation

by

CLIFFORD GUSTAV RICE

Submitted to the Graduate College of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 1984

Major Subject: Wildlife and Fisheries Sciences

THE BEHAVIOR AND ECOLOGY OF NILGIRI TAHR

(*HEMITRAGUS HYLOCRIUS* OGILBY, 1838)

A Dissertation

by

CLIFFORD GUSTAV RICE

Approved as to style and content by:

Fritz R. Walther.

Fritz R. Walther
(Chairman of Committee)

Theodore H. Friend
(Member)

Jack M. Inglis
(Member)

Nova J. Silvy
(Member)

Wallace G. Klussmann
(Head of Department)

May 1984

ABSTRACT

The Behavior and Ecology of Nilgiri Tahr
(*Hemitragus hylocrius* Ogilby, 1838) (May 1984)
Clifford Gustav Rice, B.A., Macalester College;
M.S., Colorado State University
Chairman of Advisory Committee: Dr. Fritz R. Walther

The behavior and ecology of Nilgiri tahr was investigated during a two-year field study at Eravikulam National Park, Kerala, India. The primary method of investigation was direct observations on wild tahr. The Nilgiri tahr is one of three species of tahr comprising the genus *Hemitragus* in the subfamily Caprinae. The distribution and current status of Nilgiri tahr is reviewed.

Nilgiri tahr assembled in mixed groups of all sizes up to 150. Males separated from mixed groups outside the rut, and were found in small groups (up to 20) or alone. While mixed groups primarily utilized the grassy plateau margins, males also ventured further onto the center of the plateau and onto shrubby areas below cliffs and slabs.

The Nilgiri tahr populations whose history is known have remained stable, despite a variable reproductive rate. Mortality was estimated at about 40% for subadults, and 20% for adults. Nilgiri tahr give birth to one young. The main birth season is in January-February, although additional births took place during the monsoon. Observations indicated that leopard, Asiatic wild dog, and man were the main predators on the Eravikulam tahr population. Tiger and jackal, although present, did not seem to play a significant role in Nilgiri tahr life history.

The social behavior of Nilgiri tahr is described, with emphasis on agonistic and sexual behavior. The role of these behaviors in the rutting season is discussed, and comparisons drawn with related species.

Recommendations are presented for the maintainance of existing Nilgiri tahr populations, and it is suggested the reintroductions be attempted if suitable sites can be found and protected.

ACKNOWLEDGEMENTS

This study received finacial support from the Caesar Kleberg Program in Wildlife Ecology (preparation, field work, and writing), the American Institute of Indian Studies (Junior Fellowship, field work), and the New York Zoological Society (field work). I am most grateful to these organizations for their support. In addition, I thank the Government of India and the Kerala State Government for their cooperation and permission to conduct the field work.

Members of the High Range Wildlife Preservation Association were of invaluable assistance with many daily logistical apsects of the study. In particular I would like to thank M.P. Lappin, S. Singh, and I.P. Prem without whose assistance, the project would have been much more difficult. I also thank P.R. Chandran, J. Lewis, D. Penny, and C. Wilson for sharing information concerning their captive groups of Nilgiri tahr. P.V. Shreekumar (Botanical Survey of India) identified the grasses, and P.V.K Nambiar (Kerala Forest Research Insititute) kindly provided names for many other plant specimens. J.C. Daniel identified the herpetological specimens. I am also grateful to Ralph Daly for the invitation to visit Oman, and for the the assistance and hospitality of his staff, J. Usher-Smith, M. Stanley-Price, and D. Insall during my visit there. Lastly, I offer my thanks to Fritz Walther, my advisor, and to my collegues at Texas A&M University for their support, encouragement, and helpful suggestions on all phases of the study. A special vote of thanks goes to A. E. King, for her assistance in preparing the manuscript.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

INTRODUCTION

The Indian subcontinent is an area of wide diversity in many respects. Physiographic forms range from ocean coastlines, flat expansive plains, and rolling plateaus, to the worlds highest mountains. Biotic conditions span the extremes of tropical lowlands, sun-bleached desert, soaking rain forest, the "third pole" of the Himalayas. This variability has engendered a corresponding diversity of plant and animal life forms, a process encouraged by contributions from the Ethiopean, Palearctic, and Oriental realms. Superimposed on this natural diversity, is a complex collage of human diversity, in terms of ethnic groups, religion, culture, and politics.

Perhaps it is the ubiquitous human presence and the resultant pressing considerations of economics and development, overshadowing the natural biotic processes in the area, which is responsible for the general exclusion of wildlife from most perceptions of the area. Whether it was for this, or for some other reason, as the fields of investigation in ecology and behavior of large mammals expanded to Africa and other tropical areas, the Indian subcontintent was largely ignored. My own interests in these affairs stemmed from experiences as an adolescent, hunting some of India's large mammal species. However, as I became familiar with the disciplines of ecology, ethology, and wildlife management, I was struck by the complete lack

---

The style and format on the following pages follow that of the Journal of Mammalogy.

of information on most basic aspects of these species' biology. Most of the information on large mammals consisted of anectdotal sketches by hunters. Yet a more complete accounting was both appropriate and needed. It was appropriate as a compliment and point of comparison with studies elsewhere, but it was needed as a basis for management and conservation efforts aimed at preserving India's fast dissappearing wildlife (Talbot, 1960; Gee, 1964; Seshadri, 1969; Mountfort, 1970; Singh, 1973).

Today all this has changed, as there have been a number of wildlife studies making a significant contribution to our knowledge of the area (e.g. Schaller, 1967, 1978; Gadgil and Grubb, 1980; Sunquist, 1981; Johnsingh, 1982). Yet, most species have, at most, received attention for a single study in a single locality. The purpose of this study is to help fill this gap for a yet unstudied species, the Nilgiri tahr (Hemitragus hylocrius). To date this species has received only cursory attention (Schaller, 1971), although the distribution of the species is fairly well known (Davidar, 1978).

Nilgiri tahr are of interest from the perspectives of ethology, ecology, and conservation. Although they are goat-like in many ways, tahr also are similar in some respects to the more primitive rupicaprines. For this reason, the behavior of tahr can be expected to reflect this intermediate status, making it possible to examine trends in the evolution of behavior within this group.

Most Caprini occupy mountainous habitats at temperate latitudes. The Nilgiri tahr inhabits the hills along the western side of South

India, from the Nilgiri Hills, virtually to the tip of India. This makes it the worlds most equatorial wild member of the Caprinae, and the southernmost natrually occurring species in this group. The environmental conditions and habitat in which Nilgiri tahr live are also quite different from that of most other species of this group. The annual cycle is not geared to the usual four seasons, but rather, the monsoon dominates the annual pattern, lashing the highlands with heavy rains. Abundant rainfall and other factors have resulted in a lush grassland at higher elevations, and this grassland and adjacent cliffs are the main habitat of Nilgiri tahr. It is therefore of considerable interest to describe the effects these ecological circumstances have on the life history of the species.

The objectives of this study are aimed at providing information on all these aspects of Nilgiri tahr biology. Overall, I simply tried to learn as much as possible about Nilgiri tahr, primarily by watching them in the wild. Such observations are of little meaning, however, without a discussion of the context of the observations. Thus a preliminary objective is the description of the ecological milleu of the species in terms of weather, vegetation, and the physical nature of the study site. Behavioral and ecological comparisons depend on sound taxonomy, and I have therefore reviewed the taxonomy of this genus.

With regards to behavior, my main concern is with social behavior, that is, the displays and acts by which the tahr relate to one another, and how these behaviors function in the social organization of the species. This then serves as a basis for comparisons with related species.

The ecological objectives include the description of the life of the Nilgiri tahr with respect to the environment in which it lives, namely: the habitats it occuppies and the elements of these habitats which are important to the tahr. Another important aspect is the population dynamics of the species, including the reproductive biology of the species, and the factors responsible for mortality.

Due to its restricted distribution and limited numbers, and given the human pressures prevailing on the Indian subcontinent, conservation is probably the most signifacant and timely aspect of Nilgiri tahr ecology. Nilgiri tahr are considered vulnerable by the Internation Union for the Conservation of Nature and Natural Resources (IUCN, Goodwin and Holloway, 1972), and are barred from sport hunting under the India Wildlife Protection Act (1972). With only about 2,200 tahr existing in wild populations, it is appropriate to determine the steps necessary for maintaining current populations.

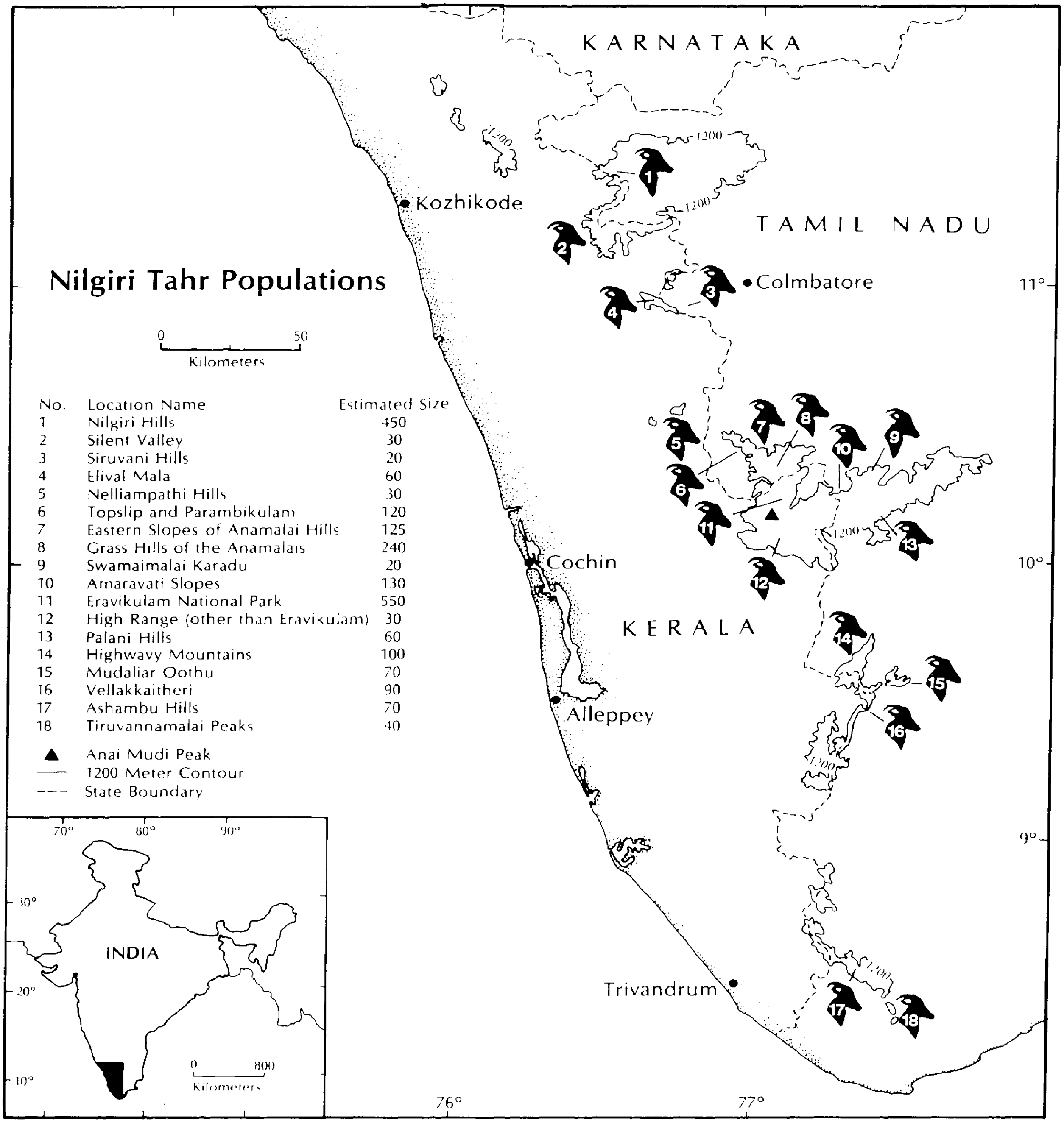
STUDY AREAS

The main study area was Eravikulam National Park in Kerala, India. Visits were also made to the adjoining Grass Hills of the Anamalais and the Mukerti area of the Nilgiri Hills in Tamil Nadu.

Eravikulam National Park

A range of hills know as the Western Ghats runs along the west coast of peninsular India. Along its length, this range bears various names, including the Nilgiri Hills, the Anamalai Hills, the High Range, the Cardomon Hills, the Highwavy Mountains, and the Ashambu Hills. Eravikulam National Park falls along the crest of the Western Ghats in the High Range, Idukki District, Kerala, at about 10° 15' N and 77° 5' E. (Population 11 in Fig. 1). Anai Mudi, at 2,697 m, the highest point south of the Himalayas, falls in the southern part of the park. Part of the northern boundary of the park coincides with the state boundary between Tamil Nadu and Kerala (Fig 2). It is bordered on the west side by reserve forest, and on the south and east by tea estates.

The closest town is Munnar (Kerala), just to the south of Eravikulam National Park, and the a road from Munnar to Udumalpet (Tamil Nadu) passes just east of the park. No roads penetrate into the park, and access from the east is through the tea estates of Tata-Finlay Ltd. A trail, passable by motorcycle, is maintained from Vaguvarrai Estate to the Eravikulam Hut on the central plateau (Fig. 2). Another bike trail leads from Eravikulam Hut to Poovar Hut in



No.	Location Name	Estimated Size
1	Nilgiri Hills	450
2	Silent Valley	30
3	Siruvani Hills	20
4	Elival Mala	60
5	Nelliampathi Hills	30
6	Topslip and Parambikulam	120
7	Eastern Slopes of Anamalai Hills	125
8	Grass Hills of the Anamalais	240
9	Swamaimalai Karadu	20
10	Amaravati Slopes	130
11	Eravikulam National Park	550
12	High Range (other than Eravikulam)	30
13	Palani Hills	60
14	Highwavy Mountains	100
15	Mudaliar Oothu	70
16	Vellakkaltheri	90
17	Ashambu Hills	70
18	Tiruvannamalai Peaks	40

▲ Anai Mudi Peak
—— 1200 Meter Contour
--- State Boundary

Fig. 1.--Distribution and estimated size of Nilgiri tahr populations in South India (based on Davidar, 1978 and this study).

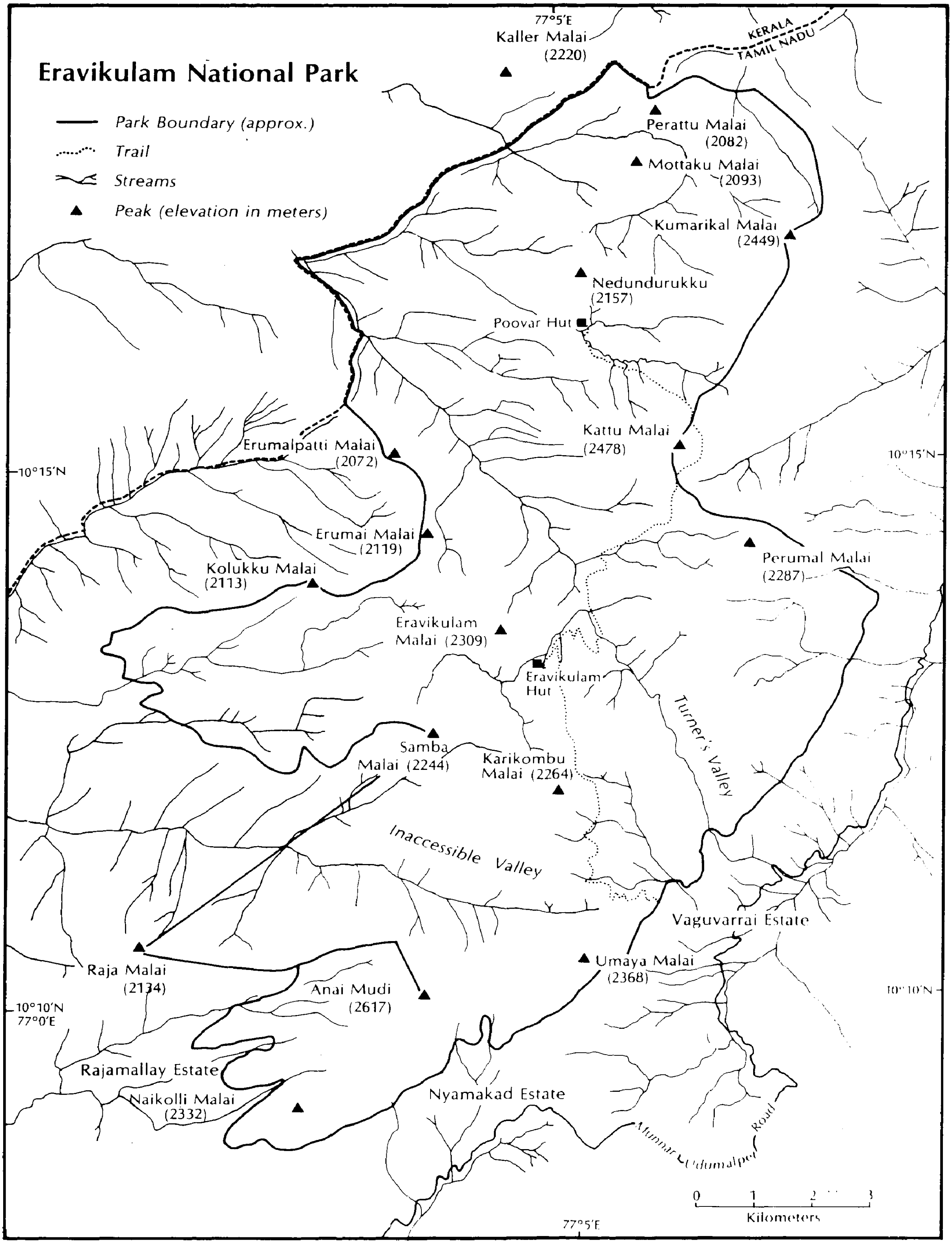


Fig. 2.--Approximate boundary of Eravikulam National Park. Adapted from Survey of India, 1925, sheet 58 F./S.W.

the northern section of the park, but this trail is less frequently maintained.

As is recounted by Baig and Henderson (1978), modern settlement of the High Range began with the establishment of the North Travancore Land Planting and Agricultural Society in 1879. Estates were developed in the ensuing years, which yielded such crops as tea, coffee, and cinchona. Over the years, tea became the predominant crop.

The early plantation managers were from the United Kingdom and they maintained an active interest in outdoor sports including hunting and fishing. Game taken included Nilgiri tahr (Hemitragus hylocrious), *sambar* (*Cervus unicolor*), *barking deer* (*Muntiacus muntjak*), *gaur* (*Bos gaurus*), *wild boar* (*Sus scrofa*), leopard (*Panthera pardus*), and tiger (*Panthera tigris*), while angling focused on the introduced brown and rainbow trout (*Salmo trutta* and *S. gairdneir*). To improve and regulate these activities, the estate managers formed the High Range Wildlife Preservation Association, and the High Range Angling Association in 1928 and 1933, respectively. The high country, including the plateau of what is now Eravikulam National Park were too high and too cold, and had soils unsuitable for plantation crops. Such areas that fell under the Associations' purview were maintained in a wild state for use in outdoor sport. The associations maintained low levels of harvest of fish and game, and the land was kept in its original condition. Mudhuvan tribals were employed as game watchers, and the managers of nearby estates were appointed as wardens for the various areas.

In 1971, the Kanan Devan Hills (Resumption of Lands) Act ruled that all land not actually under cultivation be vested with the government as part of a land reform program. This caused some concern that the unspoiled land of the Eravikulam Plateau would be converted to agricultural uses. However, thanks to the representations on behalf of preserving the area by J.C. Gouldsbury, then chairman of the High Range Wildlife Preservation Association, and to the foresight of the Kerala state government, the area was declared a wildlife sanctuary in 1975, and then, in 1978, upgraded to a national park.

The planting community in the Nilgiri Hills filled a similar role. Formed in 1877, the Nilgiri Wildlife Association gave support and advice on the regulation of sportsmans' activities in the area. However, with the current total ban on sport hunting, its activities have diminished.

The main body of the National Park is comprised of a high rolling plateau area, with a base elevation of about 2,000 m (Fig. 3). Most of the knolls and peaks on the plateau rise 100-300 m above it. The highest mountains rising from the plateau (Kattu Malai and Kumarikal Malai) reach an altitude of over 2,500 m. The main plateau area is split roughly in half from northwest to southeast by Turner's Valley. Streams flow from the Park through Turner's Valley both to the northwest and to the southeast, but despite this, the highest point in the valley is still 150 m below the plateau level (i.e the

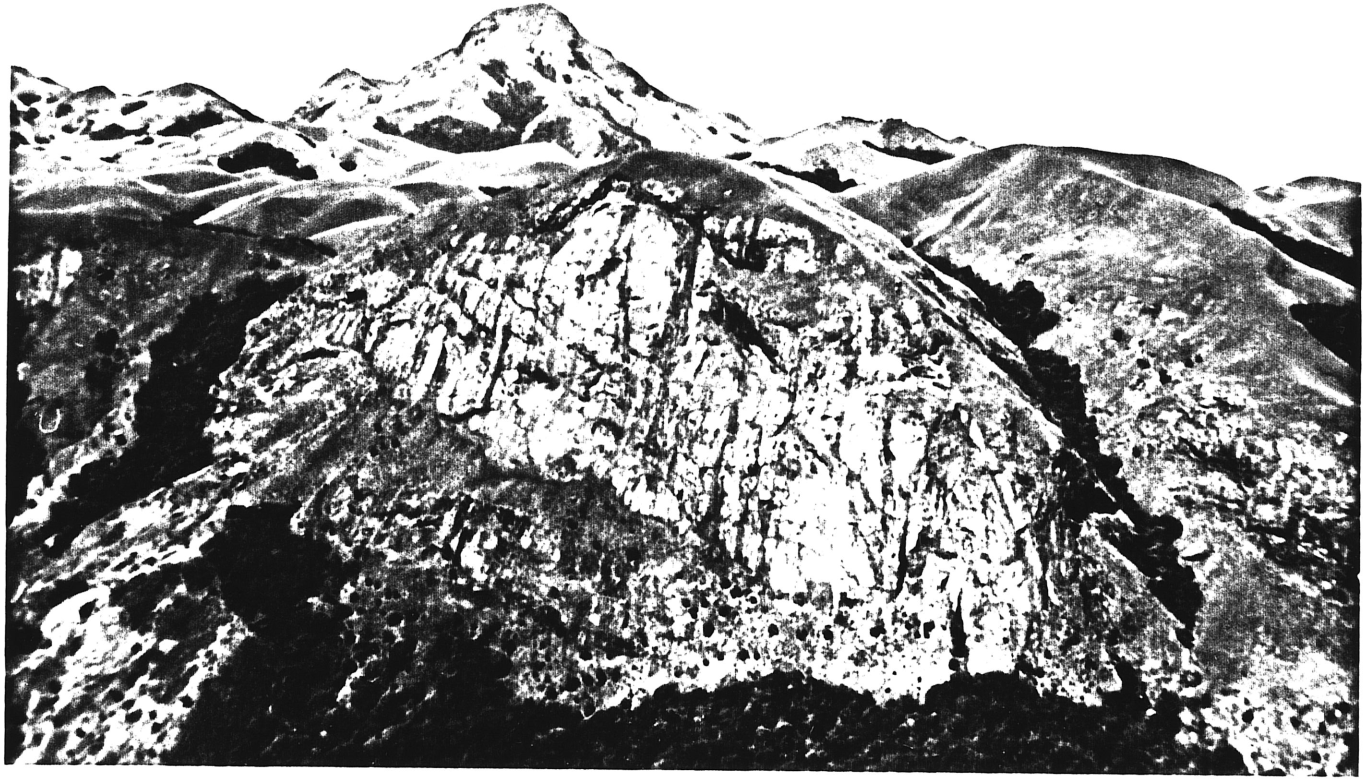


Fig. 3.--Nilgiri tahr habitat at Eravikulam National Park. The prominent peak on the skyline is Anai Mudi. The cross section in Fig. 4 runs from the next bump on the skyline to the right (Karikombu Malai) towards the camera and over the summit of the dome in the foreground.

valley is continuous, despite the change of watersheds). The maximum depth of the valley within the park is about 600 m.

At the south end of the park the complex of mountains around Anai Mudi is joined to the plateau by a thin peninsula of high country (Umaya Malai). The fringes of the plateau (and the Anai Mudi massif) are frequently precipitous, often with broken cliffs and steep slopes. For the most part the National Park boundary is coincident with the edge of the plateau. In contrast to the sustained and extremely steep escarpment along the eastern fringe of the Nilgiri Plateau, the plateau fringe in the Eravikulam area is generally less steep with cliffs often grading into rock slabs with numerous breaks of grassland, shrubs, or forests. Only along the west-facing crest between Kattu Malai and Kumarikal Malai (Fig. 2) does the edge of the plateau resemble that of the Nilgiri plateau in this regard. In addition, cliffs are usually not abrupt, but rounded, both horizontally and vertically (Fig 4). Where exposed, the rock usually has an irregular surface, with numerous small dikes and discontinuities.

Three major types of plant communities are found within Eravikulam National Park; grassland, shrubland, and forests. As is typical for the Western Ghats, the high country, (terrain above about 2,000 m), is covered primarily by grassland. However, there are numerous small patches of forests in hollows and gullies in these areas. The deeper valleys are extensively forested. Shrublands predominate along the bases of the cliffs and intersperced in rocky

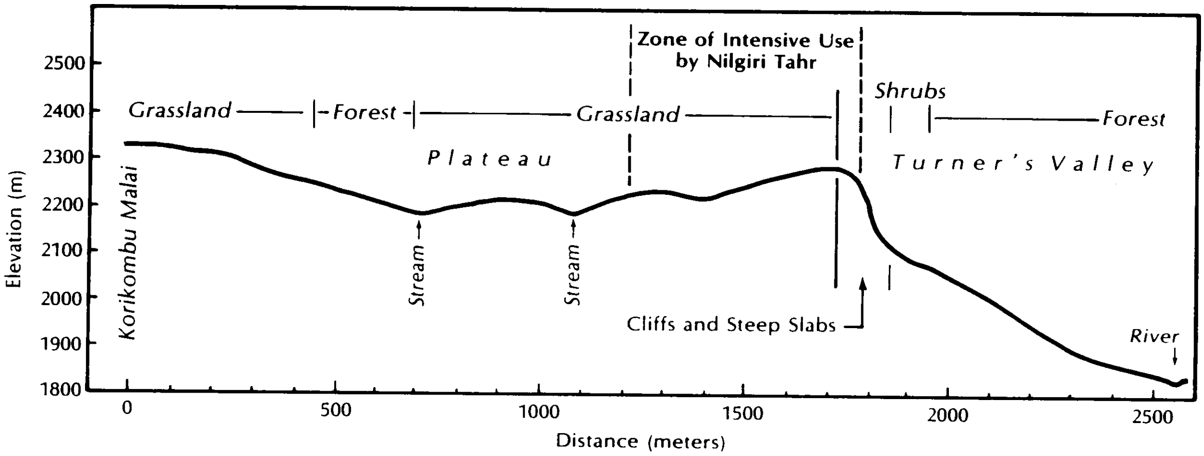


Fig. 4.--Topographic and vegetational cross section at a bearing of 45° N from Karikombu Malai to Turner's Valley (see Fig. 2).

slab areas. A cross section of these vegetational types is shown in Fig. 4.

The forest areas, locally known as "sholas", are classified as Southern Montane Wet Temperate Forest (Chandrashekaran, 1962). The trees in these sholas form a continuous canopy usually not exceeding 10 m in height. There is no marked differentiation into canopy layers (Shetty and Vivekananthan, 1971). Species present include *Actinodaphne bourdillonii*, *Elaeocarpus recurvatus*, *Ilex denticulata*, *Ligustrum perrottetii*, *Litsea wightiana*, *Michelia nilagirica*, *Microtropis ramiflora*, *Pithecellobium subcoriaceum*, *Pittosporum tetraspermum*, *Shefflera racemosa*, *Symplocos pendula* and *Syzygium arnottianum* (Shetty and Vivekananthan, 1971). On the basis of species composition and structure, Meher-Homji (1969) described the mixed tree and shrub transition zone at the margin of the sholas as a separate physiognomic type. Species present in this zone include *Eurya nitida*, *Photina notoniana*, *Rhododendron nilagiricum*, *Rhodomyrtus tomentosa*, *Ternstroemia japonica*, *Turpina cochinchinensis*, *Berberis tinctoria*, *Gautheria fragrantissima*, *Heydotis stylosa*, *Leucas lanceaefolia* and *Smithia blanda*. However, the transition from shola forest to grassland is usually quite abrupt, and therefore does not warrant a separate classification of habitat.

The shrublands at Eravikulam differ from those described by Meher-Homji (1969) for the Kodaikanal area in that they are not the result of disturbance, but rather seem to be a stable vegetative association occurring on steep slopes below cliffs and interspersed among rock slabs. Species common in these areas include *Chrysopogon zelanicus*, *Eupatorium adenophorum*, *Strobilanthes kunthianus* and *Cynbopogon sp*. Vegetative height in these areas usually ranges between 1 and 2 m.

Within Eravikulam National Park grasslands account for most of the terrain above about 2,000 m. I made no attempt to quantify variation in species composition in grassland throughout the park, but most of the area was one of two types: the first, dominated by *Eulalia phaeothrix* and the second by *Sehima nervosum*. Cover values obtained by a modified point frequency (Daubenmire, 1968a; Mueller-Dombois and Ellenberg, 1974) for species in representative areas for these two types are shown in Table 1. Basically, the *Eulalia phaeothrix* dominated grassland is more diverse than the *Sehima nervosum* grassland, although they have numerous elements in common. The *Sehima nervosum* grassland is also perhaps richer in forbs (Table 2), but total vegetative coverage is very similar. For the Nilgiri Hills, Blasco (1970) describes four savannah (grassland) types of which only his *Eulalia phaeothrix-Arundinella fuscata*) probably corresponds to my *E. phaeothrix* type in Eravikulam National Park.

Similar ecological conditions prevail along the higher elevations of the Western Ghats, from the Nilgiri Hills in the north, almost to the tip of India, and in the highlands ("patenas") of Sri Lanka. In all of these areas, the factors responsible for the distribution of forests and grasslands are not obvious. Moreover, the distribution of these communities has remained highly stable over

Table 1.--Percent cover for grasslands dominated by *Eulalia phaeothrix* and *Sehima nervosum*. Based on 500 points for each sample.

Dominant species Burned/Unburned Date sampled	*Eulalia* Burned 09 Sep 81	*Eulalia* Unburned 28 Aug 81	*Sehima* Unburned 15 Nov 80
Eulalia phaeothrix	25.2	34.6	11.0
Ischaemum indicum	18.2	18.2	1.0
Sehima nervosum	16.2	18.2	67.6
Bare ground	9.0	1.2	1.4
Tripogon bromoides	8.2	5.4	3.6[*]
Andropogon lividis	6.4	7.6	2.4
Arundinella fuscata	5.6	6.8	1.0
Tripogon ananthaswamianus	4.8	1.2	[*]
Litter	2.4	4.4	5.6
Unidentified			3.6
Cyanotis sp.	1.0	0.4	0.6
Unidentified sedge	0.6	0.4	0.4
Curculigo orchoides	0.6	0.4	
Unidentified sedge	0.6		
Drosera peltata	0.4		
Anaphalis lawii	P	0.4	P
Indigofera pedicilatta	P		0.4
Impatiens sp.	P	P	0.4
Olenandia swertioides	0.2	P	
Unknown forb	0.2		
Unidentified	0.2	P	P
Indochloa oligantha		0.2	0.2
Pimpenella candeoleana	P	0.2	P
Unknown sedge		0.2	
Unknown sedge		0.2	
Agrostis peninsularis			0.2
Polygala sibirica	P		0.2
Wahlenbergia gracilis		P	0.2
Crotalaria fysonii			0.2
Ranunculus reniformis	P	P	
Osbeckia cupularis	P	P	
Swertia corymbosa	P	P	P
Sopubia trifida		P	P
Leucas suffruticosa		P	P
Helictotrichon asperum			P

[*] *Tripogon bromoides* includes *T. ananthaswamianus* in this count.
P = present but not counted.

Table 2.--Total percent cover by plant type for grassland dominated by Eulalia phaeothrix and Sehima nervosum. Based on 500 points for each sample. Litter refers to dead plant material not attached to a living plant.

Dominant species Burned/Unburned Date sampled	Eulalia Burned 09 Sep 81	Eulalia Unburned 28 Aug 81	Sehima Unburned 15 Nov 80
Total grasses	84.6	92.2	87.0
Total forbs	2.8	1.4	5.6
Total sedges	1.2	0.8	0.4
Bare ground	9.0	1.2	1.4
Litter	2.4	4.4	5.6

the years, with little expansion or contraction in the shola forests. In addition, there is an abrupt transition between the two types, the border being quite distinct.

The ecological explanations given for these plant distributions fall into two groups: those which describe the grassland-shola habitat as a polyclimax; and those which maintain that the shola forest is the true climax, and that the grassland is a sub-climax maintained by human disturbance, fire and grazing in particular. In support of the first point of view, Meher-Homji (1965), in his studies in the Nilgiris, noted that nearly all the shola species have distributions limited to the tropical latitudes, whereas species that are found in the open are of temperate origin. On this basis he postulates that the frosts which occur during the winter months at higher elevations, prevent tropical species from colonizing open grassland. Wind and soil moisture are also considered as factors possibly limiting the expansion of sholas.

The contrasting point of view, that the shola forest represents the single climax vegetation type for the area, and that the grassland is a man-maintained subclimax is more widely accepted. In this view, fires limit the the amount of woody vegetation in the grassland, as has been shown to be the case in other grassland or savannah habitats (Brynard, 1964; Daubenmire, 1968b) and thus prevents the establishment of shola species. Because species at the margin of the sholas such as Gautheria fragrentissima, Eupatorium adenophorum and Strobilanthes kunthianus inhibit grass understory, and are only temporarily damaged by fires, the true shola species are not harmed by grass fires. However, the reasons that these marginal species do not colonize further areas of grassland are not clear.

Species of large mammals present in Eravikulam National Park include Nilgiri tahr, sambar, gaur, barking deer, Asiatic elephant (Elephas maximus), tiger, leopard, Asiatic wild dog (Cuon alpinus), jackal (Canis aureus), jungle cat (Felis chaus), Nilgiri marten (Martes gwatkinsi), stripe-necked mongoose (Herpestes viticollis), and Nilgiri langur (Presbytis johnii).

The monsoon dominates the annual weather cycle in most of the Indian subcontinent, and Eravikulam is no exception. Commencing in June, it is characterized by prevailing southwest winds which bring moist warm air from the Indian Ocean over the Indian peninsula. Throughout most of the subcontinent, rainfall is concentrated during this season and in many locations this accounts for over 90% of the annual rainfall (Ramdas, 1974). In South India and Sri Lanka, the monsoon is followed by a season of lighter rainfall, often referred to as the northeast monsoon. Then, during the winter, depressions moving in from the west bring occasional rain to northern India, but in the south this is the dry season. As the new year progresses, temperatures climb and rainfall is low. For these reasons the months of April and May are referred to as summer over much of India. Thus the year consists of four seasons which are quite unlike those usually associated with temperate climates: (1) Winter, from December to February; (2) summer or pre-monsoon, from March to May; (3) Southwest monsoon, from June to August; and (4) post-monsoon or northeast monsoon, from September to November (Ramdas, 1974).

This pattern of seasons applies to Eravikulam National Park as well. However, as is the case with most Indian hills and mountain ranges, the amount of rainfall is greatly increased by orographic effects. Rainfall figures were kindly provided for Vaguvarrai Estate (Lower Division), which lies on the southeast border of the park. The average annual rainfall for the years 1967-79 was 409 cm. This is not unusual for the region, making it one of the wettest areas in the world. The monthly rainfall for 1967-79 are summarized in Fig. 5. The dramatic increase in rainfall at the onset of the monsoon in June is plainly evident, as is the season of lesser rainfall following it. By contrast, there was almost no rainfall in January and February, with increasing amounts during March-May. This rain is in the form of thundershowers, which become more frequent as the season progresses. On the basis of the information presented in Fig. 5, it is evident that the four seasons at Eravikulam differ slightly

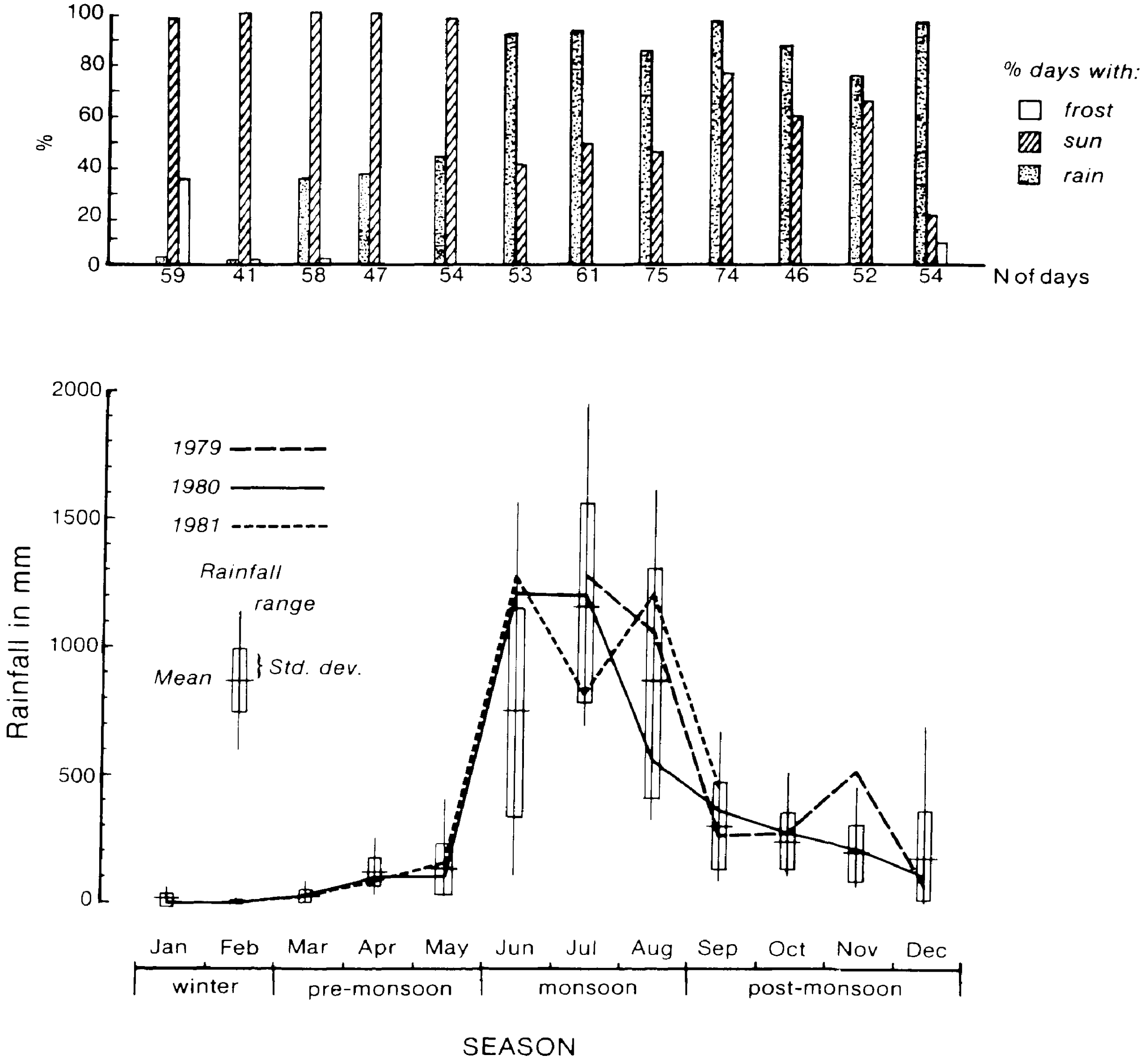


Fig. 5.--Summary of weather patterns for Eravikulam National Park. Rainfall figures provided by Vaguvarrai Estate. Rainfall mean is for years 1967-79.

from those mentioned above for the subcontinent as a whole. The seasons, as they will be used here are shown in Fig. 5. December is included in the post-monsoon by virtue of the amount of rainfall and continuing mist.

At Eravikulam National Park there are typically no or few clouds during the winter months, and winds are light or variable, mostly from the east. On the colder clear nights frost blankets the grassy hollows. During the pre-monsoon the wind is still usually from the east, but grows stronger at times (about 30 km/hr). The clear mornings change to partly cloudy, overcast and misty conditions as cumulus clouds form in the updrafts created by the stronger winds along the eastern margin of the plateau. These build to thunderheads with increasing frequency as the season progresses.

A shift of wind and increased rainfall mark the onset of the monsoon. During this season, winds are consistently from the west and strong, and at times they reach an estimated 80 km/hr (strong gale) along ridge crests. Leeward slopes are often swept by violent back-currents and turbulence. During the monsoon, the rain usually does not fall continually, but in heavy showers lasting less than an hour. However, lighter rain more often continues for longer periods. In addition, there is an inverse relationship between the rain and mist. Heavy rains clear the air, but the mist closes in upon the hills again as soon as the rain subsides. As a result, insolation gain during the day, and radiant heat loss during the night are minimal, and it was not uncommon for daily maximum and minimum temperatures to be only 1 or 2^{o} (C) apart. Still, during the study the sun managed to peek through the clouds at least once on nearly half the days (Fig. 5).

The end of the monsoon is not so clearly marked as is its beginning. During the post-monsoon season winds are again generally from the east and variable in strength. In many ways this time was like a wetter version of the pre-monsoon, with clouds and mist building up more quickly and extensively, and with heavier rainfall. While there is probably a rain-shadow effect during both the monsoon and post-monsoon seasons, it is much more evident during the post-monsoon. While clouds and mist build up along the eastern plateau margin, the center and western edge of the plateau often remain clear.

Located at 10° N, Eravikulam National Park falls in the tropics, but altitude greatly moderates this influence. No past records are available for temperatures in the park, but the highest recorded during the study was 29°C. Table 3 summarizes temperature records from Eravikulam Hut. The mean daily maximum rises steadily through the spring, but drops abruptly with the onset of the monsoon in June. The lack of penetration of solar radiation (Fig. 5) accounts for the maximum temperatures being the lowest during the monsoon, after which they rise again slightly. The lowest minimum temperatures, however, are during the winter months. During this time, the nights are often clear, and through radiant heat loss the surface temperature drops to near freezing, and frosts are not uncommon in basins and hollows.

Table 3.--Temperature records for Eravikulam Hut. Collected from September 1979 through September 1981. In °C.

		Maximum			Minimum		
Month	N	Mean	Highest	Lowest	Mean	Highest	Lowest
Jan	59	15.3	19	13	3.0	5	-3
Feb	41	16.2	22	15	6.5	11	2
Mar	58	18.4	23	15	8.2	12	0
Apr	47	21.7	24	16	10.5	12	7
May	54	24.1	29	15	10.5	12	8
Jun	53	14.1	22	10	9.9	12	6
Jul	61	14.3	23	11	9.8	11	8
Aug	60	13.1	19	10	9.4	11	8
Sep	74	16.9	25	11	9.5	12	6
Oct	46	15.3	18	11	9.5	12	6
Nov	52	15.3	19	10	9.3	11	6
Dec	54	15.1	20	10	5.5	10	0

The Grass Hills of the Anamalais and the Nilgiri Plateau

In order to gain a broader understanding of the ecology of Nilgiri tahr, I made brief visits to two other areas, the Grass Hills of the Anamalais and the Nilgiri Plateau. The Grass Hills of the Anamalai Hills border Eravikulam National Park to the North. This area is ecologically continuous with Eravikulam, although the isthmus of grassland between the two areas is quite thin. Access to the Grass Hills is usually through Valparai, Tamil Nadu, but it is also possible to walk across from Eravikulam. The Grass Hills are part of the Anamalai Wildlife Sanctuary, and this affords some measure of protection for the tahr. The habitat does not differ significantly from that of Eravikulam except for plantations of eucalyptus (*Eucalyptus sp.*) and pine (*Pinus sp.*) maintained by the forest department.

Unlike the relatively broken plateau of the High Range and and Anamalai Hills, the Nilgiri Plateau is much more extensive. Tahr now inhabit only the western edge of this plateau. The undulating plateau terminates abruptly along the western side in a long irregular escarpment, with steep cliffs several hundred feet high. I spent a few days at an area near the northern end of the tahr range named Mukerti. Easily accessible from Ootycamund, this area has been much disturbed by man (Davidar, 1976). The forest department has engaged in extensive planting of eucalyptus and wattle (*Acacia sp.*). In addition there is one large, and several smaller hydro-electric impoundments in the area.

DESCRIPTION OF TAHR SPECIES

Taxonomic History

Taxonomists recognized the affinities between tahr and goats and sheep from the beginning. In fact, the first member of this genus to be recognized scientifically was the Himalayan tahr, and it was given the name *Capra jemlahica* in 1827 by H. Smith (Lydekker, 1913), thus including it in the same genus as the goats (including ibex (*C. ibex* and markhor (*C. falconeri*)). The specific name refers to the type locality, the Jumla, or Jemla valley in western Nepal. Hodgson (1833), however, created a synomym, *Capra jharal*, using the Nepali term for the animal as the specific epithet and making no reference to Smith's earlier description. In 1835, he modified this to *C. quadrimammis*, when he discovered that it has four mammae. Then, in 1841, Hodgson again changed the name (Lydekker, 1913), this time to *Hemitragus quadrimammis*, the first time this generic designation was used. In 1847, Gray established a variation on the original specific name of the Himalayan tahr, referring to it as *H. jemlaicus* (Lydekker, 1913). This became the standard for many years, lasting at least until 1910 (Lydekker, 1913). Gervais was apparently the first to recognize the affinities between Himalayan and Nilgiri tahr, as he adopted the then current name for Nilgiri tahr in naming the Himalayan tahr *Kemas jemlaicus* (Lydekker, 1913). However, as late as 1891, Sclater was still using the genus *Capra* for both the Himalayan and Nilgiri species. Then in 1913, Lydekker re-established the original specific name, calling the Himalayan tahr, *H. jemlahicus* (changing the gender to match the new genus name), the name by which it is known today.

The Nilgiri tahr was first named *Kemas hylocrius* by Ogilby (1838). However, in 1842, Gray rechristened the Nilgiri tahr *Capra warryato*, changing this to *Kemas warryato* in 1852 (Lydekker, 1913). Warryato is a English rendition of the Tamil term for the Nilgiri tahr (see below). In 1859 Blyth included the Nilgiri tahr in the genus *Hemitragus*, naming it *H. hylocrius* (Lydekker, 1913).

The classification of the Arabian tahr has had a history free from such convolutions. First described by Thomas in 1894 it was given the name *Hemitragus jayakari*, which still holds today.

Haltenorth (1963) has more recently been of the opinion that the three types of tahr are actually subspecies. However, this has not seen general acceptance (Schaller, 1978; Prater, 1965) and chromosomal evidence argues against it (see below). Thus, the current view is that there are three species of tahr, the Himalayan tahr (*Hemitragus jemlahicus*), the Nilgiri tahr (*H. hylocrius*), and the Arabian tahr (*H. jayakari*; Corbett, 1978; Honaki et al., 1982; Novak and Paradiso, 1983).

There is some variation in the spelling of the English name for this genus, it appearing both as "tahr" and "thar". Both are a Anglicized form of the Nepali term for serow (*Capricornis sumatraensis*; Green, 1978). This apparent misidentification notwithstanding, "tahr" is the accepted spelling for the Himalayan species, and is the only spelling used in reference to the Nilgiri and Arabian species.

However, English speaking South Indians rarely refer to Nilgiri tahr, but rather use the term "ibex" or "Nilgiri ibex". The Tamil name for Nilgiri tahr is "varai ard" or "varai ardoo" which translates to "cliff goat". The comparable Malayalam term is "mulla atu" (Prater, 1965). Interestingly, Ogilby (1838) based the original name for Nilgiri tahr, (Kemas hylocrius) on the understanding that it's local name was "jungle sheep" (jungle or wood corresponding to the root "hyla" and the greek "krios" which means ram). However, in the English speaking community in the High Range, "jungle sheep" refers to the barking deer (Muntiacus muntjak), whereas "ibex" is the longstanding name for Nilgiri tahr (Jerdon, 1874; Fletcher, 1911). Due to this misidentification, Gray's (1842) "warryato" is a much more appropriate name, but Ogilby's (1838) remains the standard by rules of precedence.

Species Characteristics

The physical characteristics of Nilgiri tahr are best considered in comparison with the other two tahr species. For an account of the variation and development of the characteristics for Nilgiri tahr, see the section on sex and age classes. Some salient physical characteristics of mature members of both sexes of the three species of tahr are summarized in Table 4 and the three

Table 4.--Some physical characteristics of the three tahr species.

Species	Nilgiri		Himalayan		Arabian	
Sex	Male	Female	Male	Female	Male	Female
Height at shoulder: (approx)	100 cm	80 cm	100 cm	80 cm	60 cm	50 cm
Overall color:	dark brown or black	gray	brown or gray	brown or gray	brown	sandy gray
Hair length:	short	short	long	medium	long	short
Carpal marks:	white on black	black on gray	none	none	none	black on gray
Facial marks:	white line anterior to eye	less distinct than male	black face and neck[a]	light line anterior to eye	black face[a]	light line anterior to eye
Number of teats	2		4		2	
Horn divergence: (both sexes)	narrow--sub-parallel		wide		moderate	
Maturational marks: (males)	silvery saddle		prominent neck and shoulder ruff		long neck, shoulder, leg cheek and back hairs	

[a] facial stripe present on sub-mature males.

species are illustrated in Fig. 6. All three species have yellow eyes with a black horizontal pupil.

Nilgiri tahr

Male: A fully grown male Nilgiri tahr stands about 100 cm at the shoulder, and weighs about 100 kg (Schaller, 1971). The overall coloring is a deep chocolate brown. This is particularly dark; almost black on the front of the fore- and hindlegs, the shoulder, the side of the abdomen, side of the face, and the front of the muzzle. This contrasts sharply with the white facial stripe which drops from the forehead towards the corners of the mouth just anterior to the eyes, the white carpal patches on the front and outside of the forelegs, and the silvery saddle. The side of the neck where it meets the shoulder is also sometimes lightened as is the flank posterior to the saddle, and an area around the eye. Long black hairs form a mane and mid-dorsal stripe.

The horns (in both sexes) curve uniformly back, and have no twist. The outside and inside curves are constant, as shown in Fig. 7. The tips diverge slightly due to the plane of the horn being divergent from the body axis posteriorly, and tilted slightly so as to converge dorsally. This means that the tips continue to diverge the more the horns grow. The inside surface is nearly flat, and the back and outside are rounded. There is a distinct rib where the inside and front of the horns meet (Fig. 8), and the horn surface is covered with numerous fine crenulations amidst the more slightly more evident annual rings. The horns of males are heavier and

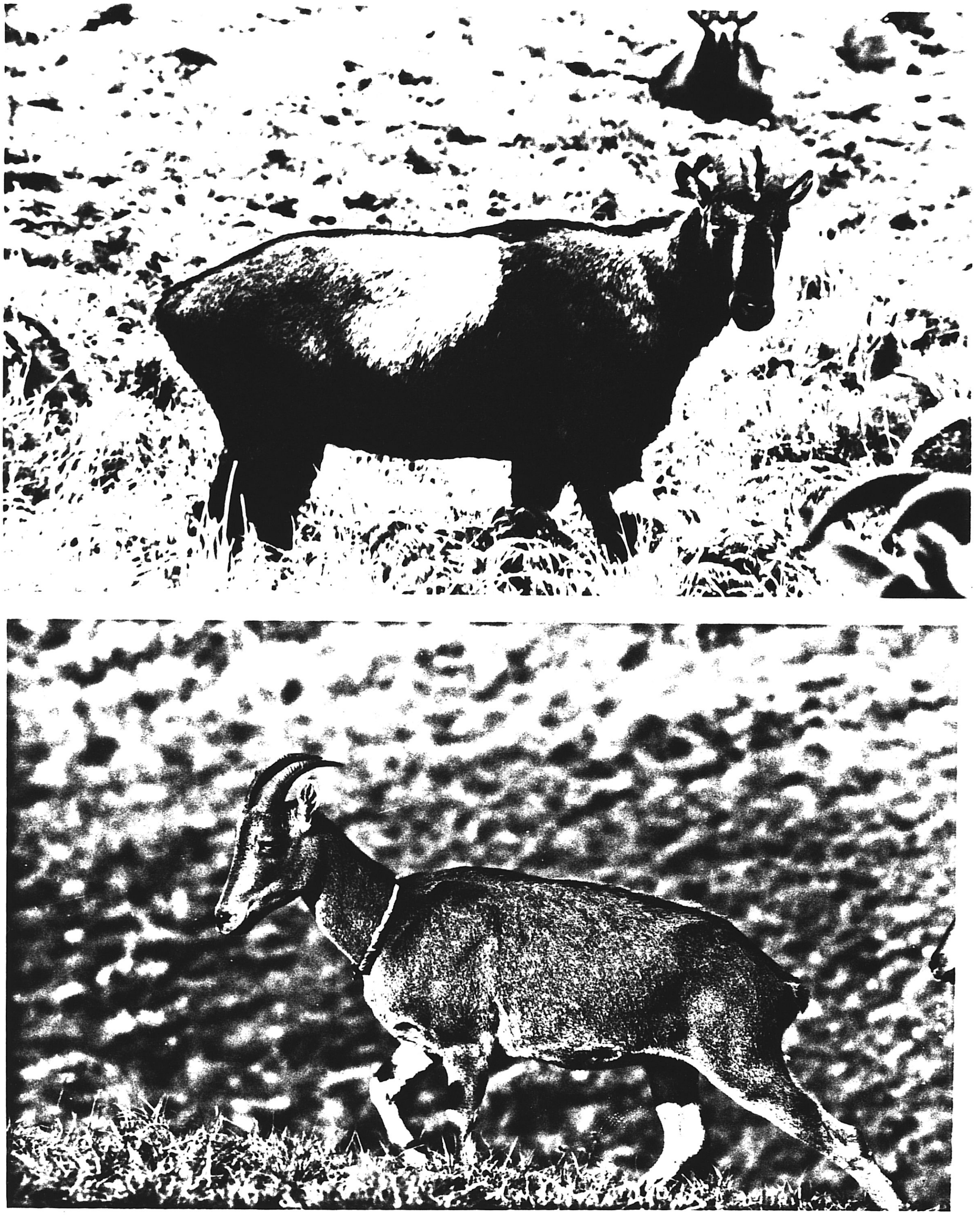


Fig. 6a.--Adult male (above) and adult female (below) Nilgiri tahr.

Fig. 6b.--Adult male (left) and adult female (right) Himalayan tahr.

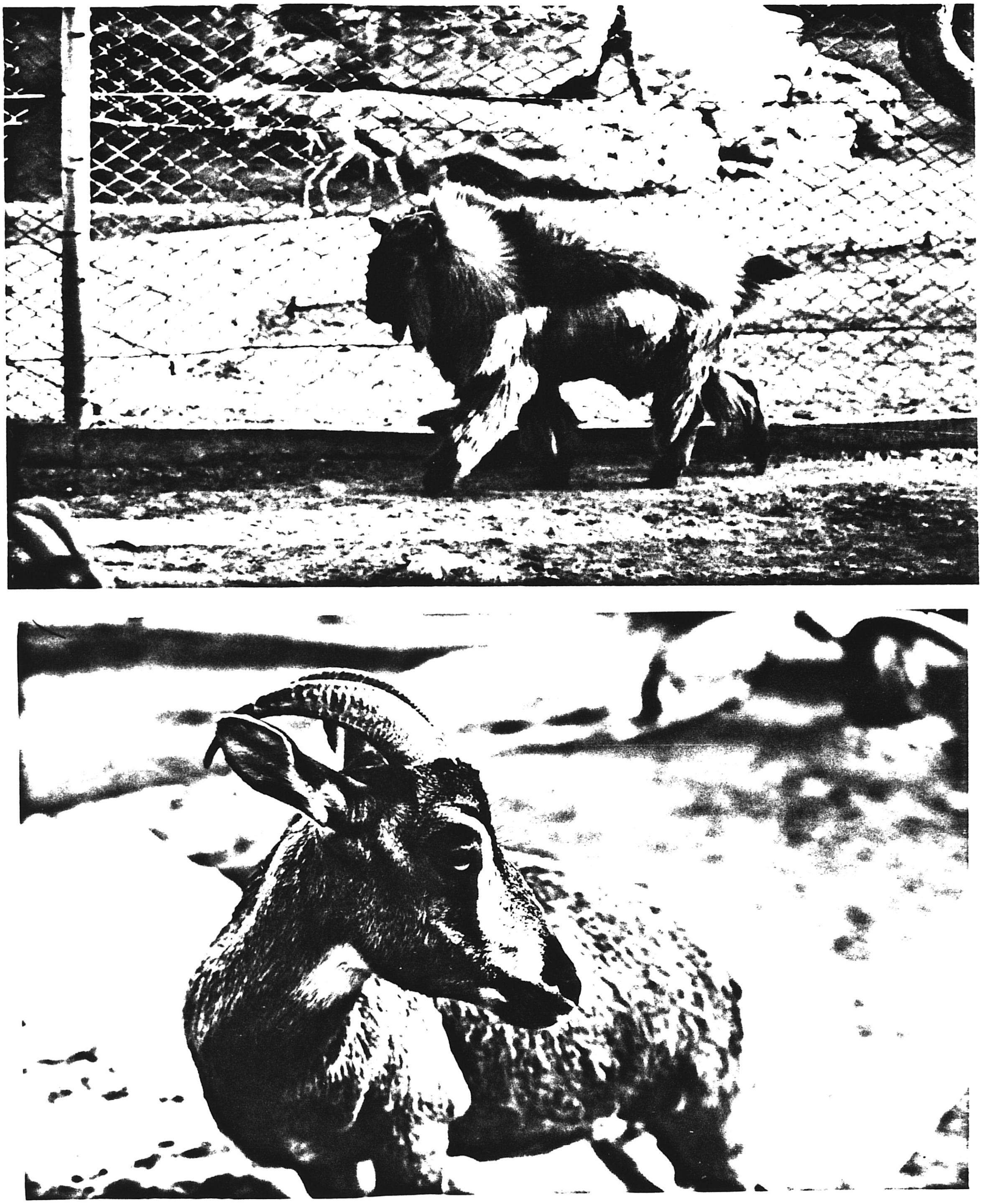


Fig. 6c.--Adult male (above) and adult female (below) Arabian tahr. Photos courtesy of Jeremy Usher-Smith.

longer than those of the females reaching a maximum length of about 40 cm (Fig. 7).

Female: Female Nilgiri tahr are shorter and slighter than their male counterparts. In contrast to the striking pelage of the male, the female is almost uniformly gray. The carpal patch is black against this light background. The facial markings are present, but only faintly, and the area around the eye and the cheek below it are brown. The mane and mid-dorsal stripe are also present, but much less conspicuous. The horns are slimmer and shorter, reaching a maximum length of about 26 cm.

Himalayan tahr

Male: The male Himalayan tahr is similar in size and build to the Nilgiri tahr. Its pelage, however, is strikingly different. The most conspicuous aspect of its pelage is a large full ruff or mane of long light brown or light gray hair on the lower neck and shoulders. The flank and front of the hindlegs are also covered with shaggy hair, though not as long as that of the mane. The face and neck above the mane is black with a medium brown area around the eyes. There are no carpal markings. The horns diverge much more widely than those of the Nilgiri tahr, due to a wide posterior divergence of the plane of the horns, combined with a considerable tilting so as to converge ventrally. As a result, the tips of the horns point back towards the neck, and would meet if they grew long enough. The horns have an irregular cross section, with the rib

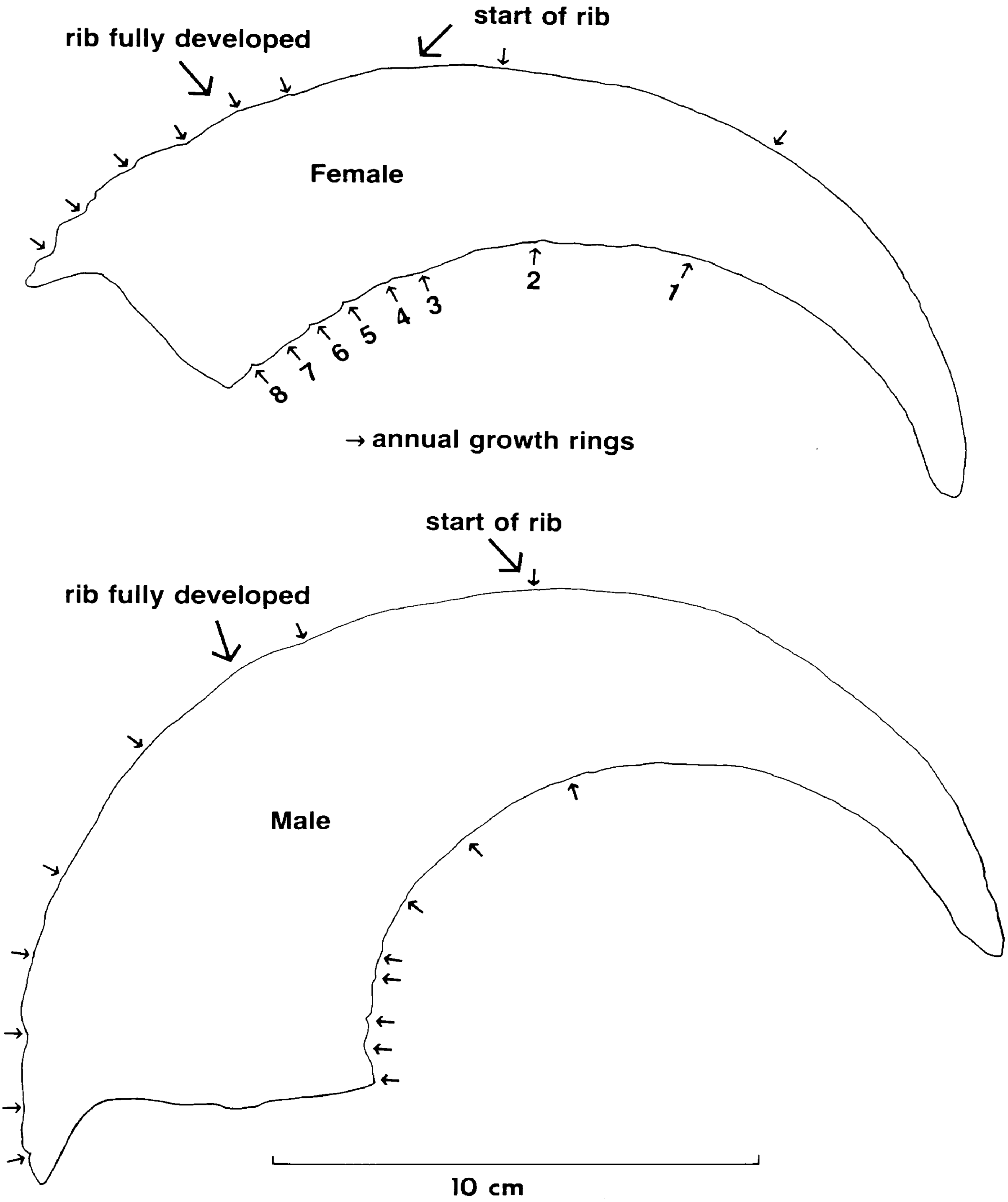


Fig. 7.--Tracings of Nilgiri tahr horns.

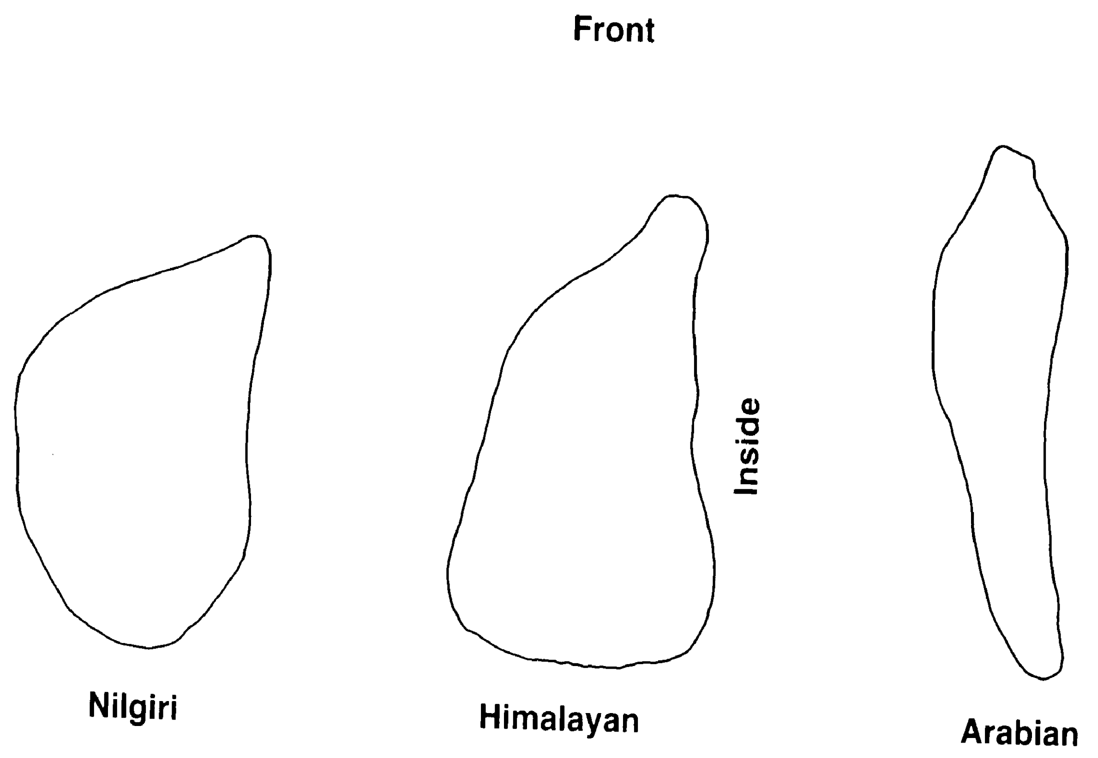


Fig. 8.--Cross section of the horns of the three tahr species near the base.

along the anterior surface. The horns also have fine crenulations and annual rings (Caughley, 1965).

Female: Like the Nilgiri species, the Himalayan tahr female is nearly uniformly colored. The over-all coloring is medium brown, and the fronts of the legs are dark brown. There is a definite, but not conspicuous facial stripe of cream between the browner muzzle and cheek. The horns are like those of the male, but slimmer and shorter.

Arabian tahr

Male: The Arabian tahr is diminutive compared to the two other species, and most Caprini, as the male stands only about 60 cm at the shoulder (Harrison, 1968). They also have a full mane on the neck and shoulder which is a light sandy brown. These long erectile hairs extend along the whole of the back as well. The foreleg and front of the hindlegs are also covered with loose long hair, and there is a conspicuous tuft of hair on the cheek. The tail is black, as is the face back to the level of the eye. The horns are set similar to those of the Nilgiri tahr, with the tips somewhat more divergent. In shape however, they are quite different, being compressed and semi-elliptical, with the keel on the leading edge.

Female: The female Arabian tahr looks somewhat like a scaled down version of the Nilgiri tahr female, although the coat is a bit browner. The black carpal patches are present, but slightly less conspicuous, and in contrast to the other two species, there are conspicuous facial markings. The area immediately around the eye and below it are black, and a white line curves around the top-front of the eye and drops towards the mouth. The stripe widens and diffuses onto the muzzle, the rest of which is gray.

Karyotypes of all three tahr species have been prepared, and the results are summarized in Table 5. Karyotypes for Nilgiri and Arabian tahr are identical (Benirschke and Kumamoto, 1982), but they both differ from the Himalayan tahr in several respects. The Nilgiri and Arabian species have a larger diploid number, differing X and Y chromosomes, and fewer biarmed chromosomes. Bernischke and Kumamoto (1980) conclude that these differences "leave no doubt" the Himalayan tahr is a different species. The geographical separation and physical differences probably make the same judgement appropriate for the Nilgiri and Arabian tahr as well. The appearance of the karyotype and the consistent fundamental number most likely indicate the occurrance of Robertsonian fusions, which are known to occur in other bovids (Wurster and Benirschke, 1968).

Affinities Within the Genus

It is evident from the physical descriptions given above that differentiation between the tahr species is most marked in the males, whereas the females are all quite similar. Although the chromosomal data strongly suggest a closer affinity between the Nilgiri and Arabian species, this relationship is not consistently born out when one considers the physical characteristics. For

Table 5.--Chromosomal characteristics of males of the three tahr species.

Species	Nilgiri	Himalayan	Arabian
Diploid number	58	48	58
Fundamental number	58	58	58
Autosomes Number of			
Acrocentrics	54	34	54
Submetacentrics	0	12	0
Metacentrics	2	0	2
X	acrocentric	acrocentric	acrocentric
Y	subacrocentric	metacentric	subacrocentric

Based on Nelson-Rees et. al, 1967; Benirschke and Kumamoto, 1980; 1982.

instance, the Nilgiri and Himalayan species are about the same size, while the Arabian species is much smaller. On the other hand, the Himalayan and Arabian tahr have prominent manes and black faces while the Nilgiri tahr has the conspicuous body coloration and facial stripes. Each species has its own orientation and shape of horns. Thus, there seems to be no clear cut subgrouping within the genus.

METHODS

This study was carried out between 8 August 1979 and 26 September 1981, and the results from a 6-week preliminary study in May and June 1978 are included where appropriate. The primary means of study was direct observation of the animals in the wild. For this purpose, one sub-population was habituated to my presence, and about 60 tahr were marked with color-coded collars. Initially, all social behaviors exhibited by the tahr were described and named, using Schaller's (1971; 1978) descriptions as a starting point.

Observations

For purposes of analysis, observations of social behavior were divided into three main types: miscellaneous, group, and focal observations. Miscellaneous observations were taken _ad libidum_ (Altmann, 1974). This included incidental observations of behavior without any attempt to quantify rates or to sample in a systematic manner. These observations were appropriate for the analysis of variation, relative dyadic frequency, and the presence and absence of displays and acts.

During group observations, social behaviors for all individuals in a group were recorded. Once it became possible to identify and/or classify all animals in a group (after November 1980), group observations were made only when all members of a group were visible, and when the rate of social interaction was low enough that all interactions could be recorded. At Eravikulam, Nilgiri tahr were particularly suited for this type of observations since the animals generally occupied open terrain, and by positioning myself on an opposing or adjacent slope, an unobstructed view of all animals could be maintained. Also, since Nilgiri tahr generally maintain a distance greater than the minimum for social interaction, social interactions could usually be anticipated. For these reasons, I could usually record all social interactions occurring during an observation period. However, this was not possible at the height of the rut, and at such times I relied on focal observations.

Focal observations were also made on social behaviors of a chosen individual when constraints of terrain or weather precluded group observations. Focal periods were usually 30 min long and focal individuals were chosen both to include a variety of individuals and classes, and to concentrate on individuals of particular interest (i.e. during the rut when it was desirable to know the rate and type of display for a particular individual or class). Focal periods were terminated if an individual rested for more than 10 consecutive minutes.

A sequence was defined as any uninterrupted series of social interactions during which a pair of animals remained attentive towards one another. During all types of observations it was noted whether the sequence being recorded was complete or not.

The conditions of observations varied considerably through the course of the study. This was a result of both weather and terrain. The rain and mist during the monsoon placed serious limitations on the observational conditions, and terrain. The distance of observations varied from a maximum of about 800 m (through a 20-40X spotting scope or 10X binoculars) on flighty animals, to a minimum of a few meters on habituated animals. Generally, I tried to maintain an intermediate distance of 50-200 m. Observations were recorded on tape in a stylized anectdotal manner, and later transcribed. Photographic records were made with 50 mm and 200 mm lenses, and a 2X tele-extender.

I considered tahr to be in one group if they were in physical proximity to each other, and showed coordination of movement or activity. Interindividual distances were usually less than about 30 m and this could be used as a more subjective criterion. If the distribution of animals within groups showed distinct breaks, these were classified as subgroupings. When conditions permitted, all the animals in a given group were classified according to sex and age and identifiable individuals were noted. With large groups this was not easily done at the onset of the study since the tahr could not be approached closely, and the characteristics distinguishing the young males from adult females were not easily seen except from certain angles. However, by the end of the study, animals from the habituated subpopulation were easily classified as to the individuals and classes present.

The location of each group was noted with each count either by a grid coordinate system and/or by descriptions relative to local landmarks, and the movements of groups were recorded in an anectdotal manner. If the count reflected the association of individuals within the group (i.e. if animals close together in the count were close together on the ground), or if the animals were moving and the composition was counted in the order of progression, this was noted.

Activity patterns were measured by scan sampling (Lehner, 1979). A maximum of once every 15 min, the activity of each individual within the group was listed. Categories used were resting, grazing, standing, moving and social behavior. Activity counts were not taken on a strict schedule, since they were considered a lower priority, nor were they always taken during observations. Rather, counts were made in an attempt to obtain an adequate number of samples for each 30 min during daylight for each month of the year. In addition, from mid-January 1981 until the end of the study, the nearest neighbor of each young, and the distance between the young and its nearest neighbor were recorded. During the rut the same information was recorded for males. In addition, when a male's nearest neighbor was a female, I gave a description of his apparent relationship to her. The categories used were tending, courting, and ignoring, if he bore no evident attitude towards the female.

Habituation

During fair weather, the open grassy hills on which the tahr lived permitted extended observations from a considerable distance with the aid of spotting scope and binoculars. Closer approach was not possible since the tahr exhibited a flight distance from man of about 300 m. However, it became clear from the onset of the study, that during the monsoon (which coincides with the rutting season) observations would be impossible due to the thick mist, heavy rain, and high winds which descended upon the hills. Consequently, I decided to habituate one subpopulation of the Eravikulam tahr to my close proximity. Geist (1971) has shown the advantage of using salt as an attractant and an aid in the habituation of bighorn sheep (*Ovis canadensis*). However, my original intention was to refrain from provisioning thus avoiding potential problems with disturbing natural patterns of movement and grouping.

Habituation, however, proved to be a lengthy process. After years of infrequent but regular hunting, the tahr maintained a stubborn shyness. My initial strategy was to always let myself be plainly visible to the tahr from a distance greater than their flight distance. This frequently called for a "reverse stalk" and long circuitous approaches to gain distant vantage points. However, I was able to continue collection of data through a spotting scope at the same time. A frequent phenomena during this period was what I came to call a "delayed departure". This was when a group of tahr, upon seeing me settle down to observations beyond their flight distance, did not move off immediately, but rather, in the apparently normal course of their activities, they moved or grazed slowly out of view. I did not keep detailed records of the tahr's responses to my presence in these situations, but there seemed to be a distinct threshold before which the flight and moving off distances remained long, and after which it dropped rapidly to a distance of about 50 m.

The consolidation of this greater tolerance was promoted by animals response to the burning in March 1980. At that time, a long narrow ridge, a frequently used part of their home range, was burned while the rest of the home range remained unburned. The tahr were attracted to the new growth, and seemed less nervous about my presence with readily available flight cover in the form of cliffs and broken steep slabs along the eastern side of the ridge. At the same time I suffered a bout of illness which was greatly fatiguing. As a result, often after making the initial approach, I lay back in the grass and fell asleep. While this hardly was an effective method of data collection, it was probably an extremely effective mode of communicating my lack of aggressive or offensive intent. At other times, I was careful not to focus my attention too intently on the tahr, and often kept my gaze averted, pretending to go about my own business. Also, since I found the fresh green sprouts in the burned areas as sweet as the tahr seemed to, I occasionally "grazed" by pulling the basal shoots, and munching on them, often making this readily visible to the tahr. In addition I was careful to move very slowly, never taking more than about one step every 2 sec and frequently stopping to stand in a relaxed manner.

All these tactics seemed to be effective in helping the tahr become more accustomed to my presence at that close range. However, by this time the 1980 monsoons were fast approaching, and it was evident that, although I had made progress in habituating the tahr, the distance at which their behavior could be considered normal was still too great for observations during the weather conditions during the monsoon.

For many years, a saltlick has been maintained at the south end of the park near a checkpost along the road that passes between Nyamakad and Rajamallay tea estates. A supply of salt was continually maintained at this location adjacent to the road, and the tahr there were habituated to the approach of automobiles, although they remained wary of humans on foot. The same salt was kindly made available to me. It was apparently unrefined salt collected from the drying flats, as it was made up of loose sandy material and soft lumps. There being no natural salt licks in the area, the tahr in the central part of the park where I was working had evidently developed no taste for it. Initially I put a small quantity out on a rock slab, but this failed to attract the tahr, so I scattered it in the grass they were feeding on. Still, although sign indicated that tahr were grazing in the area, it took them several days to learn of the substance. However, they quickly developed a great liking for it. Even then, the tahr came to the salt site for only a couple of hours each day, and finding them there seemed to be a matter of luck. When I did, I tried to use their attraction for the salt as a means of approaching them more closely, while I continued my habituating efforts on free ranging animals as well. In addition, when the tahr moved from this particular ridge, I established another salt site in the new area, in hopes of minimizing the influence on their movements.

As soon as the tahr were allowing me to approach within about 10 m, I stopped placing the salt in specific locations, but instead carried it with me and distributed it to the tahr. Initially I had to throw it towards them, gradually tempting them nearer. The general practice was to find the group, move slowly and steadily to a point close to some animals and upwind from them, where I sat down and distributed the salt. I found the best technique was to mix the loose sandy salt with water to form a thick soup, and to sprinkle and spray this around on the grass. This was much more effective than distributing lumps or loose salt, as these readily fell through the grass to be hidden on the ground below, whereas the droplets of salt soup stuck to the grass blades and were much more readily available. The tahr's desire for salt was quite evident in their willingness to approach quite close despite considerable nervousness on their part.

I also found that nervous animals were much more tolerant of me if there was at least one other tahr between them and myself. In this connection, the relatively uninhibited approach by one particular male young encouraged the other animals to come closer. Due to the extreme nervousness of the tahr at this close proximity to me, I had to be extremely careful with any movements at first. Even very slow movements were alarming to the tahr, and any sudden movement made them scatter. However, during the course of the 1980 monsoon, they gradually became accustomed to this close proximity. At the same time, they became more accustomed to my proximity when salt was not being offered, and about a year after the commencement of the habituation program, I noticed with satisfaction that grazing animals, seeing me come over a rise, would look up briefly, and then resume their grazing unperturbed.

However, the tahr quickly learned that when I approached and sat down salt was often distributed, and before long this became a problem in making observations, as if I sat within less that about 100 m from the group, they would alter their orientation and graze in my direction. Soon observations had to be terminated since all I was observing was a ring of animals standing around watching me, awaiting for salt to be put out. For this reason, once the tahr were satisfactorily habituated to my proximity, I refrained from distributing salt unless I had some specific objective (e.g. collaring). Salt also proved useful in introducing other humans to the tahr.

Sex and Age Classifications

Nilgiri tahr were divided into a number of sex and age classes. Initially, I followed Schaller's (1971) outline of classes, but as the study progressed I was able to refine this system, dividing the initial six classes into 10 by the end of the study. This was done to give the finest detail possible in describing how various aspects of tahr biology were related to sex and age. The following descriptions are presented according to the initial six classes, with subsequent subdivisions listed under each one. The abbreviation used in the text for the respective classes follows its name and is underlined.

Young (Yg): Age 0-1 years. Gray-brown or light brown coat. Up to about 45 cm at the shoulder. Horns up to about 7 cm in length.

Yearling (Yl): Age 1-2 years. Gray-brown coat. Intermediate in size between Yg and F's. Horns up to about 12 cm.

Adult Female (F): Age 2+ years. Gray-brown coat. Carpal patch black. Height about 70-80 cm. Horns somewhat more slender than those of males, up to about 30 cm in length. During the later part of the study, I distinguished 2 year-old females (F-2yr). They were somewhat smaller than the older females, and had horns about as long as yearling males (about 12 cm). Since horn continued to grow through the year, I used one individually recognized F-2yr as a reference in classifying other females. In the text and tables, where F-2yr's are not mentioned in comparisons between classes, they are included with the F's.

Light brown male (Lbm): Age ca. 2-4 years. Similar body and horn size and pelage make these difficult to tell from F's, especially at a distance. However, close up and with experience, the slightly thicker horns were recognizable, and facial markings were sometimes slightly more distinct than those of F's. The detection of a scrotum or penis sheath, of course, provided positive identification. During most of this study, the older Lbm's were placed in their own class called Large light brown males (Llbm). These males were about 4 years old, and were slightly larger and a bit stockier than F's, and they had slightly longer, and obviously heavier horns. In addition, the top portion of the dark carpal patch had a section that was beginning to show the change to white. As with the F-2yr's, if LLbm's are not mentioned in comparisons, they are lumped with Lbm's (to enable comparisons with earlier presentations).

Dark brown male (Dbm): Age ca. 5 years. Gray-brown to dark brown coat. Larger and more robust than F's, Lbm's and LLbm's, and having an overall slightly darker pellage, larger horns, and more distinct facial markings. However, these relative characteristics were often difficult to apply. The key trait used in distinguishing Dbm's was the distinct white knee patch. Transitional cases had a white section on top of a black section of the knee patch, and such individuals were classed as Dbm's if the patch was more than half white.

Saddleback (male) (S): Age ca. 6+ years. S's are so named for the area of light brown, white, or silvery hair covering their lower back, rump and/or flanks. However, caution was called for in using this as the characteristic for the class, since Dbm's usually had a faint saddle, and sometimes a saddle could even be detected on LLbm's. Therefore, in addition to a distinct saddle which did not lose its prominence with changes in orientation or lighting, a male was not classified as an S unless the black directly above the white knee patch did not differ in coloration markedly from the rest of the front of the foreleg. During the second half of the study, S's were further divided into three classes. Initially I tried to differentiate two types of saddlebacks, S1's and S2's. The saddle on S1's was white or light brown, and their shoulders were still lighter than the deep chocolate (nearly black) coloration on the side of the belly and front of the legs. S2's had a silvery saddle, although the portion extending onto the flanks and croup was usually white or brown, and the shoulder was as dark as the adjacent sections of foreleg and side. However, no sooner than I began applying these distinctions than a certain number of S's seemed intermediate between the S1 and S2 classes. These were provisionally termed S1-2's, but this category became permanent as males, including some individually recognized animals, consistently fell into this category.

These classes are based on a mixture of characters based on age and maturation. However, in males the final series of categories was closely related to their age even though these classes were established before I was consistently able to approach the animals close enough to count their sometimes indistinct horn rings. During the 1981 rut, I aged all the males present in the Vaguvarrai intensive study area as is shown in Table 6. The resulting distribution of ages by class showed that the subdivisions were justified on the basis of age as well as maturation, and that Lbm's were usually 2-3 years old, LLbm's were usually 4, Dbm's were

Table 6.--Number of males of each age in the Vaguvarrai intensive study area on 20 July 1981 based on horn ring counts.

	Class					
Age (years)	S2	S1-2	S1	Dbm	L1bm	Lbm
2	.	.	.	.	.	2
3	.	.	.	.	2	3
4	.	.	.	1	6	.
5	.	.	.	5	.	.
6	.	.	3	.	.	.
7	.	2	.	.	.	.
8	1	.	.	.	.	.

See text for class abbreviations.

usually 5, S1's usually 6, S1-2's 7, and S2's 8 years old. Other horn ring counts made on individual males conformed to this pattern.

Individual Recognition

Apart from the differences due to sex and age, Nilgiri tahr showed a remarkable similarity between individuals. For this reason, I usually did not feel confident in recognizing individuals on a subjective basis. On the other hand, natural marks distinguished some individuals. By far the most useful characters for distinguishing individuals were those which affected the horns, since they were hard, and changes in their appearance were more or less permanent. In some cases, horns showed deformities from early in life, such as one female which had both horn tips constricted near the tips into a nipple-like shape. Two females had both horntips (about the last cm) bent slightly upwards. One young male had a distinctive groove running vertically on the anterior surface of his horn, just beside the frontal rib (Fig. 9).

On older males (Dbm and older), marks on horns proved to be a more consistently useful means of identifying individuals. While clashing horns during fighting, horns were sometimes chipped, most commonly along the inner forward rib, leaving notches of various shapes and sizes. The older the male (and the more he had fought), the easier identification of this type was. The use of marks of this sort, of course, required a close proximity to the animals. This was a significant drawback since habituated males mixed with unhabituated males outside the rutting season, and could not be approached during that time of year. As a result, it was difficult to keep track of changes in these sorts of marks, and I could not identify males consistently between successive rutting seasons. Occasionally males bore other marks which could be used to identify them, particularly scars, which showed as patches of bare skin, on the shoulders, muzzle and forehead (just below the horns). Several males also had notches in the ears, a result of the ears being caught between clashing horns.

To further aid in the identification of individuals, a total of 67 color-coded collars were placed on tahr. These collars were

Fig. 9.--Fr ("Funny rib") Llbm. Note the distinctive groove on his left horn. His right horn is normal.

self-attaching, and modeled after those used by Clarke and Henderson (1978) and Taylor (1969). The collars consisted of a length of rope, with a ring attached at one end and a clip attached at the other. Braided polyethylene rope was best suited for these collars, but when my supply ran out, I was able to construct working collars using the twisted nylon rope available in the local bazaar.

The key to these collars lay in the clip which was fashioned in a manner similar to an alligator clip. The tip of one side of the clip was curled back to form a small loop through which a light string could be fastened. This string then was threaded through the ring on the opposite end of the collar. The size of the ring was such that as it slipped over the clip, it compressed the spring by pressing on the back of the clip, and the spring returned it to the original position once the ring had passed. The very back of the base of the clip was enlarged so that the ring could not pass further up the collar. The ring then could not slip off the clip again unless the back of the clip was pressed together.

The collars I used differed slightly from those of Taylor (1969) and Clarke and Henderson (1978). They used free-hanging strips of PVC flagging strung through the collar as the color markers. To avoid having pieces of material hanging loosely from the collars, I took strips of Herculite, and wrapped them tightly around the collar in a spiral, occasionally threading the Herculite through the braid or twists of the rope. Each collar had three bands of color, in the top, middle, and bottom position (on both sides). Colors used were black, light blue, red, white, and yellow.

These collars were originally designed to be set along game trails in the same manner as a noose snare (illustrated by Taylor 1969). The collar is placed along one side of a game trail or an zone of restricted passage, with a loop between the ring and clip drawn across the trail and the end anchored, preferably high up. As the animal passes through the trail, its head is supposed to pass through the loop, and as it pulls on the loop the collar is pulled free from its setting. As the animal moves away, the string is then drawn through the ring, and this pulls the clip to, and then through the ring, fastening the collar. The string, weakened near its point of attachment, then breaks, freeing the animal with the collar in place.

I had little success with settings of this kind, since terrain the tahr occupied did not contain many locations appropriate for this kind of setting. In addition, the tahr seemed hesitant to pass through such locations, even if the collar was carefully camouflaged. This is probably the result of previous experience with wire snares in such locations, and only a half a dozen tahr were collared using this technique. However, as the approached to get salt I collared them by attaching the collar to a 2 m bamboo pole, and letting the loop hang, and slipping it over the tahr's heads. Then, by slowly pulling in the line, and/or as the tahr backed away, the collaring process was completed.

The tahr's reaction to being collared varied widely between individuals. One female remained so calm throughout the process that when the string broke before the clip has fastened, the collar remained draped across her neck. Having "reloaded" the collaring pole, I put a second collar on her, which happened so smoothly that the first remained in place. I then flicked it off with the pole lest she graze off with both collars. On the other hand, some tahr, particularly Dbm's, reacted vigorously by dashing off across the slope, stopping abruptly with head lowered, backing up, or shaking their heads. However, even the most energetic reactions subsided within an hour, and the animals resumed their normal behavior. As the collar was worn it settled into the mane at the base of the neck, and these posteriorly oriented hairs usually kept it from slipping forward. The collars usually did not interfere with the normal lives of the tahr, so far as I could determine. However, occasionally males had their collars hooked by their opponents' horn while sparring or fighting. I observed only one instance where the collar resulted in a serious problem. After carrying the collar without any noticeable problem for 8 months, a female managed to get the collar caught in her mouth and could not get it free. The collar pulled against the back of her neck, and the clip prevented her from feeding. I was able to remedy this problem by using a stout rope instead of the light string on the bamboo pole to capture her and cut the collar off.

Males were much more prone to lose their collars than were females. Of the 15 collars put on males, 6 were later found in the grassland, but only about 5 of those remaining were seen with any regularity. By contrast, of the 51 collars put on females, only 4 were later found or were known to be missing from animals recognized by natural marks.

Supplemental Information

Observational information was gathered on predators whenever opportunities arose. In addition, droppings of all large carnivores were collected. Dropping were then examined for prey remains.

Plants were collected throughout the study, concentrating on tahr habitat, particularly the grasslands. These are listed in Appendix A. In addition, an vegetative key to the grasses was developed (Appendix B). Amphibians and reptiles were also collected as opportunity arose (Appendix C).

Nilgiri tahr food habits were studied by direct observation.

Statistical tests on the goodness of fit of frequencies were made using the G statistic, also known as the log-liklihood ratio (Zar, 1974). G is used in the same manner as the more traditional Chi square, and in fact, the calculated G closely approximates the Chi square, and the calculated value is compared with the appropriate values from a Chi-square table. G is preferred over the Chi square for two reasons. First, it is still valid in cases where an excessive number of expected values are low (Zar, 1974). Second, in two-way contingency table analysis, the total G can be partitioned by row and/or column. This makes it possible to assess the significance of the contribution of each row and/or column to the total G (Sokal and Rolf, 1969). G tests were made with the use of a microcomputer program developed for that purpose (Appendix D). Values of G were tested at a significance level of 0.05.

DISTRIBUTION AND NUMBERS

Nilgiri tahr are found only along the Western Ghats in South India, and even within this small area they are mostly confined to the crest of the range, usually at altitudes of over 1,200 m. It is thought that tahr once ranged through most of the Western Ghats (Davidar, 1978), but current populations are distributed between the Nilgiri Hills in the north, and the Tiruvannamalai Peaks in the south. Tahr are generally associated with the grassy highlands along the crest of the Western Ghats since nearly all populations known today inhabit such terrain. There are, however exceptions. Davidar (1978) lists two locations (both included in the Amaravati Slopes population in Fig. 1), one at Jambukal, and the other at Erumai Malai, or Bison Hill. These two locations are not far from "proper" tahr habitat, but they are both only about 900 m in altitude, and the habitat is, understandably, quite different (See Habitat Use). Since most country at this elevation is intensively used by humans, it is not possible to tell whether these lower level populations are exceptional cases, or vestiges of a previously much wider lowland distribution.

In this connection, it is interesting to note Mukherjee's (1974) representation of the previous distribution of Nilgiri tahr. Although he cites no source, his map shows a past distribution which covers much of the southern half of peninsular India, extending north along the Western Ghats to include most of the state of Karnataka, east to cover about two-thirds of Tamil Nadu, and south and west to encompass all of Kerala. While it is quite possible that 100 years ago (as Mukherjee's map is inferred to portray) the previous distribution of Nilgiri tahr was much more extensive than it is today, both geographically and ecologically, it seems safe to say that this representation is vastly overextended. Intensive human use of much of Tamil Nadu and the coast of Kerala lend these localities as very unlikely habitations for tahr. In addition, the vast majority of the land covered by this distribution is evergreen forest, a habitat for which tahr have no predilection. Suffice it to say then, that the previous distribution remains unclear, but it was almost certainly not as extensive as that portrayed by Mukherjee.

We owe our knowledge of the distribution of current Nilgiri tahr populations to the dedicated survey work of E.R.C. Davidar and others (Davidar, 1978). The results of these surveys, updated for my own censuses of Eravikulam National Park and the Grass Hills of the Anamalais, are shown in Fig. 1. It should be noted that these locations do not necessarily represent distinct population units. For instance, some are distributed over ecologically continuous habitats, such as the Nilgiri Hills and Silent Valley populations, or the Eravikulam National Park and the Grass Hills of the Anamalais populations. On the other hand, some locations represent a number of scattered populations, such as those from the Topslip and Parambikulam area, or the Amaravati slopes. Due to the ruggedness and inaccessibility of the terrain, the shyness of the animals, and constraints of time, not all populations were actually censused. Many of the populations were estimates based upon sign and accounts given by local informants. Probably no populations have been overlooked and therefore, the best estimate of the current wild Nilgiri tahr populations is 2,235 animals.

In addition, there are four captive groups of Nilgiri tahr. Of these, one is located in India at the Trivandrum Zoo, Kerala. The other three groups are in the United States, at the Memphis Zoo and Aquarium in Tennessee, the Minnesota Zoological Garden (near Minneapolis), and the San Diego Zoo in California. The group at the Trivandrum Zoo consisted in 1981 of one adult male, two adult females, and two offspring born that year. In 1983, the Memphis Zoo group consisted of 10 adult males, 13 adult females, and 1 young born that year; the Minnesota group consisted of 6 adult males, 5 adult females, and 4 young; and the San Diego Zoo group consisted of 2 adult males and 2 adult females. All of the animals in captive groups were originally from what is now Eravikulam National Park, and all of those in the United States are descendants from an original group of one male and two females.

RESULTS AND DISCUSSION

Group Type and Size

Like many caprines, (Schaller, 1978; Geist, 1971 and Nievergelt, 1974), Nilgiri tahr have two basic types of social groups: mixed groups and all male groups. Mixed groups contain all sex and age classes, but consits primarily of adult females and their sub-adult offspring. Adult males join these groups during the rut, and depart at other times of the year. By contrast, male groups consist of adult males (of various classes) only. I have included lone individuals in the analysis of groups, although a group size of one is a logical contradiction, lone animals are valid social entities (Walther, 1972) and including them in the analysis makes for a more coherant presentation than does considering them separately.

The distribution of sightings of Nilgiri tahr in mixed groups by size range throughout the year is shown in Table 7. The maximum group size observed was of 150 animals. Considering all months, there was a remarkable evenness in the percent tahr sighted in groups in all size ranges (unweighted monthly mean). This suggests that, in general, tahr have a nearly equal tendency to occur in groups of any given size, although this tendency is somewhat less at the extremes of the distribution. Thus there is no meaningful modal group size, and the overall mean group size of 42.3 is simply the central tendency of a widely distributed range in group size.

Table 7.--Percent tahr seen in mixed group size ranges by month. August 1979-September 1981.

Season		Winter		Pre-monsoon			Monsoon			Post-monsoon				
Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Size Range	1- 10	9.7	5.6	2.6	1.4	2.5	3.6	1.3	1.9	0.9	1.2	2.3	3.6	3.0
	11- 20	13.2	12.8	5.6	4.0	2.7	7.3	2.4	3.1	2.0	3.8	5.9	9.1	6.0
	21- 30	15.7	11.9	7.3	6.3	7.2	5.1	2.2	3.8	3.2	10.2	2.3	5.2	6.7
	31- 40	19.0	14.7	9.0	2.4	4.2	12.4	3.9	10.5	3.8	7.5	2.0	7.6	8.1
	41- 50	7.5	18.2	10.2	4.2	4.1	18.1	4.1	12.7	4.4	3.5	4.5	5.5	8.1
	51- 60	5.9	10.0	8.7	11.3	3.6	7.6	4.7	5.0	7.4	9.7	8.5	8.5	7.6
	61- 70	7.3	5.9	8.8	13.3	4.3	16.4	8.9	8.0	3.4	9.9	8.3	9.8	8.7
	71- 80	14.7	0.0	11.9	13.7	13.9	12.3	7.9	13.0	8.0	5.5	4.8	0.0	8.8
	81- 90	7.0	2.5	1.8	15.4	15.3	3.9	3.7	14.5	8.1	4.2	8.3	7.5	7.7
	91-100	0.0	2.8	6.4	10.7	12.8	2.3	2.0	13.2	7.5	11.6	8.9	3.0	6.8
	101-110	0.0	3.2	16.4	9.4	9.3	4.8	6.9	0.0	8.4	5.2	13.4	3.1	6.7
	111-120	0.0	0.0	2.5	5.2	5.2	0.0	2.5	1.8	6.0	5.5	10.9	14.2	4.5
	121-130	0.0	3.9	5.5	2.7	8.5	2.9	5.4	2.0	11.7	12.2	19.6	18.8	7.8
	131-140	0.0	4.1	0.0	0.0	2.9	3.1	12.1	10.4	23.2	9.9	0.0	4.0	5.8
	141-150	0.0	4.4	3.1	0.0	3.3	0.0	31.8	0.0	1.9	0.0	0.0	0.0	3.7
Mean group size		22.1	26.0	36.9	49.1	48.3	35.0	67.7	46.3	63.9	50.0	52.2	38.6	42.3
Number of groups		164	127	122	90	93	124	68	139	118	82	61	86	1,274
Number of animals		3,620	3,300	4,502	4,423	4,494	4,335	4,591	6,437	7,541	4,097	3,182	3,321	53,843

However, when monthly variation in group size is considered, this even distribution no longer holds true. Tahr occurred in smaller mixed groups most frequently in January, a consequence of the isolation and tendencies to split into separate groups at the start of the birth season. The increase in mean group size between January and February can be accounted for by the increase in the number of animals present, since most young are born at this time. However, tahr associated in even larger groups during March, April, and May. This is probably associated with the tahr congregating in favored areas after the fires, and the drop in group sizes in June may correspond to the depletion of these resources. Tahr again associated in larger groups during the monsoon (and rut, July-August), and then group size dropped again during the post-monsoon.

The pattern of male group size was entirely different. The largest male group encountered was of 20 individuals, and lone males accounted for nearly one-fifth of all males encountered outside mixed groups (Table 8). Also, there was a distinct tendency for males to associate in smaller groups, with the number of males seen in each group size decreasing steadily as group size increased. This pattern was evident during most months of the year, but to various degrees. The largest male groups were encountered in December and January. These large groups occurred in particular areas. The hill south of Poola Malai was a noticeable congregating area for males in 1979 and 1981, and sightings from this area account for most of these larger groups. Male group size decreased

Table 8.--Percent tahr seen in male group sizes by month. August 1979-September 1981.

Season		Winter		Pre-monsoon			Monsoon			Post-monsoon				
Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Size	1	10	18	28	17	12	20	41	29	21	7	17	3	18.6
	2	11	8	14	8	18	18	25	19	23	11	12	5	14.2
	3	4	20	14	19	15	20	15	9	5	16	8	5	12.4
	4	5	13	4	10	15	6	7	17	10	12	21	2	10.3
	5	6	0	5	6	17	11	0	12	10	6	18	6	8.2
	6	14	10	0	12	7	18	0	4	3	7	11	2	7.3
	7	8	6	13	0	5	0	6	0	7	4	6	4	5.3
	8	9	0	14	0	3	6	7	6	8	0	7	3	4.8
	9	0	0	8	6	3	0	0	0	5	0	0	3	2.5
	10	6	0	0	6	4	0	0	0	0	0	0	3	1.6
	11	0	0	0	7	0	0	0	0	0	7	0	0	1.1
	12	7	0	0	0	0	0	0	0	0	14	0	0	1.8
	13	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	14	0	12	0	9	0	0	0	0	0	8	0	9	3.1
	15	0	13	0	0	0	0	0	0	8	9	0	5	2.8
	16	0	0	0	0	0	0	0	0	0	0	0	0	0.0
	17	10	0	0	0	0	0	0	0	0	0	0	10	1.7
	18	11	0	0	0	0	0	0	0	0	0	0	22	2.7
	19	0	0	0	0	0	0	0	0	0	0	0	6	0.5
	20	0	0	0	0	0	0	0	0	0	0	0	12	1.0
Mean group size		3.9	2.8	2.2	2.8	2.8	2.3	1.6	2.0	2.3	3.8	2.6	6.9	2.8
Number of groups		44	43	51	55	93	58	75	80	83	45	43	47	717
Number of animals		170	119	110	156	259	133	121	161	195	170	113	324	2,031

dramatically during the rut, since during this time, males were frequently leaving and rejoining mixed groups. They separated on their own, or in small groups, and they evidently did not remain independent for a long enough time to congregate into larger groups. When they did depart from the mixed groups, they had a tendency to remain in the vicinity.

Habitat Use

Of the four major habitat types in Eravikulam National Park (Fig. 4), mixed groups of Nilgiri tahr showed an obvious preference for grassland. When undisturbed they usually spent nearly the entire day in the grasslands, feeding and resting. However, they avoided penetrating too far onto the plateau, but usually stayed within 300 m of a set of cliffs or steep slabs, rarely lingering more than 500 m from them. However, some wider sections of the plateau were crossed when moving from the vicinity of one set of cliffs to another, but the middle portion of the plateau was never visited. Mixed groups also often moved to a restricted area adjacent to the cliffs or the top of them in the evening, and spent the night there bedding and grazing. Thus, although they spent little time actually on the steep slabs and cliffs, this habitat exerted a strong influence on the area that they used (Fig. 10).

Tahr moved onto the cliffs when disturbed by man or other predators. After the initial danger had passed, they grazed in such areas. Tahr also occasionally moved onto the slabs for no apparent

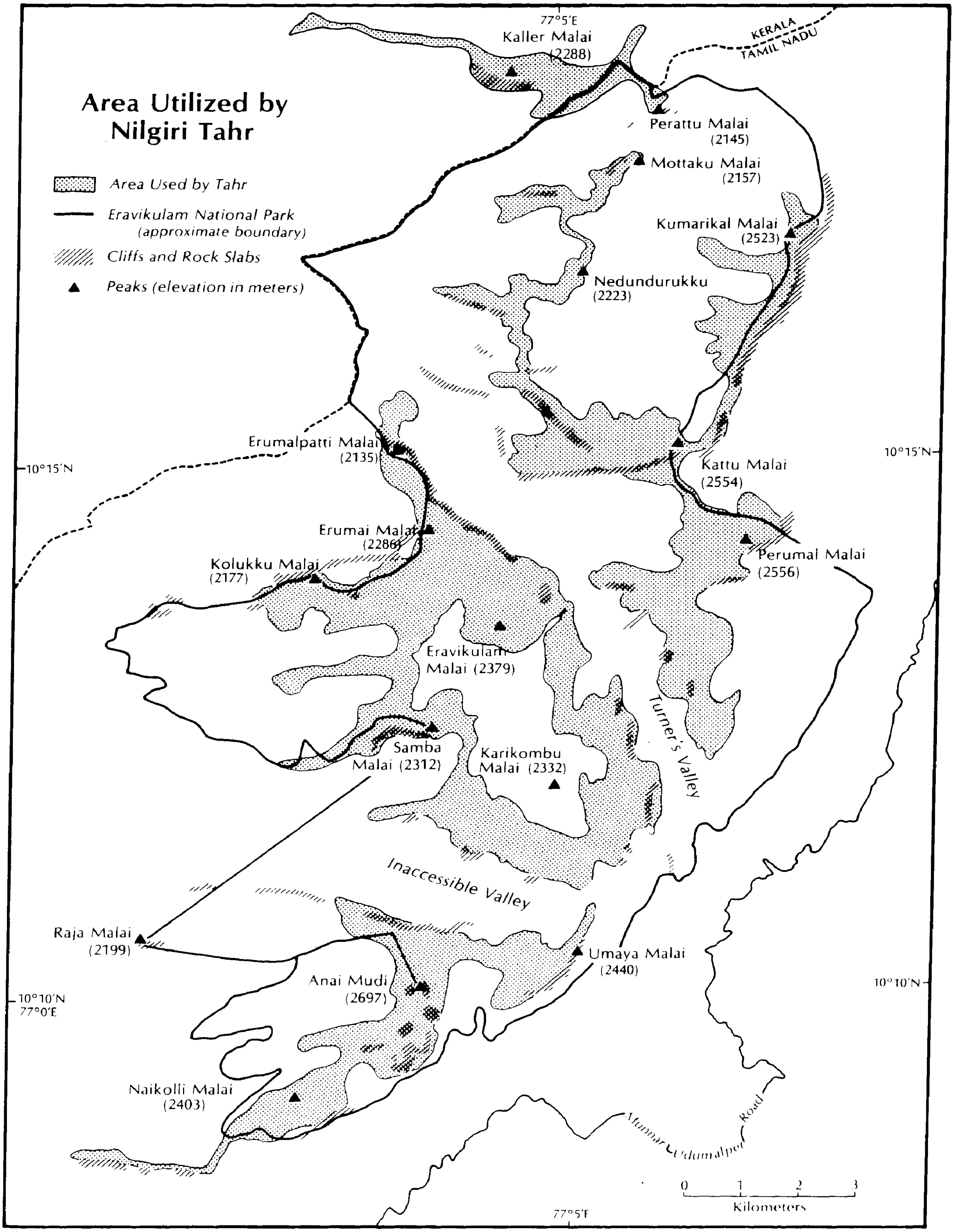


Fig. 10.--Area utilized by Nilgiri tahr in Eravikulam National Park and environs. The area enclosed by tahr range is the central plateau. Adapted from Survey of India, 1925, sheet 58 F./S.W.

reason, or, in warmer weather, to gain access the the cooling breezes rising up the cliff faces. Steep cliffs and slabs were also the most commonly chosen sites for giving birth, and females with neonate young, once united with other females and their neonates, stayed on, or in the vicinity of steep terrain for an extended period. Although mixed groups grazed in the shrubs growing amongst the rock slabs, they usually avoided the shrubby country below the slabs, and never penetrated the thick tall growths of Eupatorium adenophorum and Chrysopogon zelanicus along the base of the cliffs. Mixed groups also made some use of shola fringes. Smaller sholas, a few meters wide, were browsed occasionally. Less frequently, they penetrated the larger sholas, up to a maximum of about 10 m, to gain access to food plants.

Males showed a different pattern of habitat utilization. When not in mixed groups, they sometimes occupied the same areas that the mixed groups, but they also moved further onto the central plateau. There was, however, a central portion of the plateau where I never encountered tahr, male or otherwise. This is represented by the empty area surrounded by tahr range in Fig. 10. Males also utilized grassland areas adjacent to mixed group ranges. The knoll south of Poola Malai was one such frequently used area, as was the western flank of Turner's Valley between the Vaguvarrai and Eravikulam ranges. Males sometimes remained in those localities for several days.

Males also visited shrubby country below the slabs and cliffs more frequently, and were the only tahr to penetrate the thick tall growths of Eupatorium and Chrysopogon. Their use of these areas was frequent and extensive enough that their trails became tunnels where they penetrated sections where the plant growth was over their heads.

Such sexual differences in patterns of habitat use has been recorded in a variety of ungulate species including Himalayan tahr (Green, 1978), markhor (Schaller and Mizra, 1971), bighorn sheep (Ovis canadensis, Geist, 1971), mountain goat (Oreamnos americanus, Smith, 1977) and red deer (Cervus elaphus, Clutton-Brock, 1982). It is frequently indicated that the habitat used by the males is of an inferior quality compared to that used by the females or mixed groups. This was also apparently the case with Nilgiri tahr habitat as the thick, tall, and coarse vegetation at the base of cliffs seemed to offer much poorer grazing. While it has been stated that female mountain goats exclude males from prime habitat (Smith, 1977), there was no evidence of this in Nilgiri tahr. Rather, males seemed to leave of their own volition when they ventured into and remained in these areas.

Food Habits

Nilgiri tahr are primarily grazers, as is quite evident from Table 9. Their evident preference for members of the grass family was even more pronounced than implied by the table. Common grasses were taken in much greater volume than any of the forbs, shrubs or

Table 9.--*Plants eaten by Nilgiri tahr in Eravikulam National Park*.

Species	Family	Type
Ranunculus reniformis	Ranunculaceae	forb
Polygala sibirica	Polygonaceae	forb
Hypericum mysorense	Hypericaceae	shrub
Eurya japonica	Ternstroemiaceae	shrub/tree
Impatiens tomentosa	Balsaminaceae	forb
Crotalaria fysonii	Fabaceae	forb
Crotalaria scabrella	Fabaceae	forb
Olenandia swertioides	Rubiaceae	forb
Anaphalis bournei	Compositae	forb
Anaphalis lawii	Compositae	forb
Eupatorium adenophorum	Compositae	forb
Lactuca hastata	Compositae	forb
Wahlenbergia gracilis	Campanulaceae	forb
Lobelia sp.	Campanulaceae	forb
Vaccinium leschenaultii	Vacciniaceae	forb
Gautheria fragrantissima	Ericaceae	shrub
Pedicularis perrottetii	Scrophulariaceae	forb
Sopubia trifida	Scrophulariaceae	forb
Strobilanthes kunthianus	Acanthaceae	shrub
Polygonum chinense	Polygonaceae	forb
Elaeagnus kologa	Elaeagnaceae	forb
Curculigo orchoides	Hypoxidaceae	forb
Cyanotis sp.	Commelinaceae	forb
Eriocaulon brownianum	Eriocaulaceae	forb
Carex lindleyana	Cyperaceae	sedge
Sehima nervosum	Poaceae	grass
Chrysopogon zelanicus	Poaceae	grass
Tripogon bromoides	Poaceae	grass
Tripogon ananthaswamianus	Poaceae	grass
Ischaemum indicum	Poaceae	grass
Arundinella mesophylla	Poaceae	grass
Agrostis peninsularis	Poaceae	grass
Arundinella fuscata	Poaceae	grass
Andropogon polyptychus	Poaceae	grass
Andropogon lividus	Poaceae	grass
Themeda quadrivalvis	Poaceae	grass
Themeda triandra	Poaceae	grass
Isachne bourneorum	Poaceae	grass

Full scientific names are given in Appendix A.

trees. Composites are represented by the second greatest number of species, but the volume taken was relatively small.

Nilgiri tahr showed particular preference for some parts of certain plants. For instance, they ate only or mainly inflorescences of a number of species including *Hypericum mysorense*, *Pedicularis perrottetii*, *Crotalaria fysonii*, *Carex lindleyana*, *Anaphalis lawii*, *Anaphalis bournei*, and *Eriocaulon brownianum*. This habit was particularly noticeably in the case of *Anaphalis lawii* and *Eriocaulon brownianum*. When tahr grasped the flowering heads of these plants, the entire plant (in the first case), or the whole flowering stem (in the second) usually was pulled free. However, rather than simply eating the portion of the plant hanging from their mouths, the tahr chewed through the stems to drop the rest of the plant. On the other hand, tahr took only the tender new leaves of *Gautheria fragrentissima*, while avoiding the mature leaves. My own experience was that the tender leaflets had a characteristic wintergreen flavor, but were bitter.

Two uncommon plants which seemed to be particularly well liked were *Lactuca hastata* and *Impatiens tomentosa*.

There were some species which the tahr seemed to avoid, or at least never ate despite their ready availability. Such plants included *Rhododendron arboreum* and the grassland species of *Impatiens*.

There were also pronounced seasonal preferences for certain species and/or plant parts. For example, after the grassland was burned in the winter, the tahr eagerly took the fresh regrowth of

Chrysopogon zelanicus by grasping the leaf blades and pulling out the whole succulent stem. However, as the blades matured, less was taken. With the post-monsoon drying of the grassland the inflorescences were eaten from time to time, and the Chrysopogon growing in the wetter low lying areas was taken more frequently. One technique used by an adult female was to poke her nose deep into a Chrysopogon clump, grasp the sheath and eat it, neglecting the blade.

Activity Patterns

I estimated the time spent in the various types of activity by calculating the unweighted mean of the percent animals engaged in each activity in scan samples for 30 min periods during each month of the year. Unweighted means were calculated to estimate percent time spent in activity categories overall, for time of day (for all months), or for each month (for the entire day). this was done so that the percents from each 30 min period and/or month would have equal importance in the estimation, regardless of the number of counts that was the basis for each percentage. Based on a total of 97,404 observations during daylight hours, Nilgiri tahr spent the majority of their time grazing (59.7%) or resting (34.5%). Standing and moving were much less frequent, accounting for 2.8% and 2.2%, respectively. Social behavior was the least frequent activity, being recorded in only 0.8% of the observations. (The distribution of samples for these figures and tables are given in Appendix E).

Other activities, such as drinking, were recorded only six times (0.006%). The distribution of these values has not been analyzed.

The incidence of these activities during the course of the day (for all months) is shown if Fig. 11. Most animals rested in the very early morning, but soon started grazing. This reached a peak at 0700-0729 h. However, grazing activity quickly dropped again, for a mid-morning rest period. The percent tahr grazing then steadily increased during the course of the day, reaching a maximum at 1700-1729 h. after which there was a decline. The predominance of grazing and resting as the two main activities is readily apparent in Fig. 11. These two activities consistently accounted for over 90% of all activity observations.

Standing, moving and social activities are shown on an enlarged scale at the top of Fig. 11. The high variablility of these values probably indicates that the samples of 818-6,990 counts are not large enough to give an even presentation of the actual rates. Nevertheless, it is evident that Nilgiri tahr stood during all times of the day, with the most animals standing in the early morning (0600-0659), around midday (1130-1329), and in the evening (1700-1829). Except for one high score in the early morning (0630-0659), the percent tahr moving, while varying considerably, increased during the course of the day, with a minor depression in the early afternoon (1200-1329). Social activity was recorded more frequently than average in the morning (0730-0759), and less frequently in the late afternoon (1500-1559).

The variation in activity by month was less definitive (Table 10). Tahr spent less than average time grazing in May, July and December, and more than average during February-April. Resting scores were lower during January-April, and higher than average during May-July, and December. These scores fit no clear seasonal pattern, nor is there a ready explanation for abrupt increase in resting from April to May, or the abrupt drop from December to January. Seasonal variation in standing is more easily explained when one considers the variation by both month and time of day (see below). The same is true for moving and social activities.

The relationships between the percent tahr grazing, time of day and month are presented in Table 11. Generally, the influence of time of day on grazing was greater than that of month of the year, and therefore all months show a pattern in daily variation similar to the general trend (Fig. 11). On the other hand, there was also some variation on this routine from month to month. This is particularly evident in the morning grazing peak. During the first five months of the year, the peak coincided with the onset of observations (0600), but later in the year the earliest scores were lower, sometimes very low, and rose quickly thereafter.

This pattern would seem to be a result of the tahr's reaction to two phenomena: the shift in the time of sunrise from summer to winter, and seasonal weather variations. In fair weather conditions, which predominate in the mornings in the first half of the year, tahr generally commence grazing with the sunrise. For instance, sunrise occurs at 0640 in mid-January, and the percent

Table 10.--Percent tahr engaged in each activity in scan samples by month.

Season	Winter		Pre-monsoon			Monsoon			Post-monsoon				
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Grazing	63.8	67.1	67.6	65.7	51.8	54.4	49.4	59.7	63.1	57.7	62.5	53.5	59.7
Resting	27.3	27.4	27.1	29.7	43.3	41.2	38.2	33.9	30.9	37.8	34.5	42.6	34.5
Standing	4.5	3.5	2.2	1.2	2.2	2.0	7.3	2.7	2.5	2.4	1.2	1.8	2.8
Moving	3.2	1.7	2.9	2.4	1.9	2.0	2.3	2.6	2.7	1.3	1.3	1.8	2.2
Social	1.3	0.2	0.2	1.0	0.7	0.4	2.8	1.1	0.8	0.8	0.5	0.3	0.8

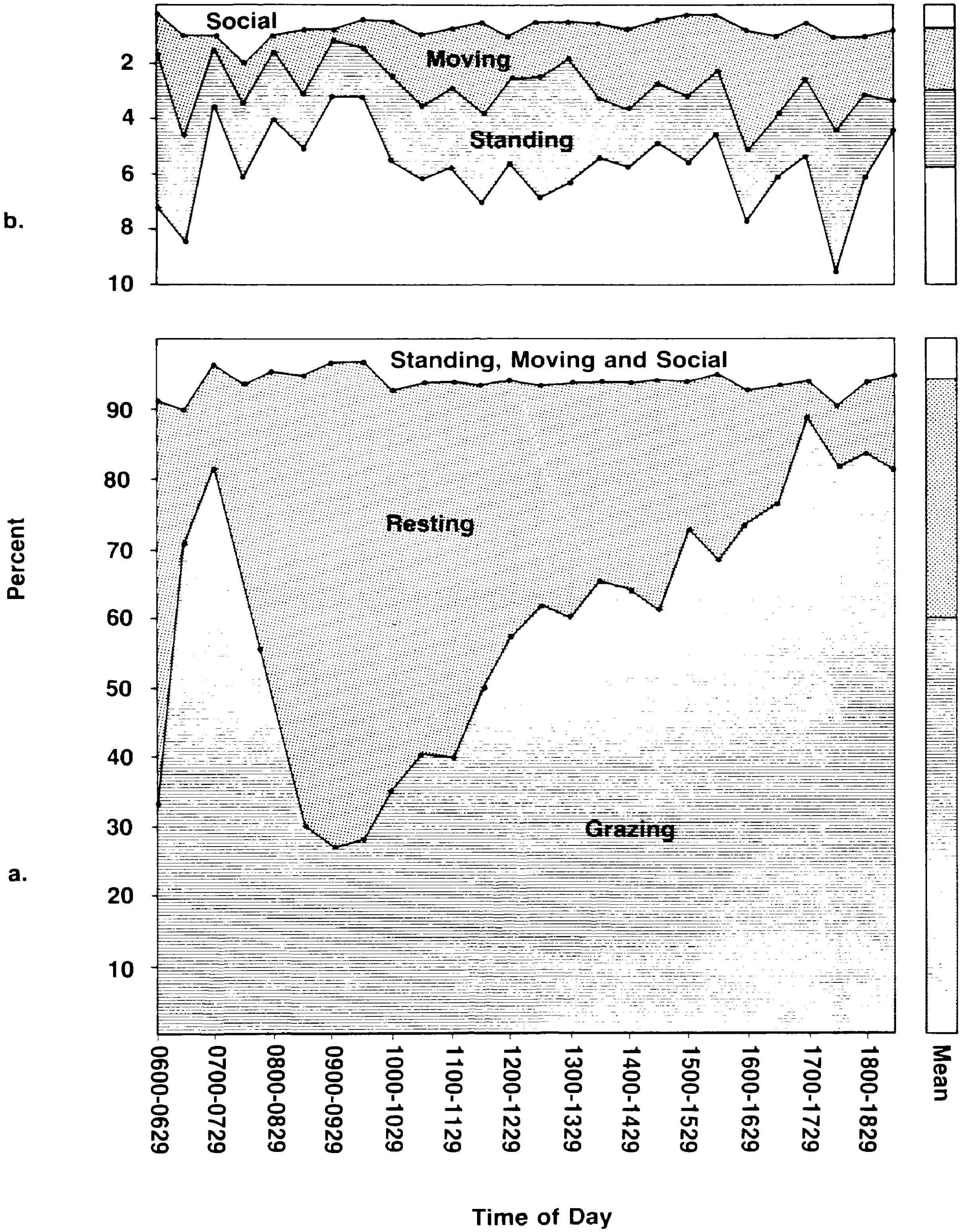


Fig. 11.--Percent tahr in activity categories in scan samples during the day.

Table 11.--Percent tahr grazing in activity scan samples by time of day and month. ND = No data. Times one hour after sunrise and one hour before sunset are underlined.

Season	Winter		Pre-monsoon			Monsoon			Post-monsoon				
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
0600-0629	85.7	ND	ND	ND	87.4	ND	ND	3.4	21.7	0.0	33.1	2.6	33.4
0630-0659	91.9	97.8	ND	90.2	83.5	69.9	63.0	93.2	51.4	32.5	81.6	34.5	71.8
0700-0729	95.6	ND	100.0	87.9	34.4	91.9	76.3	79.7	89.5	90.5	83.5	65.9	81.4
0730-0759	48.0	ND	ND	62.6	23.9	75.0	86.5	96.0	93.6	78.2	54.0	34.8	65.2
0800-0829	61.5	79.2	43.6	27.3	11.3	88.0	20.9	84.5	73.6	52.4	40.4	23.4	50.5
0830-0859	55.6	18.5	29.7	40.8	6.9	2.4	ND	26.0	50.3	41.7	50.1	6.1	29.8
0900-0929	50.9	20.9	35.0	36.1	78.6	0.9	16.9	12.7	30.8	13.2	20.3	5.2	26.8
0930-0959	14.3	20.6	51.1	50.3	40.0	36.2	11.9	21.6	38.1	22.8	15.8	12.2	27.9
1000-1029	43.6	54.5	44.2	52.2	44.5	29.4	9.5	36.5	47.9	33.6	31.0	13.7	36.7
1030-1059	34.6	52.2	50.5	63.4	35.1	28.6	10.8	32.3	38.7	53.7	30.2	52.6	40.2
1100-1129	26.4	38.8	67.9	50.9	40.9	26.8	33.3	32.4	27.7	45.9	33.3	55.0	39.9
1130-1159	28.6	53.2	61.0	55.7	27.0	65.1	33.9	62.4	46.6	48.7	58.5	50.5	49.3
1200-1229	62.0	71.9	50.8	70.3	62.6	57.3	46.0	36.1	31.2	72.4	61.8	63.4	57.1
1230-1259	73.6	80.9	66.0	69.8	49.2	16.2	35.9	74.2	55.4	56.7	77.0	83.9	61.6
1300-1329	57.0	62.6	82.1	72.9	52.2	61.1	32.5	45.6	52.2	64.1	51.5	86.2	60.0
1330-1359	61.9	74.2	69.2	68.1	64.0	65.7	70.7	75.6	48.7	71.0	50.4	67.0	65.6
1400-1429	68.2	68.5	65.9	85.1	70.9	39.8	46.8	60.5	56.5	70.8	86.0	50.2	64.1
1430-1459	54.8	77.5	70.9	67.9	52.6	55.3	26.9	62.0	59.7	56.5	89.6	60.9	61.2
1500-1529	80.2	78.0	74.5	73.6	42.3	52.9	73.8	78.7	92.6	58.4	93.0	80.4	73.2
1530-1559	74.8	82.3	92.5	60.9	2.6	68.6	57.0	86.4	83.8	41.6	94.7	70.3	68.0
1600-1629	67.3	66.7	78.7	71.4	65.8	54.8	85.6	80.5	89.5	91.8	66.8	63.5	73.5
1630-1659	78.4	81.7	86.4	53.8	70.6	65.9	69.2	93.5	87.1	83.8	65.8	83.6	76.7
1700-1729	90.1	81.2	83.3	82.5	97.1	94.0	78.0	85.1	91.9	90.6	99.1	95.8	89.1
1730-1759	90.6	90.9	89.1	87.4	67.0	71.3	47.4	61.0	96.8	86.0	97.6	93.3	81.5
1800-1829	98.8	96.1	77.5	67.9	72.9	88.4	56.6	71.7	97.0	85.0	96.6	93.0	83.5
1830-1859	ND	95.8	85.5	93.0	63.9	ND	95.6	ND	87.5	ND	ND	42.3	80.5
Mean	63.8	67.1	67.6	65.7	51.8	54.4	49.4	59.7	63.1	57.7	62.5	53.5	59.7

tahr grazing rose from 86 to 92% between 0600-0629 and 0630-0659 before dropping to the mid-morning rest period. On the other hand, in the monsoon and post-monsoon, morning weather conditions tended to be poor, and under such conditions tahr started grazing later.

This early morning peak in grazing shows a seasonal trend (Table 11). It occurs slightly earlier (minimum at about 0830-0929) in the monsoon, than in the winter (minimum at about 0900-0959). Also, the severity of this drop was not constant, the dip being less conspicuous in March and September, and reaching the lowest scores in May and June.

The manner of increase in the percent animals grazing through the rest of the day (Table 11) also varied between months. From January to April, this increase was generally steady, with only minor inflections. May has two seeming anomalies, a high score for grazing at 0900-0929 and a low score for 1530-1559. Also, May and June show the highest afternoon scores well before the end of the day, at 1700-1729. This seems odd considering that this includes the longest clear weather days of the year, when one might expect the evening grazing peak to occur later than at other times. This peak occurs even earlier in July and August. During September and October the increase through the day is again more or less even, but in November and December, times of maximum grazing occurred during the afternoon, with scores as high or nearly as high as the evening grazing peak occurring 1530-1559 in November, and at 1230-1329 and 1500-1529 in December.

Interestingly then, the nature on the increase in grazing activity during the course of the day, did not fit a strictly seasonal pattern, although consecutive months do tend to group together. January-April are characterized by a more or less steady increase in grazing, peaking at the end of the day. May-August show the same increase, but the late afternoon maximum is followed by a decrease in grazing activity. September and October seem to resemble the months earlier in the year, and November and December show peaks in grazing earlier in the afternoon.

Grazing and resting were so completely complimentary in nature that the pattern for resting is merely the opposite of that for grazing (Table 12).

The same variability seen in the average scores for standing by month and time of day is evident in the figures taking both into account (Table 13). Except for the high scores of July at 1200-1329 and 1730-1829, and August 1300-1329, no patterns are discernable.

Moving was also quite variable (Table 14). However, there seems to be a distinct propensity towards moving late in the afternoons in July-September, the rainy months. There is also a noticeable imbalance in that most moving occurred in the afternoon, with very little during the morning. A tendency towards moving between 1030 and 1259 is also evident for most months, which may be associated with in increase in grazing and decrease in resting usually taking place at that time.

Social activity shows a distinct influence of time of year (Table 15). Social behavior was particularly frequent in July, the

Table 12.--Percent tahr resting in activity scan samples by time of day and month. ND = No data. Times one hour after sunrise and one hour before sunset are underlined.

Season	Winter		Pre-monsoon			Monsoon			Post-monsoon				
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
0600-0629	14.3	ND	ND	ND	1.0	ND	ND	96.6	60.0	85.7	63.0	95.6	59.5
0630-0659	0.0	2.2	ND	5.4	13.0	1.1	15.1	2.3	38.5	55.4	15.9	62.4	19.2
0700-0729	4.4	ND	0.0	8.1	64.0	4.6	8.6	15.6	5.5	4.5	13.1	32.4	14.6
0730-0759	34.0	ND	ND	33.1	72.5	18.1	9.2	1.3	1.8	12.9	38.7	61.5	28.3
0800-0829	25.0	11.3	55.4	63.6	88.7	12.0	79.1	9.3	23.5	42.9	56.5	76.6	45.3
0830-0859	28.8	80.2	67.7	44.2	93.1	96.4	ND	63.0	49.0	51.5	48.1	93.9	65.1
0900-0929	39.6	77.3	62.0	59.6	19.1	99.1	79.0	86.6	61.6	85.5	78.5	91.7	70.0
0930-0959	75.4	79.0	46.8	46.1	55.9	61.6	85.2	76.7	58.0	76.4	82.8	84.2	69.0
1000-1029	39.3	41.6	50.0	45.7	48.0	66.4	84.7	60.8	45.9	62.3	65.7	80.4	57.6
1030-1059	62.6	41.9	38.2	32.7	57.7	67.5	83.6	56.5	56.5	33.1	69.0	43.7	53.6
1100-1129	65.6	56.6	26.5	46.0	50.1	69.0	58.5	59.9	63.5	54.1	60.9	41.6	54.3
1130-1159	63.2	38.5	33.6	39.7	56.5	33.7	56.6	35.6	37.1	48.9	38.4	44.1	43.8
1200-1229	28.9	22.9	42.6	24.8	32.2	42.2	35.4	63.4	61.0	23.1	34.7	33.6	37.1
1230-1259	25.6	12.2	20.5	17.2	47.9	83.1	32.6	21.1	42.8	40.8	21.8	13.6	31.6
1300-1329	32.0	32.4	14.3	23.0	43.8	36.3	54.0	31.6	45.6	35.2	45.2	11.0	33.7
1330-1359	23.9	19.5	26.2	28.2	31.2	33.3	23.4	21.8	49.1	27.9	39.3	24.3	29.0
1400-1429	28.6	25.7	28.8	12.5	24.3	52.4	43.8	32.8	39.7	26.0	8.2	37.4	30.0
1430-1459	38.6	18.0	27.2	29.7	44.8	43.5	63.5	35.4	36.5	41.2	7.9	21.5	34.0
1500-1529	10.5	14.0	20.6	22.9	52.2	43.0	17.4	17.6	0.9	40.5	3.5	12.2	21.3
1530-1559	9.8	13.9	5.0	37.7	97.3	30.3	33.1	9.1	6.1	56.4	5.3	26.9	27.6
1600-1629	11.3	20.0	7.7	27.6	31.3	41.3	6.6	0.0	3.5	6.5	32.0	34.7	18.5
1630-1659	9.3	5.6	12.1	45.8	26.7	26.9	0.0	5.8	9.3	11.4	33.8	14.5	16.8
1700-1729	5.0	5.2	15.7	11.5	2.2	3.7	6.7	9.1	3.4	3.2	0.0	2.6	5.7
1730-1759	4.5	6.8	1.6	9.1	17.7	22.2	19.1	8.0	1.1	9.7	0.9	6.0	8.9
1800-1829	1.1	1.3	13.3	21.9	19.8	ND	20.9	28.3	2.5	9.8	ND	7.0	10.5
1830-1859	ND	4.2	6.4	7.0	34.8	ND	0.0	ND	0.0	ND	ND	53.8	15.2
Mean	27.3	27.4	27.1	29.7	43.3	41.2	38.2	33.9	30.9	37.8	34.5	42.6	34.5

Table 13.--Percent tahr moving in activity scan samples by time of day and month. ND = No data. Times one hour after sunrise and one hour before sunset are underlined.

Season	Winter		Pre-monsoon			Monsoon			Post-monsoon				
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
0600-0629	0.0	ND	ND	ND	5.3	ND	ND	0.0	15.0	14.3	3.6	0.8	5.6
0630-0659	1.6	0.0	ND	3.3	1.9	9.7	8.5	0.0	5.6	7.6	1.0	2.5	3.8
0700-0729	0.0	ND	0.0	1.7	1.3	1.1	8.1	1.6	1.7	1.9	1.7	1.6	1.9
0730-0759	9.0	ND	ND	2.4	1.4	1.4	1.8	2.7	0.0	1.1	5.0	1.4	2.6
0800-0829	7.7	9.4	0.5	3.6	0.0	0.0	0.0	4.1	1.1	1.8	0.9	0.0	2.4
0830-0859	7.8	1.2	1.7	0.3	0.0	0.6	ND	5.9	0.0	2.6	1.6	0.0	2.0
0900-0929	6.5	1.8	2.4	0.8	1.4	0.0	1.6	0.5	4.1	1.0	0.9	3.1	2.0
0930-0959	5.1	0.4	1.1	2.0	2.4	0.3	1.7	1.0	2.3	0.6	1.0	2.5	1.7
1000-1029	5.8	2.6	3.0	0.5	4.1	3.4	4.0	1.5	2.0	3.7	1.6	5.6	3.1
1030-1059	2.1	3.4	6.4	0.6	3.6	3.2	2.6	3.4	3.3	0.5	0.7	1.5	2.6
1100-1129	5.5	3.4	1.5	1.2	4.0	3.4	3.2	2.2	6.2	0.0	0.7	1.2	2.7
1130-1159	6.0	4.6	2.7	2.0	4.6	0.8	5.4	0.4	5.6	0.6	2.2	1.8	3.1
1200-1229	3.1	4.2	1.3	1.1	2.9	0.0	14.3	0.0	5.8	1.6	1.4	0.3	3.0
1230-1259	0.8	6.8	5.0	2.1	2.9	0.6	28.3	1.4	0.8	1.5	0.2	1.5	4.3
1300-1329	8.4	3.3	2.4	1.2	3.0	0.9	11.0	20.2	0.4	0.7	0.9	1.6	4.5
1330-1359	2.8	4.8	2.0	1.4	2.1	0.9	2.3	2.1	1.1	0.8	2.8	2.3	2.1
1400-1429	1.2	1.6	1.9	0.6	0.6	4.4	4.3	1.3	2.0	1.7	1.0	4.6	2.1
1430-1459	4.7	3.5	1.9	0.0	0.5	1.2	5.8	0.7	0.4	2.3	0.4	4.6	2.2
1500-1529	6.8	3.8	0.8	0.4	4.5	3.2	3.5	0.7	0.0	1.0	0.0	4.1	2.4
1530-1559	8.9	2.5	1.2	1.4	0.0	0.0	4.2	2.8	3.5	1.3	0.0	1.4	2.3
1600-1629	8.6	5.4	1.9	0.3	1.8	1.7	4.7	2.3	1.5	1.8	1.0	0.7	2.6
1630-1659	2.9	6.7	0.0	0.0	0.9	0.9	9.2	0.0	2.0	1.2	0.0	1.3	2.1
1700-1729	5.0	8.3	1.0	0.3	0.7	0.9	7.9	3.4	0.0	4.5	0.3	0.5	2.7
1730-1759	2.7	2.3	4.7	0.9	2.9	5.6	25.7	10.0	0.2	3.1	0.7	0.7	5.0
1800-1829	0.0	0.0	3.3	2.7	3.1	4.6	17.8	0.0	0.5	2.4	0.0	0.0	2.9
1830-1859	ND	0.0	3.2	0.0	0.4	ND	0.0	ND	0.0	ND	ND	2.6	0.9
Mean	4.5	3.5	2.2	1.2	2.2	2.0	7.3	2.7	2.5	2.4	1.2	1.8	2.8

Table 14.--Percent tahr standing in activity scan samples by time of day and month. ND = No data. Times one hour after sunrise and one hour before sunset are underlined.

Season	Winter		Pre-monsoon			Monsoon			Post-monsoon				
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
0600-0629	0.0	ND	ND	ND	0.3	ND	ND	0.0	3.3	0.0	0.4	0.2	1.5
0630-0659	6.4	0.0	ND	1.1	0.4	19.3	7.3	0.0	1.7	3.2	0.4	0.5	3.7
0700-0729	0.0	ND	0.0	0.0	0.0	1.1	0.5	0.0	1.7	2.0	0.4	0.0	0.5
0730-0759	0.0	ND	ND	1.8	0.7	1.4	1.4	0.0	4.1	3.7	0.6	1.7	1.5
0800-0829	3.8	0.0	0.5	1.9	0.0	0.0	0.0	0.0	0.4	0.2	2.0	0.0	0.7
0830-0859	7.8	0.0	0.6	14.2	0.0	0.6	ND	0.0	0.0	0.9	0.0	0.0	2.2
0900-0929	1.3	0.0	0.0	1.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
0930-0959	5.1	0.0	1.1	0.7	1.6	1.9	0.0	0.3	0.5	0.0	0.0	0.4	1.0
1000-1029	10.1	0.9	2.6	1.1	2.0	0.6	0.7	0.5	0.3	0.0	1.6	0.0	1.9
1030-1059	0.2	1.9	4.6	1.3	0.6	0.4	0.0	6.1	1.4	12.3	0.0	2.2	2.6
1100-1129	1.8	0.7	4.0	0.6	4.3	0.4	2.3	4.9	1.0	0.0	4.9	1.7	2.2
1130-1159	1.3	3.7	2.5	2.2	11.9	0.4	0.8	1.1	10.3	1.6	0.6	3.3	3.3
1200-1229	4.1	0.0	4.7	2.5	0.6	0.0	1.1	0.5	0.0	1.9	0.9	2.6	1.6
1230-1259	0.0	0.0	8.3	9.8	0.0	0.0	0.0	3.2	1.0	0.0	0.2	1.0	2.0
1300-1329	1.5	1.4	0.4	1.8	1.0	1.8	2.5	1.3	1.0	0.0	2.4	0.4	1.3
1330-1359	10.9	0.9	2.5	1.4	1.9	0.0	2.3	0.0	0.2	0.3	5.5	6.4	2.7
1400-1429	0.8	3.2	3.0	1.8	3.1	3.4	1.3	4.4	1.1	0.5	4.8	7.8	2.9
1430-1459	0.9	0.9	0.0	2.1	0.0	0.0	2.9	1.4	3.4	0.0	2.1	12.3	2.2
1500-1529	2.4	4.2	4.1	2.7	0.9	0.6	4.0	2.7	6.5	0.0	3.5	3.0	2.9
1530-1559	3.8	0.8	1.2	0.0	0.0	1.1	5.6	1.7	6.5	0.7	0.0	1.4	1.9
1600-1629	9.9	7.3	11.6	0.0	1.1	2.1	1.6	14.4	4.5	0.0	0.0	0.0	4.4
1630-1659	6.1	5.6	1.5	0.0	0.2	5.2	12.3	0.7	0.8	3.3	0.0	0.6	3.0
1700-1729	0.0	5.2	0.0	5.6	0.0	0.5	5.5	1.0	4.6	1.3	0.0	1.0	2.1
1730-1759	0.4	0.0	4.7	0.4	11.5	0.9	1.3	20.0	1.8	0.6	0.0	0.0	3.5
1800-1829	0.0	2.6	5.0	5.3	1.3	7.0	1.2	0.0	0.0	0.0	0.7	0.0	2.1
1830-1859	ND	0.0	4.8	0.0	0.2	ND	0.0	ND	12.5	ND	2.6	0.0	2.5
Mean	3.2	1.7	2.9	2.4	1.9	2.0	2.3	2.6	2.7	1.3	1.3	1.8	2.2

Table 15.--Percent tahr engaged in social behavior in activity scan samples by time of day and month. ND = No data. Times one hour after sunset and one hour before sunset are underlined.

Season	Winter		Pre-monsoon			Monsoon			Post-monsoon				
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
0600-0629	0.0	ND	ND	ND	0.0	ND	ND	0.0	0.0	0.0	0.0	0.8	0.1
0630-0659	0.0	0.0	ND	0.0	1.1	0.0	6.1	4.5	2.8	1.3	1.0	0.0	1.5
0700-0729	0.0	ND	0.0	2.3	0.3	1.1	6.6	3.1	1.7	1.1	1.2	0.1	1.6
0730-0759	9.0	ND	ND	0.0	1.4	4.2	1.1	0.0	0.5	4.1	1.8	0.6	2.3
0800-0829	1.9	0.0	0.0	3.3	0.0	0.0	0.0	2.0	1.5	2.6	0.1	0.0	1.0
0830-0859	0.0	0.0	0.4	0.6	0.0	0.0	ND	5.0	0.7	3.2	0.1	0.0	0.9
0900-0929	1.7	0.0	0.6	2.2	0.0	0.0	2.4	0.2	3.5	0.3	0.2	0.0	0.9
0930-0959	0.0	0.0	0.0	1.0	0.0	0.0	1.1	0.3	1.1	0.2	0.3	0.7	0.4
1000-1029	1.2	0.4	0.2	0.5	1.3	0.1	1.0	0.7	1.2	0.4	0.1	0.3	0.6
1030-1059	0.5	0.5	0.2	2.0	3.0	0.2	3.1	1.7	0.0	0.5	0.1	0.0	1.0
1100-1129	0.7	0.5	0.0	1.2	0.8	0.4	2.7	0.5	1.5	0.0	0.3	0.5	0.8
1130-1159	0.8	0.0	0.2	0.5	0.0	0.0	3.3	0.4	0.3	0.2	0.3	0.4	0.5
1200-1229	1.8	1.0	0.0	1.3	1.6	0.6	3.2	0.0	2.0	1.0	1.2	0.1	1.2
1230-1259	0.0	0.0	0.2	1.2	0.0	0.0	3.3	0.0	0.0	1.0	0.7	0.0	0.5
1300-1329	1.1	0.3	0.8	1.0	0.0	0.0	0.0	1.3	0.7	0.0	0.0	0.8	0.5
1330-1359	0.4	0.6	0.0	0.9	0.8	0.0	1.3	0.5	0.8	0.0	2.0	0.0	0.6
1400-1429	1.2	0.9	0.3	0.0	1.0	0.0	3.9	0.9	0.7	1.0	0.0	0.0	0.8
1430-1459	0.9	0.0	0.0	0.3	2.1	0.0	1.0	0.5	0.0	0.0	0.0	0.8	0.5
1500-1529	0.0	0.0	0.0	0.4	0.0	0.3	1.3	0.3	0.0	0.0	0.0	0.4	0.2
1530-1559	2.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
1600-1629	2.9	0.6	0.0	0.6	0.0	0.0	1.6	2.3	1.0	0.0	0.2	1.1	0.9
1630-1659	3.2	0.4	0.0	0.4	1.6	1.2	9.2	0.0	0.8	0.2	0.4	0.0	1.5
1700-1729	0.0	0.0	0.0	0.0	0.0	0.9	1.8	1.4	0.0	0.4	0.6	0.0	0.4
1730-1759	1.8	0.0	0.0	2.2	1.0	0.0	6.6	1.0	0.0	0.6	0.0	0.0	1.1
1800-1829	0.0	0.0	0.8	2.1	2.8	0.0	3.4	0.0	0.0	2.8	0.7	0.0	1.1
1830-1859	0.0	0.0	0.0	0.0	0.6	0.0	4.3	0.0	0.0	0.0	0.0	1.3	0.9
Mean	1.3	0.2	0.2	1.0	0.7	0.4	2.8	1.1	0.8	0.8	0.5	0.3	0.8

height of the rut, although it was not recorded at all times of the day, there being low scores at 0800-0859, at the end of the morning grazing period (Table 11), and at 1300-1329 and 1530-1559. However, these may reflect the vagaries of sampling more than anything else. I attribute the sporadic occurrence of social activity during the month of January to the mother-infant interactions which are so frequent at that time.

These activity scores usually reflect several counts for each time and month combination, and are therefore average measures of samples from different days during the month, and combined from different years. The groups of animals show a greater degree of coordination in activity than one might expect when considering the averages. This is particularly important for those activities which affect the physical location of an individual, namely, resting, as opposed to grazing and moving. Although it is also true that a standing animal is precluded from changing its physical location, standing was usually of short duration, being a transition behavior or indication of indecision. Some longer bouts of standing did sometimes occur when animals selected windward slopes to catch a cooling breeze, but this generally was when the rest of the group was resting, as these two stationary activities required little coordination. While social interaction usually involved some physical movement, and may have a contagious effect, this rarely extended to more than a few individuals. Also, interactions were usually of too short a duration to have a pronounced effect on an individual's location.

The coordination of the activities which affect the physical distribution of animals is a prerequisite for group formation and stability. In Nilgiri tahr, this coordination is a voluntary affair. I never saw an animal attempt to affect another's activity by threat or other gesture as has been reported, for instance, in oryx (<u>Oryx beisa</u>; Walther, 1978). This is not to say that an individual's activity was not influenced by that of others, but rather that the activity it engaged in seemed to be a balance between the sometimes conflicting motivations of contagion and individual preference. This was particularly evident in observing the transition from resting to grazing in a group of animals. Almost as a rule, tahr moved slowly but steadily in one general direction while grazing, alternating between cropping the vegetation and taking a few steps. The path of the group often turned, or even wandered, but a general direction of movement was always evident. For this reason, the first animals to commence grazing usually started to drift away from those resting almost immediately.

For whatever reason, the tendency for a resting animal to follow a grazing one was much greater than for a grazing animal to remain with a resting one. Consequently, as the initial animals started to graze away, resting tahr, frequently those closest to those grazing, rose and grazed after. This pattern was so clear, that it was not uncommon to see a resting group "eroded" away from one end to the other as this contagious effect worked its way through the group. However, the tahr which initiated grazing did not hold absolute sway over those resting, and in some instances a pattern of "voting" was clearly evident. The initial grazers grazed just past the margin of the group and then stopped, and rested again. This occurred a number of times, extending the resting group in that direction until a few minutes later, when those grazing did not rest again, but continued grazing and were followed by the balance of the group. Failure of the tahr to coordinate these changes from static to moving activities was one of the two ways in which groups split. The other way was through disagreement over the direction of movement during grazing or moving.

Population Dynamics

Population size

The estimated size of Nilgiri tahr populations was presented in the section on current status. However, only the population sizes given for Eravikulam National Park, the Grass Hills of the Anaimalais, and the Nilgiri Plateau in Fig. 1 are based on censuses. The remainder are estimates based on surveys and/or information provided by local informants. In addition, some areas were surveyed only once, and therefore no estimate of trends is possible for these populations.

On the other hand, the three largest populations (the Nilgiri Plateau, the Grass Hills, and Eravikulam) have been censused more than once, and with some reservations, this gives an indication of the trends in these populations. The Nilgiri Plateau was censused by Davidar in 1963 and in 1975 (Davidar 1963, 1976). Davidar used the counts of 292 in 1963 and 334 in 1975 as a basis for estimating the population size at 400 and 450, respectively. While the number of tahr counted was greater during the second count, Davidar's large subjective correction factor makes interpretation of these figures difficult. In 1969, Schaller (Schaller 1971) censused two of the three main Nilgiri tahr areas on the plateau (Nilgiri Peak to Pichal Bettu and the Sispara Pass area), and found very similar numbers to those reported by Davidar in 1963, but felt that the population, while stable, was of about 300 animals.

Davidar (1971) also censused the Grass Hills of the Anamalais, and estimated the population at 200, based on a count of 138. However, when I censused this same area in 1980, I encountered 246 animals. However, it seems unlikely that this difference represents an increase in the number of tahr in the area, but rather, it appears that the number of animals in the northern section was underestimated by Davidar. This becomes evident when the counts for the two major sections of tahr habitat are compared. In the northern section (including Koram Parai, Tanaka Malai and Akka Malai), Davidar counted only 35 animals, whereas I encountered 144. By contrast, in the southern section (including Usi Malai, Kallar Malai, Perattu Malai and Kaladekatti Malai), Davidar counted 103 animals, and I encountered 102. Based on my experience from the sub-populations in the very similar terrain just to the south in

Eravikulam National Park, it is unlikely that there is any appreciable exchange between the Grass Hills sub-populations. Thus it seems likely that the population size for this area has probably remained about the same in the intervening years.

The Eravikulam National Park population has been censused on three occasions, by Schaller in 1969 (Schaller 1971), and by myself in 1980 and 1981. Schaller counted a total of 439 tahr, but was unable to locate one herd before mist interrupted his search, and estimated the Eravikulam population at 500. In 1980, I counted 515 tahr, but previous and subsequent sightings of a group in a particular area (around Samba Malai) where only a few tahr were encountered during the census led me to believe the total population was about 550. However, in 1981, I counted a total of 614 tahr in the National Park. While these figures might be interpreted to represent an increase in population size, I do not believe this is the case for the following reasons:

1. The production of young varies greatly from year to year (see below), and this can have a marked short term impact on the population level. Based on the proportion of young in counts where all individuals in the group were classified, the population contained 137 young in 1980, and only 103 young in 1981. This alone accounts for over half the difference in the two population estimates.

2. Despite efforts to keep them at a minimum, there is always the possibility of duplicate counts and overlooking animals, resulting in minor fluctuations in census figures. Repeated annual

censuses might show existing trends despite these fluctuations, but the limited series of census results presently available makes it impossible to differentiate between censusing error and genuine trends in population size.

With these factors in mind, and pending further evidence, it seems that all three of these Nilgiri tahr populations have remained stable over the last decade or so. This suggests that the tahr have been able to maintain their numbers despite any pressures and disturbances to which the populations have been subjected.

Population Structure

The estimated sex and age composition for the three largest Nilgiri tahr populations is shown in Table 16. Some caution is warranted in interpreting these figures since they reflect counts from different times of the year and from different observers. This is particularly true with regards to the older males, since neither Schaller (1971) nor Davidar (1971; 1976) gave detailed descriptions of the criterea they used to identify the classes. Also, the appearance of these males can be influenced considerably by viewing conditions and time of year. Nevertheless, some comparison of these values is instructive.

The percentage of adult females indicated by the different counts was fairly constant at about 40-45%, although both of Schaller's (1971) counts showed a lower proportion of females. This probably reflects the high number of both young and yearlings in

Table 16.--Estimated percent composition of several Nilgiri tahr populations.

				Sex and Age Class						
Location	Season	Year	Total	S	Dbm	Lbm	F	Yl	Yg	Source
Nilgiri Plateau	Post-monsoon	1969	164	9.1	4.3	7.9	34.1	18.9	25.6	Schaller, 1971
	Pre-monsoon	1975	334	4.5	7.5	15.3	45.2	12.0	15.6	Davidar, 1976
Grass Hills	Pre-monsoon	1971	133	0.8	3.0	9.8	45.1	14.3	27.1	Davidar, 1971
	Pre-monsoon	1980	240	2.5	5.0	20.0	41.3	11.7	19.6	This study
Eravikulam N. P.	Post-monsoon	1969	260	11.2	4.2	4.2	33.5	17.3	29.6	Schaller, 1971
	Pre-monsoon	1978	352	4.0	10.8	9.7	40.3	22.4	12.8	This study
	Winter	1980	443	4.1	7.7	12.0	42.4	9.0	24.8	This study
	Winter	1981	578	6.4	4.3	14.2	46.4	11.9	16.8	This study

S = saddleback, Dbm = dark brown male, Lbm = light brown male, F = adult female, Yl = yearling, Yg = young.

Eravikulam and Nilgiri Plateau populations in 1971. A more consistent index to population composition is desirable, since the percent composition for each class is affected by the values for every other class. Such an index is the ratio of all other classes to females. This ratio, expressed as the number of animals in each of the other class per 100 females is shown for these populations in Table 17.

The variability seen in Table 16 is even more evident in Table 17. The number of Yg per 100 F's is probably the most reliable of these figures, since all observers were experienced and probably consistent in recognizing Yg. On the other hand, if Yg have a higher mortality rate the F's, then the season (or time since the births) should influence this ratio (i.e. the greater the delay from the births, the smaller the number should be). No pattern reflecting this can be discerned (counts from post-monsoon and winter (but before the births) are not consistently lower than those from the pre-monsoon). Rather there is a wide range of variation from a low of near 30 to a high of nearly 90 Yg/100 F's. This indicates considerable difference in the reproductive success from year to year, and obscures any differences that may exist between populations.

The number of Yl's per 100 F's also shows high variability; ratios range from just over 20 to about 55. This variability between years and the lack of consecutive counts make these data unsuitable for standard life table analysis. However, the generally lower scores for Yl's reflects the mortality incurred during the age

Table 17.--Estimated number of Nilgiri tahr in sex and age classes per 100 females in several Nilgiri tahr populations.

				Sex and Age Class							
Location	Season	Year	No. F	S	Dbm	Lbm	Yl	Yg	S+Dbm	Male	Source
Nilgiri Plateau	Post-monsoon	1969	56	26.8	12.5	23.2	55.4	75.5	39.3	62.5	Schaller, 1971
	Pre-monsoon	1975	151	9.9	16.6	33.8	26.5	34.4	26.5	60.3	Davidar, 1976
Grass Hills	Pre-monsoon	1971	60	1.7	6.7	21.7	31.7	60.0	8.3	30.0	Davidar, 1971
	Pre-monsoon	1980	99	6.1	12.1	48.5	28.3	47.5	18.2	66.7	This study
Eravikulam N. P.	Post-monsoon	1969	87	33.3	12.6	12.6	51.7	88.5	46.0	58.6	Schaller, 1971
	Pre-monsoon	1978	142	9.9	23.9	23.9	55.6	31.7	36.6	60.6	This study
	Winter	1980	188	9.6	28.2	28.2	21.3	58.5	27.7	55.9	This study
	Winter	1981	268	13.8	30.6	9.3	25.7	36.2	23.1	53.7	This study
Mean				13.9	14.3	27.8	37.0	54.0	28.2	56.0	
Mean excluding Grass Hills 1971				15.6	15.4	28.7	37.8	53.1	31.0	59.7	

S = saddleback, Dbm = dark brown male, Lbm = light brown male, F = adult female, Yl = yearling, Yg = young.

interval, and an indication of the mortality responsible for this difference can be obtained by averaging the number of Yg and Yl per 100 F's across all populations, and calculating the decrease. This gives a value of 0.31. (Including only the post-monsoon and winter counts gives a value of 0.40). The data include one series of consecutive counts, the 1980 and 1981 censuses. These reconstructed populations contained 137 Yg in 1980 and 107 Yl in 1981, a decrease of 0.46. Since these tahr were yearlings for the period being considered, the estimate of the mortality in Yl in 1980 is 0.46, and the overall figures suggest a similar, but slightly lower figure for all years and populations. Obviously, more information would be of great value in assessing these factors, but a mortality rate of about 0.40, or 40% seems a good estimate for this age class.

The number of males of the various classes per 100 F's shows an even wider variation between populations and years. Only the lack of a stable age distribution can be responsible for this, since only the Dbm class represents a single age. However, this variation may not truly reflect the composition of the populations. Rather, I am more inclined to account for it in terms of variation between observers and the change in appearance in these males during the course of the year. For instance, Davidar's (1971) low estimate for S's and Dbm's in the Grass Hills probably coincides with his apparent underestimation of the population as a whole (see above). Considering that the males frequent the low terrain at the bases of cliffs and other areas outside the usual haunts of the females at this time of year, there is considerable likelihood of overlooking a sizeable proportion of the older males when surveying unfamiliar ground. With this exception, the male:female ratio is quite constant between all estimates, varying from 53.7 - 66.7, with a mean of 59.7.

Much of the remaining, yet considerable variation in the scores for older males may be attributed to differing standards used is placing animals into sex and age classes. The maturational marks used, particularly the saddle, reach their greatest development during the rut (monsoon), and become less distinct afterwards and the divisions between the classes become less clear. Thus, the judgement as to whether or not a particular animals has a "distinct saddle" may vary. This could well explain the relatively high number of S's compared to Dbm's in Davidar's (1971; 1976) counts, since he may have been making his judgements on the basis of the more prominent markings seen during the rut. On the other hand, Schaller (1971), not having seen the males during the rutting season, may have tended to place more of the males in the S's class. A similar pattern is evident in my own counts. In 1980, I was unaware of this partial regression in maturational characters and my counts reflect this with a relatively high number of Dbm. However, in 1981, I compensated for this change, and the greater proportion of S's reflects this.

Since, with the exception of Dbm's, the male classes contain more than one age of tahr, these figures are of little help in estimating mortality for adult males. The overall mortality for adults can, however, be estimated on the basis of the conclusion of a steady population, and the number of Y1 entering the adult population each year. For the populations combined, the replacement rate to an averages 0.21, indicating that about 1/5th of the adults of both sexes must die each year. Also, in both Schaller's (1971) estimation, and in my counts, the sex ratio among Y1's did not differ significantly from 1:1, so the biased adult sex ratio, with only about 55-60 males:100 F's, indicates a higher mortality rate for adult males compared to that of adult females.

It was possible to age all tahr in the Vaguvarrai intensive study group by counting horn rings. This was done in the monsoon (at the height of the rut), when it was assumed that all males were in mixed groups, and that the Vaguvarrai mixed groups did not have a biased representation of males. The data for males was averaged for three counts on large groups of 150, 139, and 150 on 15, 20, and 25 July 1981, respectively. The age distribution for females was taken on 3 July 1981, from a group of 119, which contained 57 females, and increased proportionately to total the average number of females in the male count groups. This hypothetical age structure (Table 18) cannot be used to construct a life table since the age distribution is not stable, as is quite evident by the cases in which older animals outnumber younger. However, it can give some indication of the differences in mortality between the sexes. Both sexes show a similar decrease between ages 0-1, but the drop to age 2 is much more conspicuous in the males. In addition, the number of 3-yr old

Table 18.--Estimated age structure of the Vaguvarrai sub-population. July 1981.

Females				Males	
Class	#	Age	Year of birth	#	Class
Yg	17	0	1981	17	Yg
Yl	7	1	1980	10	Yl
F	7	2	1979	3	Lbm
F	15	3	1978	3	Lbm
F	13	4	1977	8	LLbm
F	9	5	1976	7	Dbm
F	6	6	1975	4	S1
F	6	7	1974	2	S1-2
F	4	8	1973	2	S2
F	2	9	1972	0	S2
Total	86			57	
Adult	62			30	

For an explanation of class abbreviations, see text.

females is twice as high as the number of 2-yr old females, whereas in the males, there is no change. The suggestion is, that differential mortality between sexes at the age of 2-3 years is responsible for the skewed sex ratio in adults.

The Annual Cycle of Reproduction

The reproductive cycle of a species is closely attuned to the ecological conditions under which it lives. The reproductive cycle of Nilgiri tahr is therefore of interest in light of the climatic and biotic cycles in which it lives. This information can be compared to

Caughley's (1971) work on the closely related Himalayan tahr inhabiting a decidedly temperate regime in New Zealand.

Jerdon (1874) stated that the Nilgiri tahr "is said to produce two young at birth", and this was apparently the prevailing opinion when Fletcher (1911) wrote that he was more inclined to judge one to be the usual number. Prater (1965) maintained that sometimes two, but more commonly one young are produced. However, more recent observations in both the wild (Davidar, 1978; Schaller, 1978; and this study) and captivity (Wilson, 1980; Waterhouse pers. comm) indicate that one young per female is the rule. Davidar (1978) reports one instance of twin fetuses and states that "occasionally, a mother with two young at heel have been observed." However, I encountered no indications of twinning during the course of my study. So, although twins may occasionally occur, the usual number of young is one.

Detailed information on reproduction during the study was obtained during the birth and rutting seasons of 1981. Flighty animals, adverse weather conditions, and the lack of individually recognizable females precluded a comparable accounting during 1879 and 1980. The distribution of births was well charted in the winter of 1981, and the occurrences of estrus was observed during the monsoon of that followed. Unfortunately, the study ended before the births which resulted from the 1981 rut. However, by good fortune, one of the first females to be collared at the end of the 1980 rut was one of the last females to be bred, and both the breeding and birth dates were documented. She was bred on 03 September 1980, and gave birth on 01 March 1981, an gestation of 179 days. This gestation period compares favorably with the one period of 180 days reported by Winbigler (1977), and the 180 days estimated for Himalayan tahr (Caughley, 1971). This gestation period can be used to estimate dates of conceptions leading to the 1981 births, as a means of comparing the 1980 and 1981 rutting seasons.

In 1981, the first young of the year was observed on 10 January, and this was considered as the start of the birth season. From then until births declined in mid-February, I attempted to find all females in the Vaguvarrai intensive study subpopulation daily Because of the large number of collared females, it was possible to keep track of the subsequent births on a daily basis. The distribution of these births is shown in Fig. 12. There was an initial peak, with additional births trailing off until the last of the season on 01 April. However, there was also a conspicuous gap in the parturitions between 23 January and 31 January.

This distribution of births spread over a period of 80 days shows a remarkable similarity to the skewed distribution of births calculated by Caughley (1971) for Himalayan tahr, especially if the Nilgiri tahr distribution curve were smoothed by probit analysis as Caughley's was.

Estrous, as indicated by copulation, tolerance of mounting, and high frequency of courtship displays was recorded for 28 females (Fig. 12). Only one female was recorded in estrus twice, at an interval of 49 days (15 July-02 September). Since nearly all

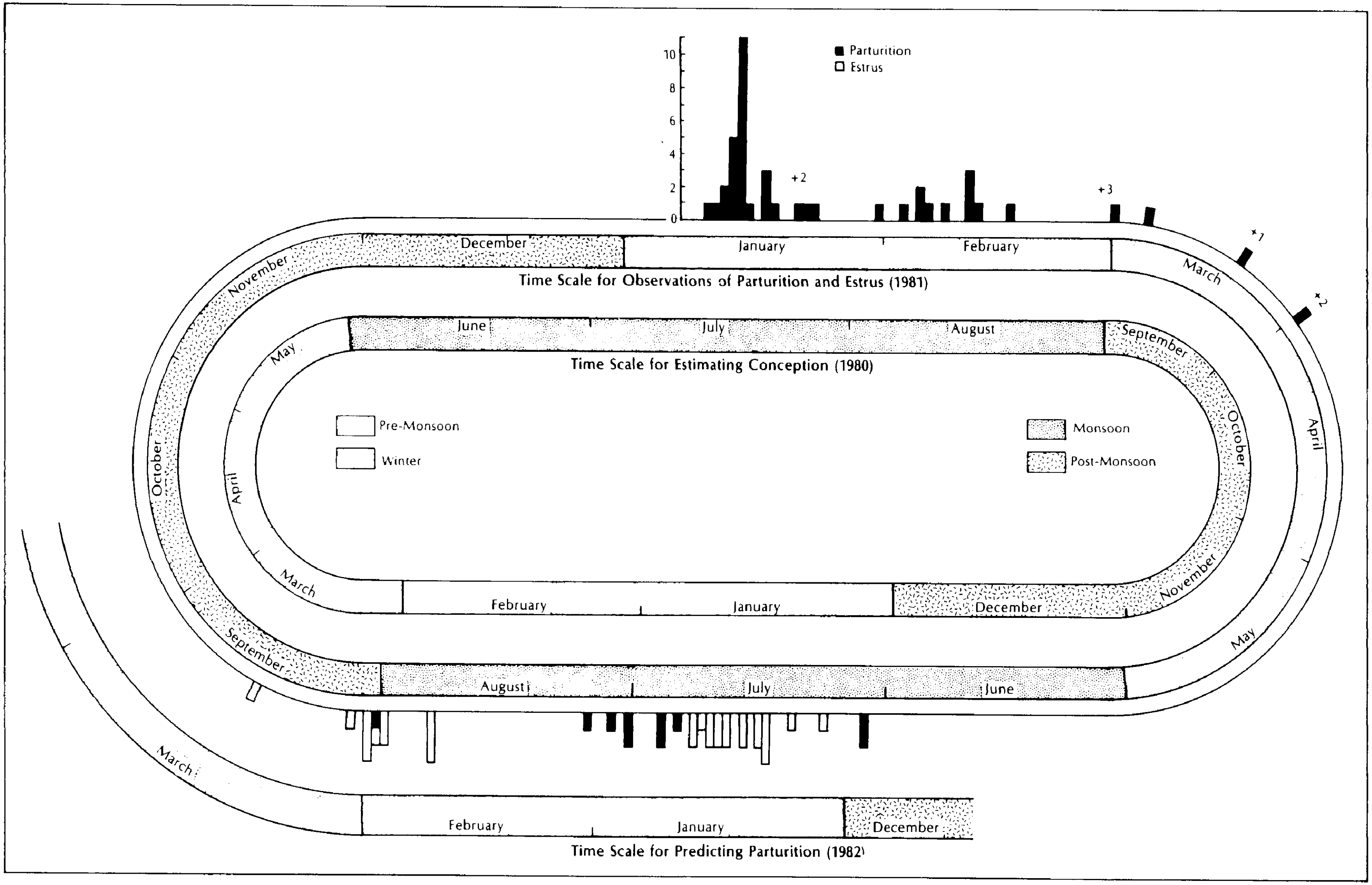


Fig. 12.--Reproductive activity: Histograms show observed births and estrus for 1981. Scales for estimating 1980 conceptions (from 1981 births), and predicting 1982 births (from 1981 estrus) are also given.

sexually mature females gave birth in the main (winter) birth season of 1981, and assuming that this was the case in 1982 (after the study ended), the logical conclusion is that the conception rate (per estrus) was very high (over 90%).

There were also two distinct periods of estrous activity, separated by a gap of 32 days (Fig. 12).

In 1981 there was also a series of births which occurred during the monsoon. Their distribution is shown in Fig. 12. Of these births, two were to collared females whose young had died early in the season. Blrw's was first seen on 12 January 1981, already dead. She gave birth to her second young that year 197 days later. Rrw's first young was born on 15 January 1981 and was missing 14 days later. She gave birth to her second young 184 days after this. These records indicate that females which lost their young early in the birth season, come into estrus again quite soon, and conceived again. The clustering of the other monsoon births would seem to indicate that the other females showed a similiar pattern. Of the individually recognized females which gave birth in the monsoon, two showed definite subsequent signs of estrus 36 and 24 days later.

In New Zealand, Himalayan tahr give birth from November-January, with the mean day of birth calcualted as 26 November (Caughley, 1971). In the Himalayas, the birth season falls from mid-April--mid-July (Schaller, 1973). These spring-early summer birth seasons are typical of temperate ungulate species, and are presumably an adaptation which favors survival of offspring born at the time of warming temperatures and increasing forage production.

In contrast, the births season for Nilgiri tahr was January-March, with the mean date of birth at 26 January. This means that most births preceded the burning and subsequent vegetative regrowth. Since energetic requirements for the female are highest during late gestation and early lactation, it seems clear that the selective pressure for births to coincide with vegetative conditions are not significant. Either that, or the burning has not occurred for a long enough time to change pre-existing patterns.

The start of the birth season does, however, correspond to the final withdrawal of the post-monsoon moisture, a time when days are sunny and mild, and night cold and clear. The occurrence of the birth season at this time would seem to indicate that timing of births is primarily an adaptation to these conditions.

Nilgiri tahr are also capable of giving birth during the monsoon, enabling a female to have two attempts at raising a young in a year. Thus, unless reports of twinning are mistaken, female Nilgiri tahr have two options for maximizing reproductive output.

The Predators

There is ample evidence that predation is an important mortality factor in Nilgiri tahr life history. Predators observed in Eravikulam National Park which might prey upon tahr include: tiger, leopard, Asiatic wild dog, jackal, and humans. This evidence is both in the form of direct observations, and indirect inferences. For recent kills the predator involved can often be identified by examining the kill and the surrounding ground. For instance, the wild dog's propensity for killing sambar in the water usually leaves little doubt as to their involvement. Tooth marks or the manner in which the prey has been consumed can also be important indicators. In other cases droppings or tracks in the vicinity implicated a certain species. A summary of observations on predator species made during the study is shown in Table 19. The number of sightings refers to the total number of times a species of predator was seen, regardless of the number of individuals involved. The number of interactions, on the other hand, reflects the number of interactions with any one prey, including mutiple chases and kills. The earlier stages of an approach, attack, and kill sequence were assumed to have taken place in cases where only the later stages were observed. Although these frequencies reflect my own movements and habits as much as it does those of the predators, some insight into the roles these predators play is reflected in them.

Remains of prey found in predator droppings also gives an indication of the activities of these predators. The occurrence of prey remains in predator droppings collected during the study is given in Table 20.

Tiger

Tiger are not numerous at Eravikulam National Park, as one might expect considering the elevation, rough terrain and open habitat.

Table 19.--Number of observations on predators during this study in Eravikulam National Park.

		Leopard					
	Tiger	Black	Spotted	Both	Wild Dog	Jackal	Human
Sign							
Tracks	43	-	-	8	2	4	-
Scrape	2	-	-	9	-	-	-
Sightings							
Total	11	7	3	11	17	21	8
In tahr home range	4	7	3	11	11	11	2
Apparently hunting							
Tahr		2	2	4	4		2
Sambar	1	1		1	4		2
Interactions							
Approach							
Tahr		2	2	4	8		2
Sambar	1	1		1	4		
Attack							
Tahr		1	2	3	7		1
Sambar	1				2		
Kill observed							
Tahr			1	1	6		1
Sambar					1		
Kills attributed							
Tahr				1	1		1
Sambar	1				13		
Gaur	1						

In fact, all four of the tiger sightings during the study and the one sighting during the preliminary study in 1978 in which I could see the facial markings were of the same female. All of my sightings were of solitary tigers, but Wildlife Preservation Officer M. Alambuth (pers. comm.) encountered a subadult tiger and tracks of an adult and subadult on the north side of Kattu Malai. Whether

Table 20.--Percent occurrence of prey remains in predator droppings collected during this study from Eravikulam National Park.

	Tiger	Leopard	Wild dog	Jackal
Gaur				1
Sambar	94	38	90	6
Nilgiri tahr		29	8	1
Barking deer	11	10	5	1
Nilgiri langur		27		
Porcupine		4		1
Rodent		6		91
Bird				6
Lizard or Snake		6	3	31
Crab				1
Insect		4		10
No. of droppings	18	48	40	139

this was the same individual female is uncertain. I encountered tiger tracks much more frequently than those of other predators, on a total of 43 occasions (Table 19). This is probably more an indication of their propensity to travel along man-made roads (Schaller, 1967; Seidensticker, 1976; Sunquist, 1981), than it is an indication of their level of activity in the area. Tiger scrapes, on the other hand, were rarely encountered.

Of the 11 tiger sightings, only 4 were in a tahr home range, and in none of these cases did the tiger appear to be hunting tahr. I observed tahr and tiger encounter each other twice, both times apparently by coincidence. On 29 March 1981, a group of 27 tahr were climbing a ridge on the northeastern flank of Turner's Valley. At 1130 a tiger casually crossed the west side of a knoll about 250 m ahead of them. Although the tiger did not seem to notice the tahr, they saw the tiger. They did not show a strong alarm reaction at that distance, but did cease their movement, and by 1200 they had reversed their direction of movement.

Another encounter occurred when a tiger climbed out of a ravine, surprising a group of tahr on a grassy ridge top during a rain shower on 19 June 1981. The first tahr to see the tiger, a female resting on the group's perimeter, jumped up and ran directly away from the tiger, and as the tiger came into full view, the entire group dashed off, and then kept moving, running and walking, until I found them 7 min later, standing about 150 m away, still some 75 m from the nearest cliffs. Although the tiger had moved right to this group, it made no attempt to conceal itself, either before being seen by the tahr, or afterwards, despite the availability of cover in the form of numerous *Strobilanthes* shrubs. The interaction, however, was interrupted prematurely when the tiger caught a glimpse of me, at which it turned and slipped back into the ravine from which it had come.

I found one fresh sambar kill near a small lake in open grassland which I attributed to tiger. Hairs in tiger droppings gave another indication of the extent to which tiger prey on sambar (Table 20). This evidence supports the observational evidence that tiger do not prey on tahr, but depend primarily on sambar for sustenance. On the other hand, Davidar (1971) found tahr hair in two of the five tiger droppings he examined from the Grass Hills.

While Sunquist (1981) maintains that gaur are "virtually invulnerable" to tiger predation by virtue of their large size, this was not the case at Eravikulam. I found one gaur cow on the flats of the central plateau which had evidently been killed by a tiger. She bore numerous canine punctures on both the throat and nape, indicating numerous bites by the tiger, and a claw mark on the shoulder. Sunquist (1981) and McDougal (1977) agree that the nape bite is used for smaller kills, while the throat bite is used in killing larger animals (over about 90 kg). This tiger had quite obviously used both repeatedly on this very large prey (about 500 kg). Also, of the four tiger droppings collected in the Grass Hills in 1978, an area where gaur seemed to be more plentiful, three contained gaur hair. Schaller (1967) also reported gaur remains in tiger droppings from Kanha National Park in central India.

Leopard

Both black and spotted phases of leopard occurred in Eravikulam National Park. Although the number of sightings of the black phase is more than twice that of the spotted, these may all be of two individuals as they were all within a limited area of about 6 km^2. These leopards probably ranged outside of the area in which I encountered them, and probably used an area similar in size to the 8-10 km^2 estimated for leopards at Wilpattu National Park, Sri Lanka (Eisenberg and Lockhart, 1972), or Chitwan National Park, Nepal (Seidensticker, 1976). If this is the case, Eravikulam National Park could harbor upwards of 10 leopards, with others inhabiting adjacent forested areas. With the exception of one pair, all sightings were of single leopards.

Leopard tracks were met with much less frequently than those of tiger, primarily because leopards used man-made trails much less frequently than tiger (see also Sunquist 1981). Most of the tracks I encountered were along a soft dirt game trail along the western rim of Turner's Valley. Leopards also frequently left scrapes in this area, which coincided with the southernmost limit of my observations of the black phase.

In marked contrast to tiger, all leopard sightings were within tahr home range, and they appeared to be hunting tahr on 4 of the 11 sightings. Tahr reacted strongly to the presence of a leopard, but nevertheless, tolerated and even maintained a close proximity to them as is illustrated by the following observations from my field notes:

> At 1410 on 29 April 1980 the tahr I am observing alert me to the presence of a spotted leopard on a rock slab below the grassy slopes we are on. Several tahr cluster at the top edge of the slabs, standing alert and giving numerous alarm calls. The leopard, without any attempt at concealment, moves across towards the tahr,

passing about 10 m below them. At the same time, the tahr at the edge of the slabs mill about, some individuals turning as if to run up the slope, only to turn about and return to the edge of the bluff. The leopard moves out of sight briefly, but the tahr's attention stays on it as it moves around below. The leopard makes a sudden rush up through a break in the slabs and the tahr scatter, some turning up hill, others down onto the slabs, but all turn in a tight circle to face the leopard again. The leopard looks up, directly at me 25 m in front of it, sits for a moment, and then drops to the ground and slips from view into a small gully at 1420.

On 22 May 1980 the tahr again draw my attention to a black leopard with a series of alarm calls. As I locate it on the slabs across the ravine they are turning to watch it at a distance of 10-15 m, with only rock slabs between them. The leopard runs through the group and past them and around the corner of a ridge. The tahr follow as the leopard moves from view, and cluster tightly at the corner of the ridge, calling continually. Occasionally some turn and run from the edge, then turn about to join others. In this fashion the tahr "leap-frog" up the ridge, evidently as the leopard moves along the far side at 1220. I move to a vantage point on the other side of the same ridge to find the leopard and tahr looking at each other about 8 m apart. The leopard walks towards some of the tahr, and they, in turn move from it, calling continually and giving an occasional stamp. At 1303 the leopard lays down on a patch of grass, looking at about 15 tahr clustered above, looking back at it. Tahr calling continues. Leopard rests head on the grass at 1306, but continues watching the tahr. Leopard gives a grimace, 1308, then raises and waves his tail, and rises at 1313. Tahr renew their calling. The leopard moves forward and the tahr scatter, keeping about 6 m from it as it moves from view. Part of the leopard is visible as it rests again, 1317. Tahr relax somewhat, look away, and one rests on a slab at only 10 m from the leopard, 1323. At 1329 some of the upper animals start to drift up the slope. As the leopard crouches, then rises tahr call, 1352. The leopard yawns, turns and moves from view. The tahr watch as it evidently moves off, follow it a bit, and then turn back to the slabs at 1359. I later estimated the slope of these slabs at 45°, a steepness over which I could move only with great care.

The following generalizations can be drawn from these accounts.

The tahr show typical alarm behavior in the presence of a leopard, including an erect, attentive posture, alarm calling, and clustering together. However, despite the obvious arousal evidenced by their behavior, the tahr do not flee from a leopard when they encounter it on steep rock slabs, but remain in the vicinity, and keep close watch until it departs.

These accounts also illustrate the importance of surprise for a leopard hunting tahr. Neither one seemed to have the slightest chance of obtaining a meal once the tahr were aware of their presence. Suprise appeared to play an important role in the one kill I did observe. On 16 September 1980 at 1800 a group of tahr were just moving from view around a ridge about 200 m across a valley from my observation point. Abruptly their attention focused into a small gully below and beside them, and they clustered together giving the characteristic alarm calls. A few seconds later a spotted leopard emerged from the bottom of the gully, with a tahr Yg, apparently already dead, grasped by the throat. The leopard paused to look back up at the mob of tahr, and then continued down and across the slope, dragging its kill between its forelegs. The leopard then moved on into a nearby shola.

Upon investigation the kill site, I flushed the leopard down into the shola. The next morning, I located the Yg, about 100 m further down. It had not been eaten, and the tooth marks on the throat were the only injuries. The leopard's left canine had penetrated below the left ear, and the right canine, just at the back of the mandible. The leopard's lower jaw had clamped on the throat, probably causing death by strangulation. There was considerable internal hemoraging but no external bleeding.

The practice of dragging the kill into a nearby shola appears to be typical for leopards. Game guide R. Mudhuvan recounted a nearly identical incident to me. I also found an LLbm which had apparently been killed by a leopard, which had started to drag it down the slope. However, the tahr's horns and chin had become wedged between two clumps of Chrysopogon zelanica, and the leopard had fed of the hindquarters in the open. However, after I collected the head, the leopard returned, and dragged the carcass to the brink of some steep slabs, and let it tumble to a patch of forest below. Sign showed that the leopard proceeded to drag the carcass a few meters into the shola, and then fed from it on several successive nights.

Since leopards depend on concealment to get close enough to their prey to gain the advantage of surprise, the sharply contrasting color phases of leopard, spotted and black, has important implications for their success in hunting. In the relatively open terrain of Eravikulam, the jet black coloring of the dark phase is conspicuous to such an extent that one might expect them to be obligatory nocturnal hunters. However, this was not the case, as black leopards were seen active and hunting in broad daylight, as evident in the accounts given above. Robinson (1969) has demonstrated that the black phase represents a double recessive genotype, and gives evidence that the recessive incurs some reproductive cost. Spotted females had an average litter size of

2.09, whereas black females had an average litter size of 1.70. This apparent cost of melanism must be counteracted by other advantages for the trait to remain in the population. Presumeably, the advantage is that black leopards have greater success in hunting at night.

In addition to tahr, a leopard was observed stalking sambar on one occasion, and prey remains in leopard droppings indicate that sambar, Nilgiri langur, and barking deer are important prey for the leopards at Eravikulam (Table 20). Leopards clearly have the most diverse diet of the predators in the area. Leopard droppings from the Grass Hills indicate that they also prey on gaur calves, since five of the six droppings contained the characteristic light brown hair of gaur calves. On the other hand, all of the dozen leopard droppings I collected in tahr habitat in the Mukerti area of the Nilgiri Plateau contained tahr hair.

Asiatic wild dog

Unlike tiger and leopard, all indications are that wild dog are not resident within Eravikulam National Park. Prior to 1981, I encountered them on only three occasions, which consisted of sightings of a single dog, a pair, and one trio. The first evidence that a pack was present was when a sambar kill was made near Eravikulam Hut around the first of the year (1981). They continued to be active in the area until the end of the study in September 1981. According to Game Guide R. Mudhavan, wild dog in the area follow a vertical migration. He told me that for about the last 5 years large packs of 20-25 have moved up from the lowlands in the vicinity of Chinnar, to the northeast. The dogs reportedly split up into smaller groups in the high country, and stay 6-8 weeks before returning to the lowlands. This pattern was said to be repeated about every six months. I was unable to confirm this pattern, but the lack of observations for extended periods certainly indicate that they spend a large proportion of their time elsewhere. Despite this short term of activity, wild dog were encountered more often than both tiger and leopard, an indication of the wild dog's diurnal habits.

Most of the sightings were of the entire pack of nine dogs. Wild dog do not show a predeliction for roads, and their tracks were rarely encountered. Unlike the felids, wild dog did not leave scrapes, but they did occasionally deposit feces in group defecation sites.

Also, unlike felids, wild dog made no attempt at concealment, but approached their prey openly. By the same token, tahr did not show a very pronounced reaction to wild dog, as the following account from my field notes illustrates:

> At 1143 on 19 May 1981 a few dozen tahr are on the slopes of Eravikulam Malai. They are about 120 m from, and around the corner from the rock slabs on the east end. Moving in a single line, nine wild dogs traverse across about 100 m below the tahr. One dog is out in front, as five of them rest at a gap in a subsidiary spur. The lead dog continues ahead as the tahr stand and watch and give a few alarm calls, 1147. More dogs come onto the crest of the spur, and one dog cuts off to the west, as the main body remains clustered at the gap. The tahr just stand

> above 1153. A couple of the dogs start zigzagging up the hill towards the tahr. At about 30 m the first tahr turns to move off, while most just stand. The topmost dog gallops up the slope and all the tahr now start moving, then gallop around the corner. Only one dog continues the pursuit just 5-6 m from the last tahr, most of which continue around the corner. The second of the leading dogs turns back towards the others scattered 40-60 m below. As the only dog near the tahr approaches, two straggling tahr stand and watch, one looking back over his shoulder, the other facing the dog. As it runs towards them, the tahr turn only when it approaches within about 1.5 m, and take flight. The dog runs along with them, keeping parallel and above. Tahr on slabs above stand watching. At 1202 one of the dogs still below at the gap in the spur initiates the pursuit of a sambar doe and fawn, and all the dogs scattered above come down to join in (see below).

Tahr also are capable of fending off attack by wild dog. The was demonstrated by a Dbm earlier on the same day. The dogs came across the base of Eravikulam Malai at 1110, surprising some tahr in a gully low down on the mountainside. Several tahr took flight across to the east, but one Dbm climbed onto a small rock projection and turned to face the two dogs that approached him. Wild dog and tahr faced each other, about 1 m apart, the tails of the dogs waving high in the air, as a third dog joined them. Meanwhile two of their companions have chased another tahr off to the east, and leaving the Dbm, these three turned to follow. The Dbm then moved to another, slightly higher nearby outcrop. As some of the pack moved down onto the grassy flats just below, two dogs returned to the first boulder, and then up to the new location of the Dbm. The tahr moved out onto the small (ca. 2 m^2) flat top of the the projection, and whirled to present horns to the first wild dog to arrive. More dogs arrived, and the tahr continued to stand facing them as they crowded around the entrance onto the flat top of the boulder, 1119. Two dropped down the side in an apparent attempt to find a way up the back side of the boulder, without success, and the dogs departed at 1120. The dogs, now clearly nine, moved off to the east in single file 3-10 m apart. The Dbm left the rock projection and moved west and up the slope at 1123.

However, one should not infer from these accounts of the tahr's mild reaction and successful defense that wild dog are not a threat to tahr, as quite the opposite is the case.

> 17 July 1981. At 0750 a wild dog arrives from the west disturbing a large group of tahr at an artificial salt lick at the base of the south side of Eravikulam Malai. Tahr take flight across the slope to the east, the balance of the pack arrives and quickly closes in on a lagging F tahr. First one, and then a second dog bite and hold the back of the F's thigh, greatly slowing her progress as she makes no apparent move to defend herself. A third dog runs around the front and grabs her by the nose, hanging onto it as she struggles to remain upright. After about 1 min, she is pulled to the ground, as tahr and sambar watch from a distance, although none give alarm calls.
>
> As two of these dogs commence feeding, one of the three dogs leaves the fresh kill and runs up the slope towards a isolated F standing on a rock slab. The F turns from the approaching dog, but runs across the slab only when nipped in the flank. The dog appears hesitant to cross the wet slabs and turns back down to the kill. As the rest of the tahr and sambar move off to the east.
>
> Now, 5 min after the wild dogs first appeared, it becomes evident why only three dogs attacked the F. Four more are feeding on another kill, a Yg, about 150 m to the west. Another two dogs are feeding on a third kill, also as Yg, about 75 m below the second.

The manner of attack by Asiatic wild dog resembles in many way that of other pack hunting canids such as the wolf (Canis lupus; Mech, 1966) and African wild dog (Lycaon pictus; Estes, 1967). The prey is chased, and grabbed by whatever location is available, the back of the thigh in this case, and when opportunity presents itself, the muzzle is grasped by one individual, and the combined attack of the predators pulls the prey to the ground. There are, of course variations, but this general technique is found in all of these species.

Evidence from scats (Table 20) indicated that sambar were the primary prey of wild dog, and that tahr and barking deer were also taken on occasion. They also will evidently eat an occasional reptile when the opportunity arises, although I never saw them hunting them. Like most predators (Schaller, 1967; Kruuk, 1972), wild dog will scavenge when given the opportunity. This same pack consumed a tahr carcass known to be a few days old.

Jackal

Jackals were seen occasionally, sometimes in pairs, but more commonly alone. Many of these sightings were in tahr home range (Table 19), but they were never seen pursuing tahr. Probably the only time jackals could prey on tahr would be during the first week or two after the tahr's birth, as older tahr would most likely be able to defend themselves from attack. However, there was no indication that even this occurred, and the only observations I had of them hunting, were of small grassland animals, probably rodents. On a few occasions jackals passed close to groups of tahr, but neither species showed much interest in the other. This may be a factor in the tahr's rather mild reaction to wild dogs. Although there are certainly differences in size and coloring between jackal and wild dog, they resemble each other closely in many respects. Since jackals are resident on the plateau, and the wild dogs are only occasional visitors, it seems at least possible that the tahr are in fact, reacting in part to the wild dogs as if they were jackals.

Remains of prey in jackal droppings (Table 20) indicate that jackal use a wide variety of food sources, but are heavily dependent on rodents. The one dropping containing gaur hair was found in proximity to the gaur killed by a tiger described earlier. This was obviously a case of scavenging, and the same is presumed to be the case with the other ungulate remains found in jackal droppings.

Humans

The potential for humans having an impact on prey populations in Eravikulam National Park is great considering the small size of the park and the proximity and concentration of human settlements along the southern and eastern boundaries (Fig. 2). Much of the human population in these areas is labor for the tea estates bordering on the park. The managers of these estates are very supportive of conservation and preservation of wildlife within the park and in adjacent areas, and they use their influence to minimize disturbances. However, such are measures are not absolutely effective, and some incursions do take place. Of even greater importance are the settlements of independent farmers and townfolk further to the north. These people have ready access to the park, as do those living in isolated settlements west of the park.

Of course, some humans enter the park legally, but there are no tourist facilities, and visitation to the park is infrequent. Also, some people enter the park in order to gather plants or plant parts. This is confined primarily to two species. Cane (Calumus tenuis) is collected from some shola areas for use in making furniture and other handicrafts. Also, Drosera peltata, a small grassland forb desired for its medicinal properties, is gathered in the post-monsoon. I encountered 19 parties totalling 80 individuals gathering this plant between 14 October and 16 December 1980.

None of these types of visitors have been included in Table 19. Of the eight parties seen, six contained men armed with muzzleloaders. I heard one or more gunshots on 11 occasions during the course of the study, giving some indication of the frequency with which these guns are used. Domestic dogs were also used in hunting, and three of the parties were accompanied by dogs. Hunting in Eravikulam was presumably for meat. However, a comercial meat operation based on wildlife products was rumored to operate out of the town of Marayur, to the northeast of the park.

One party of men unknowingly demonstrated their method of hunting tahr to me. On 21 February 1980, five men, two of whom were armed, accompanied by five domestic dogs were first seen along the northern flank of Inaccessible Valley at 1115. After apparently not locating suitable prey on the slopes above, the men moved down towards the valley floor, and out of sight at 1130. Then at 1145 the two armed men and one of the dogs reappeared traversing along the top of a low set of cliffs. Two other men were at the base, and three dogs were up amongst the cliffs, where they were attempting to reach a solitary S. However, before the lower men could signal those up top, the S made its way off to the side and out of sight. The men then reassembled and moved off in the direction the S had gone at 1239. In light of the behavior described earlier for the Dbm confronted with wild dogs, it appears that these men anticipated a similar reaction, and using their domestic dogs to confine and occupy the tahr, hoped to then be able to approach and shoot it.

This was evidently what transpired in another incident on 16 July 1981. I first heard dogs barking, evidently in chase, and a shot fired across Turner's Valley at 0953, but mist obscured the view. The barking resumed at 1002, followed by another gunshot. The mist then cleared at 1014, and I saw five men, two of them armed, dropping down a ridge on Poola Malai, to a point where it ends in a set of cliffs. The men apparently saw me as well, as I was sitting in the open about 1 km across the valley, and they moved down beside the cliffs to the edge of a strip of shola, apparently hiding. One of their dogs, however, moved up to where a S was lying in a shallow gully. Eventually one man crawled up and brought the S down to the shola, which was the last I saw of them.

If my deductions are correct, one collared female was shot a day or two before I found her on 03 May 1981. The only marks on her body were a pencil sized hole in the middle of her right side, and some flesh missing from her udder and inguinal region, which probably corresponded to the exit point. (The pack of wild dogs scavenged this kill before I had the opportunity to perform a more complete necropsy).

Tahr are also poached using wire snares. I found one such setting at the southern end of the park, made of stiff wire about 3 mm in diameter. An LLbm showed up in the Vaguvarrai home range wearing a collar of similar wire, and one female in a large mixed group in the Grass Hills sported a colorful wire noose.

Although I have scanty data on interactions between tahr and poachers, I had ample opportunity to observe their reactions to my own presence. At the onset of the study, tahr showed a flight distance from me of about 300 m, and individuals outside the Vaguvarrai intensive study area retained this response through the course of the study. Tahr moved away at even greater distances, but then usually at a walk. When surprised at closer proximity when the nature of the disturbance was plain, tahr took immediate and direct flight. The nature of this flight was as if the tahr had two priorities: (1) to increase the distance between themselves and the human, and (2) to get out of sight. In cases where these two aspects conflicted, the later seemed to take precedence. However, I never saw tahr move closer in an attempt to get out of sight, but they did sometimes move at right angles to the line between us if that took them immediately out of my view. If the tahr were away from the typical flight cover of steps cliffs and slabs, moving in the direction of these also seemed to be a priority. Once out of sight, tahr usually walked quickly to slabs or cliffs if none were in the immediate vicinity. Once on the slabs, they usually stopped and stood, the grey pelage of the females and subadults closely matching the color of the gneiss. They often did not move further than the nearest appropriate terrain upon first being disturbed, but moved much farther if disturbed a second time. On rare occasions tahr took flight across the open plateau. The longest flight I recorded was about 1,200 m, across the north side of the top of Kattu Malai.

When not running flat out, alarmed tahr gallop with a distinct rocking horse-like gait, striking the ground forcefully with both the hind and forelegs.

Comparisons

In Eravikulam National Park, tiger, leopard, and jackal may be considered residents. While it is not possible to state their abundance in absolute numbers, the evidence indicates that tiger are few, whereas leopards are more numerous. Asiatic wild dog and humans are temporary visitors to the park, and their numbers may fluctuate accordingly. Wild dog appear to visit the high country, including the park, for several months at a time, whereas human visits are presumably of a duration of a few days or less. At present there does not appear to be any immediate danger of the park being overrun by humans.

It is clear that tahr react quite differently to the different predator species. The leopard, a stalking predator, is kept under surveilance until it leaves the area, whereas wild dog do not elicit a strong reaction. A similar difference in the reaction of prey species to stalking and non-stalking predators was noted by Schaller (1972) in the Serengeti ecosystem. The tahr's flight distance from man is commensurate with the distance at which man can inflict damage on tahr. The manner of flight is also in keeping with the method of attack, since line of sight, and "line of bullet" are essentially the same. Thus, one cannot specify a generalize "predator response" for tahr, since the response varies significantly with the predator involved.

This review of predator-prey relations at Eravikulam National Park has shown that while tiger probably play an insignificant role in Nilgiri tahr life history, leopard and Asiatic wild dog have a significant role in this regard. However, both leopard and wild dog utilize the sambar prey base more heavily than they do the tahr.

Social Behavior

Description of Social Behavior

The explicit social behavior of Nilgiri tahr falls into three main categories: agonistic, sexual, and mother-infant behavior. Each of these categories can in turn be divided into various subcategories, as is shown in Table 21. A categorization such as this has both advantages and disadvantages. One of the main

Table 21.--*Percent observations of each category of Nilgiri tahr social behavior during June-September 1981.*

Behavior category	%
All interactions recorded	
Agonistic behavior	41.7
Sexual behavior	52.7
Mother-infant relations	2.5
Related maintenance behaviors	1.7
Not defined	1.1
Total: 16,637	
Agonistic behavior	
Aggressive displays	28.9
Aggressive actions	48.8
Submissive actions	22.2
Total: 6,816	
Aggressive displays	
Threats	34.5
Dominance displays	35.0
Arousal context	26.7
Uncertain designation	3.7
Total: 1,978	
Threats	
Horn present	82.6
Lunge	17.4
Total: 683	
Dominance displays	
Hunch	78.1
Head out	8.2
Stare	7.8
Hunch-sidle	5.9
Total: 693	
Aggressive display in arousal context	
Spray urine	52.9
Bump forehead	6.6
Object aggression	34.2
Cavort	4.4
Jump twist	0.2
Mouth penis	1.7
Total: 529	

continued

Table 21.--Continued

Behavior category	%
Aggressive display of uncertain designation	
Nod	8.2
Headshake	87.7
Poke	4.1
Total: 73	
Aggressive actions	
Head-on clash	6.5
Side clash	38.2
Reverse parallel fight	12.7
Neck fight	2.6
Hook hoof	1.6
Butt	2.9
Hornjab	1.2
Parallel shoulder push	1.1
Hook behind foreleg	0.1
Chase	2.7
Approach	25.8
Side clash pressing	2.2
Head-on clash pressing	0.9
Hook hind hoof	0.5
Hook horn	0.9
Total: 3,537	
Approach	
Walk	89.4
Rush	10.3
Not specified	0.2
Total: 909	
Submissive actions	
Defer	94.2
Flight	5.4
Dribble urine	0.4
Total: 1,515	

continued

Table 21.--Continued

Behavior category	%
Defer	
Stop "offensive act"	6.4
Turn away	11.4
Graze	1.5
Turn and cut	2.2
Move away	53.3
Scoot aside	13.3
Back away	2.2
Not specified	9.6
Total: 1,427	
Sexual behavior	
Courtship displays	68.7
Sexual acts	15.6
Female responses	15.8
Total: 8,938	
Courtship displays	
Side twist	40.1
Side sniff	14.7
Rear twist	39.6
Rear sniff	4.7
Flick (alone)	0.6
Kick (alone)	0.2
Total: 6,140	
Sniffs and twists	
with Kick	17.0
with Flick	22.8
with Whoosh	7.6
with Hum	1.1
Total: 6,138	
Sexual acts	
Mount intention	5.5
Mount attempt	7.9
Mount	18.8
Perineum sniff	17.8
Flehmen	50.0
Total: 1,391	

continued

Table 21.--Continued

Behavior category	%
Mounts with:	
Thrusting	28.2
Groan	4.6
Both	5.0
Not specified	62.2
Total: 262	
Mount copulation status	
Very likely	6.9
Possibly	20.6
Not likely	46.9
Not specified	25.6
Total: 262	
Female responses	
Urinate	52.7
Flinch	6.5
Scoot away or out	14.1
Struggle out	2.8
Rise	17.7
Anxiety call	1.1
Run	5.1
Total: 1,409	

advantages is that it provides a conceptual framework in which to consider the individual behaviors. A major disadvantage is that it requires considerable interpretation as to the meaning and function of the various behavior patterns, and does not lend itself to the consideration of transitional or multi-functional behavior.

The social behavior of Nilgiri tahr has been described to some extent by Schaller (1971, 1978). I have usually chosen to follow Schaller's names for the various behavior patterns, but have deviated from his terminology on a few for which an alternate term seemed more appropriate Schaller himself uses different terms for some of the behaviors in his 1971 and 1978 accounts, and these are referenced in parenthesis where they differ from mine.

In Nilgiri tahr, agonistic behavior consists of aggressive acts, aggressive displays, and submissive acts. I saw no indication of distinct postures or displays associated with submission, and therefore, there is no category of submissive displays.

Aggressive actions usually involved physical contact between the opponents, and the physical contact, or the positioning for it, was the apparent intent of the action. The simplest of these was an approach, where the initiator moved towards its opponent with aggressive intent, either at a walk or a rush, but while giving no clear display or posture. Of course, a tahr might approach another for any of a number of non-aggressive reasons, and it was not always possible to determine the exact motivational state of such an individual. For this reason, approaches were only recorded as such, when the aggressive motivation of the initiator was clear to me. There were, no doubt, other occasions upon which such an intention was present, but not noticed.

A chase simply refers to a tahr's pursuit of another according to the usual meaning of the word. I divided chases into those which were short, that is more-or-less linear, and contained within the perimeter of the group; those which were long, that is also more or less linear, but where the opponent was chased out of the group; and those where one animal was chased around through the group.

The preceding aggressive acts were somewhat exceptional, in that they did not involve contact between the two partners. The simplest form of contact was in the butt, where one tahr swung his head down, bringing the front of the horns into contact with the body of another animal. Such a move was sometimes accompanied by a step forward, emphasizing the blow. Of 99 butts, 20% were to the flank, 13% to the shoulder, 10% to the neck, 10% to the muzzle, 7% to the rump, 6% to the horns, and 10% to the head, side, chest or leg. The place butted was not specified in 23%.

On the other hand, sometimes the initiator pulled his chin in as he lowered his head and pulled it to one side, to make contact with the opponent with the tip of his horns as he swung his head back up and/or across in a horn jab. Forty-three hornjabs were directed towards the hind leg (26%), the flank (26%), the shoulder (9%), or the chest, foreleg, belly or rump (16%). The place hornjabbed was not specified in 23%.

Aggressive contact was often with the horns. In the head-on clash (head-on butt, Schaller 1971), both partners lowered their heads to make contact in a mutually frontal orientation, at least with respect to their heads. Usually, the contact was in the form of a quick sharp blow, but occasionally tahr also sustained contact by pressing their horns together for a second or so.

In the side clash, tahr typically stood with an angle of about 45° between their body axes, and bending their necks, brought the rounded outside-front surface of the one horn on that side in contact with the opponent's horn. As was the case with the head-on clash, side clashing was also sometimes a sustained pressing contact.

Tahr also uncommonly hooked their horns together (hook horn). This happened sometimes as two partners were reverse parallel fighting. As they swung back from the lateral blow at the same time, and caught each other's horns. It also occurred in the course of sparring among younger males.

However, much of the fighting and sparring in tahr was not in the form of horn to horn contact. When reverse parallel fighting (shoulder push, Schaller 1971, head-to-tail, 1978) the opponents stood parallel to each other, but facing in the opposite direction. They stood roughly shoulder to shoulder, and thus each animal's head was about even with the flank of his opponent (not the tail as Schaller's term indicates). The contact consisted of a combination of movements, including pushing against the partner with the shoulder and, while turning the horns in towards the opponent's flank, pulling the head across, upwards and back, usually striking the opponent in the side. These movements were performed mutually, but not necessarily simultaneously, as each tahr attempted to avoid the blows of the opponent by stepping away from them with his hind legs, while remaining in contact or at least close to the opponent at the shoulder. In this manner, reverse parallel fighting tahr usually circled rapidly about each other.

Several fighting techniques were also usually associated with fighting in a reverse parallel position. To hook hoof, a tahr lowered his head to catch his opponents foreleg just above the hoof between his horns. The initiator then pulled his head up, raising the foreleg of the opponent.

A similar technique was sometimes directed towards the hind hoof in hook hind hoof.

Another fighting move, hook behind foreleg sometimes occurred during serious fights. As one tahr swung back in the blow in reverse parallel fighting, the horn tip caught behind the foreleg of the opponent, in the axillary region (the "armpit"). The hooking animal usually continued to pull back and up as his opponent tried to extricate himself.

When neck fighting tahr adopted a variety of orientations, from frontal to nearly parallel. Most commonly the angle between the partners' body axes was more than 90°. The opponents pushed against each others' necks, usually emphasizing the basal portion. Tahr often made a smooth transition between neck fighting and reverse parallel fighting, and there was no clear line separating the two.

Another type of contact was the parallel shoulder push in which the opponents stood side by side and parallel to each other, and pushed and leaned against each other.

In contrast to the aggressive acts, aggressive displays did not involve bodily contact. Some occurred in situations of aggressive arousal, such as when a new male showed up during the rut. Aggressive displays indicating arousal have much in common with dominance displays (and might be considered a subcategory of them), but were not addressed or directed to an a particular individual.

Although a particular individual commonly elicited these behaviors, this was deduced from the context and sequencing only, and was not evident in the nature of the display. To spray urine the male typically lowered his head and tucked his chin in, so that his forehead was a few centimeters off the ground. The penis was erected, and urine squirted or sprayed in a thin stream from the urethral process (Fig. 13). At the same time, the urethral process flicked up and down, directing the flow of urine onto the belly, chest, throat and chin. As a result, males had a distinct, strong odor. The site of a urine spray also had this odor, indicating the smell was the result of the contents of urine, rather than a chemical or biolgical changes having taken place in the urine-impregnated hair.

Often while, or immediately after spraying urine, the male pressed his forehead against the grass one to several times in bump forehead. During spraying, some of the urine ran down and around the outside of the muzzle, and it appeared likely that the bumping of the forehead served to work this urine into the facial hairs.

Aggressively aroused tahr also resorted to object aggression (rub, Schaller 1971). In Nilgiri tahr, object aggression was most commonly directed at the grassy slope, or at a patch of dirt left by a previous animal. However, Strobilanthes or Rhododendron shrubs were also recipients of this behavior on occasion. Generally, a tahr lowered and turned its head sideways so that the side of the head lay approximately flat on the grass. The head was then swept across and back as the horn tips were dug into the ground. At the

Fig. 13.--When spraying urine the flow of urine is directed onto the belly, chest, forelegs, throat, and chin as the urethral flicks up and down.

completion of the sweep, the head was sometimes turned over, so that contact was on the other side for the sweep back, or the head was turned all or partially upright and the chin and or cheek dragged back across the grass or dirt. Tahr often kneeled when performing this behavior, and in such cases the throat was also rubbed on the surface. When directed towards shrubs, object aggression was more similar to simple sparring with the branches.

Several other actions took place consistently in aggressive contexts, but were less clearly linked with other aggressive displays. These included cavorting, in which the animal ran a few strides with an exaggerated bucking, sometimes throwing the hind legs high in the air.

The jump twist took place as a tahr facing another reared up on his hind legs, and then twisted, first the head, followed by the rest of the body, to come down facing away from the other animal. The initiatior then moved away.

A male also mouthed his penis in aggressive contexts, although the display value of this behavior was not clear (Fig. 15).

While the aggressive displays listed so far had display value, that is, they communicated to other animals something of the motivational state of the displaying animal, they were not truly directed in that no particular conspecific was indicated as a consequence of the display. On the other hand, threats and dominance displays did usually quite definitely indicate a recipient. I have followed Walther's (1974) formulations in categorizing threats and dominance displays. Threats are those aggressive displays which indicate "the readiness to fight", often by the use of intention movements towards fighting. For this reason, weapons, horns in the case of tahr, are often brought into play. Dominance displays, on the other hand, do not specifically incorporate the weapons, but rather they seem aimed at impressing the recipient by emphasising certain characteristics of the displaying animal, such as his size or conspicuous markings.

By the terms of this classification, Nilgiri tahr use only two threats. One is the <u>horn present</u>, in which (in the typical case), the initiator oriented towards the recipient, lowered the head and pulled in the chin, directing the front of the horns towards the other animal. This was quite clearly an intention movement to clash or butt, and in some cases (e.g. when the recipient returned the threat), the initial threat was followed through with just that. The orientation for the horn present was generally with the head only, and could be directed in any direction relative the the body axis of the initiator. The extreme case of this was the horn present given by a resting female when courted by males standing behind them, in which the female raised her chin, thus displaying her horns over her back.

The other threat, the <u>lunge</u> consisted of a horn present combined with a rapid rush at the opponent. There is some question as to whether the lunge is truly a threat, or might more appropriately be considered an aggressive act, or attack. This is because the movement of the initiator generally took it to or past the location of the recipient at the start of the interaction, and only the movement of the recipient away from the initiator accounted for the lack of physical contact. However, the consistency with which the lunge-retreat interaction lacked physical contact, and the somewhat standardized intensity with which the interaction took place, suggest that this behavior is frequently primarily of display value. On the other hand, with some lunges is was quite evident that the initiator was making a full attempt at bodily contact, and that only the rapid retreat of the recipient prevented this.

Three displays occurred in aggressive contexts, but it was not quite clear if they were threats or patterns which merely indicated aggressive arousal. Rarely a tahr gave a nod, a quick pull in of the chin. The nod differed, however, from the horn presentation in that the head itself was not lowered, nor was the nod necessarily, or even usually directed towards another animal.

The headshake was a quick lateral twisting of the whole head, without any other appreciable change in posture.

In the poke, the muzzle and neck neck were thrust towards the recipient, and then withdrawn.

Tahr employed several dominance displays. In the hunch (head-down, Schaller 1978) the animal arched its back, lowered the head, often pulling the chin in slightly, and moved with mincing rigid steps. Hunches varied considerably in intensity. At the lowest intensity, the animal arched the back only slightly, and angled the neck downwards and kept the chin extended, while moving with near normal gait. This graded to the opposite extreme, in which the back was very rounded, the neck lowered and the chin tucked in so as to place the muzzle in the vicinity of the forelegs (Fig. 14). At the same time, the tahr moved with a distinctive stiff-legged mincing gait, often moving in an arc around the recipient. The hunch was given while moving, generally in more or less broadside orientation to the opponent, particularly in the more intense displays. Sometimes, however, a tahr hunched while approaching another. Having observed apparently the same display in Himalayan tahr, Schaller (1978) considered this a separate display, the humped approach. However, since the essential posture was not different, I have included these as hunches, although such hunches were usually of a lower intensity. Walther (1974) considers the similar hunched posture of mountain goat (Oreamnos americanus) as a threat, since mountain goats fight in a similar posture in a reverse parallel position, and thus the broadside hunched posture signals a readiness to fight. Nilgiri tahr also fought in reverse parallel position, but serious fights were never initiated with this behavior. Rather there was a bout of side clashing, and the tahr changed to reverse parallel fighting after a number of clashes. Consequently the hunch is not a threat is this species.

Unlike the hunch which was performed while moving, the head out (broadside of Himalayan tahr, Schaller 1978) was given while standing still. While the rest of the body was not maintained in any particular posture, the neck was lowered to slightly below horizontal, and the chin was extended slightly (Fig. 15). This

Fig. 14.--The hunch is often accompanied by short mincing steps.

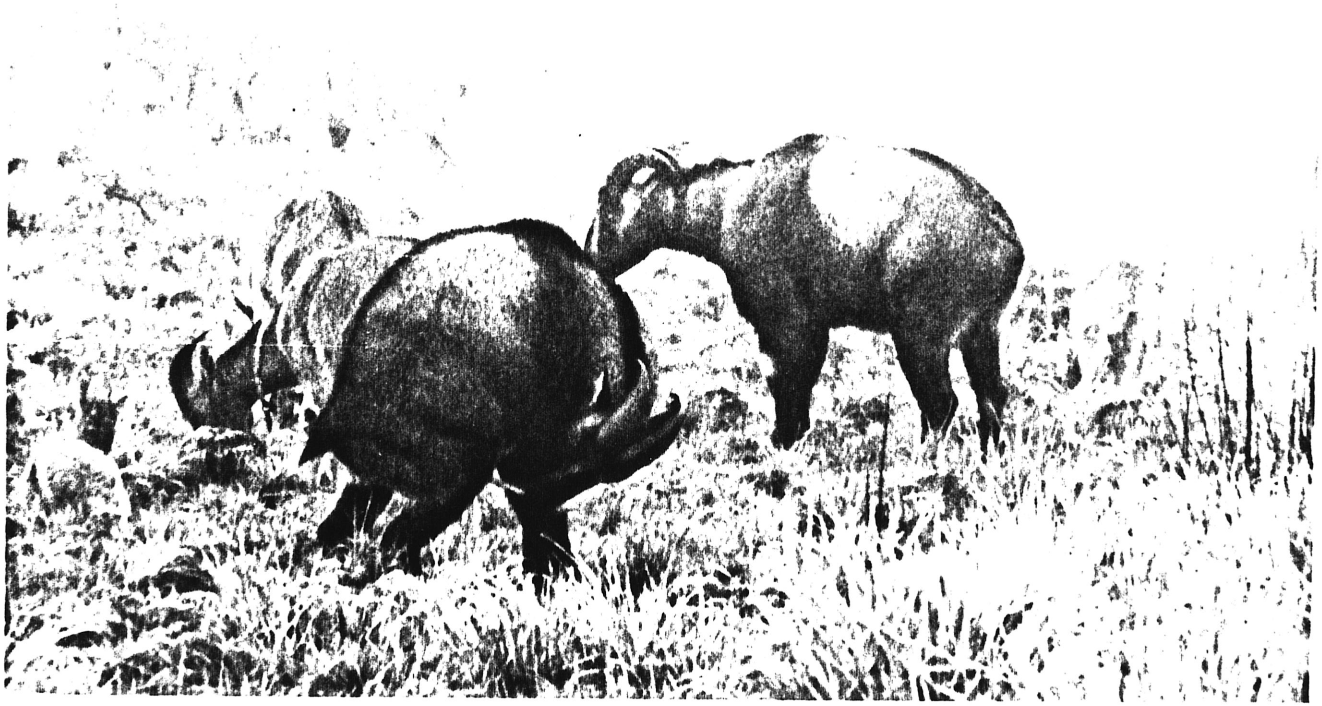


Fig. 15.--As one saddleback ends his hunch with a head out display, the closer one turns and mouths his penis. He is tending the collared female to his left.

display was often give in broadside orientation, particularly if it followed a hunch (as was often the case). The otherwise rather unobtrusive posture was made more striking by practice of holding the pose for a few seconds.

Another dominance display was to stare at another animal. It was, of course, not always a simple matter to distinguish mere visual attention from a stare, but in other cases, the stare was obvious in the nature of the fixed steady gaze. After observing similar interactions between tahr, the importance of this display was demonstrated quite effectively in my own interaction during the monsoon with a newly arrived, and only partially habituated male. During the transition from unhabituated to habituation, such males tended to treat me like a dominant conspecific. At the same time, I tried to focus as little attention on them as possible, to encourage them to relax. On the other hand, I was eager to record any individual markings, and this required close scrutiny. In this particular case, I moved up the slope, eyes to the ground, diagonalling closer to the male whom I could see watching me out of the corner of his eye. Then as I stopped, raised my binoculars and directed my gaze at him, he turned away and grazed, both submissive responses (see below). By being linked sequentially with other less specifically addressed displays, such as object aggression and spraying urine, the stare also served to impart an addressing to these displays.

The hunch-sidle was given in parallel orientation. The initiator hunched the back, twisted the head so that the muzzle pointed towards the opponent (and the horns away), and stepped sideways towards the opponent. This display contained elements of both dominance and threat. The dominance element was evident in the hunched posture, while the approach in a threatening move. In addition, the angling of the horns away may be construed as a "swing out" movement (Walther 1976) in preparation to side clash.

When they did not release reciprocal responses, aggressive actions and displays often resulted in a submissive action on the part of the recipient. The simplest of these was to stop the "offensive act". For example, a subordinate male might stop his approach or courting of a female upon receiving the stare or approach of a dominant male. No other postures or movements were necessary in some cases to signal his subordinate status, and the dominant did not pursue the interaction further.

A slightly more definite response was for the submissive tahr to turn away.

The submissive attitude was made more emphatic by moving away, or scooting away, that is, moving away rapidly.

Depending on their mutual orientation, the submissive animal could also back away.

Another submissive action was for the tahr to turn in from the parallel orientation, and cut back, passing behind the dominant animal (termed turn and cut). This action was often noted in the context of conflict while grazing. Unlike other submissive actions, in the turn and cut the submissive animal turned its horns towards, rather than away from the dominant animal while turning back to pass behind. However, this action gave the dominant animal the option to graze at the location at which the conflict took place. On the other hand, turning or moving away would give the dominant animal the same prerogative. It may be that the turn and cut is a defense tactic used by the submissive animal so it does not have to expose its side to the dominant animal.

To graze was also a submissive response in some circumstances. This was particularly evident in interactions between males in context of courting females during the rut. In such instances the subordinate male's approach or courting of a female was interrupted by the approach or display of a dominant male. As was the case with staring, the motivational state of the grazing animal was not always easy to judge, but in some cases the connection between the subordinate's grazing and the actions of the dominant male was quite evident. This was so not only because the onset of grazing coincided with the later's approach or display, but also in the cessation of grazing as the dominant's attention turned elsewhere (to the female is question, or back to the female the dominant male was initially tending and guarding). In one case the subordinate Dbm did not graze, but simply lowered the tip of his muzzle to the grass and stood still, suggesting that grazing has considerable signal value.

To dribble urine from a non-erect penis was also interpreted as an indication of subordinance. This occurred in contexts similar to that of the urine spray, except that the close proximity of a dominant animal seemed to inhibit its full expression. Consequently, the penis was not erected, nor was any particular posture adopted as urine trickled from the penis.

Flight was the submissive complement to being chased.

I grouped the submissive behaviors of stopping the "offensive act", turning away, grazing, turning and cutting, moving away, scooting away, and backing away together under the category of defering.

Sexual behaviors consisted of acts and displays by the males, and responses by the females. The mount was, of course, a sexual act. In mounting, tahr often clasped the mounted animal with the forelegs just anterior to its hindquarters. The head was usually held up in an approximanately normal position, but on a few occasions the mounting animal lowered its muzzle onto the back of the mounted one. Mounts were sometimes accompanied by rapid pelvic thrusting, and some were terminated by a thrust of greater amplitude and/or a groan. In the terminal thrusts, the mounter's hindquarters were brought quickly forward against the hindquarters of the mounted animal, and the body was raised and straightened, but these acts were much smaller in amplitude than the terminal thrusts observed in some cervids (Struhsaker, 1967; Blakeslee, 1979), where the hind legs sometimes even left the ground. Terminal thrusts and the accompanying groan were presumed to coincide with ejaculation. On the basis of these behaviors and the response of the mounted animal, mounts were scored as to where copulation was considered very likely, possibly, or not likely to have occurred.

Cases where the mounted animal disrupted the mount by moving forward before the action was successfully completed were considered as a mount attempt, and if the recipient moved before physical contact was established, this was called a mount intention. The distinction between mounts, mount attempts, and mount intentions was determined more by the reaction of the mounted animal than the actions of the mounter, and as such were a useful indication of the receptive state of the one being mounted.

Males also simply placed their muzzle near to the perinium of the female in the perinium sniff.

Flehmen was performed after placing the muzzle in a stream of falling urine. In Nilgiri tahr, flehmen did not differ markedly from the usual ungulate pattern (Schneider 1930). In giving the flehmen response, the head was typically held in the normal position and the chin elevated only slightly. Sometimes the head was turned slowly back and forth.

Sexual or courtship displays by males are all variations and elaborations on a common theme, in which the muzzle of the male is projected towards the inguinal region of the female. In the rear twist, the male stood behind the female and twisting his head sideways, extended his neck and muzzle forward, in the direction of, or to the udder of the female. In some cases this move was so pronounced that he literally jabbed the udder with his muzzle.

The typical side twist was performed from further forward, with the male's shoulders beside and level with, or just behind the female's hindquarters. The male then lowered his head, twisting it axially, and moved his head towards the female so that his muzzle pointed at or touched her belly, just anterior to the hind leg. Some side twists were from further forward, the muzzle being directed along the female's side, just behind her foreleg, just anterior to her forleg (towards her chest), or even against her throat or chin. Both rear and side twists were also given from other than a parallel orientation, and in this connection, any twist which was oriented at a part of the female's body anterior to the hind legs was considered a side twist. In some side twists, the male also leaned or pushed against the female's hindquarters with his shoulder.

Displays to resting females were similar in orientation, but not in form, since the resting female's inguinal region was, of course, much lower. I called the comparable versions of these displays the side and rear sniff. As with the twists, in the rear sniff the display was from the rear of the female. The male lowered his head, twisted it, and extended it towards her. The same was the case with the side sniff, except that the male stood to the side of the female. The amplitude of the twisting movement in these displays was dependent largely on the position of the male. For instance, a side sniffing male standing essentially behind the female, but far enough forward so that the display was directed anterior to the female's hind legs, lowered his head almost straight down, and twisted only very slightly towards the female's inguinal region. On the other hand, if he was standing off to the side somewhat, the twisting movement was much more pronounced, as it would have to be to achieve the same orientation with respect to the male's muzzle and the female's inguinal region. These differences emphasized the importance of the orientation of the display over the actual form they took. As was the case with twists, side sniffs were also sometimes directed towards anterior portions of the female's body.

Both twists and sniffs were often embellished with other displays performed at the same time. In the foreleg kick, the male raised and lowered one foreleg 10-20 cm and dropped it back to the ground. Usually this action was repeated a few times in succession. In Nilgiri tahr, the foreleg is held straight, but not necessarily rigid, and emphasis is placed on the downward stroke, so that the kicking produced a rhythmic thumping.

In the tongue flick, the male rapidly flicked his tongue in and out. This also produced a rhythmic "flapping" noise. Both the foreleg kick and tongue flick generally occurred in connection with twists or sniffs, but sometimes they were performed by themselves.

The whoosh was a rapid expellation of air, apparently through the mouth. When combined with the tongue flick, this produced a broken slurping sound.

Males also sometimes accompanied sexual displays with a hum, a soft, closed mouth vocalization of about 1-2 sec duration.

Female tahr reacted to the attentions of males in various ways. The flinch was a quick movement which seemed to indicate that they were startled or uneasy. Females also moved quickly a few paces to scoot away, or they kept going to run off. A response of resting females was to rise. Mounted females sometimes struggled in an attempt to break the clasping hold of the male.

In reaction to the approach or courting of a male, females also frequently urinated. Their posture in doing so did not differ noticeably from the normal, slightly crouched urination posture. The usual response of the male was to place his muzzle in the falling urine and perform flehmen.

Severely harrassed females also gave a series of calls. These were quite similar to those given by alarmed tahr, but had a more breathy quality. However, this appeared to be related more to the fact that they were usually running at the time, than that they occurred in a sexual context (running alarmed tahr gave a call that sounded virtually the same).

A complete account of mother-infant relations will be forthcoming in a later report, but a general description of the behaviors involved is included here for completeness. Grooming was the action of licking the Yg by a female tahr. Neonates were groomed on all parts of the body, particularly the shoulders and head, but later grooming was confined to the perineal region and the exit of the penis sheath (in males). Grooming was frequently combined with bouts of suckling.

For a Yg to suckle the actions of the female and her Yg had to be coordinated. Suckling occurred in reverse parallel position (with the rump of the Yg sticking out to the side, back to belly, with the back of the Yg located directly under the belly of the female, and from the rear, between the hind legs. To initiate suckling, the Yg often moved straight in from the side, but on other occasions cut around the front of the female, or ducked between her forelegs. Suckling was terminated either by the Yg quiting of its own accord, or by the female stepping forward or pivoting off.

Apart from the typical bunting during suckling, Nilgiri tahr performed two specialized forms of bunting, independent of suckling. In the rear bunt, the Yg extended its muzzle and neck, and quickly jabbed at the udder of the female. Whether this contact was with a nipple, or just the udder, was not clear. Nor was it always clear if the Yg was attempting to suckle in performing this action. However, in some cases it was quite evident that this was not the case, since the Yg withdrew his muzzle and moved on despite the lack of response or objection on the part of the female.

The same type of move from the side, as the Yg turned the muzzle sideways and jabbed it at the udder was considered a side bunt.

As a method of or refusing rear suckling, or in response to rear bunts, females gave a stamp with a hindleg. The effectiveness of this action lay not so much in the stamp, as in the elevation of the hind leg to do so. This brought the tendon along the back of the hind leg into sharp contact with the jaw of the Yg, pushing or knocking its head up and back.

Females and their offspring often moved rather independently within a group of animals, and frequently relocated each other by giving a call or bleat. This was a somewhat sustained, open-mouthed vocalization, lasting about 1 sec. The pitch of the call decreased with the size of the calling animal, but otherwise the calls of both Yg and F were the same.

Several higher order behavioral categories also proved useful in describing the actions of Nilgiri tahr. These categories incorporated one or more of the behavioral units described above, and gave and indication of the motivational state of the animal involved. For example, courting described the activities of a male towards a female, but the term referred to any number of sexual displays or actions.

As a female approached estrous, a male, usually the dominant male tended her. A tending male stayed in the proximity of the female, courting her occasionaly. This bond was a one-way affair, in that the male stayed with the female, but not vice-versa. Nor did I ever observe attempts by the male to limit the movements or dictate the activity of the female. As a result, it was the female who determined the pairs' movements, and to a large extent, their activity (a male might well graze in the vicinity of a resting female, but he could not remain resting if she moved off grazing). By his courting the male did, of course, sometimes influence the activity of the female in that she often moved away from him, interrupting her resting in many cases. However, I could discern no intention or attempt on his part to subsequently control or limit her movemerts, nor did the response of moving seem to be the objective of the displays.

On the other hand, tending males were very particular about any approach or courtship on the part of other males towards the female being tended. This response was in the form of aggressive actions or displays, and the other males deferred to the tending male (or the tending bout ended). Thus tending was a process by which a male maintained an association with a female, and restricted access to her on the part of other males.

Subordinate males, however, did not always completely abandon tended females, but in some cases they remained in the vicinity. They apparently were attracted by the female, but refrained from approaching or courting her on account of the presence of the tending male. I refered to this as <u>attend</u>ing the female and the tending male.

Extended sequences of aggressive acts fell into two categories, <u>fighting</u>, and <u>sparring</u>. Fighting and sparring both involved the same aggressive behavior patterns, but differed in the context, intensity, course and outcome. Fights occurred at moments of conflict, particularly when two males simultaneously attempted to court the same female. They were of high intensity, as each tahr seemed to try with all its strength to damage its opponent, and they ran their course from beginning to end without pause or interruption. In fights there never was any question as to which of the partners was the winner, and which was the loser (since the loser was usually chased out of the group by the winner).

Sparring, on the other hand, took place during general daily activity. The same fighting behaviors as used in fighting occurred, but they were of much lower intensity, and the possibility of injury seemed remote. There were often pauses in the proceedings as one or both of the partners stood or groomed, and changes in partner were not uncommon. Lastly, it was usually impossible to designate a winner or loser. Rather it appeared more as if one of the partners just lost interest and turned away.

Social Organization During The Rut

The discussion of Nilgiri tahr social organization will consider the rut (June-September) of 1981. With the exception of mother-infant relations (which will be considered in a later report), the social life of tahr focuses on this season. During the rut of 1981, the tahr in the intensive study area were fully habituated, and consequently the record from that year is the most comprehensive.

Socially, the rut primarily involved interactions of two basic types, agonistic and sexual. These two categories accounted for nearly 95% of the social interactions recorded during this period (Table 21). These types, are, of course, directly related to the two primary activities of males during the rut. First, the males court and attempt to copulate with females, and second they try to minimize these activities on the part of other males. Sexual behavior is the means to the former end, and aggressive behavior is the means to the latter. These activities are exemplified, but not restricted to the process of tending. In tending the male directs most of his courtship towards one particular female, and guards her from the approach and/or courtship by other males. On the other hand, dominant males will also interfere with courtship by subordinant males even if they are not tending, as will tending males interfere with courtship of other females than the one they are tending, if their proximity allows them to do so. Thus, tending is a special case in which the more general activities of courting and interfering with courting are focused on one female.

Not all aggressive interactions took place in the context of interfering with courtship. They were also involved in space claim interactions, such as the maintenance of individual distance, or competition over resources other than females.

The general sequence of aggressive interactions which focused on conflict over a resource was as follows. Initially the recipient of the aggressive behavior performs some "offensive act". This may be courting a female, or being in a particular location, or grazing on a particular item. This prompts the aggression on the part of the "offended" animal. Depending of the situation, this may or may not proceed through a progression of intensity. For instance, the initiator of the aggression may start off with an approach, and if this elicits submissive behavior in the recipient, the interaction ended. If, on the other hand, a submissive behavior did not result, then the initiator often escalated the aggression with a display, or even an aggressive act. If the recipient still refrained from behaving in a submissive manner, this could lead to a series of aggressive exchanges, as in a fight, before one of the two adopted the submissive role.

During the 1981 rut, more aggressive actions were observed than aggressive displays (Table 21). This is largely due to the great number of acts employed in fights. On the other hand, aggressive displays are an important reflection of the manner in which an animal relates to its conspecifics. The percent of observations of the various types of aggressive displays is shown in Table 21, and these are broken down by the class in the initiator in Table 22. Threats, dominance displays, and displays given in the context of aggressive arousal were all commonly observed, while those of uncertain designation were much rarer. The frequency of occurrence of the display types showed a significant interaction ($G = 1007$, d.f. = 27), and all classes but Llbm's had a significant contribution to the total G ($20.3 \leq G \geq 479.0$, d.f. = 3). Although all classes of tahr employed threats, these were the most common displays for F's, including the F-2yr's, Yl's, and Yg. By contrast, the older males gave the dominance displays and displays indicating arousal most commonly, and with nearly equal relative frequency. The younger adult males were somewhat intermediate, in that they utilized threats proportionately more than the older males, but less

Table 22.--Percent observations of aggressive display types by initiating class from June-September 1981.

	Class									
Type	S2	S1-2	S1	Dbm	Llbm	Lbm	F	F-2yr	Yl	Yg
Threats	13.5	8.3	10.1	10.3	26.4	36.4	76.2	74.1	37.1	55.8
Dominance	47.0	57.1	47.6	46.4	50.9	16.9	14.3	11.1	8.6	3.9
Arousal	37.7	34.1	41.5	42.3	15.1	42.9	4.6	7.4	37.1	11.5
Uncertain	1.9	0.5	0.9	1.0	7.5	3.9	4.9	7.4	17.1	28.8
Total	483	217	328	97	53	77	593	27	35	52

For an explanation of class abbreviations, see text.

than the F's and subadults. While LLbm's gave a comparable proportion of dominance displays, but fewer displays in arousal context, the Lbm's inclined towards the converse. The importance of the aggressive displays of uncertain classification decreased greatly with increasing age.

In threatening, the horn presentation was much more common than the lunge (Table 21), but this was not the case in all classes (Table 23). With respect to the use of threats, Nilgiri tahr classes fit into three groups: (1) S's, which lunged about twice as often as they gave the horn presentation; (2) Younger males and Dbm's, which relied heavily on the horn presentation, and also lunged, but much (2-6 times) less frequently); (3) and females and

Table 23.--Percent observations of threat types by initiating class from June-September 1981.

	Class									
Type	S2	S1-2	S1	Dbm	Llbm	Lbm	F	F-2yr	Yl	Yg
Horn present	30.8	27.8	39.4	80.0	85.7	71.4	94.2	95.0	100.	96.6
Lunge	69.2	72.2	60.6	20.0	14.3	28.6	5.8	5.0	0.0	3.4
Total	65	18	33	10	14	28	452	20	13	29

For an explanation of class abbreviations, see text.

subadults, which used the horn presentation over 90% of the time, and rarely lunged (G = 212.0, d.f. = 9). When grouped this manner, there is no significant interaction within any of the groups, but the interaction between the groups is significant.

Of the dominance displays, the hunch was the most frequently employed (Table 21), and despite the fact that the data are uncorrected for observation time per class, it is quite evident that subadult tahr gave dominance displays much less frequently than adults (Table 24). The hunch occurred in all classes, and the hunch-sidle in most of them. However, only adult males, followed their hunches with a head out, and the stare was given only by saddlebacks. This is closely related to the use of the stare in conjunction with tending of estrous females, something done only by S's.

Table 24.--Percent observations of all dominance displays by initiating class from June-September 1981.

	Class									
Display	S2	S1-2	S1	Dbm	Llbm	Lbm	F	F-2yr	Yl	Yg
Hunch	74.4	78.2	80.8	95.6	85.2	84.6	69.4	100.	33.3	100.
Head out	10.1	10.5	11.5	0.0	7.4	7.7	0.0	0.0	0.0	0.0
Stare	14.5	9.7	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hunch-side	0.9	1.6	2.6	4.4	7.4	7.7	30.6	0.0	66.7	0.0
Total	227	124	156	45	27	13	85	3	3	2

For an explanation of class abbreviations, see text.

Spraying urine and object aggression were the two most frequently observed of the aggressive displays in arousal context (Table 21). Their distribution by class is shown in Table 25. Naturally, F's did not spray urine or mouth their penises. However, the G for interaction is significant if F's and subadtults are removed from the analysis (G = 213.9, d.f. = 45 and G = 87.0, d.f. = 25 respectively). Spraying urine was used more frequently with increasing age in males. Younger males did not bump their forehead, although adult females did. This behavior was usually linked with spraying urine, but in the case of females was more of a low intensity object aggression. Object aggression was employed by all classes but Yg, and was the most frequent display of aggressive arousal in F's and Lbm's. Cavorting was seen mostly in subadults,

Table 25.--Percent observations of aggressive displays in arousal context by initiating class from June-September 1981.

	Class									
Display	S2	S1-2	S1	Dbm	Llbm	Lbm	F	F-2yr	Yl	Yg
Spray urine	6.70	58.1	60.3	48.8	37.5	21.1	0.0	0.0	0.0	0.0
Bump forehead	5.5	8.1	6.6	12.2	0.0	0.0	18.5	0.0	0.0	0.0
Object aggression	26.9	32.4	31.6	36.6	25.0	51.5	74.1	100.	69.2	0.0
Cavort	0.0	0.0	0.0	0.0	0.0	24.2	7.4	0.0	30.8	100.
Jump twist	0.0	0.0	0.0	0.0	12.5	0.0	0.0	0.0	0.0	0.0
Mouth penis	0.6	1.4	1.5	2.4	25.0	3.0	0.0	0.0	0.0	0.0
Total	182	74	126	41	8	33	27	2	13	6

For an explanation of class abbreviations, see text.

and more rarely in younger adults. All classes of males mouthed their penises.

Most of the aggressive displays of uncertain designation were headshakes (Table 21). These displays did not show significant interaction between classes (G = 22.7, d.f. = 18), probably because of the small sample size involved.

Of the wide array of aggressive acts, side clashing was observed most frequently, but the approach was also commonly employed (Table 21). Reverse parallel fighting and head-on clashing were also often incorporated in aggressive acts in comparison to the balance of the behaviors. The use of aggressive acts differed between classes (Table 26, G = 1063.4, d.f. = 108). All classes employed the head-on clash, but it was given most frequently by Yg, and proportionately more frequently by Yl's and Lbm's than the remaining classes. Considering the various roles it played--from fights between rutting males, to brief aggressive encounters--side clashing showed a surprising evenness in utilization.

Although the variation in frequency of side clashing between classes is significant (G = 37.8, d.f. = 9), there was no clear cut pattern in terms of sex and age. Reverse parallel fighting was used most commonly by S2's, and to a considerable degree (about 10-15% of aggressive acts) by S1-2's, S1's, younger males, Yl's and Yg. F's and F-2yr's rarely reverse parallel fought, and interestingly, this method of fighting was also rare in Dbm's. Compared with the other classes, neck fighting was common in Yg, and present, but less common in Yl's and younger males, and relatively rare in older males. It was not recorded for females over one year of age. Hook hoof was employed most by younger males and Yl's (of which the males probably made the greatest contribution), and occurred sporadically in other classes. Butting was an important aggressive act for both F's and F-2yr's, and was used also by younger males, Yl's and Yg, but was uncommon in older males. The hornjab figured most prominently in the aggressive actions of younger males, adult females and Yl's, but was rare in Yg and older males. The parallel

Table 26.--Percent aggressive acts by initiating class from June-September 1981.

Act	S2	S1-2	S1	Dbm	Llbm	Lbm	F	F-2yr	Yl	Yg
Head-on clash	5.5	4.3	3.8	5.4	9.4	19.8	6.5	11.8	19.6	36.0
Side clash	33.7	49.6	39.2	38.7	33.6	36.3	49.1	55.9	36.6	28.8
Reverse parallel fight	21.0	9.1	8.9	1.2	15.6	12.9	1.4	0.0	14.3	10.8
Neck fight	2.9	1.4	0.7	1.2	5.5	5.6	0.0	0.0	7.2	12.6
Hook hoof	1.7	0.0	0.7	0.6	6.2	4.8	0.7	0.0	5.4	0.0
Butt	0.9	0.5	0.7	0.6	3.1	5.6	14.9	14.7	7.1	8.1
Hornjab	0.2	0.0	0.0	0.0	3.1	3.6	5.8	8.8	7.1	0.9
Parallel shoulder push	2.3	0.2	0.2	0.0	1.6	1.6	0.4	0.0	0.9	1.8
Hook behind foreleg	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chase	2.8	3.1	4.7	2.4	0.0	0.4	2.6	0.0	0.0	0.0
Approach	27.4	31.3	39.8	48.8	21.1	6.9	18.2	5.9	1.8	0.0
Hook hind hoof	0.5	0.2	0.2	1.2	0.8	1.6	0.4	0.0	0.9	0.9
Hook horn	1.0	1.4	1.0	0.0	0.0	0.8	0.0	2.9	0.0	0.0
Total	1155	581	581	168	128	248	275	34	112	111

For an explanation of class abbreviations, see text.

shoulder push was infrequent in all classes, but was used more frequently by S2's, younger males, Y1's and Yg.

Hook behind foreleg, hook hind hoof, and hook horn did not show significant variation between classes ($4.4 \leq G \leq 16.8$, d.f. = 9), and none accounted for a very high percentage of aggressive acts for any class. The relative amount of chasing increased with age in males, and F's also chased, but subadults did not chase. The use of an approach as an aggressive act also generally increased with age in both sexes, and was the most common aggressive act in Dbm's.

Walking approaches were much more common than rushes (Table 21), and although there was significant interaction between classes ($G = 36.8$, d.f. = 9), the percentage of rushes showed no distinct pattern with regards to class.

Most submissive behavior was in the form of deferals and of these, moving away predominated (Table 21). This was true for all classes (Table 27), and there was no significant variation between classes ($G = 6.6$, d.f. = 9). All other types of submission had a significant contribution to the total G of 267.4 (d.f. = 63). (This included the category of not specified, but removing it from analysis did not affect the pattern of significance in the other categories). Stopping the "offensive act" was shown almost exclusively by adult males, and more or less equally by all adult male classes. Turning away was a relatively favored mode of submission in older males and females. Grazing as an indication of submission was used solely by males of intermediate age class. F's

Table 27.--Percent deferal type by initiating class from June-September 1981.

	Class									
Type	S2	S1-2	S1	Dbm	Llbm	Lbm	F	F-2yr	Yl	Yg
Stop "offensive act"	9.3	6.3	9.0	8.7	9.9	5.4	0.5	0.0	0.0	0.0
Graze	0.0	0.7	4.1	1.9	1.2	0.0	0.0	0.0	0.0	0.0
Turn away	24.7	16.9	11.2	5.7	6.8	12.5	14.8	14.3	2.0	5.4
Move away	43.3	62.7	55.9	51.7	54.0	56.2	47.5	60.7	54.0	50.2
Scoot away	12.4	9.7	7.0	14.3	16.8	13.4	14.8	10.7	28.0	28.6
Back away	7.2	0.0	2.6	1.1	3.1	0.0	1.5	0.0	4.0	3.6
Turn and cut	0.0	0.0	0.0	0.4	0.0	2.7	11.2	7.1	4.0	3.6
Not specified	3.1	3.5	10.2	16.2	8.1	9.8	9.7	7.1	8.0	8.9
Total	97	142	313	265	161	112	196	28	50	56

For an explanation of class abbreviations, see text.

and F-2yr's exhibited the turn and cut much more frequently, and its occurrence was otherwise confined to subadults and younger males. Scooting away was a common submissive act among subadults, but was fairly commonly employed by all classes. Backing away varied significantly between classes (G = 23.1, d.f. = 9), but showed no distinct pattern of occurrence.

Deferals are of particular importance during the rut, as they are the best indication of the dominance relationship between individuals and classes, and as such give the best measure of an individual's or classes' access to resources. Table 28 shows the pattern of deferals between classes during the 1981 rutting season. This (and the following) interaction matrix has been arranged to place the elements of the matrix in order of dominance. Where ambiguities in the linear ranking of elements occurred, the arrangement which resulted in the lowest total for the upper right

Table 28.--Number of deferals by class from June-September 1981. "." = 0. Diagonal elements are underlined.

	Recipient										
Sender	F	S2	S1-2	S1	F-2yr	Dbm	Llbm	Lbm	Yl	Yg	Total
F	64	5	3	3	.	4*	1	14	1	.	195
S2	19	41	22	14	.	.	.	1	.	.	97
S1-2	3	75	32	32	.	.	.	.	.	.	142
S1	6	126	85	93	.	2	.	.	.	.	312
F-2yr	22	.	.	2	1	.	1	1	1	.	28
Dbm	1*	91	39	95	1	38	.	.	.	.	265
Llbm	6	47	19	50	.	34	4	1	.	.	161
Lbm	22	26	4	16	1	11	19	13	.	.	112
Yl	31	4	.	2	5	1	.	3	3	1	50
Yg	20	5	3	2	7	2	.	2	5	10	56
Total	294	420	207	309	15	92	25	35	10	11	1418

*reversal
For an explanation of class abbreviations, see text.

half of the matrix was selected. This arrangement was made using the computer program listed in Appendix F. Scores which do fall in the upper right half of the matrix are the result of two types of relationships. If the score was greater than the reciprocal score (in the lower left half of the matrix), these represent reversals, where the element considered as subordinant recieved more deferals than they sent to the corresponding element. If, however, the score was less than the reciprocal score, this indicated a lack of rigidity or consistency in the relationship between the elements.

As Table 28 shows, the dominance order among male classes was in the order of their maturational stages. However, the relationships between the classes of males was not entirely consistent, with an average of 9% of the interactions not fitting the overall pattern. This inconsistency was particularly marked between S1's and S1.5's and S1-2's and S2's, where 38% and 29% of the deferals did not conform to the respective pattern. In males deferals were most frequent to and from adjacent classes. This has been reported in other species for aggressive interactions in general (Geist, 1971; Walther, 1980), but in Nilgiri tahr this pattern also holds for submissive behavior.

Females received more deferals from all classes then they sent to them and therefore are located first in the dominance order in Table 28. An uncritical interpretation of this matrix would lead one to the conclusion that during the rut Nilgiri tahr females are dominant to males, as Geist (1965) maintains is the case with mountain goats. This apparent dominance by females is, however, questionable when one considers the special social situations which pertain during the rut, the categories under which behavioral responses were placed, and the form the displays take in these interactions. Normally, two animals compete over a resource which is a third entity, such as two tahr over a grazing item or salt, or two males over a female. In such situations, the two animals have the same relationship towards the resource, that is, they desire to utilize it in the same way. However, in conflicts between a female and the courting male, the nature of the resource, and therefore the nature of the conflict, is different for the two individuals. The male attempts to court and copulate with the female, whereas the female, in threatening the male, is defending her individual space. However, since copulation requires the cooperation of the female, a male would gain nothing by ignoring the female's assertions of her individual space, and such tactics would probably incur considerable energetic costs. This is because the female's most likely response would be to move off, and the male, if he is to succeed in copulating with her eventually, must follow. On the other hand, the male need not abandon his courting completely, as is the case when the conflict is with another male, but must only respect the female's space claim. Outside the context of courtship and in the usual conflict situation (such as over salt), older males are consistently dominant over females.

The discussion presented so far would support the contention that females are dominant over males in the context of courting.

However, this does not adequately describe the situation, for the following reasons. Because they followed sexual displays or acts on the part of males, I considered withdrawal on the part of the female as a response to the courtship, rather than a submissive act. However, this does not mean that the withdrawal of the female does not have a submissive component. I believe it definitely does. Thus, I have not included, and often not recorded the hundreds if not thousands of instances where females withdrew from courting males. Such withdrawal was often as definite and precipitous as in the normal moving and scooting away. On the other hand, the aggressive behavior of females towards courting males often showed great hesitancy. This was evident in the lower amplitude of the horn presentations, in the quick performance of aggressive acts, and the tendency to retract from the aggressive posture or orientation very quickly regardless of the response of the male. Thus, although females gave aggressive displays, and occasionally directed aggressive acts towards courting males, they usually showed an insecurity in doing so. This was another indication of their subordinant status.

During the rut, most of the male-male deferals took place in the context of competition over females. I made incidental mention of this in 27% of all male deferals. Deferals sometimes took place over considerable distance. For instance, if a subordinate male often showed his submission long before the approaching male came close. I did not always note the distance at which deferal occurred, but those I did estimate are shown in Table 29. Two to 3 m was the most commonly recorded distance for deferal, but distances up to 10 m were not uncommon, and the maximum distance recorded for a deferal was 20 m. This means that a tahr usually had to be in the general proximity to influence a conspecific in this manner, but such interactions sometimes took place over a considerable distance.

Tahr sometimes combined their demonstration of submission (usually moving away) by hunching as they did so. While females did not do this, the tendency to combine the hunch with the submissive act increased steadily with age in males. I never noted it in Lbm's or LLbm's, but I did in 1% of the deferals given by Dbm's, in 3% of those of S1's, 7% of S1-2's and 12% of S2's.

Table 29.--Distances noted at which deferal was elicited.

	Observations	
Distance (m)	No.	%
2	4	9
3	6	14
4	11	26
5	4	9
6	3	7
7	2	5
8	3	7
10	7	16
15	1	2
20	2	5
Total	43	100

For an observer, deferals were the best indication of the relative status of two individuals. This was particularly the case in males as they interfered with the courtship of subordinant males. Thus the priority of access to females that individual males had can best be judged, not by the occurrence of aggression between two individuals, but by the occurrence of submissive behavior. Table 30 shows the number of deferals sent and recieved by individual males during the 1981 rut. (Several males which were recorded in only one or two interactions are not included). The scores in the upper right half of the matrix are an indication of the lack of linearity and consistency in the relations between males. Many of these scores, and most of the large ones are reversals. This indicates that even though the overall pattern for all males does not fit a linear hierarchy very well, the relationship within dyads was usually consistent.

Of course every male did not interact with every other male, and this resulted in some ambiguity in the dominance ordering. For instance, S1 Rhc show subordinance to S1-2 Ts, and dominance over LLbm's, so he could be placed in the hierarchy anywhere between these two. Table 30 shows that in general individual males were grouped in dominance according to their class. However, there were some exceptions. S1's Cl and Ne were dominant over S1-2's and several S2's. However, they were also involved in many of the reversals. These reversals represent triangular or circular relationships between the males, and, given that the members of these circular relationships were present in the group at the same

Table 30.--Number of deferals by individual males during June-September 1981. "." = 0. Diagonal elements are underlined. Class for each individual is given in the sender column. N.S. = individual of that class not specified.

Sender	Recipient																								
	Wh	V2	Blrr	Lb	Cl	Ne	V9	V5	Wybl	Dcr	S2	S1-2	Ts	Wybl	Wwy	Bkybk	Dch	S1	Rt	Rd	Dbm	Rhc	Rrbk	LLbm	Lbm	Total
Wh (S2)	$\underline{.}$	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1
V2 (S2)	2	$\underline{.}$	.	.	.	.	1	.	.	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	.	5
Blrr (S2)	.	4	$\underline{.}$	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Lb (S2)	2	.	.	$\underline{.}$	.	.	.	.	.	.	.	.	.	.	.	.	.	1*	.	.	.	.	.	.	.	3
Cl (S1)	5	2	.	1	$\underline{.}$	.	.	.	1	.	.	.	4*	.	.	.	.	.	.	.	.	.	.	.	.	13
Ne (S1)	.	5	.	.	7	$\underline{.}$	2	.	7*	1*	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	23
V9 (S2)	.	5	.	.	1	2	$\underline{.}$	2	.	.	.	1	2	.	.	.	.	.	.	.	.	.	.	.	.	13
V5 (S2)	1	9	.	.	.	4	3	$\underline{.}$	1	.	.	.	4	3	.	2	8*	.	.	.	.	.	.	.	.	35
Wybl (S1-2)	.	1	.	.	5	5*	5	13	$\underline{.}$	.	.	.	2	.	.	.	.	1	.	.	.	.	.	.	.	32
Dcr (S2)	.	1	.	.	.	.*	1	2	1	$\underline{.}$	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5
N.S. S2	.	2	.	.	.	.	.	.	3	2	$\underline{.}$	.	.	.	.	.	.	1	.	.	.	.	.	.	.	8
N.S. S1-2	.	.	.	.	.	.	2	1	1	.	.	$\underline{5}$	.	.	.	2	.	.	.	.	.	.	.	.	.	11
Ts (S1-2)	19	4	1	.	2*	2	13	5	13	.	.	.	$\underline{.}$	2	.	.	4*	.	1	.	.	.	.	.	.	66
Wblr (S1)	19	7	.	1	8	3	2	6	4	1	.	1	16	$\underline{.}$	.	6*	1*	3*	.	.	.	.	.	.	.	78
Wyy (S1)	.	5	.	.	5	5	8	4	3	1	.	.	8	8	$\underline{.}$	.	2*	6*	.	.	1	.	.	.	.	56
Bkybk (S1)	1	1	.	.	.	5	4	6	2	.	.	.	9	1*	9	$\underline{.}$	.	.	.	.	1	.	.	.	.	39
Dch (S1-2)	.	1	.	.	4	4	6	4*	6	1	.	.	1*	.*	.*	4	$\underline{.}$	.	.	.	.	.	.	.	.	31
N.S S1	1	3	4	.*	1	.	3	.	5	.	2	.	1	2*	.*	1	1	$\underline{1}$	.	.	.	.	.	.	.	25
Rt (S1)	15	.	.	2	6	.	.	6	.	.	.	.	18	9	.	.	.	1	$\underline{.}$	.	.	.	.	.	.	57
Rd (Dbm)	.	.	.	.	2	.	.	.	.	.	.	.	2	5	.	.	.	.	1	$\underline{.}$	.	.	.	.	.	10
N.S. Dbm	8	12	4	.	8	9	23	11	13	.	.	2	13	14	10	7	4	10	5	2	$\underline{23}$	.	5	.	.	183
Rhc (S1)	6	.	.	.	2	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	$\underline{.}$	.	.	.	9
Rrbk (Dbm)	22	2	.	.	5	2	2	7	2	.	.	.	3	7	3	1	.	1	3	.	7	.	$\underline{.}$	.	.	67
N.S. Llbm	18	11	.	1	17	2	11	5	3	1	.	1	12	9	9	4	3	3	3	.	29	3	4	$\underline{4}$	1	154
N.S. Lbm	16	3	.	.	2	3	3	2	1	2	.	.	2	3	.	1	.	3	3	.	7	.	4	19	13	87
Total	135	78	9	5	75	46	89	74	66	9	3	10	99	63	31	28	24	31	16	2	68	3	13	23	15	1015

*reversals
See text for class abbreviations.

time, as they often were, this lack of linearity had important effects on the sequence of events during the rut (see below).

Table 31 shows the behavior which elicited deferals during the 1981 rut. Approach elicited by far the greatest number of elicited by aggressive displays and acts is given in Table 32. deferals, followed by the horn present. The overall interaction G of 162.8 (d.f. = 7) was partitioned between the deferal types to show that: (1) stopping the offensive act was elicited by acts more than would be expected considering the overall pattern, (2) displays elicited turning away more than expected, (3) moving away was elicited more by acts, as was scooting away, and (4) the turn and cut was elicited more by displays ($12.8 \le G \le 79.6$, d.f. = 1). The type of aggression which elicited grazing and backing away did not vary significantly from the expected values ($0.5 \le G \le 1.2$, d.f. = 1).

There was a definite relationship between the particular aggressive displays, and the types of deferals they elicited (Table 33, G = 288.6, d.f. = 28). Tahr defered from horn presentation by turning away, moving away, backing away, and turning and cutting more often than expected. The pattern of deferal type following the hunch sidle did not vary significantly from the expected (G = 14.0, d.f. = 7). Hunching resulted in deferals of stopping the offensive act, and moving away more than was expected. The most frequent response to lunging was to scoot away, whereas when staring elicited a deferal, it resulted in the subordinant animal stopping the

Table 31.--Number and percent of behaviors eliciting deferals. June-September 1981.

Behavior	No.	%
Approach	720	60.5
Horn present	171	14.3
Lunge	88	7.3
Hunch	83	6.9
Side clash	37	3.2
Hunch sidle	21	1.8
Butt	18	1.5
Stare	13	1.1
Head-on clash	9	0.8
Shake	5	0.4
Hornjab	5	0.4
Side twist	5	0.4
Spray urine	3	0.2
Ram	2	0.2
Flinch	2	0.2
Head out	2	0.2
Reverse parallel fight	2	0.2
Object aggression	2	0.2
Poke	2	0.2
Bump forehead	2	0.2
Other*	4	0.3
Total	1,197	100.0

*Other includes one each of attempt side clash, hook hoof, mount, and neckfight.

Table 32.--Number of deferals of each type elicited by aggressive displays and aggressive acts. June-September 1981.

Type	Displays	Acts	Total
Stop "offensive act"	8	67	75
Graze	4	12	16
Turn away	69	77	146
Move away	139	472	611
Scoot away	117	61	178
Back away	13	16	28
Turn and cut	20	12	32
Not specified	22	78	100
Total	391	795	1,186

offensive act, grazing, or turning away (partitioned G's $\geq$ 31.3 and $\leq$ 168.3, d.f. = 7).

With regards to aggressive acts, tahr defered from approaches with a wide variety of deferal types (Table 34), but slightly favored stopping the offensive act and grazing. Relatively frequent deferals from butting were backing away, turning and cutting, scooting away, and turning away. Tahr deferred from side clashes by turning and cutting 19 times more frequent than expected. Turning away, backing away, and scooting away were also more frequent than expected for this aggressive act.

Table 33.--Number of deferals of each type elicited by aggressive displays. June-September 1981.

	Display					
Type	Horn present	Hunch sidle	Hunch	Lunge	Stare	Total
Stop "offensive act"	1	1	4	0	1	7
Graze	0	0	3	0	1	4
Turn away	39	5	14	0	9	67
Move away	70	8	48	5	0	131
Scoot away	26	1	5	83	0	115
Back away	8	1	2	0	0	11
Turn and cut	11	4	3	0	0	18
Not specified	16	1	4	0	1	22
Total	171	21	83	88	12	375

Unlike aggression, displays were more common than acts in sexual behavior (Table 21). Most of these displays were either side or rear twists or sniffs. When side or rear sniffing, males had a greater tendency to give their displays from the side (G = 249, d.f. = 1). About a fifth of their displays were accompanied by foreleg kicks or tongue flicking, while whooshes were less common, and humming rare. Of the behaviors in the category of sexual acts, half were flehmen. Mounts outnumbered both mount intentions and mount attempts, indicating that males usually tried to mount when

Table 34.--Number of deferals of each type elicited by aggressive acts. June-September 1981.

	Act					
Type	Approach	Butt	Hornjab	Head-on clash	Side clash	Total
Stop "offensive act"	66	0	0	1	0	67
Graze	12	0	0	0	0	12
Turn away	57	3	1	3	11	76
Move away	451	6	1	2	11	471
Scoot away	49	4	2	1	4	60
Back away	9	3	1	0	1	14
Turn and cut	0	1	0	0	9	10
Not specified	76	1	0	0	1	78
Total	720	18	5	7	37	787

they were likely to be successful. Although many mounts were accompanied by pelvic thrusting, relatively few were accompanied by groans. Groaning seemed to accompany ejaculation, but thrusting apparently did not indicate it. Despite the fact that males seemed to mount primarily when they would be allowed to, this did not mean that they would be successful in copulating with the female. On the contrary. I judged only 6.9% of the mounts as probable copulations, and nearly half of them did not seem to be.

Although I did not note the female's response to every sexual display or act, more than half of those noted were urination. Scooting away and rising were also relatively common.

Until now, the discussion has proceeded as if agonistic and sexual activities were discrete aspects of rutting. However, in actuality they were closely linked. The actual sequence of events varied depending on the circumstances, i.e., the number and condition of estrous females in the group, the number and respective relationships between the males, and the strategy each male was employing at the time. Male Nilgiri tahr were alert to courtship by other males within the group, and generally speaking, any subordinant male that courted a female was likely to be supplanted by a dominant male. However, dominant males did not usually concern themselves with the activities of all males subordinate to them. Rather, they generally only moved to intervene in courtship by males of their own class, or the next younger class. Therefore, excepting cases where the courtship was unusually enthusiastic, or included mounting, an S1, for instance, would not move to interfere with courtship by an Lbm. This explains the lower frequency of deferals by the Lbm's and LLbm's to the oldest males in Table 28.

On the other hand, a frequent occurrence was for a female to be "passed" from younger male to older males as a succession of individuals of increasingly older classes intervened with the courting of a younger or subordinant male, and then defered to another older dominant male. What prevented this process from continuing until the dominant male ended up with every female that was courted was apparently the attractiveness of the female. Sooner or later one of the males did not continue to court the female, (or did not court her at all in some cases), and as a result there were no subsequent interventions. This means that younger males had a lower threshold for courting than did the older males. This pattern of events also allowed dominant males to concentrate on the most receptive females, as the degree of attractivity of the other females in the group was evidenced by the interactions involving subordinant males.

The fact that males sometimes intervened in the courtship by subordinant males, but then did not continue to court the females strongly suggests that they made some sort of assessment of her reproductive condition. The means by which they did this was not evident. Some investigators (e.g. Knappe 1964, Estes 1974) have postulated that male ungulates assess the reproduction condition of females by testing for certain chemicals in their urine while performing flehmen. Experimental work with domestic goats by Ladewig et al. (1980) and Ladewig and Hart (1980) lends strong support to this view. However, in the wild, Nilgiri tahr males often, if not usually, refrained from courting females after interfering with another male's courting without participating in the urine-flehmen sequence. Therefore, they must have been using other cues to make their assessment.

Another situation in which a dominant male did not intervene with the courtship of a subordinate, was when the dominant male was tending a particular female. Tending was evidently the most effective way for the dominant male to insure that he, and only he copulated with a female, but it also had its drawbacks. Because the tending male could not (or at least did not) influence the movements and activity of the female he was tending, he was obliged to stay with her. This meant that he was not at liberty to interfere with courtship, or even copulation by other males with other females without jeopardizing his exclusive control over the tended female. It was frequently quite clear that the tending male was highly motivated to interfere with other courting, but given the large number of males in tahr groups during the rut, another male usually moved to court the tended female as soon as the tending male turned his attentions elsewhere. This was especially the case if there were several attending males accompanying the tending male and his female.

As the term implies, a tending male usually stayed with one particular female for an extend period of time, at least several hours. Presumeably he chose to tend or not to tend a female on the basis of the same or similar cues as those used in choosing whether to court a female or not. If more than one female elicited this response at one time, the second female would be tended by the second most dominant male. This often led to a fairly stable situation, in which the most attractive females in the group were tended by the most dominant males, with occasional court occurring between the other males and females.

However, such a stable pattern of tending and courting depended on a linear dominance order among the males. Normally for a male to tend a female, he must be dominant over all other non-tending males in the group. Otherwise, a non-tending dominant male is likely to interfere and court the female himself. As mentioned earlier, an attractive female was thus "passed" from male to male, and if the males were arranged in a triangular or circular pattern of dominance, this took on a cyclical pattern. As a result, it was impossible for any one male to maintain control over the female, and the relatively stable system of pairing associated with tending broke down.

In some cases, the presence of attending males, which were usually of the younger classes, magnified the destabilizing effects of circular dominance relationships among the older males. This was the case when one of the older males, upon interfering with the courting of a subordinate, followed through with a short chase, which left the female momentarily unattended. In such situations, one or more of the attending males took this opportunity to court or attempt to copulate with the female. The manner of courtship by these younger males was understandably rather hurried, and the usual response of the female was to run from them. This in turn attracted the attention of all the males in the vicinity, increasing the likelihood that all members of the circular dominance hierarchy would continue to take an interest in the female. The situation was all the more extreme if the female is at the height of receptivity and attractiveness, and in those cases, a number of males might copulate with her in rapid succession.

Tending males did not court their females all the time, but seemed to court in distinct bouts. these bouts may have been for the purpose of updating their assessment of the female's receptivity. As a female approached receptivity, the nature of the male's displays changed. Whereas the majority of displays are usually towards the rear or hindquarters of the female, around the time of copulation, more and more display were directed to her chest, axial region, throat, or chin. At the same time, the male often leaned or pushed against her with his shoulder while twisting. It may be that the male determines the readiness of the female for mounting (see above) on the basis of her tolerance of these displays. A few observations also indicated that while females very near, but not quite at the height of estrus, tolerated mounting but not intromission. In this situation the female made no apparent attempt to move from the male's mounts until his penis attempted intromission, at which point she moved out of the mount.

Comparisons With Other Species

A comparison of Nilgiri tahr behavior with that of other tahr species is hampered by the lack of extensive material on them. Published information on the behavior of Himalayan tahr is limited to a few observations by Schaller (1973, 1977), and incidental observations on a captive group by Hassenberg (1981). I know of no published information on the social behavior of the Arabian tahr, but I did have the opportunity to watch a small captive group for a few hours. Consequently, the lack of a certain behavior having been described for these species does not preclude it from the species repertoire.

All three tahr species use horn present (jerk, Schaller, 1977) and lunge. This is not surprising, as these moves are common to most horned ungulates (Walther 1979).

Both Nilgiri and Himalayan tahr give a hunch, and the Arabian species may do so too. Himalayan tahr erect the hairs of their mane during hunches, and the erected neck hairs often frame the black face with an apron of ruff, and the tail is raised. Nilgiri tahr erected their manes when hunching, but the tail remained in the normal position. Similar, although less conspicuous postures are also given by other caprines such as wild goat, Punjab urial, bharal, or takin (Schaller, 1977), mountain goat (Geist, 1965), and chamois (Walther, 1961). However, whether these postures are completely homologous to those found in tahr is not clear. Most of these species reach the extremity of their display with the head held low, but stretched forward. Nilgiri tahr, however, pull the chin back, partially inverting the head in the full expression of the display. Mountain goat also have a similarly extreme form of hunch, but they give it as a static standing display in contrast to the moving, mincing gait used by tahr. As has already been mentioned, Walther (1974) considers the hunch as a threat in mountain goat, since in hunching the animal adopts the posture for reverse parallel fighting. Since Nilgiri and Himalayan tahr also fight in reverse parallel position, we may also conclude that this was originally the case with these species. However, in Nilgiri tahr, serious fights commence with side clashing, not reverse parallel fighting, and thus the hunch does not signal immediate readiness to fight in this species, but rather status and general motivational state of the sender. This would seem to indicate a change in the meaning of this display, not on the basis of changes in its own form (e.g. through ritualization or modification), but on the basis of changes in the social context in which it occurs.

Schaller's (1973) description of a broadside display in Himalayan tahr is quite like the head-out I observed in the Nilgiri species. However, it apparently is not so conspicously linked with spraying urine in Himalayan tahr. While many other caprines give broadside displays, none maintain a posture very close to this while doing so.

I know of no accounts which mention the importance of staring as an aggressive display in ungulates. However, this may be because its communicative effect is difficult to assess, especially if observations are made over a considerable distance. This is often, if not usually the case, and it seems likely that similar interactions occur in other species.

The hunch-sidle seems to be a display unique to Nilgiri tahr, as similar displays have not been reported in other caprines.

Within the Caprinae, spraying urine occurs in takin (Schaller, 1977) and chamois (Kramer, 1969), in many Capra species (Walther, 1961, Schaller, 1977), and in all three tahr species. Unlike the Nilgir tahr, which sprays urine onto and between its forelegs, the Arabian tahr male turns his head sideways and arcs his body laterally to spray the urine beside one foreleg onto the side of his face (Usher-Smith, pers. comm.). This is not surprising considering the thick "leggings" of long hair adorning the forelegs of Arabian tahr, since these would block most of urine spray directed between the forelegs. Bumping the forehead in connection with spraying urine, seems to be another unique aspect of Nilgiri tahr behavior, although the method of spraying of Himalayan tahr has not been described.

Object aggression is widely employed by caprines, and probably all species perform it in some manner (horn vegetation, Schaller, 1977). In Nilgiri and Arabian tahr, however, object aggression seemed to serve a somewhat specialized function. This function was closely related to the "object" involved. Although Nilgiri tahr did sometimes direct their object aggression towards shrubs, the most common recipient of this behavior was the grass and the underlying earth as well. Extensive or recurrent bouts of object aggression at the same site (as was frequently the case), left an earth colored patch of up at about 1 m in diameter, where the digging of the horn tips and the rubbing of the neck and head dug up and soiled the vegetation. In Nilgiri tahr, both object aggression and spraying urine occurred in the same context of aggressive arousal, and as result, these sites often bore the typical male scent. In addition, in the process the male's face often became covered with mud made of the dark moist soil. Thus, object aggression not only served the usual functions of providing a (redirected) outlet for aggressive intentions and displaying the vigor and strength of the animal, it also served as a visual and olfactory mark, and enhanced the maturational appearance of the male by darkening his facial area.

Object aggression seems to have quite a different function in Arabian tahr. Like Nilgiri tahr, Arabian tahr evidently do perform object aggression against plants, but the majority of the few displays I witnessed in the captive group were directed at the ground. Certain sites with dry loose sandy dirt were favored. As with Nilgiri tahr, the display incorporated the digging of the horns into the earth, but in this case, the back and forth movement with the head turned sideways served to slice into the sand with the relatively flat horns. The display was terminated by raising the head as the tahr continued to hold its head sideways, and the flat inner margin of the Arabian tahr's horns thus lifted a quantity of sand. The head was usually brought up sharply, and this motion threw the sand onto the back of the animal. As a result, the coats the Arabian tahr were impregnated with dust and sand, as was amply evident whenever they shook. Although this behavior has not been observed in the wild, the resulting shallow sandy pits are quite in evidence in areas Arabian tahr occupy (Munton, 1979).

In horned ungulates, the forms of fighting used by a species is often closely related to the form of its horns. Within the Caprinae, the horns of tahr are intermediate between the short, sharp, often dagger like horns of the more primitive members of this subfamily (Nemorhaedus, Capricornis, Rupicapra, and Oreamnos), and the long, curved or twisted horns of other Caprines such as the sheep and the goats. With the exception of the chamois which has a hook shaped horn, the relatively straight, sharp horns of the rupicaprines are most suited for poking, jabbing, or stabbing with the tips. Unfortunately, the fighting methods for many of these species have not been described. However, the mountain goat is typical of this group with regards to horn shape, and its major method of fighting is in a reverse parallel position. Although rupicaprines may make horn to horn contact, this is likely to be more of a head to head mutual butt, since the rounded horn surface is not suitable for catching a blow.

The sheep and goats represent the other end of the spectrum. In adult males of these species, the horns are massive, long, and curled or twisted in such as manner as to make the tips virtually useless as weapons. Rather, it is the front of the horns, near the base which is the point of contact. In addition, this contact is not horn to body, but horn to horn. At this area of contact, two basic types of horn surface can be distinguished in the sheep and goats. The first is a broad, more or less flat surface typical of sheep and the Alpine ibex. The second is a projecting rib along the anterior edge of the horn, exemplified by the other Capra species.

In both types, the significance of these structures is evidenced by the well developed fighting techniques of these species which strongly emphasize this frontal contact. In the sheep this is seen in the bipedal charge leading to mutual frontal ramming, and the corresponding rearing to clash in the goats.

In tahr, the males' horns are heavier and more curved than those of rupicaprines, but they are nevertheless lighter and much shorter than those of the sheep and goats. However, although one might say there is a continium in horn shape and size, the same cannot be said the respective fighting behaviors as there is not fighting style "half way" between reverse parallel fighting and frontal clashing. Rather in tahr, as exemplified by Nilgir tahr, both fighting techniques are used. Furthermore, both fighting techniques are used in an intermediate way. When Nilgiri tahr reverse parallel fight, for instance, the curvature of the horns is too great to allow the horntips to jab directly into the body of the opponent, yet the blow is still delivered with the most distal portion of the outside surface of the horns. This means that, although the tip itself does not dig into the opponent, the impact of the blow is still concentrated on a relatively small surface. Furthermore, the horntips can still play an important role in some circumstances, such as in the hook behind foreleg.

On the other hand, clashing with the horns is also an important fighting method in Nilgiri tahr, in which two basic types of clashing occur. In head-on clashing, the flat frontal surface(s) of the horn(s) accepts and delivers the blow, as is the case in sheep and Alpine ibex. However, such clashing is not so well developed in Nilgiri tahr, as both animals usually remain stationary while clashing. In one fight I observed, the males backed away from each other and then rushed forward on all fours to clash, but I never observered rearing to clash as Hutton (1947) reported for this species. In contrast to head-on clashing, in side clashing Nilgiri tahr make contact with the outside of one horn. The configuration and shape of Nilgiri tahr horns are particularly suited to this type of clash. Since the horns do not diverge markedly, the sides can be brought together as the opponents stand parallel to one another, and the rounded cross section gives a relatively flat outside surface to catch and deliver the blows. Side clashing has not been reported to date in either of the other tahr species, and considering their horn configuration, it seems unlikely that it will be. This is because the horns of the other two species diverge, and are more oblong in cross section. Thus, there is not a suitable surface to deliver or accept this form of clashing.

Most caprines probably show similar submissive behaviors as do Nilgiri tahr, although they may not be classified in exactly the same way. The turn and cut of Nilgiri tahr, however, appears to be a unique method of indicating inferiority. This may be because of the particular relevance of turning and cutting to conflict between animals standing in a parallel position. As noted above, this is a more important orientation for Nilgiri tahr than most other related species. It comes into play in the hunch sidle and the side clash, two forms of aggression which are unique or particularly well developed in Nilgiri tahr. These two aggressive behaviors and the horn presentation (which was also often given in parallel orientation) elicited most of the turning and cutting (Tables 25 and 26). Thus this particualar mode of indicating submission employed by Nilgiri tahr is specific to the unique forms of aggression they emphasize.

The four most common sexual displays I have described for Nilgiri tahr, the rear twist, side twist, rear sniff and side sniff are essentially variations on a single type of display. This twisting movement, often combined with foreleg kick or tongue flicking are widespread, in fact nearly universal among the Caprinae (Walther, 1979; Schaller, 1977). However, unlike most of these species, including Himalayan tahr (Schaller, 1973), Nilgiri tahr do not perform the accompanying low stretch. Nilgiri tahr do adopt the position corresponding to the low stretch at the full extend of the rear twist, and sometimes a male displaying to a resting female from a short distance maintained a similar attitude between side sniffs. However, in the first case, the posture is not maintained, but only attained momentarily at the extremity of the display, and in the second case the posture is adopted more as a stance of less than complete withdrawal from the side sniff than as a display in its own right. This contrasts markedly with the rigid stereotyped posture of mountain sheep (Geist, 1968) or Alpine ibex. My own somewhat limited observations on courtship in captive Himalayan tahr suggested that the low stretch in this species occupies an intermediate position. In contrast to Nilgiri tahr, Himalayan tahr males adopt a low stretch posture when approaching females (Schaller, 1973, pers. obs.), but it still lacked the rigid and greatly extended posture seen in the sheep and goats.

CONSERVATION

The preceding discussion on the behavior and ecology of Nilgiri tahr provides an appropriate backdrop against which to consider aspects of the conservation of the species. While such information is considerable interest in our understanding of the life history of the species, the concerns of conservation are of a much more direct and immediate nature, and although life history studies are a necessary prerequisite for effective conservation action, the major concern has to do with human activities and their impact on Nilgiri tahr populations. With this in mind, I present here some remarks on the conservation of Nilgiri tahr as an important element in the fauna of Eravikulam National Park, and some suggestions for converving Nilgiri tahr in the entire region.

Conservation and Management at Eravikulam National Park

Burning

Current policy is that some grassland should be burned every spring using a rotational system, so that any given area is burned every 2 or 3 years. Areas near Vaguvarrai and Eravikulam are burned intentionally as part of a management scheme, while more remote areas are often set ablaze by trespassers. Given adequate moisture, the perennial grasses quickly sprout succulent green shoots, which are favored by the tahr. So favored in fact, that about 60 tahr deserted their common home range in 1981 to graze on these shoots.

In addition, observations on play in young suggest that burning is beneficial to the tahr. In January 1980, recently born young were commonly observed running, playing and fighting, but such activities were seldom seen during February and March. However, with the improved foraging conditions following burning, these activities resumed and increased in frequency. For these reasons, it is suggested that the practice of burning be maintained.

However, certain aspects of the burning program could be improved. In 1980 for instance, burning in the Vaguvarrai and Eravikulam areas was carried out over a period of 3 days, with the result that the entire home range of some animals was burned. Although this did not seem to cause any hardship, a staggered burning program would probably be more beneficial. Burning during the fair weather in October might also be possible, and this would make fresh vegetative regrowth available to females late in gestation and early lactation. A more detailed burning plan could easily be devised, but its execution would require a greater amount of manpower and supervision than has been allotted to the task.

National Park Boundaries

As is shown in Fig. 10, there is a considerable area used by Nilgiri tahr which is situated outside the National Park. Much of this area is used primarily by a few adult males. These peripheral portions of the male ranges are often at lower altitudes, and are therefore much more accessible to poachers. In other instances, substantial parts of common home ranges for females and subadults lie outside the National Park, particularly on the north side of Anai Mudi and on the gently west sloping side of Erumal Patti. It should be pointed out that tahr are completely protected, both inside and outside the National Park. However, forest officers in charge of areas bordering the Park have numerous other responsibilities, and strict protection of wildlife in the most distant portions of their areas of jurisdiction cannot be reasonably expected. Therefore, it is recommended that areas which tahr utilize that do not receive adequate protection at present be included within the park. Since wildlife protection is a high priority within the park, this would place the entire Eravikulam tahr population under this protection.

In addition, forested areas immediately adjacent to Eravikulam National Park are essential to many of the other large mammal species found there. Since the National Park often follows the edge of the plateau, most of the terrain included is grassland. Although tiger, gaur, elephant, leopard, and other forest species do visit the grassland, they primarily inhabit the forests. Therefore, the effectiveness of the Park in preserving a wide variety of species would be greatly enhanced by including additional forested areas within the park.

One such area is the west-facing slopes of Erumal Patti. Besides being a frequently used part of a tahr common home range, this is probably the best place in the area to see gaur, as they frequently move out of the adjacent forest and onto the meadows to graze. There is ample evidence that elephant move through the area as well. However, this area falls outside the park and it is therefore recommended that the northern boundary of the park be made to coincide with the state line between Kerala and Tamil Nadu in this area, to encompass all the area used by tahr and some of the forest below.

Boundary Demarcation

At present, the boundary of the National Park, as described by the Kerala Government notification, is clearly marked only where it coincides with the state boundary, or the old Kanan Devan Hills Produce Corporation boundary. In other areas, the distinction between National Park, Reserve Forest and tea company land is not clear. Such is the case, for instance, with the ridge that extends west from the Rajamallay salt lick, between Rajamallay and Kadalaar Estates, or the region between Perumal Malai and Chattamunnar Estate along the eastern boundary. Both the enforcement officers and leading conservationists in the area were not completely clear on the extent of the park in these areas and, to my knowledge, no adequate map of the National Park exists. Therefore, it seems advisable that a survey of the boundary be completed, and an authoritative map produced (including extensions and additions).

Reducing Disturbances

People enter the Eravikulam National Park illegally to obtain both animal and plant products. Sambar and gaur are often pursued with firearms, and Nilgiri tahr are also often hunted with the aid of domestic dogs. Wire snares are also used, particularly in areas near settlements where they can be easily checked. It can be extremely difficult to reduce this type of disturbance since it requires constant vigilance on the part of the enforcement staff, and a willingness to patrol portions of the park not accessible without considerable effort. Also, since the violators are armed, pursuit and capture by enforcement personnel is impossible if they are not armed as well. In addition, effective reduction in this type of activity can only be accomplished if those apprehended are punished accordingly which requires the cooperation of the local judiciary.

There are two plants which are harvested from Eravikulam National Park. Cane, which grows in the lower forested valleys, is used for handicrafts such as furniture. The second is a small insectivorous plant, Drosera peltata. This is gathered from the grassland in October, a time when it is widely distributed throughout the park (and presumably other grassland areas). This plant is desired for its medicinal properties. Curtailment of these activities has been hampered in the past by the practice of local forest offices of issuing permits for their collection within the park, despite their lack of authority to do so. Thus, the cooperation of Forest Department Officials and their superiors is needed in order to halt these activities.

Management and Development

Given the near pristine conditions prevailing within Eravikulam National Park and its small size, and the fact that the major object of the park is the protection and preservation of the natural system, an extremely conservative attitude towards management and development is suggested. Special consideration should be given to maintaining the ecological and scenic integrity of the area. The healthy and stable population of Nilgiri tahr is an indication of the health and stability of the park as a whole. Consequently, there is no evidence that any remedial management is needed. Rather, the major focus should be upon removing, or at least minimizing, disturbances.

Although the presence of Nilgiri tahr may have been the primary reason for creating the National Park, this does not mean that maximizing the tahr population should be the primary management objective, especially considering the large population. Rather, the objective should be to maintain the tahr and the entire ecosystem in which they have evolved. In this context provisioning and pasture development are inappropriate. Also, despite indications of a fairly high incidence of parasites in tahr, there is no indication that this is threatening the population. It is more likely that the parasites, in conjunction with varying levels of forage, the density of the tahr, and the predators in the park, act as an important natural mechanism maintaining the tahr population at ecologically sound levels. Therefore, it is recommended that no therapeutic or prophylactic measures be undertaken in this regard.

Public use should also be considered in light of the uniqueness and majesty of the area. Every year more and more grassland in the western ghats is lost to plantations of wattle and eucalyptus (Davidar 1976, 1978), and before long Eravikulam National Park may remain as a last vestige of the original plateau grassland habitat. It therefore seems appropriate that this remnant should be kept in its original condition as much as possible. This will benefit, not only the plant and animal species now found within the National Park, but visitors to the park as well. Just as every year more and more Indians are discovering the value of their natural wildlife heritage, so are they discovering the value of the little undisturbed wilderness that India has left. Those who wish to see the park and Nilgiri tahr without leaving their cars may do so at the Rajamallay checkpost. With roads penetrating every other corner of the high country, it would seem fitting to leave Eravikulam National Park as a last remnant of wilderness in South India place where people can come to appreciate their natural heritage without the help of internal combustion engines.

Future Investigations

Continued monitoring and study of the ecology of Eravikulam National Park is needed, both to better understand the functioning of the ecosystem, and to assess the status of conservation issues. Consequently the following investigations are suggested:

1. Annual census and estimate of reproduction of Nilgiri tahr. Eight to 12 days are required to completely census all areas of the park. If personnel or time are limiting, all common home range areas need not be counted every year. If the personnel have adequate experience, then all animals should be classified by sex and age, which would give an estimate of reproduction for the year, provided the counts are done after most of the births, i.e. in March.

2. Faunal and floral species inventory. The only systematic plant collections done to date have been those by Shetty and Vivekananthan (1971) in the area of Anai Mudi, and my own collections from grassland areas. A more comprehensive floral collection and survey should be undertaken or encouraged to identify key floral elements and endangered and rare species. At present only incidental observations are available for vertebrates other than large mammals. The park's assets in these areas should be inventoried

3. Continued research on the ecology of Nilgiri tahr and other species. The Nilgiri tahr population at Eravikulam National Park should be studied further. Such information will be highly useful for future conservation efforts, both within the park, and elsewhere. In addition, the parks capability to support sustainable populations of other mammals, particularly the large predators, needs to be investigated.

4. The effects of fire on grassland. Burning should be continued because it is a practice of long standing, and is beneficial to the tahr. However, the long term effects of burning on the grassland in terms of species composition, vegetative cover, productivity, nutrition and soils need to be assessed.

Captive Propagation

With only about 2,200 Nilgiri tahr in the wild, the success of captive breeding is reassuring. However, such efforts may flounder due to the results of inbreeding depression if the entire captive stock continues to be developed entirely from the original small group (Frankel and Soule 1981). Proposals to augment the genetic material in the captive populations has met with approval from the Indian authorities on the state and national levels. However, current regulations governing the importation of both wild animals and semen into the United States have blocked all efforts in this direction. Continued efforts to find ways of increasing the genetic diversity in captive groups without endangering the health of domestic and native American stock are essential if captive breeding programs of this and other species are to be successful in the long run.

Captive groups can also play an important role in educating visitors about endangered species. An informative display at the Trivandrum Zoo would help increase the public's awareness of the status of this unique animal occurring in their state.

Regional Strategies for Conservation

Sport Hunting

In view of the historical significance played by sport hunters and their organizations in conserving the two largest populations of Nilgiri tahr, the possibility of reopening tahr to sport hunting should not be dismissed. Although it may seem strange to hunt an animal of which only a couple of thousand survive, such a policy might be the most effective method of perpetuating some populations. This is simply because it is in the vested interest of these organizations to maintain a healthy standing crop of animals from which to select a small number of trophies. Since sport hunting is for trophies, the mortality from hunting would be confined to adult males. Thus, as Davidar (1976) has pointed out, hunters who maintain a population of tahr for hunting purposes, give absolute protection to over 90% of the population (the females and subadults).

Without any prospect of pursuing their traditional interest in sport hunting, many members of the High Range Wildlife Preservation Association and the Nilgiri Wildlife Association have lost much of their previous interest in wildlife and conservation in their respective regions. As a consequence the cause of conservation in those areas has lost a valuable ally. By removing Nilgiri from Schedule I of the Wildlife Act, and reopening hunting at one or two selected sites, the involvement, participation and support of these and other similar organizations could be reestablished. For such a system to work as well as it has in the past, these organizations should be afforded a large role, if not the primary role, in the protection, management, administration and costs of maintaining the hunting activities in such areas.

Any plan for hunting would require close management and supervision. This would be required to guard against over-harvest and excessive stress being incurred as a result of the social disruption associated with harvesting trophy males only (Stringham and Bubenik 1975).

Reintroductions

Davidar (1978) has made an assessment of the status and condition of all areas where he located Nilgiri tahr, or where they have existed in the recent past. While reintroductions can in no way compensate for effective enforcement and protection, and will never be successful without these measures, Nilgiri tahr are likely candidates for reintroductions into parts of their range once the agents responsible for their extirpation have been eliminated. Although they do show affinities for particular ranges, their fidelity to these areas is not absolute, and Nilgiri tahr are probably able colonizers of new range, as their close relatives the Himalayan tahr have proved to be in New Zealand (Caughley 1970).

Such reintroductions might require some experimentation, but would probably best be done with groups of animals. Because males leave their original birth ranges, and travel more widely than do females, the initial group might best be a group of males. They would presumably be more accustomed to new terrain, and also less essential to the maintenance of the parent population. The male group could then be followed by a group of females if it manages to survive the initial few months of adjustment. On the other hand, if the males desert the reintroduction cite immediately, a group of the more sedentary females might prove more successful. For mountain sheep, Geist (1975) proposed that lambs imprinted to humans be led over the new range, and after a year wild yearlings be released with them. Such an involved scheme would probably not be necessary with tahr, but the possibility of using it should be kept in mind, should the initial efforts fail.

Reintroduction might be coupled to a proposal for sport hunting to great advantage. A club or organization could take on the responsibilities for the the protection of the new area and assist in the logistics of the transfer. In return they would have the right to hunt the tahr once the population reached a level at which it could support a sustained yield.

Other Large Mammals

Because of the small size of many parks and sanctuaries in this region, large mammals, particularly elephants and the large carnivores, cannot be effectively conserved within their boundaries. For these species, populations of adequate size can only be maintained through cooperative management policies in adjoining areas of forest, with greater emphasis placed upon conservation and the maintenance of ecological stability in these areas. This implies a reassessment of current policies which are directly focused on the generation of revenue, a change needed in the formulation of policy on forestry operations as well (Gadgil et. al., 1983).

SUMMARY AND CONCLUSIONS

This report on the behavior and ecology of Nilgiri tahr has focused on the population at Eravikulam National Park in the State of Kerala in southern India. The tahr habitat in the park is a rolling grassland plateau at an altitude of about 2,000 m. The edges of the plateau are often abrupt, with rock cliffs and slabs, usually intersperced with grassland or shrubs. Deep valleys and hollows are forested. The annual cycle is dominated by the monsoon, which is responsible for most of the heavy rainfall (400 cm annually).

Tahr were initially placed in the genus Capra, but currently there is agreement that they represent a distinct genus, Hemitragus. However, authorities differ on how members of the genus should be grouped. In contrast to earlier treatments and most recent summaries (Honaki et.al., 1982; Corbet 1978), which consider tahr as three species, with no subspecies, Haltenorth (1963) considers all forms to be in one species, with the various forms as subspecies.

Our knowledge of the status of current wild populations of Nilgiri tahr is based mainly on the survey work of Davidar (1978). Current estimates indicate that the wild population totals about 2,200 tahr. In addition there a few collection of Nilgiri tahr in zoos, totalling 55 animals.

The primary method of employed during this study was direct observation of Nilgiri tahr in the wild. Observations were made incidentally, on focal individuals, or on entire groups. To allow observations to continue through the poor viewing conditions of the monsoon, one subpopulation was habituated to the presence of an observer. Some tahr could be distinguished by natural marks, and in addition about 60 animals were marked with self-attaching collars. Incidental information was collected on habitat and predator activities.

Nilgiri tahr assemble into large mixed groups. The maximum number of animals seen in one group during this study was 150. However, tahr also occur in groups of all sizes. When separate from mixed groups, males formed smaller, unstable groups of up to 20. However, smaller groups were more common, and lone males were frequently sighted.

When in these male groups, males frequented quite different habitat than did the mixed groups. Mixed groups generally confined their activities to certain sections of the plateau fringe and the adjacent cliffs and slabs. They rarely penetrated far towards the center of the plateau, nor did they spend much time along the bases of the cliffs and slabs. Males, on the other hand, penetrated further towards the center of the plateau, utilized portions of the plateau fringe which females eschewed, and spent considerable time in the shrublands along the bases of the cliffs and slabs.

Nilgiri tahr can be active an all times of the day, but showed a definite overall pattern. An early morning grazing peak was followed by a rest period from about 0830 h. to noon. Grazing increased through the afternoon, but dropped off slightly around 1800 h.

Information on population trends is lacking for most populations. However, the three populations which have seen more than one census seem to be stable. While Davidar (1978) terms this "stagnation", and considers it a problem, it seems more likely that the stability of these populations more likely indicate that these populations are at ecological equilibrium, and thus further increase in population size is not necessarily desirable.

The variation in population structure between years and populations indicates a highly variable reproductive rate. This is so great between years as to obscure any differences that might exist between populations. Also, the resulting unstable age distribution makes inferences on mortality from the population structure difficult. The overall pattern however, seems to be that mortality is higher, about 40%, for subadults, and lower, about 20% for adults. However, the male:female ratio also indicates that mortality is higher for males than females, and indications are that this effect is most prominent at the age of 2-3 years.

Although exceptions apparently occur, Nilgiri tahr have one offspring at a time. No twinning was observed or implicated during this study. Most of the young were born in January and February, with a few births later in the pre-monsoon season. There is another cluster of births during the monsoon, and records on individually known females indicate that these were females which had given birth in the winter and had lost their young soon after. With a gestation of 180 days, a rut during the monsoon corresponds to the main winter births.

Several predators were active in Eravikulam Nation Park during the study, including tiger, leopard, wild dog, jackal, and humans. Observations and examination of predator droppings indicated that while tiger and jackal do not prey on Nilgiri tahr to any appreciable extent, leopard, wild dog, and humans do. However, both wild dog and leopard prey on sambar more frequently than they do on tahr, and humans use tahr as only an occasional food source. The reactions of tahr to the various predators varies considerably, and is related to the method of attack each predator uses. The stalking leopard is kept under surveilance, whereas the reaction of unhabituated tahr to humans is flight away and out of sight from them.

The social behavior exhibited by Nilgiri tahr was considered in light of their functions and contexts. Quantitative analysis was confined to the 1981 rut. All behaviors were categorized as sexual, agonistic, or related to the mother-infant context. Agonistic behaviors were divided into aggressive actions, aggressive displays, and submissive actions. There were no distinct submissive displays. There were four categories of aggressive displays: threats, dominance displays, aggressive displays which occurred in the context of arousal, and aggressive displays which did not clearly fit into on of these categories. Nilgiri tahr use two types of threat, the horn presentation and the lunge. In contrast, I described four dominance displays, namely hunch, head out, stare, and hunch sidle. Aggressive displays in the context of arousal included spray urine, bump forehead, object aggression, cavort, jump twist, and mouth penis. Aggressive displays which were of uncertain designation were nod, headshake, and poke. Aggressive actions were head-on clash, side clash, reverse parallel fight, neck fight, hook hoof, butt, hornjab, parallel shoulder push, hook behind foreleg, chase, approach, hook hind hoof, and hook horn. I distinguished two types of approach: walking and rushing.

Submissive actions were divided into deferals, flight, and dribbling urine. Deferals were stopping the "offensive act", turning away, grazing, turning and cutting, moving away, scooting aside, and backing away.

Sexual behavior was made up of courtship displays, sexual acts, and female responses. The sexual displays side twist, side sniff, rear twist, and rear sniff were all quite similar, the differences between them being primarily one of orientation. Foreleg kicks and tongue flicks were separate displays on rare occasions, but mainly were performed in combination with the side and rear twists and sniffs, as were whooshes and hums.

Sexual acts were overt behaviors which occurred in a sexual context. These were mount intention, mount attempt, mount, perinium sniff, and flehmen. Mounts accompanied by thrusting and/or groaning were noted.

Female responses were to urinate, flinch, scoot away, struggle out (of a mount), rise, call, and run.

The utilization of the above behaviors varied with the sex and age of the animal. Threats were the most common aggressive displays for F's, Yl's and Yg, whereas older males gave the dominance displays and displays indicating arousal more commonly. When threatening, females and subadults usually gave the horn presentation, whereas older males lunged more than they horn presented. Younger males were intermediate in this regard. Although dominance displays were rare in subadults, the hunch was observed in all classes. However, only older males gave the head out, and only S's stared. In males, spraying urine increased in relative frequency with age, but all classes mouthed their penises. Object aggression was employed by all classes but Yg, but cavorting was seen mostly in subadults.

With regards to aggressive displays, head-on clashing was the most frequent act for Yg, whereas the side clash was commonly used by all classes. Reverse parallel fighting was used considerably by all males but Dbm's, as well as Yl's and Yg, but was rare in females. Neck fighting was relatively common in Yg, and rare in older males. Hook hoof was employed mostly by younger males. Butting was used by all classes, but was relatively rare in older males. The hornjab was used by younger males, females, and Yl's, but was rare in Yg and older males. Chasing increased with age in males, and subadults did not chase. Approaching as an aggressive act increased in relative frequency in both sexes.

All classes deferred by moving away more than any other way, and moving away showed no significant variation between classes. Grazing as a submissive act was used solely by males of intermediate age class, whereas all adult males stopped their "offensive acts". Turning away was relatively favored by older males and females, whereas scooting away, while employed by all classes, was common in subadults. Turning and cutting was exhibited frequently by females, and was otherwise confined to subadults and younger males.

Analysis of deferals by age class showed that they were arranged in a nearly linear hierarchy, but there were a number of interactions which did not follow this overall pattern. Females received more deferals than they sent to most classes, and were therefore first on the hierarchy. However, this pattern pertains to the special conditions which apply during courtship, and it is probably not correct to state that F's are dominant over the older males. Generally, individual males were positioned in the dominance hierarchy according to their class, but there were a few exceptions. There were also a number of triangular relationships among the males. However, the pattern of interactions within individual dyads was fairly consistent.

Approach was overwhelmingly the most common behavior to elicit deferals. The type of deferal was related to the type of behavior preceding it. Stopping the offensive act was elicited more than expected by aggressive acts than displays, as were moving and scooting away, but displays elicited turning away more. There was also a definite relationship between the particular aggressive displays or acts and the type of deferal they elicited.

In contrast to aggressive behavior, in sexual behavior displays were more common than acts. Even then, only a small proportion of sexual displays were mounts, and on only 7% of these instances was it judged likely that copulation occurred.

Dominant males supplanted subordinant males which were courting females, and sometimes several males courted a female in sequence. However, generally speaking, males only interfered in the courtship of subordinates of their own class or one class younger. In addition, younger males had a lower threshold for courting, and it was not uncommon for a older male to supplant a younger one, and then not proceed with courting the female. Thus, by watching the activities of the group in general, the most dominant males could "monitor" the attractiveness of all females being courted on the basis of what age class males were courting them.

When a female came into estrus she was tended by the dominant male. He kept other males from courting her, but was unable to interfere in other interactions without loosing "control" over the estrus female. If two females came into estrus, the dominant male tended one, and the second most dominant male took the other. This led to a stable association and pattern of courtship within the group as long as the hierarchy was linear. However, when triangular relationships involved the upper levels of the hierarchy, the estrous female was "passed" around the triangle, resulting in considerable confusion.

Besides courting a number of females and tending, a third strategy, attending, was practices mostly by younger males. Attending males remained in the proximity of a estrous females and their tending males, but generally did not attempt to court the female unless the tending male became involved in a conflict with another older male.

Thanks to the efforts of the individuals, organizations and governments involved, the survival of Nilgiri tahr seems assured in the near future. While there is ample cause for a feeling of satisfaction at having arrived at that state, the potential exists for improvement and development in the maintenance and study of these populations. Current recommendations include the need to continue to monitor the status of existing populations, and integrate management of wildlife areas in the region in a more coordinated manner. As conditions improve, the opportunity to renew sport hunting activities may be considered as an effective conservation strategy for Nilgiri tahr.

LITERATURE CITED

ALTMANN, J. 1974. Observational study of behavior: sampling methods. Behaviour 49:227-265.

BAIG, A. and W. HENDERSON. 1978. A centenary of planting in the Kanan Devan Hills Concession, 1879-1978. Tatal Finlay Ltd. Calcutta, 162 pp.

BELL, R.H.V. 1971. A grazing ecosystem in the Serengeti. Sci. Amer., 225:86-93.

BENIRSCHKE, K. and A.T. KUMAMOTO. 1980. The chromosomes of the Nilgiri tahr. Internat. Zoo Yearb., 20:274-275.

BENIRSCHKE, K. and A.T. KUMAMOTO. 1982. The chromosomes of Arabian tahr. Mamm. Chromosomes Newsl., 23:67-68.

BLAKESLEE, C.K., C.G. RICE and K. RALLS. 1979. Behavior and reproduction of captive brow-antlered deer *Cervus eldi thamin* (Thomas, 1918). Saugetierk. Mitt., 27:114-127.

BLASCO, F. 1970. Aspects of the flora, and ecology of savannas of the south Indian hills. J. Bombay Nat. Hist. Soc. 67:522-534.

BRYNARD, A.M. 1964. The influence of veld burning on the vegetation and gave of the Kruger National Park. Pp. 371-393 *in*: Ecological Studies in Southern Africa (D.H.S. Davis, ed.) Monographiae Biologicae Vol. 14. W. Junk, The Hague.

CAUGHLEY, G. 1965. Horn rings and tooth erruption as criteria of age in the Himalayan tahr *Hemitragus jemahicus*. New Zealand J. Sci. 8:333-351.

CAUGHLEY, G. 1970. Eruption of ungulate populations with emphasis on Himalayan thar in New Zealand. Ecology, 51:53-72.

CAUGHLEY, G. 1971. The seasons of births for northern-hemisphere ungulates in New Zealand. Mammalia, 25:204-219

CHANDRASEKHARAN, C. 1962. Forest types of Kerala State (3). Indian For. 88:837-847.

CLARKE, C.M.H. and R.J. HENDERSON. 1978. Snare-marking chamois in New Zealand. Z. Saugeteirk. 43:232-239.

CLUTTON-BROCK, T.H., F.E. GUINESS, and S.D. ALBON. 1982. Red Deer. Univ. Chicago Press, Chicago, 356 pp.

CORBETT, G.B. 1978. The mammals of the paleartic region. Brit. Mus. Nat. Hist., Cornell Univ. Press, London and Ithaca, 314 pp.

DAUBENMIRE, R. 1968a. Plant communities. Harper & Row, New York, 300 pp.

DAUBENMIRE, R. 1968b. Ecology of fire in grasslands. Pp. 201-266 in: Adv. Ecol. Res. No. 5 (J.B. Cragg, ed.) Academic Press, New York.

DAVIDAR, E.R.C. 1963. Census of the Nilgiri tahr *Hemitragus hylocrius* (Ogilby) in the Nilgiris. J. Bombay Nat. Hist. Soc., 60:251-252.

DAVIDAR, E.R.C. 1971. A note on the status of the nilgiri tahr (*Hemitragus hylocrius*) on the grass hills in the Animallais. J. Bombay Nat. Hist. Soc. 68:347-354.

DAVIDAR, E.R.C. 1976. Census of the Nilgiri tahr in the Nilgiris, Tamil Nadu. J. Bombay Nat. Hist. Soc. 73:142-148.

DAVIDAR, E.R.C. 1978. Distribution and status of the Nilgiri tahr (*Hemitragus hylocrius*) 1975-78. J. Bombay Nat. Hist. Soc. 75:815-844.

EISENBERG, J. and M. LOCKHART. 1972. An ecological reconnaissance of Wilpattu National Park, Ceylon. Smith. Contr. to Zool., 101:1-118.

ESTES, R.D. 1974. Social organization of the African Bovidae. Pp. 166-205, in The behavior of ungulates and its relation to management (V. Geist and F. Walther, eds.). Morges: IUCN.

ESTES, R.D. and J. GODDARD. 1967. Prey selection and hunting behavior of the African wild dog. J. Wildl. Mgmt., 31:52-70.

FLETCHER, F.W.F. 1911. Sport on the Nilgiris. Macmillan, London, 455 pp.

FRANKEL, O.H. and M.E. SOULE. 1981. Conservation and evolution. Cambridge Univ. Press, Cambridge. 327 pp.

GADGIL, M. and R.B. GRUBB (eds). 1980. Proceedings of the symposium Ecology and Conservation of Birds and Mammals in India. J. Bombay Nat. Hist. Soc. 75(suppl.):949-1267.

GADGIL, M., S.N. PRASAD and R. ALI. 1983. An alternative forest policy. WWF-India Newsletter No. 44. 4:2-4 and 10.

GEE, E.P. 1964. The wild life of India. Collins, London, 192 pp.

GEIST, V. 1968. On the inter-relation of external appearance, social behavior and social structure of mountain sheep. Z. Tierpsych. 25:199-215.

GEIST, V. 1971. Mountain sheep. Univ. Chicago Press, Chicago, 383 pp.

GEIST, V. 1974. On the relationship of social evolution and ecology in ungulates. Amer. Zool., 14:205-220.

GEIST, V. 1975. On the management of mountain sheep: theoretical considerations. Pp. 77-100, in The wild sheep in modern North America (J.B. Trefethen, ed.). The Club, Washington.

GOODWIN, H.A. and C.W. HOLLOWAY. 1972. Red data book. Vol. 1, Mammalia. IUCN, Morges. Loose-leaf.

GRAY, J.E. 1842. Descriptions of some new genera and fifty unrecorded species of Mammalia. Ann. Mag. Nat. Hist., 10:255-267.

GREEN, M.J.B. 1978. The ecology and feeding behavior of the Himalayan tahr (Hemitragus jemlahicus) in the Langtang Valley, Nepal. Unpubl. M.S. Thesis, Univ. Durham, Durham, Eng., 151 pp.

HALTENORTH, T. 1963. Klassification des Saugetiere: Artiodactyla. Internat. Handb. Zool., Berlin, 8:1-167.

HARRISON, D.L. 1968. The mammals of Arabia. Ernt Benn Ltd., London, 381 pp.

HASSENBERG, L. 1981. Verhaltensbeobachtungen am Himalaja-Tahr, Hemitragus jemlahicus (H. Smith, 1826), in Gefangenschaft. Saugetierk. Mitt., 29:1-45.

HODGSON, B.H. 1833. The wild goat, and the wild sheep, of Nepal. Asiat. Researches, 2:129-135.

HODGSON, B.H. 1835. Postscript to the account of the wild goat of Nipal. J. Asiat. Soc., 4:710.

HONAKI, J.H., K.E. KINMAN, and J.W. KOEPPL. 1982. Mammal species of the World. Allen Press, Lawrence, Kansas, 694 pp.

HUTTON, A. 1947. The Nilgiri tahr (Hemitragus hylocrius). J. Bombay Nat. Hist. Soc., 47:374-76.

JERDON, T.C. 1874. The mammals of India; a natural history of all the animals known to inhabit Continental India. Roorkee, 1867. 319 pp.

JOHNSINGH, A.J.T. 1982. Reproductive and social behavior of the dole, Cuon alpinus (Canidae). J. Zool., London 198:443-463.

KNAPPE, H. 1964. Zur Funktion des Jacobsonschen Organs. D. Zoolog. Garten, Leipzig, 28:188-194.

KRAMER, A. 1969. Soziale organisation und sozialverhalten einer gemspopulation (Rupicapra rupicapra). Z. Tierpsych. 26:889-964.

KRUUK, H. 1972. The spotted hyena. Univ. Chicago Press, Chicago, 335 pp.

LADEWIG, J. and B.L. HART. 1980. Flehmen and vomeronasal organ function in male goats. Physiol. and Behav., 24:1067-1071.

LADEWIG, J., E.O. PRICE, and B.L. HART. 1980. Flehmen in male goats: role in sexual behavior. Behav. Neural Biol., 30:312-322.

LEHNER, P.N. 1979. Handbook of ethological methods. Gartland STMP Press, New York, 403 pp.

LYDEKKER, R. 1913. Catalogue of ungulate mammals in the British Museum. 1966. Johnson Reprint Corp., New York.

MCDOUGAL, C. 1977. The face of the tiger. Rivington Books, London, 180 pp.

MECH, L.D. 1966. The wolves of Isle Royale. Fauna of the National Parks of the U.S. Series, no. 7.

MEHER-HOMJI, V.M. 1965. Ecological status of the montane grasslands of the south Indian hills: a phytogeographic reassessment. Indian For. 91:210-215.

MEHER-HOMJI, V.M. 1969. Some considerations on the succession of vegetation around Kodaikanal. J. Indian Bot. Soc. 48:42-51.

MOUNTFORT, G. 1970. The vanishing jungle. Houghton Miffin Co., Boston.

MUELLER-DOMBOIS, D. and H. ELLENBERG. 1974. Aims and methods of vegetation ecology. John Wiley & Sons, New York, 547 pp.

MUKHERJEE, A.K. 1974. Some examples of recent faunal impoverishment and regression. Pp. 99-134 in: Ecology and Biogeography in India. (M.S. Mani, ed.) Monotraphiae Biologicae Vol. 23. Dr. W. Junk Publishers, The Hague.

MUNTON, P. 1979. The conservation of the Arabian tahr Hemitragus jayakari. Project 1290 IUCN/WWF Joint Operations.

NELSON-REES, W.A., A.J. KNIAZEFF, R.L. MALLEY and N.B. DARBY. 1967. On the karyotype of the Tahr Hemitragus jemlahicus and the Y-chromosome of goats and sheep. Chromosoma, 23:154-161.

NIEVERGELT, B. 1974. A comparison of rutting behavior and grouping in the Ethiopian and Alpine Ibex, in The behavior of ungulates and its relation to management (V. Geist and F. Walther, eds.). Morges: IUCN.

NOVAK, R.M. and J.L. PARADISO. 1983. Walker's Mammals of the World. John Hopkins Univ. Press, Baltimore, 1362 pp.

OGILBY, W. 1838. Exhibition of the skins of two species of the genus Kemas. Proc. Zool. Soc. 5:81.

PRATER, S.H. 1965. The book of Indian animals. Bombay Natural History Society, Bombay.

RAMDAS, L.A. 1974. Weather and climatic patterns. Pp. 99-134 in: Ecology and Biogeography in India (M.S. Mani, ed.). Monotraphiae Biologicae Vol. 23. Dr. W. Junk Publishers, The Hague.

ROBINSON, R. 1969. The breeding of spotted and black leopards. J. Bombay Nat. Hist. Soc., 66:923-929.

SCHALLER, G.B. 1967. The Deer and the Tiger. A study of wildlife in India. Univ. Chicago Press, Chicago and London, 370 pp.

SCHALLER, G.B. 1971. Observations on Nilgiri tahr (Hemitragus hylocrius Ogilby 1838). J. Bombay Nat. Hist. Soc. 67:365-89.

SCHALLER, G.B. 1972. The Serengeti lion: a study of predator-prey relations. Univ. Chicago Press, Chicago, 480 pp.

SCHALLER, G.B. 1973. Observations on Himalayan tahr J. Bombay Nat. Hist. Soc. 70: 1: 24.

SCHALLER, G.B. 1978. Mountain monarchs. Univ. Chicago Press, Chicago, 425 pp.

SCHALLER, G.B. and Z. MIZRA. 1971. On the behavior of Kashmir markhor (Capra cashmiriensis). Mammalia, 35:548-567.

SCHNEIDER, K.M. 1930. Das flehman. D. Zool. Garten, 3:183-198.

SCLATER, P.L. 1886. Remarks on the various species of wild goats. Proc. Zool. Soc., 314-318.

SEIDENSTICKER, J. 1976. On the ecological separation between tigers and leopards. Biotropica, 8:225-234.

SESHADRI, B. 1969. The twilight of India's wildlife. John Baker Publishers, London, 212 pp.

SHETTY, B.V. and K. VIVEKANANTHAN. 1971. Studies on the vascular flora of Anaimudi and the surrounding regions, Kottayam District, Kerala. Bull. Bot. Surv. India. 13:16-42.

SINGH, A. 1973. Tiger Haven. Harper & Row, New York, 237 pp.

SMITH, B.L. 1977. Influence of snow conditions on winter distribution, habitat use, and group size of mountain goats. Proc. First Int. Mountain Goat Sym., 174-189.

SOKAL, R.R. and F.J. ROHLF. 1969. Biometry. W.H. Freeman Co., San Francisco, 776 pp.

STRINGHAM, S.S. and A.B. BUBENIK. 1975. Condition physique et taux de survie du chamois, Rupricapra rupricapra L. fonction des classes d'age et de sexe de la population. Bulletin de l'office national de la chasse. Etudes scientifiques et techniques. Special 3:199-224.

STRUHSAKER, T. 1967. Behavior of elk (Cervis canadensis) during the rut. Z. Tierpsychol., 24:80-114.

SUNQUIST, M.E. 1981. The social organization of tigers (Panthera tigris) in Royal Chitawan National Park, Nepal. Smith. Contr. to Zool., 336:1-98.

TALBOT, L.M. 1960. A look at threatened species. IUCN, 137 pp.

TAYLOR, R.H. 1969. Self-attaching collars for marking red deer in New Zealand. Deer, 1:404-407.

THOMAS, O. 1894. Preliminary description of a new goat of the genus Hemitragus, from south-eastern Arabia. Ann. Mag. Nat. Hist., 13: 365-366.

WALTHER, F.R. 1972. Social grouping in Grant's gazelle (Gazella granti Brooke 1872) in the Serengeti National Park. Z. Tierpsychol., 31:348-403.

WALTHER, F.R. 1974. Some reflections on expressive behavior in combats and courtship of certain horned ungulates. pp. 56-106, in The behavior of ungulates and its relation to management (V. Geist and F. Walther, eds.).

WALTHER, F.R. 1977. Artiodactyla. Pp. 655-714, in How animals communicate (T.A. Sebeok, ed.). Indiana Univ. Press, Bloomington, 1128 pp.

WALTHER, F.R. 1978. Behavioral observations on oryx antelope (Oryx beisa) invading Serengeti National Park, Tanzania. J. Mamm., 59:243-260.

WALTHER, F.R. 1979. Handbuch der Zoologie. W. De Gruyter, Berlin and New York, 184 pp.

WILSON, C.G. 1980. The breeding and management of Nilgiri tahr Hemitragus hylocrius at Memphis zoo. Internat. Zoo Yearb., 20: 104-106.

WINBIGLER, H. 1977. Notes on a herd of captive Nilgiri tahr. Unpubl. report, Memphis Zool. Gardens, 5 pp.

WURSTER, D.H. and K. BENIRSCHKE. 1968. Chromosome studies in the super family Bovoidea. Chromosoma, 25:152-171.

ZAR, J.H. 1974. Biostatistical Analysis. Prentice-Hall, Inc., Englewood Cliffs, 620 pp.

APPENDIX A: LIST OF PLANTS COLLECTED IN ERAVIKULAM NATIONAL PARK

Eaten by tahr	Name	Family
*	*Ranunculus reniformis* Wall.	Ranunculaceae
	Viola patrini Ging ex D.C.	Violaceae
*	*Polygala sibirica* Linn. var. *heyneana* (Wall.) Benn	Polygonaceae
*	*Polygonum chinense* Linn.	Polygonaceae
*	*Hypericum mysorense* Heyne ex Wight & Arn.	Hypericaceae
*	*Eurya japonica* Thumb.	Ternstroemiaceae
	Impatiens tangachee Bedd.	Balsaminaceae
*	*Impatiens tomentosa* Heyne	Balsaminaceae
*	*Crotalaria fysonii* Dunn.	Fabaceae
*	*Crotalaria scabrella* Wight & Arn.	Fabaceae
	Indigofera pedicellata W.A.	Papilionaceae
	Parnassia mysorensis Heyne X W.A.	Saxifragaceae
	Drosera peltata Sm.	Droseraceae
	Osbeckia cupularis Don.	Melastomaceae
	Bupleurum distichophyllum W. A.	Umbelliferae
	Pimpenella candolleana W.A.	Umbelliferae
	Anotis leschenaultiana Banth. et Hook F.	Rubiaceae
	Hedyotis stylosa R. Br.	Rubiaceae
*	*Olenandia swertioides* O. Kze.	Rubiaceae
	Anaphalis aristata D.C.	Compositae
*	*Anaphalis bournei* Fyson	Compositae
*	*Anaphalis lawii* Gamble	Compositae
	Emilia scabra DC.	Compositae
	Emilia sonchifolia DC.	Compositae
*	*Eupatorium adenophorum* Spreng	Compositae
*	*Lactuca hastata* DC.	Compositae
	Campanula alphonsii	Campanulaceae
	Lobelia heyniana Roem. & Shult.	Campanulaceae
*	*Wahlenbergia gracilis* Schrad	Campanulaceae
*	*Vaccinium leschenaultii* Wight	Vacciniaceae
*	*Gautheria fragrantissima* Wall	Ericaceae
	Lysimachia deltoidea Wight	Primulaceae
	Lysimachia leschenaultii Duby	Primulaceae
	Exacum anamallayanum Bedd.	Gentianaceae
	Exacum wightianum Arn.	Gentianaceae
	Swertia corymbosa Wt.	Gentianaceae
*	*Pedicularis perrottetii* Benth.	Scrophulariaceae
	Pedicularis zeylanica Benth.	Schrophulariaceae
*	*Sopubia trifida* Ham.	Scrophulariaceae
	Utricularia caerulea Linn.	Lentibulariaceae
	Utricularia graminifolia Vabl.	Lentibulariaceae
	Leucas suffruticosa Benth	Labiatae

Eaten by tahr	Name	Family
	Micromeria biflora Benth	Labiatae
*	_Strobilanthes kunthianus_	Acanthaceae
*	_Elaeagnus kologa_ Schlecht.	Elaeagnaceae
	Dendrobium nanum Hook. f.	Orchidaceae
	Malaxis densiflora(A. Rich.) O. Kuntze	Orchidaceae
	Spiranthes australis Lind.	Orchidaceae
	Spiranthes lancea (Thumb. ex Sw.) Backer	Orchidaceae
	Spiranthes sinensis (Pers.) Ames.	Orchidaceae
*	_Curculigo orchoides_ Gaertn.	Hypoxidaceae
	Xyris schoenoides Mart.	Xyridaceae
*	_Cyanotis sp._	Commelinaceae
*	_Eriocaulon brownianum_ Mart var _niligirense_ Fyson	Eriocaulaceae
	Eriocaulon melaleucum Mart.	Eriocaulaceae
*	_Carex lindleyana_ Nees	Cyperaceae
	Agrostis peninsularis Hook. f.	Poaceae
*	_Andropogon polyptychus_ Steud.	Poaceae
*	_Andropogon lividus_ Thw.	Poaceae
	Arundinella ciliata (Roxb.) Nees	Poaceae
*	_Arundinella fuscata_ Nees	Poaceae
*	_Arundinella mesophylla_ Nees	Poaceae
	Arundinella vaginata Bor	Poaceae
*	_Chrysopogon zelanicus_ (Nees) Thw.	Poaceae
	Coelachne perpusilla (Arn. ex Steud.) Thw.	Poaceae
	Coelachne simpliciuseula (Wight et Arn.) Munr.	Poaceae
	Eragrostis unioloides (Retz.) Nees	Poaceae
	Eragrostis nigra Nees ex Stued.	Poaceae
	Eulalia phaeothrix (Hack.) O. Ktz.	Poaceae
	Eulalia thwaitesii (Hack.) O. Ktze	Poaceae
	Garnotia arundinacea Hook. f.	Poaceae
	Garnotia courtallensis (Arn. et Nees) Thw.	Poaceae
	Helictotrichon asperum (Munro) Bor	Poaceae
	Indochloa oligantha (Hochst.) Bor	Poaceae
*	_Isachne bourneorum_ C.E.C. Fisher	Poaceae
	Isachne setosa C.E.C. Fisher	Poaceae
*	_Ischaemum indicum_ (Houtt.) Merr.	Poaceae
	Jansenella griffithiana (C. Nuell.) Bor	Poaceae
	Microstylis densiflora Fisher	Poaceae
	Poa annua Linn.	Poaceae
*	_Sehima nervosum_	Poaceae
*	_Tripogon ananthaswamianus_ Sreek.	Poaceae
*	_Tripogon bromoides_ Roem and Schult.	Poaceae
*	_Themeda triandra_ Forsk.	Poaceae
*	_Themeda quadrivalvis_ (Linn.) O. Ktze	Poaceae

APPENDIX B: A KEY TO THE GRASSES OF ERAVIKULAM NATIONAL PARK

By Clifford G. Rice and Greg E. Edblom

An Artificial Key to the Grasses of Eravikulum National Park Based on Vegetative Characters

by Clifford G. Rice and Greg E. Edblom

1a Ligule absent or not clearly distinguishable

2a Blade margin entire

3a Blade width 15 mm or more . . . .#42

3b Blade width less than 5 mm

4a Blades linear, less than 2 mm wide, about 25-30 cm long . . . . #3

4b Blades lanceolate-linear, 3-4 mm wide, about 7-11 cm long. . . . .#90

2b Blade margins serrate or barbed (if even minutely)

5a Leaves convolute, shoots circular at base, 16-21 mm wide . . . . #42

5b Leaves conduplicate, shoots compressed at base, 2-4 mm wide . . . .#1

1b Ligule present as a membrane or ring of hairs

6a Ligule a membrane

7a Blade margin entire (not serrate or barbed)

8a Blade margins with tubercle based hairs

9a Ligule is a membrane tipped with hairs . . . .#9

9b Ligule is a membrane not tipped with hairs

10a A perrenial, blades 7-14 mm wide, 8-15 cm long . . . . #19

10b An annual, blades 5-8 mm wide, 5-10 cm long . . . . #92

8b Blade margins without tubercle based hairs

11a Blade tightly folded concealing upper surface when fresh . . . . #63

11b Blade not tightly folded

12a Upper surface of blade glabrous

13a Sheath closing less than 1 cm below collar

14a Ligule clasping stem

15a Blade margins with a thin hyaline membraneous edge . . . . #203

15b Blade margins without a thin hyaline membraneous edge

16a Median rib prominent with light keel . . #66

16b Median rib present, indistinct . . . . . #11

14b Ligule not clasping stem

17a Median rib absent . . #186
17b Median rib prominent, keeled . . . .#76
13b Sheath open 1 cm or more below collar
18a Ligule 1 mm long, median rib prominent and keeled . . . . .#76
18b Ligule 2 mm or more, median rib inconspicuous . . . . . . #62
12b Upper surface of blade hairy
19a Median rib absent. . . . . #2
19b Median rib present
20a Median rib present, but not prominent . . . .#40
20b Median rib keeled, conspicuous
21a Stem covered with dense rust colored hairs at very base . . . . #4
21b Stem not covered with dense rust colored hairs at very base
22a Upper surface of blade sparsely haired, blade 3-4 mm . . . .#112
22b Upper surface of blade hairy. Blade length 35 to 65 cm, ligule 0-2 mm
23a Hairs on blade surfaces tubercle based . . . . . #77
23b Hairs on blade surfaces not tubercle based . . #42
7b Blade margins serrate, barbed (even minutely)
24a Blade margins with hairs arising from tubercles
25a Leaf sheath convolute, stems circular at base
26a Blade lower surface sparsely haired or glabrous, blades 8-9 cm long, hairs 1 mm . . . . #19
26b Blade lower surface densely haired (furry), blades 30-45 cm long, hairs 2-6 mm on blades and margins . . . . #40
25b Leaf sheath conduplicate, stems compressed at base
27a Lower surface of blade haired. . . . . .#10
27b Lower surface of blade glabrous. . . . .#54
24b Blade margins without hairs arising from tubercles
28a Blade cross section 1 cm from collar a winged rib

29a Lower surface of blade glabrous

30a Blade length 10-17 cm, blade width 5-6 mm . . . . #52

30b Blade length 75-105 cm, blade width 7-14 mm. . . . . #84

29b Lower surface of blade hairy

31a Upper blade surface glabrous . . #59

31b Upper blade surface haired

32a Upper blade surface sparsely haired, blade length 5-11 cm, ligule 3-4 mm . . . . #112

32b Upper blade surface hairy, blade length 35-65 cm, ligule 0-2 mm

33a Hairs on blade surfaces tubercle based . . . . . #77

33b Hairs on blade surfaces not tubercle based . . . . . #42

28b Blade cross section 1 cm from collar a "V", "U", or flat

34a Ligule membrane tipped with small hairs

35a Lower surface of blade glabrous

36a Blades 4-7 cm long, purplish-brown in senescence, lower surface not shiny . . . . . #54

36b Blades 10-40 cm long, not purplish-brown in senescence lower surface shiny

37a Upper surface of collar glabrous, blade width 8-19 mm . . . . #15

37b Upper surface of collar haired, blade width 5-9 mm. . . . . #64

35b Lower surface of blade haired

38a Lower surface of blade sparsely haired, width 2-3 mm . . . . #10

38b Lower surface of blade densely haired, width 5-7 mm . . . . #40

34b Ligule membrane not tipped with small hairs

39a Upper surface of blade haired or sparsely haired

40a Lower surface of blade

41a Hairs on upper surface of blade tubercle based . . . . #5

41b Hairs on upper surface of blade not tubercle based . . . . #55

40b Lower surface of blade glabrous or nearly so

42a Median rib prominent above and below, barbed on distinct keel . . . . #1

42b Median rib inconspicuous above, keeled at collar, not barbed . . . #64

39b Upper surface of blade glabrous

43a Median rib inconspicuous among other veins, blades convolute (stems circular)

44a Sheath (outside) haired . . . . #62

44b Sheath (outside) glabrous . . . . #11

43b Median rib distinct, blades conduplicate (stems compressed)

45a Lower surface of blade hairy, (especially distally) . . . .#172

45b Lower surface of blade glabrous . . . . #233

6b Ligule a ring of hairs

46a Blade margins entire and hairless

47a Stem covered with dense rust colored hairs at very base . . . . #4

47b Stem not covered with dense rust colored hairs at very base . . . . #69

46b Blade margins haired or serrate or barbed

48a Blade margins hairless or with tubercle based hairs

49a Blade length less than 1 cm, width 2-3 mm annual . . . .#33

49b Blade length more than 2 cm, width 3 mm or more, perennial

50a Sheath (outside) without tubercle based hairs

51a Upper surface of blade haired

52a Blade length 5-10 cm, upper surface of blade

52b Blade length 15-45 cm, upper surface of blade not beet purple

53a Blade width 5-9 mm. Single indentation on blade as if previously constricted . . . . . . #64

53b Blade width 9-21 mm. Without indentation on blade . . . . #60

51b Upper surface of blade glabrous

54a Lower surface of blade with hairs increasing distally. . . . . #172

54b Lower surface of blade glabrous

55a Leaf sheath convolute stems circular at base . . . . #64

55b Leaf sheath conduplicate, stems compressed at base . . . . #69

50b Sheath (outside) with tubercle based hairs

56a Blade margins with many hairs

57a Blade length 5-10 cm, width 3-4 mm, margins turn dark reddish-brown when approaching senescence . . . . #9

57b Blade length 30-45 cm, width 5-7 mm, margins do not turn dark reddish-brown when approaching senescence . . . . #40

56b Blade margins with few or no hairs . . . . #65

48b Blade margins with hairs, not tubercle based

58a Blade lower surface glabrous . . . . #199

58b Blade lower surface haired

59a Sheath closing in less than 1 cm, blades 2-5 cm long . . . .#189

59b Sheath open more than 1 cm, blades 30-45 cm long . . . .#40

SPECIES CHARACTERS

Number 1 Chrysopogon zelanicus (Nees) Thw.

Blade characteristics: Blades linear, 20-50 cm long, 2-4 mm wide, minutely barbed, antorsely serrate. Blade surface top sparsely, minutely haired, blade bottom glabrous. Prominent keeled midrib with 4-5 lateral ribs.

Additional characteristics: Perennial 50-70 cm high with flowering stems to 80 cm. Ligule either absent or a minute membrane. Margins moderately hairy. Blades exit at 30°, either straight or drooping. Sheath open, compressed, keeled, and with a row of keel hairs. Usually in conspicuous clumps, stems conduplicate. Inflorescence a raceme.

Number 2 Tripogon bromoides Roem and Schult.

Blade Characteristics: Blades linear, 10-20 cm long, 2-3 mm wide. Blade margins hairy and minute serrations are often visible at tip (but not at midpoint). Blade top surface densely hairy (ca 2 mm long), bottom surface with few fine hairs. Median rib absent, about 2 dozen veins.

Additional characteristics: Perennial 10-15 cm high with flowering stem ca 20 cm (drooping). Blade exit about 60°. Sheath closes in 2 mm and is hairy. Ligule is a fine membrane, tipped with hairs, laterally hairy sometimes appearing as a pointed auricle. Convolute. Inflorescence a thin, drooping, arched spike.

Number 3 Tripogon ananthaswamianus Sreek.

Blade characteristics: Blades linear, 25-30 cm long, less than 2 mm wide. Blade margins smooth and entire. Blade top surface very finely haired (seen only with 10x). Median rib with 2 lateral and 2 sub-marginal veins (1 on each side).

Additional characteristics: Perennial to 25 cm high, with drooping flowering stems to 50 cm. No ligule. Sheath is glabrous, compressed, variable in opening. Blade exit 40° or less. Inflorescence a drooping, arched spike.

Number 4 Eulalia phaeothrix (Hack) O. Ktze

Blade characteristics: Blades linear-lanceolate, 10 to 25 cm long, 4 to 8 mm wide. Blade margins smooth, somewhat inrolled, and serrate near distal end. Blade top surface usually hairy (ca 4 mm), hairs erect, sometimes sparsely or glabrous. Bottom surface usually hairy (ca 2 mm), often leaves from flowering stalks have few or no hairs. Median rib present, sometimes lightly keeled. Blade exit 20-30°.

Additional characteristics: Perennial to 25 cm high, flowering stems 40-55 cm. Ligule a membrane with 2 latinal "horns" of hair. Sheath glabrous or hairy, closing in 3 mm. Inflorescence a spicate raceme. Joints on flowering stems glabrous, sometimes bent at 10-15°.

Number 5 Ischaemum indicum (Houtt.) Merr.

Blade characteristics: Blades lanceolate-linear, 5-15 cm long, 8-12 mm wide. Blade margins serrate. Blade top surface has numerous, erect (2-3 mm) hairs, tubercle based. Bottom surface also hairy. Median rib present and keeled (not heavy). Blade exit 20-30°.

Additional characteristics: Perennial to 25 cm high, flowering stems 30-50 cm. Ligule a membrane (2 mm). Sheath is compressed and keeled, glabrous or somewhat hairy near distal end, and open 2-3 cm. Inflorescence a 2 branched, spreading, spicate raceme. Nodes are bearded.

Number 9 Arundinella mesophylla Nees

Blade characteristics: Blade lanceolate, 5-10 cm long, 3-4 mm wide. Margins entire with some glands at base of hairs. Blade top and bottom surfaces are moderately hairy with hairs arising from glands. Median rib is faint, evident only on the proximal half of the blade.

Additional characteristics: Perennial 20-25 cm high, flowering stems 40-45 cm. Ligule is a very short membrane with a ring of short hairs (¼2 mm). Sheath closes ca 1 cm. Inflorescence is a panicle. Margins turn dark reddish-brown before senescence.

Number 10 Themeda trianda Forsk.

Blade characteristics: Blades linear, 30-35 cm long, 2-3 mm wide. Margins minutely serrate, pointing forward, some with sparse 3-5 mm hairs with basal glands. Blade top and bottom surfaces sparsely haired. Median rib lightly keeled with 4 lateral veins. Blade exit 20° or less.

Additional characteristics: Perennial 20-50 cm high with flowering stems to 65 cm. Ligule is a membrane tipped with small hairs. Sheath is open for 3 cm or more. Inflorescence is a panicle.

Number 11 Agrostis peninsularis Hook. f.

Blade characteristics: Blades linear, 10-20 cm long, 2-3 mm wide. Margins very finely serrate and can only be felt and seen with difficulty at the midpoint and tip (10x). Blade top and bottom surfaces are glabrous. Bottom surface has small hairs, pointing forward, and difficult to see. Median rib is present but difficult to distinguish from others (about 14, both sides).

Additional characteristics: Perennial 25-40 cm high with flowering stems 40-70 cm. Ligule is a prominent membrane (2-3 mm), glabrous throughout. Sheath usually closes within 1 cm, but some are open for 2-3 cm. Sheath is glabrous. Inflorescence is a many-branched panicle with secondary and tertiary branches in 3's. Convolute.

Number 15

Blade characteristics: Blades linear-lanceolate, 10-30 cm long, 8-19 mm wide. Margins haired or glabrous with minute serrations. Margins are sometimes wavy and inrolled. Blade top surface is very sparsely haired or glabrous. Bottom surface is glabrous and shiny. Median rib is present but hard to distinguish from 24 or so other veins on top surface. Median rib is keeled on bottom. Blade exit 20-30°.

Additional characteristics: Perennial 60 cm high with flowering stalks to 80 cm. Ligule is a membrane tipped with very small hairs, with the margins of blade often forming a wavy, flaring "collar." Sheath opening varies-closing in 0-3 cm. Inflorescence is a panicle. Blades flare off a central stem. A conspicuous light yellow-green color in fall. Convolute.

Number 19 Arundinella fuscata Nees

Blade characteristics: Blades lanceolate-linear, 8-15 cm long, 7-8 to 14 mm wide. Margins with regularly spaced gland-based hairs, pointing distally. Margins are entire centrally, minutely serrate distally. Blade top and bottom surfaces are sparsely haired - hairs with glands at base, or glabrous. Median rib is present and keeled. Blade exit 20-30°.

Additional characteristics: Perennial to ca 30 cm high, with flowering stems 35-50 cm high. Ligule is level (even lengthened) membrane. Sheath is closed except in senescence. Inflorescence is a spicate raceme.

Number 33 Isachne setosa C.E.C. Fisher

Blade characteristics: Blades broadly lanceolate, 5-9 mm long, 2-3 mm wide. Margins minutely serrate. Blade top surface glabrous or nearly so. Bottom surface sparsely very finely haired. Median rib is absent, but present on sheath. Blade exit 45°.

Additional characteristics: Perennial to 4 cm high, with flowering stems 4-7 cm high. Ligule is a few hairs. Sheath is closed. Veins are prominent on upper blade surface, absent below. Nodes hairy. Inflorescence is a raceme.

Number 40 Arundinella vaginata Bor

Blade characteristics: Blades lanceolate-linear, 30-45 cm long, 5-7 mm wide. Margins are densely hairy, tubercles more readily visible on less densely haired senescent blades (up to 6 mm long). Margins very minutely serrate (key also entire). Does not turn dark reddish-brown as approaching senescence (as does #9). Blade top surface is haired, 2-3 mm long. Bottom surface is densely hairy or furry. Median rib is present but inconspicuous. Blade exit 20°.

Additional characteristics: Perennial to 60 cm high, with flowering stems to 100 cm. Ligule is a row of hairs, 2 mm, above a 0.5 mm membrane. Sheath is open 1 cm or more. Grass is furry and light green in appearance. Inflorescence is a spicate raceme with branches along the stem or clustered at apex. Leaf sheath very hairy (tubercle based).

Number 42

Blade characteristics: Blades lanceolate-linear, 25 to 35 cm long, 16-21 mm wide. Margins very minutely serrate. Blade top surface is finely haired. Bottom surface is glabrous near base, haired near tip. Median rib is prominent and keeled. Blade exit 25°.

Additional characteristics: Perennial to 75 cm high with flowering stem to 130 cm. Ligule absent but 2 auricles of hair present. Sheath is open for several cm. Inflorescence is a panicle. Nodeless stem.

Number 52 Andropogon lividus Thw.

Blade characteristics: Blades lanceolate-linear, 10-17 cm long, 4-6 mm wide. Margins serrate (midpoint and tip). Blade top and bottom surfaces are glabrous. Median rib evident in a slight keel. Blade exit 20°.

Additional characteristics: Perennial up to 30 cm high with flowering stems to 45 cm. Ligule a prominent membrane, clasping stem 3-4 mm. Sheath opening variable, usually closing within 1 cm. Purplish tinge to leaves and inflorescence. Inflorescence is a panicle with spicate branches.

Number 54 Themeda quadrivalvis (Linn.) O.Ktze

Blade characteristics: Blades lanceolate-linear, 10-13 cm long, 4-7 mm wide. Margins finely antorsely serrate (midpoint and end), with or without a few tubercle based hairs (3-7 mm long, nearly perpendicular to surface, more numerous towards proximal end). Blade top and bottom surfaces are glabrous. Median rib is evident. Blade exit 30°.

Additional characteristics: Perennial. Ligule is a haline membrane, 1 mm, tipped with short hairs. Sheath is closed. Inflorescence is a panicle. Numerous joints. This species found trailing or "leaning" on other grasses.

Number 55 Indochloa oligantha (Hochst.) Bor

Blade characteristics: Blades lanceolate-linear, 3-5 cm long, 2-4 mm wide. Margins finely antorsely serrate. Blade top and bottom surfaces are haired. Median rib is evident below, inconspicuous from above. Blade exit 20°.

Additional characteristics: Annual to 30 cm high with flowering stems to 35 cm (often less). Ligule is a hyaline membrane. Sheath is closed. Inflorescence is a spike with conspicuous awns.

Number 59

Blade characteristics: Blades lanceolate-linear, 25-40 cm long, 2-3 mm wide. Margins serrate (midpoint and tip). Blade top surface is glabrous. Bottom surface with many fine distally running hairs. Median rib is prominent, keeled. Blade exit 30°.

Additional characteristics: Perennial to 30 cm high. Ligule is a membrane surrounded by hairs. Sheath is open. Distinctive in having blades with an inverted "w" cross section distally, margins inrolled on bottom.

Number 60

Blade characteristics: Blades lanceolate-linear, 35-45 cm long, 9-21 mm wide. Margins hairless, serrate on hyaline margins (midpoint and tip). Blade top surface is sparsely haired. Bottom surface is glabrous and shiny. Median rib absent on upper surface, but roundly keeled on proximal half of lower surface. Blade exit 20°.

Additional characteristics: Perennial to 40 cm high with flowering stems to 65 cm. Ligule is of hairs (1 mm). Sheath is open for more than 1 cm. Grows in clumps on rock outcrops, usually precariously placed. Leaves and stems convolute. One margin especially prone to roll in, giving appearance and hyaline characteristic only on opposite margin. Inflorescence is a panicle.

Number 62 Helictotrichon asperum (Munro) Bor

Blade characteristics: Blades lanceolate-linear, 25-35 cm long, 3-5 mm wide. Blade top and bottom surfaces are glabrous. Margins are smooth and entire. Median rib is indistinct below. Blade exit variable.

Additional characteristics: Perennial to 65 cm high with flowering stems to 120 cm. Ligule is a membrane (2 mm). Sheath is haired and open. Inflorescence is a panicle.

Number 63

Blade characteristics: Blades lanceolate-linear. Two forms:

Blade length	(a) 4-8 mm	(b) 15-25 cm
Blade width	(a) 1 mm folded	(b) to 6 mm
Margins	(a) entire	(b) entire
Top surface	(a) hidden	(b) glabrous
Bottom surface	(a) glabrous	(b) glabrous
Median rib	(a) absent	(b) absent

Blade exit 5°.

Additional characteristics: Annual to 10 cm high with flowering stems 15-22 cm high. Ligule is a thin hyaline membrane (4 mm). Sheath open for more than 1 cm. Two types of blades (a) thin inrolled (folded) (b) broad, enclosing inflorescence and extending past it. Inflorescence is a panicle. Conduplicate.

Number 64 Eragrostis nigra Nees ex Steud.

Blade characteristics: Blades lanceolate-linear, 18-43 cm long, 5-9 mm wide. Margins serrate (midpoint and distal end), hairless. Blade top surface is glabrous or with scattered hairs, ca. 3 mm in length (more numerous near collar and margins). Bottom surface is glabrous and shiny. Median rib is keeled at the collar to almost inconspicuous at blade tip. Median rib is indistinct on upper surface.

Additional characteristics: Perennial to 20 cm high with flowering stems to 35 cm. Ligule is a minute hairlike membrane below a thin ring of 3-4 mm hairs (clasping). Sheath is variable. A single indentation occurs, usually in the upper half of the blade, as if previously constricted. Inflorescence is a panicle.

Number 65 Isachne boureorum C.E.C. Fisher

Blade characteristics: Blades lanceolate, 2-4 cm long, 4-9 mm wide. Margins minutely serrate, or with a few tubercle hairs (variable). Blade top and bottom surfaces are glabrous, or with a few tubercle based hairs. Median rib is indistinct or absent. Blade exit 90°.

Additional characteristics: Perennial to 25 cm high with flowering stems to 40 cm. Ligule is a ring of hairs just under 1 cm. Sheath closes within 1 cm. Sheaths are hairy, from tubercles. Grass has trailing runners. Inflorescence is a panicle.

Number 66 Digitaria wallichiana

Blade characteristics: Blades lanceolate-linear, 7-10 cm long, 3-5 mm wide. Margins serrate (midpoint checked). Blade top and bottom surfaces are glabrous or with a few hairs near margin (can be keyed as sparsely haired only as only a very few are glabrous). Median rib is prominent and lightly keeled. Blade exit 20°.

Additional characteristics: Perennial with trailing runners. Ligule is a membrane (2 mm), clasping the stem. Sheath closed. Inflorescence a panicle.

Number 69

Blade characteristics: Blades linear, 5-11 cm long, 4-5 mm wide. Margins serrate (tip to midpoint - key also as entire). Blade top and bottom surfaces are glabrous. Median rib is present and keeled. Other veins are also present, ca 5 per side. Blade exit 25°.

Additional characteristics: Perennial. Ligule is a brushy row of hairs with margins having long silky hairs. Sheath is variable, closing 0-2 mm. Sheath is compressed, glabrous. Blades often fold together to "close" V exit after leaving stem. Inflorescence is a spike with long awns that twist around each other. Some blades end abruptly at collar.

Number 76

Blade characteristics: Blades lanceolate-linear, 30-35 cm long, 5-7 mm wide. Margins entire, serrate near tip. Blade top and bottom surfaces are glabrous. Median rib is present and keeled. Blade exit 20-30°.

Additional characteristics: Perennial to 45 cm high with flowering stems to 95 cm. Ligule is a membrane, 1 mm, with a few hairs. Sheath closes within 1 cm. Stem nodes are glabrous. Inflorescence is a raceme with spicate branches. Similiar to 77 but blades are glabrous.

Number 77 Andropogon polyptychus Steud.

Blade characteristics: Blades lanceolate-linear, 35-45 cm long, 7-9 mm wide. Margins entire (also keyed), smooth, serrate. Blade top surface is hairy, lightly furred, tubercle based. Bottom surface is also hairy, especially along median rib and near margins. Median rib is keeled, conspicuous below. Blade exit 20°.

Additional characteristics: Perennial to 70 cm high with flowering stems to 110 cm. Ligule a membrane, 1-2 mm, surrounded by dense hairs. Sheath closing before 1 cm. Stem nodes with ring of dense hairs, blades widest at about 2/3 length. Inflorescence is a raceme with spicate branches. Similiar to 76, differs in having hairs along midrib and margins on underside.

Number 84 Cynbopogon

Blade characteristics: Blades lanceolate-linear, 75-105 cm long, 7-14 mm wide. Margins serrate. Blade top and bottom surfaces are glabrous. Median rib is prominent and keeled. Blade exit 20°.

Additional characteristics: Perennial to 100 cm high with flowering stems to 200 cm. Ligule is a membrane, 2-7 mm. Sheath is open for more than 1 cm. A large grass. Inflorescence is a panicle. Conduplicate.

Number 90 Eragrotis

Blade characteristics: Blades lanceolate-linear, 7-14 cm long, 3-4 mm wide. Margins entire. Blade top surface is glabrous. Bottom surface very sparsely haired. Median rib is faint, no keel, absent distally. Blade exit 30°.

Additional characteristics: Perennial to 15 cm high with flowering stems to 23 cm. No ligule. Sheath is open for more than 1 cm. Stems compressed below. Inflorescence is a panicle.

Number 92

Blade characteristics: Blades lanceolate, 4-10 cm long, up to 8 mm wide (5-8). Margins with numerous hairs arising from glands. Blade top and bottom surfaces also have numerous hairs arising from glands. Median rib is present. Blade exit 20°.

Additional characteristics: Annual about 10 cm high, but up to 25 cm, with flowering stems 25-50 cm high. Ligule is a membrane. Sheath variable. Inflorescence is a raceme.

Number 112

Blade characteristics: Blades lanceolate-linear, 5-11 cm long (18 cm rare), 7-12 mm wide. Margins vary: some serrate, some haired, serrations often end abruptly about midpoint. Blade top surface has a few hairs, tubercle based. Bottom surface is hairy. Median rib is evident, keeled. Blade exit variable.

Additional characteristics: Perennial, 10-15 cm high with flowering stems to 40 cm. Ligule is a prominent membrane, clasping 3-4 mm (5 mm rare). Sheath is open. Inflorescence is a spike, florets lightly appressed to stem. Often one side of blade is serrate, the other haired. In many terminal blades the outside fold is serrate, the inside haired. Many blades end with a constriction, leaving the median rib to form a "petiole" 1-2 cm.

Number 166

Blade characteristics: Blades lanceolate, 5-10 cm long, 5-7 mm wide. Margins are hairless and serrate (midpoint and tip). Blade top surface has a few long silky hairs (3-4 mm). Bottom surface is glabrous. Median rib is prominent and keeled. Blade exit 30°.

Additional characteristics: Perennial. Ligule of hairs. Sheath closes in less than 1 cm. Upper surfaces are often beet purplish. Bottom surface green. Inflorescence is a raceme.

Number 172 Eulalia thwaitesii (Hack.) O. Ktze

Blade characteristics: Blades lanceolate-linear, 7-13 cm long, 3-6 mm wide. Margins minutely serrate throughout. Blade top surface is glabrous. Bottom surface haired (few or none proximally, increasing distally). Median rib is present and keeled. Blade exit 30°.

Additional characteristics: Perennial to 25 cm high with flowering stems to 50 cm. Ligule of hairs, irregular and variable, with small membrane below hairs. Sheath closed. Lacks the rusty fuzz of Eulalia phaeothrix. Inflorescence a spicate raceme.

Number 186 Jansenella griffithiana (C. Nuell.) Bor

Blade characteristics: Blades lanceolate, 1-3 cm long, 2-3 mm wide. Margins with a few hairs at base of blade and serrate (midpoint checked). Blade top and bottom surfaces are glabrous. Median rib absent.

Additional characteristics: Annual to 15 cm high with flowering stems to 25 cm. Ligule is a membrane. Sheath closed. Inflorescence is a panicle.

Number 189 Garnotia courtallensis (Arn. et Nees) Thw.

Blade characteristics: Blades lanceolate, 2-5 cm long, 2-5 mm wide. Margins haired and serrate (midpoint checked). Blade top and bottom surfaces are hairy. Median rib present and keeled.

Additional characteristics: Perennial to 25 cm high with flowering stems to 50 cm. Ligule of hairs. Sheath closed. Inflorescence is a panicle.

Number 199 Garnotia arundinacea Hook. f.

Blade characteristics: Blades lanceolate, 10-14 cm long, 12-20 mm wide. Margins finely serrate with hairs. Blade top and bottom surfaces are glabrous. Median rib is prominent and keeled.

Additional characteristics: Perennial to 150 cm high with flowering stems to 200 cm. Ligule is of hairs. Sheath closed. Inflorescence is a panicle.

Number 203

Blade characteristics: Blades lanceolate, 3-6 cm long, 4-5 mm wide. Margins with a hyaline membraneous edge and serrate (midpoint checked). Blade top and bottom surfaces are glabrous. Median rib is present, sometimes as a firm keel. Blade exit 10-20°.

Additional characteristics: Perennial to ca 5 cm high with flowering stems to ca 25 cm. Ligule a clasping, hyaline membrane ca 2 mm long. Sheath closed. This grass often has prominent joints. Inflorescence is a spicate raceme.

Number 223 Coelachne perpusilla (Arn. ex Steud.) Thw.

Blade characteristics: Blades lanceolate, 1-2.3 cm long, 2-3 mm wide. Margins serrate (midpoint and distal end) and hairless. Blade top and bottom surfaces are glabrous. Median rib absent or nearly so.

Additional characteristics: Annual to 15 cm high with flowering stems to 17 cm. Ligule is a ring of hairs, 0.5 mm. Sheath closed (less than 1 cm). Convolute. Nodes hairy.

Number 230 Eragrostis unioloides (Retz.) Nees

Blade characteristics: Blades lanceolate, 5-10 cm long, 5-6 mm wide. Margins serrate (midpoint to tip) and hairless. Blade top surface is sparsely haired, ca 2 mm long. Bottom surface is glabrous. Median rib is indistinct above, inconspicuous below.

Additional characteristics: Perennial to 11 cm high with flowering stems to 18 cm. Ligule is a minute membrane. Sheath generally closes in less than 1 cm. Conduplicate.

Number 233 Poa annua Linn.

Blade characteristics: Blades linear, 7-10 cm long (shorter on flowering stems- rarely to 14 cm), 2-4 mm wide. Margins hairless, serrate (midpoint and tip), serrations widely spaced at midpoint. Blade top and bottom surfaces are glabrous. Median rib lightly keeled, visible but not prominent on upper surface.

Additional characteristics: Perennial to ca 15 cm high with flowering stems to ca 25-30 cm (supported by other vegetation). Ligule is a membrane not tipped with hairs, ca 2 mm (ca 3 mm on flowering stem). Sheath closed on new growth, but opening to more than 1 cm with age. Conduplicate. Inflorescence is a panicle.

Number 234 *Coelachne simpliciuseula* (Wight et Arn.) Munr.

Blade characteristics: Blades lanceolate, 2-3 cm long, 1.5-2.5 mm wide. Margins entire (a few margins with minute serrations distally of midpoint), hairless. Blade top and bottom surfaces are glabrous. Median rib is inconspicuous, but faintly visible below, absent above.

Additional characteristics: Grass is variable height. Ligule is a ring of hairs. Sheath variable. Aquatic, convolute.

APPENDIX C: REPTILES AND AMPHIBIANS COLLECTED IN ERAVIKULAM NATIONAL PARK

Reptiles

- Lizards
  - *Leiolopisma travancoricus*
  - *Mabuya carinata*
  - *Salea anamalayana*

- Snakes
  - *Ahaetulla dispar*
  - *Amphiesma stolata*
  - *Trimeresurus macrolepis*
  - *Uropeltis maculatus*
  - *Xylophis perroteti*

Amphibians

- *Bufo microtympanum*
- *Philautus leucorhinus*
- *Rana limnocharis*
- *Rana leptodactyla*
- *Rhacophorus pleurostictus*

APPENDIX D: BASIC PROGRAM FOR CALCULATING G-STATISTIC

G-STATISTIC

```
10 CS = 4: REM    SPACING FOR COLUMNS
15 RS = 2: REM  SPACING FOR ROWS
16 MR =  INT (16 / RS)
20 MC = 8: REM          NUMBER OF COLUMNS ON SREEN
30  DIM FB(55,55),FE(55,55): DIM YP(55),XP(55),YN(55),XN(55),CH(5
     5),RH(55),CG(55),RG(55)
40 D$ =  CHR$ (4)
50  REM   MENU
60  HOME
70  PRINT "G-STATISTIC
"
80  REM  PRINT ".......................................""
81  PRINT "<><><><><><><><><><><><><><><><><><><><><""
90  PRINT : PRINT "1 —>ENTER OBSERVED OR EXPECTED VALUES"
100  PRINT : PRINT "2 —>SAVE OBSERVED OR EXPECTED VALUES
      TO DISK"
110  PRINT : PRINT "3 —>READ OBSERVED OR EXPECTED VALUES
      FROM DISK"
120  PRINT : PRINT "4 —>REVIEW OBSERVED OR EXPECTED VALUES"
130  PRINT : PRINT "5 -->CALCULATE G"
140  PRINT : PRINT "6 —>CHANGE TABLE COLUMN WIDTH FROM ";CS: HTA
     B 17: PRINT "OR ROW SPACING FROM ";RS
150  REM PRINT "........................................
........................................
151  PRINT "^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^
^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^"

160  PRINT : PRINT "   PLEASE CHOOSE A NUMBER"
170  PRINT : GET G$: IF  VAL (G$) < 1 OR  VAL (G$) > 6 THEN  PRIN
     T  CHR$ (7): GOTO 50
180 G =  VAL (G$)
190  ON G GOSUB 1000,2000,3000,4000,5000,7000
200  GOTO 50
210 :
220 :
1000  HOME : INVERSE : PRINT "ENTRY ROUTINE": NORMAL : PRINT : PR
      INT "ENTER"
1010  GOSUB 6000
1020  IF TT$ = "EXPECTED" THEN EX$ = "ENTERED":CF$ = "":FE$ = ""

      1022  IF TT$ = "OBSERVED" THEN FB$ = ""
1030  FOR X = 1 TO NR + 1: FOR Y = 1 TO NC + 1
1040  IF TT$ = "OBSERVED" THEN FB(X,Y) = 0
1050  IF TT$ = "EXPECTED" THEN FE(X,Y) = 0
1060  NEXT Y,X
1065  IF TT$ = "EXPECTED" THEN  GOTO 1110
1070  INPUT "1-WAY OR
2-WAY TABLE? ";WA
1080  IF WA < 1 OR WA > 2 THEN 1070
```

G-STATISTIC

```
1090  INPUT "ENTER NUMBER OF COLUMNS: ";NC
1100 NR = 1: IF WA = 2 THEN  INPUT "ENTER NUMBER OF ROWS: ";NR
1110  IF TT$ = "EXPECTED" THEN  GOSUB 1380: IF ET$ = "RATIO" THEN
       GOTO 1300
1120  FOR J = 0 TO NC - 1 STEP MC
1130  GOSUB 1320
1140  INVERSE : PRINT "ROW": NORMAL
1150  FOR X = 1 TO NR
1160 VT = RS * X + 3
1170  IF VT < 23 THEN  VTAB VT: INVERSE : PRINT X;: NORMAL
1180  IF VT >  = 23 THEN VT = 23: POKE 34,3: PRINT : PRINT : VTAB
      VT: INVERSE : PRINT X;: NORMAL
1190  FOR JJ = 1 TO MC
1200 Y = J + JJ
1210  VTAB VT
1220  HTAB CS * (JJ - 1) + 5
1230  IF TT$ = "OBSERVED" THEN  INPUT FB(X,Y):FB(NR + 1,Y) = FB(N
     R + 1,Y) + FB(X,Y):FB(X,NC + 1) = FB(X,NC + 1) + FB(X,Y):FB(
     NR + 1,NC + 1) = FB(NR + 1,NC + 1) + FB(X,Y)
1240  IF TT$ = "EXPECTED" THEN  INPUT FE(X,Y):FE(NR + 1,Y) = FE(N
     R + 1,Y) + FE(X,Y):FE(X,NC + 1) = FE(X,NC + 1) + FE(X,Y):FE(
     NR + 1,NC + 1) = FE(NR + 1,NC + 1) + FE(X,Y)
1250  IF Y = NC THEN  GOTO 1270
1260  NEXT JJ
1270  NEXT X
1275  GOSUB 1320
1280  NEXT J
1290 :
1300  POKE 34,0: RETURN
1310 :
1320  POKE 34,0: HOME : PRINT TT$;: HTAB 12: INVERSE : PRINT "COL
     UMN": FOR I = 1 TO MC
1330  HTAB ((I - 1) * CS + 6): PRINT I + J;: IF I + J = NC THEN
     GOTO 1350
1340  NEXT I
1350  NORMAL : PRINT : RETURN
1360 :
1370 :
1380  PRINT : PRINT "DO YOU WISH TO ENTER

-->T)ABLE VALUES, OR
-->R)OW AND COLUMN PROPORTIONS?

PLEASE PRESS 'T' OR 'R'
1390  GET G$: IF G$ <  > "T" AND G$ <  > "R" THEN  GOTO 1380
1400  IF G$ = "T" THEN ET$ = "TABLE": GOTO 1580
1410 ET$ = "RATIO"
1420  IF FB(NR + 1,NC + 1) = 0 THEN  FLASH : PRINT  CHR$ (7): PRI
     NT : PRINT "PLEASE ENTER OBSERVED VALUES FIRST": FOR I = 1 T
```

```
     0 2000: NEXT : NORMAL : GOTO 1580
1430  PRINT "PRESS RETURN TO SKIP
(FOR EXPECTED VALUES TO BE DETERMINED
BY ROW OR COLUMN SUMS)"
1440  PRINT : PRINT "ENTER PROPORTION FOR COLUMN: ";
1450  FOR Y = 1 TO NC
1460  HTAB 30: PRINT Y;" ";: INPUT YP$
1470  IF YP$ = "" THEN  FOR YY = 1 TO NC:YP(YY) = FB(NR + 1,YY) /
      FB(NR + 1,NC + 1): NEXT : GOTO 1500
1480 YP(Y) =  VAL (YP$)
1490  NEXT Y
1500 PT = 0: FOR Y = 1 TO NC:PT = PT + YP(Y): NEXT : IF PT * 100
     < 99 OR PT * 100 > 101 THEN  INVERSE : PRINT : PRINT "SUM OF
      PROBABILITIES,";: NORMAL : PRINT " ";PT: INVERSE : PRINT "I
     S NOT EQUAL TO 1.  PLEASE REENTER": NORMAL : GOTO 1440
1510  IF NR = 1 THEN XP(1) = 1: GOTO 1570
1520  PRINT : PRINT "ENTER PROPORTION FOR    ROW: ";
1530  FOR X = 1 TO NR
1540  HTAB 30: PRINT X;" ";: INPUT XP$
1545  IF XP$ = "" THEN  FOR XX = 1 TO NR:XP(XX) = FB(XX,NC + 1) /
      FB(NR + 1,NC + 1): NEXT : GOTO 1560
1546 XP(X) =  VAL (XP$)
1550  NEXT X
1560 PT = 0: FOR X = 1 TO NR:PT = PT + XP(X): NEXT : IF PT * 100
     < 99 OR PT * 100 > 101 THEN  INVERSE : PRINT : PRINT "SUM OF
      PROBABILITIES,";: NORMAL : PRINT " ";PT: INVERSE : PRINT "I
     S NOT EQUAL TO 1.  PLEASE REENTER": NORMAL : GOTO 1520
1570  GOSUB 1600
1580  RETURN
1590 :
1600 FE(NR + 1,NC + 1) = 0
1601  FOR X = 1 TO NR
1602 FE(X,NC + 1) = 0: NEXT
1604  FOR Y = 1 TO NC
1608 FE(NR + 1,Y) = 0: NEXT
1609  FOR X = 1 TO NR: FOR Y = 1 TO NC
1610 FE(X,Y) = XP(X) * YP(Y) * FB(NR + 1,NC + 1)
1620 FE(NR + 1,Y) = FE(NR + 1,Y) + FE(X,Y):FE(X,NC + 1) = FE(X,NC
      + 1) + FE(X,Y):FE(NR + 1,NC + 1) = FE(NR + 1,NC + 1) + FE(X
     ,Y)
1630  NEXT Y,X
1640  RETURN
1650 :
1660 :
2000  HOME : INVERSE : PRINT "SAVE TO DISK ROUTINE": NORMAL : PRI
     NT
2010  GOSUB 6000
2015  IF TT$ = "EXPECTED" THEN CF$ = ""
2020  INPUT "ENTER NAME OF FILE TO SAVE: ";NF$
```

G-STATISTIC

```
2030 NF$ = NF$ + "." +  LEFT$ (TT$,3)
2040  INVERSE : PRINT : HTAB 13: PRINT " SAVING FILE ": HTAB (20
     - .5 * ( LEN (NF$))): FLASH : PRINT NF$: INVERSE : HTAB 15:
     PRINT " TO DISK ": NORMAL
2050  PRINT D$;"OPEN ";NF$
2060  PRINT D$;"WRITE";NF$
2070  PRINT NR: PRINT NC
2080  FOR X = 1 TO NR + 1: FOR Y = 1 TO NC + 1
2090  IF TT$ = "OBSERVED" THEN  PRINT FB(X,Y)
2100  IF TT$ = "EXPECTED" THEN  PRINT FE(X,Y)
2110  NEXT Y,X
2120  PRINT D$;"CLOSE ";NF$
2990  RETURN
3000  HOME : INVERSE : PRINT "READ FROM DISK ROUTINE": NORMAL : P
     RINT
3020  GOSUB 6000
3025  IF TT$ = "EXPECTED" THEN EX$ = "READ":ET$ = "READ"
3030  INPUT "ENTER NAME OF FILE TO READ: ";NF$
3044  IF TT$ = "OBSERVED" THEN FB$ = NF$
3045  IF TT$ = "EXPECTED" THEN FE$ = NF$
3047 NF$ = NF$ + "." +  LEFT$ (TT$,3)
3050  INVERSE : PRINT : HTAB 13: PRINT " READING FILE ": FLASH :
     HTAB (20 - .5 * ( LEN (NF$))): PRINT NF$: INVERSE : HTAB 15:
      PRINT " FROM DISK ": NORMAL
3060  PRINT D$;"OPEN ";NF$
3070  PRINT D$;"READ ";NF$
3080  INPUT NR: INPUT NC
3090  FOR X = 1 TO NR + 1: FOR Y = 1 TO NC + 1
3100  IF TT$ = "OBSERVED" THEN  INPUT FB(X,Y)
3110  IF TT$ = "EXPECTED" THEN  INPUT FE(X,Y)
3120  NEXT Y,X
3130  PRINT D$;"CLOSE ";NF$
3990  RETURN
4000  HOME : PRINT "REVIEW"
4010  GOSUB 6000
4020  FOR K = 0 TO NR STEP MR
4030  FOR J = 0 TO NC STEP MC
4040  GOSUB 4410
4050  INVERSE : PRINT "ROW": NORMAL
4060  FOR KK = 1 TO MR
4070  FOR JJ = 1 TO MC
4080 X = K + KK:Y = J + JJ
4090  VTAB KK * RS + 4
4100  IF X <  = NR THEN  INVERSE : PRINT X;: NORMAL
4110  IF X = NR + 1 THEN  INVERSE : PRINT "SUM";: NORMAL
4120  HTAB CS * (JJ - 1) + 5: PRINT " ";
4130  IF TT$ = "OBSERVED" THEN PT$ =  STR$ (FB(X,Y))
4140  IF TT$ = "EXPECTED" THEN PT$ =  STR$ (FE(X,Y))
4145  IF TT$ = "RATIO" THEN PT$ =  STR$ (FB(X,Y) / FE(X,Y))
```

G-STATISTIC

```
4150  PRINT  LEFT$ (PT$,CS)
4160  IF Y = NC + 1 THEN  GOTO 4180
4170  NEXT JJ
4180  IF X = NR + 1 THEN  GOTO 4200
4190  NEXT KK
4200 VT = 22: VTAB VT: PRINT "CORRECT A VALUE? ";: GET G$: PRINT
     G$: IF G$ = "Y" THEN  GOSUB 4270: GOTO 4040
4210  NEXT J
4220  NEXT K
4230  IF TT$ < > "OBSERVED" OR ET$ < > "RATIO" OR CF$ < > "MAD
     E" THEN  GOTO 4250
4240  HOME : FLASH : PRINT "WARNING:";: SPEED= 120: NORMAL : PRIN
     T " EXPECTED VALUES CALULATED
ON THE BASIS OF THE UNCORRECTED OBSERVED VALUES WILL NO LONGER BE
      APPROPRIATE": PRINT : FOR I = 1 TO 32: HTAB 1: PRINT " ";:
     NEXT : SPEED= 255: HOME
4250  RETURN
4260  :
4270 CF$ = "MADE":NF$ = "": VTAB VT: CALL  - 868: INPUT "   ENTER
      ROW OF ENTRY TO CORRECT: ";RC
4280  IF RC < K + 1 OR (RC > K + MR OR RC > NR) THEN  VTAB VT: CA
     LL  - 868: FLASH : PRINT  CHR$ (7);: PRINT "OUT OF RANGE": N
     ORMAL : FOR I = 1 TO 1000: NEXT : GOTO 4270
4290  VTAB VT: CALL  - 868: INPUT "ENTER COLUMN OF ENTRY TO CORRE
     CT: ";CC
4300  IF CC < J + 1 OR (CC > J + MC OR CC > NC) THEN  VTAB VT: CA
     LL  - 868: FLASH : PRINT  CHR$ (7);: PRINT "OUT OF RANGE": N
     ORMAL : FOR I = 1 TO 1000: NEXT : GOTO 4290
4310  VTAB VT: CALL  - 868: PRINT "ENTRY AT ROW ";RC;" AND COLUMN
      ";CC;" IS ";
4320  INVERSE
4330  IF TT$ = "OBSERVED" THEN  PRINT FB(RC,CC): NORMAL : INPUT "
     ENTER THE CORRECT VALUE: ";FB(RC,CC)
4340  IF TT$ = "OBSERVED" THEN FB(NR + 1,CC) = 0: FOR XX = 1 TO N
     R:FB(NR + 1,CC) = FB(NR + 1,CC) + FB(XX,CC): NEXT :FB(RC,NC
     + 1) = 0: FOR YY = 1 TO NC:FB(RC,NC + 1) = FB(RC,NC + 1) + F
     B(RC,YY): NEXT :FB(NR + 1,NC + 1) = 0
4345  IF TT$ = "OBSERVED" THEN  FOR XX = 1 TO NR:FB(NR + 1,NC + 1
     ) = FB(NR + 1,NC + 1) + FB(XX,NC + 1): NEXT
4350  NORMAL
4360  IF TT$ = "EXPECTED" THEN  PRINT FE(RC,CC): NORMAL : INPUT "
     ENTER THE CORRECT VALUE: ";FE(RC,CC)
4370  IF TT$ = "EXPECTED" THEN FE(NR + 1,CC) = 0: FOR XX = 1 TO N
     R:FE(NR + 1,CC) = FE(NR + 1,CC) + FE(XX,CC): NEXT :FE(RC,NC
     + 1) = 0: FOR YY = 1 TO NC:FE(RC,NC + 1) = FE(RC,NC + 1) + F
     E(RC,YY): NEXT :FE(NR + 1,NC + 1) = 0
4375  IF TT$ = "EXPECTED" THEN  FOR XX = 1 TO NR:FE(NR + 1,NC + 1
     ) = FE(NR + 1,NC + 1) + FE(XX,NC + 1): NEXT
4380  IF TT$ = "EXPECTED" AND FE(NR + 1,NC + 1) < > FB(NR + 1,NC
```

```
      + 1) THEN  PRINT  CHR$ (7): HOME : FLASH : PRINT "CAUTION--
     OBSERVED AND EXPECTED
GRAND TOTALS NOT EQUAL": FOR I = 1 TO 2000: NEXT : NORMAL
4390  RETURN
4400 :
4410  POKE 34,0: HOME : IF FE$ <  > "" AND TT$ = "EXPECTED" THEN
      NORMAL : PRINT "FILE: ";FE$
4412  IF FB$ <  > "" AND TT$ = "OBSERVED" THEN  NORMAL : PRINT "F
     ILE: ";FB$
4413  PRINT TT$;: HTAB 13: INVERSE : PRINT "COLUMN";
4416  INVERSE : PRINT : FOR I = 1 TO MC
4420  HTAB ((I - 1) * CS + 6)
4430  IF I + J = NC + 1 THEN  PRINT "SUM";: GOTO 4460
4440  PRINT I + J;
4450  NEXT I
4460  PRINT : RETURN
4470 :
4480 :
5000  HOME : INVERSE : PRINT "CALCULATE G": NORMAL : PRINT
5010  IF EX$ = "ENTERED" THEN  PRINT "USE ENTERED EXPECTED VALUES
     ? ";: GET G$: PRINT G$: IF G$ = "Y" THEN  GOTO 5050
5020  IF EX$ = "ENTERED" AND G$ = "N" THEN EX$ = "NEW"
5030  IF EX$ <  > "ENTERED" AND EX$ <  > "READ" THEN  PRINT "CALC
     ULATE EXPECTED VALUES? ";: GET G$: PRINT G$: IF G$ = "Y" THE
     N  GOSUB 5490
5040 :
5050  PRINT : PRINT "CALCULATE G'S"
5070 TH = 0:HR = 0:CG = 0:HC = 0:TC = 0:TR = 0
5080  FOR X = 1 TO NR:RH(X) = 0: NEXT
5085  PRINT ".";
5090  FOR Y = 1 TO NC:CH(Y) = 0: NEXT
5100  IF NR > 1 THEN  FOR X = 1 TO NR + 1
5105  PRINT ".";
5110  IF NR = 1 THEN X = 1
5120  FOR Y = 1 TO NC + 1
5130 RT = FB(X,Y) / FE(X,Y): REM   : PRINT RT,X,Y
5140  IF RT = 0 THEN LR = 0
5145  IF RT <  > 0 THEN LR = FB(X,Y) *  LOG (RT): REM       PRINT
      "LR=";LR
5150  IF Y = NC + 1 THEN HC = HC + LR: GOTO 5200
5160 CH(Y) = CH(Y) + LR
5170  IF X = NR + 1 THEN HR = HR + LR: GOTO 5200
5180  IF NR > 1 THEN RH(X) = RH(X) + LR
5190 TH = TH + LR
5200  NEXT Y
5210  IF NR > 1 THEN  NEXT X
5215  PRINT
5220 :
5230 :
```

G-STATISTIC

```
5235  PRINT : PRINT "PRINTED OUTPUT (Y/N)? ";: GET PG$: PRINT PG$
    : IF PG$ = "Y" THEN  HOME : PRINT "PRINTING...": PRINT D$;"P
    R# 1": PRINT  CHR$ (27); CHR$ (15): PRINT  CHR$ (9)"200N"
5240 GT = 2 * TH:RG = HR * 2:CG = HC * 2
5245  IF PG$ < > "Y" THEN  HOME
5247  IF FB$ < > "" THEN  PRINT "FILE: ";FB$: PRINT
5250  PRINT "G'S PARTITIONED BY ROW: "
5260  FOR X = 1 TO NR
5270 RG(X) = 2 * RH(X)
5280  HTAB 17: PRINT X;: HTAB 20: PRINT RG(X)
5290 TR = TR + RG(X)
5300  NEXT X
5310  PRINT " ROW G'S TOTAL TO  ";TR
5320  PRINT " G-POOLED ROWS IS  ";RG
5330  PRINT "ROW HETEROGENIETY= ";TR - RG
5340  IF PG$ < > "Y" AND NR + NC > 15 THEN  GET G$
5350 :
5360  PRINT : PRINT "G'S PARTIONED BY COLUMNS:"
5370  FOR Y = 1 TO NC
5380 CG(Y) = 2 * CH(Y)
5390  HTAB 20: PRINT Y;: HTAB 23: PRINT CG(Y)
5400 TC = TC + CG(Y)
5410  NEXT Y
5420  PRINT " COLUMN G'S TOTAL TO  ";TC
5430  PRINT " G-POOLED COLUMNS IS  ";CG
5440  PRINT "COLUMN HETEROGENIETY= ";TC - CG
5450  PRINT : PRINT "TOTAL G: ";GT
5455  IF PG$ = "Y" THEN  PRINT D$;"PR# 0"
5460  IF PG$ < > "Y" THEN  GET G$
5462  RETURN
5470 :
5480 :
5490  PRINT : PRINT "EXPECTED VALUES CALCULATED ON BASIS OF
ROW AND COLUMN TOTALS"
5492 CF$ = ""
5495  FOR X = 1 TO NR:FE(X,NC + 1) = 0: NEXT
5496  FOR Y = 1 TO NC:FE(NR + 1,Y) = 0: NEXT
5497 FE(NR + 1,NC + 1) = 0
5500  FOR X = 1 TO NR: PRINT ".";: FOR Y = 1 TO NC
5600 FE(X,Y) = (FB(X,NC + 1) * FB(NR + 1,Y)) / FB(NR + 1,NC + 1)

     5610 FE(NR + 1,Y) = FE(NR + 1,Y) + FE(X,Y):FE(X,NC + 1) = FE(X,NC
      + 1) + FE(X,Y):FE(NR + 1,NC + 1) = FE(NR + 1,NC + 1) + FE(X
     ,Y)
5630  NEXT Y,X: PRINT
5640  RETURN
5650 :
5660 :
6000  PRINT "O)BSERVED OR
```

G-STATISTIC

```
E)XPECTED";
6002  IF G = 4 THEN  PRINT " OR
R)ATIO OF OBSERVED TO EXPECTED";
6004  PRINT
6010  PRINT : PRINT "PLEASE PRESS 'O' OR 'E'
6020  GET G$: PRINT G$: IF G$ = "E" OR G$ = "O" OR (G = 4 AND G$
     = "R") THEN  GOTO 6030
6025  GOTO 6000
6030  IF G$ = "O" THEN TT$ = "OBSERVED"
6040  IF G$ = "E" THEN TT$ = "EXPECTED"
6045  IF G$ = "R" THEN TT$ = "RATIO"
6050  PRINT : RETURN
7000  HOME : PRINT "CHANGE R)OW, OR
       C)OLUMN SPACING

PRESS 'R' OR 'C'": GET G$: IF G$ <  > "R" AND G$ <  > "C" THEN  G
     OTO 7000
7010  IF G$ = "R" THEN  GOSUB 7050: GOTO 7030
7020  IF G$ = "C" THEN  GOSUB 7120
7030  RETURN
7040 :
7050  PRINT : PRINT : PRINT "ROW SPACING IS NOW ";RS
7060  INPUT "ENTER DESIRED ROW SPACING: ";RS
7070 MR =  INT (16 / RS)
7080  PRINT "ROW SPACING OF ";RS;" GIVES ";MR;" ROWS
PER SCREEN"
7090  FOR I = 1 TO 1000: NEXT
7100  RETURN
7110 :
7120  PRINT : PRINT : PRINT "COLUMN WIDTH IS NOW ";CS
7130  INPUT "ENTER DESIRED COLUMN WIDTH: ";CS
7140 MC =  INT (35 / CS)
7150  PRINT "COLUMN WIDTH OF ";CS;" GIVES ";MC;" COLUMNS
PER SCREEN"
7160  FOR I = 1 TO 1000: NEXT
7170  RETURN
7220 :
7230 :


]
```

APPENDIX E: SAMPLE SIZE FOR ACTIVITY SCAN SAMPLES.

Table D-1.--Sample size for activity scan samples by time of day and month.

Season	Winter		Pre-monsoon			Monsoon			Post-monsoon				
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
0600-0629	7	0	0	0	95	0	0	88	60	14	281	496	1041
0630-0659	62	46	0	92	261	93	165	44	179	157	778	764	2641
0700-0729	135	0	5	173	311	87	198	64	238	537	686	692	3126
0730-0759	100	0	0	163	138	72	281	75	388	271	504	348	2340
0800-0829	52	53	195	363	115	25	91	246	473	496	649	351	3109
0830-0859	153	81	532	360	29	167	0	119	149	652	684	164	3090
0900-0929	230	163	334	498	355	112	124	433	172	1035	838	192	4486
0930-0959	350	243	466	712	372	362	176	602	436	939	886	278	5822
1000-1029	427	233	538	435	752	772	400	411	662	986	1053	321	6990
1030-1059	425	205	481	153	638	468	195	294	421	423	898	536	5137
1100-1129	273	417	599	161	909	261	598	182	386	209	905	411	5311
1130-1159	381	218	485	406	285	264	242	444	622	614	718	547	5226
1200-1229	540	192	526	552	484	358	189	205	295	576	346	724	5987
1230-1259	246	147	556	338	559	154	92	279	626	201	431	595	4224
1300-1329	546	364	251	487	203	113	200	79	800	145	674	254	4116
1330-1359	247	524	439	213	728	219	307	381	827	642	397	440	5364
1400-1429	255	432	361	168	477	475	233	542	710	408	207	219	4487
1430-1459	321	423	213	337	192	416	104	590	233	301	280	261	3671
1500-1529	248	236	243	258	111	342	397	586	216	291	230	270	3428
1530-1559	572	238	80	215	113	264	142	176	260	305	580	212	3157
1600-1629	444	330	207	311	278	237	319	174	602	170	488	277	3837
1630-1659	278	252	199	251	445	346	65	138	248	420	222	159	3023
1700-1729	161	192	102	286	277	216	164	208	583	469	343	193	3198
1730-1759	223	88	64	231	209	108	152	100	438	349	545	134	2641
1800-1829	87	77	120	187	388	86	320	106	201	254	269	43	2138
1830-1859	0	24	62	71	474	0	69	0	40	0	0	78	818
Total	6763	5178	7058	7421	9198	6017	5223	6566	10265	10864	13892	8959	97404

APPENDIX F: BASIC PROGRAM TO SORT INTERACTION MATRIX INTO DOMINANCE HIERARCHY ORDER

INTERACTION MATRIX SORTER

```
10  ONERR  GOTO 2130
20  DIM IM(26,26),PS(120),M1(120),DR(26)
30  DIM TD(120,26),TM(26,26)
40  DIM OD$(120)
50  DIM ID$(26)
60 NN = 26
70  TEXT : HOME :NT = 120
80 CQ = 5: REM    COLLUMN SPACING
90  HOME
100 D$ =  CHR$ (4)
110  HOME : VTAB 3: PRINT "INTERACTION MATRIX SORTER"
120  VTAB 8: PRINT "TYPE 'R' TO READ A FILE": PRINT : PRINT "TYPE
      'F' TO FIND THE DOMINANCE ORDER"
130  PRINT : PRINT "TYPE 'M' TO SHOW INTERACTION MATRIX"
140  PRINT : PRINT "TYPE 'C' TO CHANGE COLUMN SPACING FROM ";CQ
150  PRINT : PRINT "TYPE 'Q' TO QUIT AND RETURN TO MAIN MENU": GE
     T G$: PRINT G$: NORMAL
160  IF G$ <  > "F" AND G$ <  > "M" AND G$ <  > "Q" AND G$ <  > "
     R" AND G$ <  > "C" THEN  INVERSE : PRINT  CHR$ (7): GOTO 110

170  IF G$ = "M" THEN  HOME : GOSUB 1080
180  IF G$ = "F" THEN  HOME : GOSUB 410
190  IF G$ = "R" THEN  GOSUB 250
200  IF G$ = "C" THEN  GOSUB 2100
210  IF G$ <  > "Q" THEN  GOTO 110
220  HOME : PRINT D$;"BRUN MENU 1"
230 :
240 DSUM = 0
250  HOME
260  INPUT "ENTER NAME OF FILE TO READ: ";NF$
270  INVERSE : PRINT : PRINT "READING FILE ";: FLASH : PRINT NF$;
     : INVERSE : PRINT " FROM DISK": NORMAL
280  PRINT D$;"OPEN ";NF$
290  PRINT D$;"READ ";NF$
300  INPUT NI: INPUT NI
310  FOR I = 1 TO NI:ID$(I) =  CHR$ (I + 64): NEXT
320  FOR I = 1 TO NI:IM(0,I) = I:IM(I,0) = I: NEXT :IM(0,NI + 1)
     =  - 21:IM(NI + 1,0) =  - 21
330  FOR X = 1 TO NI + 1: FOR Y = 1 TO NI + 1
340  INPUT IM(X,Y)
350  NEXT Y,X
360  PRINT D$;"CLOSE ";NF$
370  RETURN
380 :
390 :
400 :
410  FOR TI = 1 TO CN:OD$(TI) = "": NEXT :CN = 0:VT = 0:EX$ = "BE
     GIN":TR$ = "NONE"
```

INTERACTION MATRIX SORTER

```
420  IF TR$ = "SECOND SEARCH" THEN  PRINT : INVERSE : PRINT TR$:
     NORMAL
430 IS = 1:JS = 1
440  FOR J = JS TO NI: FOR I = IS TO NI
450  IF J >  = I THEN  GOTO 510
460  IF IM(I,J) < IM(J,I) AND EX$ = "BEGIN" THEN  VTAB 1: HTAB 1:
      PRINT "    MOVING  ";: HTAB 17: PRINT "NEW";: HTAB 33
470  IF IM(I,J) < IM(J,I) AND EX$ = "BEGIN" THEN  PRINT "PARTIAL"
     : PRINT "N  ELEMENTS";: HTAB 16: PRINT "ORDER";: HTAB 35: PR
     INT "SUM": PRINT : POKE 34,3
480  IF IM(I,J) < IM(J,I) THEN M1 = I:M2 = J
490  IF IM(I,J) < IM(J,I) THEN  PRINT CN + 1;: INVERSE : HTAB 4:
     PRINT M2;: NORMAL : PRINT "<----";: INVERSE : PRINT M1;: NOR
     MAL
500  IF IM(I,J) < IM(J,I) THEN EX$ = "YES": GOSUB 750:I = NI:J =
     NI
510  NEXT I: NEXT J
520  IF EX$ = "RESTART" THEN  GOTO 660
530 CN = CN + 1:LM = CN:M1(CN) = M1
540  IF CN = NT THEN  GOTO 410
550  FOR IC = 1 TO NI
560 OD$(CN) = OD$(CN) +  CHR$ (IM(IC,0) + 64)
570  GOTO 580
580  NEXT IC
590  IF EX$ = "DONE" THEN  FOR I = 1 TO NI:TD(CN,IM(0,I)) = I: NE
     XT
600  IF EX$ = "DONE" THEN  HTAB 16: PRINT OD$(CN);
610  IF CN < 2 THEN  GOTO 660
620  IF CN = 1 THEN LT = 1
630  FOR IC = CN - 1 TO 0 STEP  - 1
640  IF OD$(CN) = OD$(IC) THEN LT = IC: GOSUB 1610:IC = 1
650  NEXT IC
660  IF EX$ = "DONE" OR EX$ = "SELECTED" THEN  GOSUB 1500: HTAB 3
     6: PRINT PS(CN): IF TF$ = "FOUND" THEN TF$ = "RESET": PRINT
     "TRIANGULAR RELATIONSHIP FOUND"
670  IF EX$ = "SELECTED" THEN EX$ = "RESTART": GOTO 440
680  IF EX$ = "DONE" THEN EX$ = "RESTART": GOTO 440
690  IF EX$ = "RESTART" AND TR$ = "FIRST SEARCH" THEN TR$ = "SECO
     ND SEARCH": GOTO 420
700  GOSUB 1080
710  FOR I = 1 TO NI:DR(IM(0,I)) = I: NEXT
720  POKE 34,0: RETURN
730 :
740 :
750  FOR KY = 0 TO NI + 1
760 TV = IM(M1,KY)
770  FOR KX = M1 TO M2 + 1 STEP  - 1
780 IM(KX,KY) = IM(KX - 1,KY)
790  NEXT KX
```

INTERACTION MATRIX SORTER

```
800 IM(M2,KY) = TV
810  NEXT KY
820 :
830  FOR KX = 0 TO NI + 1
840 TV = IM(KX,M1)
850  FOR KY = M1 TO M2 + 1 STEP  - 1
860 IM(KX,KY) = IM(KX,KY - 1)
870  NEXT KY
880 IM(KX,M2) = TV
890  NEXT KX
900 EX$ = "DONE"
910  RETURN
920 :
930 :
940  FOR SI = 1 TO NI
950 DSUM = DSUM + ((RA(SI) - LR(SI)) ^ 2)
960  NEXT SI
970 RS(RC) = 1 - (DSUM / (NI * (NI ^ 2 - 1)))
980  RETURN
990 :
1000 :
1010  VTAB 12: INVERSE : PRINT "I";: NORMAL : FOR I = 1 TO NI: HT
     AB I * 4: PRINT ID$(I);: NEXT
1020  PRINT : PRINT : INVERSE : PRINT "P";: NORMAL : FOR I = 1 TO
      NI: HTAB I * 4 - 1: PRINT PD(I);"  ";: NEXT
1030  PRINT : PRINT : INVERSE : PRINT "F";: NORMAL : FOR I = 1 TO
      NI: HTAB I * 4 - 1: PRINT SC(I);"  ";: NEXT : PRINT
1040  IF TP$ = "4" THEN  PRINT : INVERSE : PRINT "T";: NORMAL : F
     OR I = 1 TO NI: HTAB I * 4: PRINT TA$(I);: NEXT
1050  RETURN
1060 :
1070 :
1080  POKE 34,0: HOME : PRINT "PRINT MATRIX ON PRINTER?": GET G$:
      PRINT G$
1090  IF G$ = "Y" THEN  PRINT D$;"PR# 1": PRINT  CHR$ (27); CHR$
     (15); CHR$ (9)"220N": GOTO 1110
1100  PRINT : PRINT "SAVE MATRIX ON DISK?": GET DG$: PRINT DG$: I
     F DG$ = "Y" THEN  GOSUB 2010
1110  HOME : PRINT "INTERACTION MATRIX": PRINT
1120  PRINT "   ";
1130  FOR I = 0 TO NI + 1
1140  FOR J = 0 TO NI + 1
1150 SR$ = "NORMAL"
1160  IF I = 0 AND J <  > 0 AND J <  = NI THEN SP = CQ:SR$ = "INV
     ERSE":PT$ =  CHR$ (IM(J,I) + 64):
1170  IF I = 0 AND J <  > 0 AND J > NI THEN SP = CQ + 2:SR$ = "IN
     VERSE":PT$ = "SUM"
1180  IF J = 0 AND I <  > 0 AND I <  = NI THEN SR$ = "INVERSE":PT
     $ =  CHR$ (IM(J,I) + 64):SP = 3
```

INTERACTION MATRIX SORTER

```
1190  IF J = 0 AND I <  > 0 AND I > NI THEN SR$ = "INVERSE":PT$ =
      "SUM":SP = 3
1200  IF J > 0 AND I <  > 0 AND J <  = NI THEN SP = CQ: IF I = J
     THEN SR$ = "INVERSE"
1210  IF J > 0 AND I <  > 0 AND J = NI + 1 THEN SP = CQ + 1: IF I
      = J AND J < NI + 1 THEN SR$ = "INVERSE"
1220  IF J > 0 AND I <  > 0 AND I <  = NI AND IM(I,J) = 0 THEN PT
     $ = "."
1230  IF J > 0 AND I <  > 0 AND I = NI + 1 AND IM(I,J) = 0 THEN P
     T$ = "."
1240  IF J > 0 AND I <  > 0 AND J <  = NI AND IM(I,J) <  > 0 THEN
      PT$ =  STR$ (IM(I,J))
1250  IF J > 0 AND I <  > 0 AND J = NI + 1 AND IM(I,J) <  > 0 THE
     N PT$ =  STR$ (IM(I,J))
1260  IF I = 0 AND J = 0 THEN  GOTO 1300
1270  PRINT  SPC( SP -  LEN (PT$))
1280  IF SR$ = "INVERSE" THEN  INVERSE
1290  PRINT PT$;: NORMAL
1300  NORMAL : NEXT J: PRINT : PRINT : IF I = NI THEN  PRINT
1310  NEXT I
1320  PRINT : PRINT "PARTIAL SUM = ";PS(LM)
1330  IF DG$ = "Y" THEN  RETURN
1340  PRINT D$;"PR# 0"
1350  PRINT : PRINT "PRESS A KEY TO CONTINUE";: GET GG$: RETURN

    1360 :
1370 :
1380  RETURN
1390  VTAB 8: HTAB 12: PRINT "ROWS"
1400  FOR I = 1 TO NI + 1: FOR J = 1 TO NI
1410 IM(I,NI + 1) = IM(I,NI + 1) + IM(I,J)
1420 IM(NI + 1,I) = IM(NI + 1,I) + IM(J,I)
1430  IF I > NI / 3 THEN  VTAB 16: HTAB 17: PRINT "AND"
1440  IF I > 2 * NI / 3 THEN  VTAB 18: HTAB 20: PRINT "COLUMNS"
1450  NEXT J: NEXT I
1460 IM(NI + 1,NI + 1) = IM(NI + 1,NI + 1) / 2
1470  HOME : RETURN
1480 :
1490 :
1500  IF CN = 1 THEN LS = 10 ^ 10:LM = 0: FOR I = 1 TO NT:PS(I) =
      0: NEXT
1510  FOR C1 = 1 TO NI
1520  FOR C2 = 1 TO NI
1530  IF C1 =  > C2 THEN  GOTO 1550
1540 PS(CN) = PS(CN) + IM(C1,C2)
1550  NEXT C2
1560  NEXT C1
1570  IF PS(CN) < LS THEN LS = PS(CN):ML = CN
1580  RETURN
```

INTERACTION MATRIX SORTER

```
1590 :
1600 :
1610 TF$ = "FOUND": IF TR$ = "NONE" THEN TR$ = "FIRST SEARCH"
1620  GOTO 1760
1630  FOR I = 1 TO CN:PS(I) = 0: NEXT
1640 LS = 10 ^ 10
1650  FOR TC = IC + 1 TO CN
1660  FOR C1 = 1 TO NI
1670  FOR C2 = 1 TO NI
1680  IF TD(TC,C1) > TD(TC,C2) THEN  GOTO 1710
1690 PS(TC) = PS(TC) + IM(TD(TC,C1),TD(TC,C2))
1700  PRINT ,PS(TC)
1710  NEXT C2
1720  NEXT C1
1730  PRINT "TC=";TC,"PS=";PS(TC)
1740  IF PS(TC) < LS THEN LS = PS(TC):LM = TC
1750  NEXT TC
1760 MM = 0
1770  FOR C1 = 0 TO NI
1780  FOR C2 = 0 TO NI
1790 TM(TD(ML,C1),TD(ML,C2)) = IM(TD(CN,C1),TD(CN,C2))
1800 TM(NI + 1,TD(ML,C1)) = IM(NI + 1,TD(CN,C1))
1810 TM(TD(ML,C2),NI + 1) = IM(TD(CN,C2),NI + 1)
1820  NEXT C2: NEXT C1
1830 TM(NI + 1,NI + 1) = IM(NI + 1,NI + 1)
1840  FOR TC = 0 TO NI + 1: FOR CT = 0 TO NI + 1
1850 IM(TC,CT) = TM(TC,CT)
1860  NEXT CT: NEXT TC
1870  FOR I = LT + 1 TO CN
1880  IF M1(I) > MM THEN MM = M1(I)
1890  NEXT I
1900  IF MM < NI AND M2 < NI THEN IS = MM + 1:JS = M2
1910  IF MM = NI AND M2 < NI THEN IS = MM:JS = M2 + 1
1920  IF MM = NI AND M2 = NI THEN IS = MM:JS = M2
1930  FOR I = 1 TO NI:TD(0,I) = TD(ML,I): NEXT
1940 PS(0) = PS(ML)
1950 EX$ = "SELECTED"
1960  RETURN
1970 :
1980 :
1990 :
2000 :
2010  PRINT : INPUT "NAME OF FILE: ";NF$
2020  PRINT "SAVING FILE: ";: FLASH : PRINT NF$: NORMAL
2030  PRINT D$;"OPEN ";NF$
2040  PRINT D$;"WRITE";NF$
2050  PRINT "FILE: ";NF$
2060  GOSUB 1110
2070  PRINT D$;"CLOSE";NF$
```

INTERACTION MATRIX SORTER

```
2080  RETURN
2090  END
2100  PRINT : PRINT "COLUMN SPACING IS NOW: ";CQ
2110  PRINT : INPUT "ENTER NEW SPACING: ";CQ
2120  RETURN
2130  PRINT  CHR$ (7); CHR$ (7): HOME : VTAB 12: PRINT "SORRY, TH
    AT WAS A...": VTAB 15: FLASH : PRINT "FATAL ERROR": NORMAL

    2140  FOR I = 1 TO 500: VTAB 20: HTAB 3: PRINT " ";: NEXT
2150  CLEAR : GOTO 10


]
```