FOOD SELECTION AND RANGING IN HOOLOCK GIBBON (*Hylobates hoolock* HARLAN 1834) IN BORAJAN RESERVED FOREST, ASSAM

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CERTIFICATE

This is to certify that Ms. Kashmira Kakati of the Wildlife Institute of India has carried out a piece of original research work entitled "Food Selection and Ranging in Hoolock gibbon (*Hylobates hoolock* Harlan 1834) in Borajan Reserved Forest, Assam" in partial fulfilment of M.Sc.(Wildlife Science) degree of Saurashtra University, Rajkot. These investigations were carried out under my supervision at the Wildlife Institute of India from November 1996 to July 1997. I also certify that this work has not been submitted for any other degree of any other university.

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SUMMARY

This study on food selection and ranging in the hoolock gibbon (*Hylobates hoolock* Harlan 1834) was carried out between December 1996 and April 1997 in Borajan Reserve Forest, a disturbed and fragmented patch of remnant tropical evergreen forest in Upper Assam, India.

The hoolock gibbon is a primarily frugivorous species, confined to closed-canopy evergreen forests of North-east India, Bangladesh and Burma. This ape is highly endangered in its entire range. Threats to the continued existence of the hoolock are from large-scale destruction of its habitat and hunting.

Two troops of gibbons were followed intensively for four months and behavioural data were collected by continuous focal animal observations. Data were also collected ad libitum on a third troop. Data on the structural components of the vegetation and on the availability of food resources in the intensive study area were collected systematically.

The results of the study show that food availability influenced the diet, movement patterns, home-range sizes and behaviour of hoolock gibbons. Gibbons were selective in their diet using only forty-three plant species out of the more than two-hundred species present. Figs constituted important keystone resources for the gibbons. In months of low fruit availability, the gibbons had a predominantly folivorous diet. Home ranges were small (10.4 ha and 5.4 ha) and habitat degradation represents the greatest threat to the gibbons in Borajan R.F.

CHAPTER I

1.0. INTRODUCTION

The hoolock or white-browed gibbon (*Hylobates hoolock* Harlan 1834) is the only lesser ape found on the Indian sub-continent. It is an arboreal and primarily frugivorous species of the closed-canopy forests of North-East India, Bangladesh and Myanmar. Its geographical range extends from south of the Brahmaputra river in the west to the Salween river in the east. Its present distribution in Assam and Bangladesh is confined to undisturbed natural evergreen and wetter semi-deciduous forest (Groves 1967, Gittins & Tilson 1984, Choudhury 1987 and Alfred & Sati 1990a).

The hoolock gibbon is highly endangered throughout its range chiefly due to destruction and fragmentation of its habitat and to a lesser extent due to poaching. Though given protected status internationally under the IUCN Red data book and nationally under Schedule I of the Wildlife (Protection) Act, 1972 (Anon. 1992) populations have very rapidly dropped to relict status in most parts of the species range (Brockelman & Chivers 1984).

Only an estimated 4500 km^2 of forest area remains in Assam which approximates the description of "natural gibbon habitat". The combined factors of progressively decreasing forest cover, isolation from neighbouring populations and human disturbance have made a redefinition of "natural gibbon habitat" imperative in order to include depleted isolates to which gibbon populations are restricted. This amounts to an estimated area of 2500-3500 km^2 (Choudhury 1989). Borajan Reserve Forest in Assam where this study was conducted is one such isolate.

1.1. LITERATURE REVIEW

1.1.1. Gibbon Ecology

There are nine recognised species of gibbons (family - Hylobatidae) or lesser apes - *Hylobates agilis, H. klossii, H. lar, H. moloch, H. muelleri, H. pileatus, H.syndactylus, H. concolor* and *H. hoolock* (Marshall & Marshall 1976, Chivers 1977). Their distribution is confined to tropical evergreen and the less seasonal parts of semi-evergreen rain forests in South and South-East Asia.

Aspects of the behavioural ecology of majority of the nine species have been studied in the field (Ellefson 1968, Tilson 1979, Chivers & Raemakers 1980, Gittins & Raemakers 1980, Chivers 1984, Whitten 1984, Kappeler 1984, Srikosomatra 1984, Brockelman 1984, MacKinnon & MacKinnon 1984, Haimoff 1984 and Islam & Feeroz 1992).

The lesser apes are distinguished from other primate groups by a unique set of behavioural and functional characters such as monogamy, territoriality, complex songs, frugivory, a short unimodal activity period and a distinctive mode of suspensory locomotion called brachiation. The information base that exists for this group is fairly extensive relative to other groups of mammals (Preuschoft *et al.*, 1984) and there seems to be remarkable consistency in the ecology and behaviour at both the intra and interspecies levels (Leighton 1987). One exception seems to be the food habits of the largest gibbon *H.syndactylus* (siamang) in that it is more folivorous than frugivorous (Whitten 1984) unlike all the other species. Sexual dimorphism in coat colour of three species - *H.hoolock, H.concolor and H.pileatus* and in the vocal repertoires of all except *H.hoolock* comprise the other notable interspecies differences.

Gibbons are long-lived and attain sexual maturity between 8-10 years of age. Demographic data is limited and it is presumed that winter birth peaks may occur in the relatively more seasonal environments for populations further from the equatorial belt (McCann 1933, Tilson 1979, Chivers & Raemakers 1980 and Leighton 1987,).

Gibbons have home ranges that are thirty-four hectares on average, with a territory within it which is defended by loud songs and occasional encounters with neighbours. The mean group size is four comprising of a family unit of a mated adult pair and their offspring. Day ranges vary between 800m to 1500m and the period of activity averages 8-10 hours. Their diet shows a marked dependency on ripe, sugar-rich, juicy fruits (Gittins & Raemakers 1980) with a large proportion of this being figs (*Ficus* spp.) (Leighton 1987).

1.1.2. The Hoolock gibbon

The Hoolock gibbon was first described by Harlan (1834) and assigned to the genus *Hylobates* by Blanford (1888-1891). Most of the earlier descriptions of the hoolock are of taxonomic interest or natural history observations (Alfred & Sati 1986). After McCann's (1933) two month study on the behaviour of the hoolock in the Naga Hills in 1930, until the last decade, the only other published account of the behaviour of hoolock gibbon in the wild was an exploratory study by Tilson (1979) in the Hollongapar Reserve Forest in Upper Assam. The study duration was 62 days between 1971 and 1973. Since then there has been two major ecological studies on hoolock gibbons by Islam & Feeroz (1992) in Bangladesh and Alfred & Sati (1987,1990a,1990b and1991) in the Garo hills of Meghalaya. The findings of the studies carried out on the hoolock in the wild are summarised below:

The geographical range of the hoolock gibbon extends from south of the Brahmaputra river in the west to the Salween river in the east, covering Myanmar, all the seven North-Eastern states of India between latitudes 22^{0}N and 28^{0}N and longitudes 93° and 97°E and Bangladesh. Groves (1967) had identified two sub-species of *H.hoolock* - *H.h.hoolock* and *H.h.leuconedys* on the west and east of the Chindwin river of Myanmar respectively (Groves 1967, Choudhury 1987 and Alfred & Sati 1990b). In Assam, the hoolock gibbon is found in almost all the districts south of the Brahmaputra but in much depleted numbers because of its shrinking habitat. Choudhury (1987) estimated 6000 hoolock gibbons surviving in the relatively better forested areas in Assam.

The hoolock is the only gibbon species whose range extends beyond the tropics. It is therefore subjected to a more marked seasonality than the other species in the relatively constant climate of the equatorial region. This factor would be expected to significantly influence both the behaviour and the ecology of the species (Gittins & Tilson 1984).

Hoolocks are diurnal, largely arboreal and frugivorous. Locomotion is by jumping, leaping, brachiation and bipedal walking. The day range varies from 0.6 to 1.6 kms. They spend the largest proportion of their active period in feeding on fruits - mainly figs, buds, leaves, shoots, flowers, petioles and insects (Tilson 1979, Alfred & Sati 1990a, Choudhury

1991, Islam & Feeroz 1992). The number of food tree species of hoolock gibbon identified so far are 43 from Hollongapar Reserve Forest of Assam (Tilson 1979), 40 from Bangladesh (Islam & Feeroz 1992) and 104 from the Garo Hills of Meghalaya (Alfred & Sati 1994).

The group size varies between two and six individuals consisting of a monogamously mated pair and their offspring, although occasionally solitary individuals have been encountered. Adults are sexually dimorphic. November to March is regarded as the breeding season (McCann 1933, Roonwal & Mohnot 1977, Tilson 1979, Prater 1980 and Islam & Feeroz 1992) and the inter-birth interval is nearly two years (Alfred & Sati 1987). There is also one record of infanticide (Alfred & Sati 1991). The activity period of hoolock gibbons is restricted to daylight hours (Gittins & Tilson 1984 and Islam & Feeroz 1992).

The home range size of hoolocks irrespective of group size varies between 15-35 ha. The smallest home range size of 3.2 ha was recorded for a group at West Bhanugach in Sylhet (Gittins & Tilson 1984). Hoolock gibbons defend territories by calls and patrolling.

1.1.3. Food selection

Food selection in animals, particularly in herbivores assumes a central role in the ecology of the animal. It forms the link between plant community structure and behavioural attributes such as foraging movements, activity pattern and social systems of the animal. It also determines animal population densities (McKey *et al.* 1981).

Food selection can be viewed in the light of the optimal foraging theory, as largely an issue of balancing relative costs and benefits while fulfilling the nutritional requirements of the forager (McKey *et al.* 1981, Oftedal 1991). Although the goal may be singular, the factors that determine food selection or avoidance are diverse. Primate diets are defined by energy needs, nutrient requirements, constraints of the digestive system, digestion inhibitors or toxic compounds in foods, spatial and temporal distribution of food resources, intra- and interspecific competition and predation (Hladik 1978, McKey *et al.* 1981, Waterman 1984, Strier 1991, Oftedal 1991,).

1.1.3.1. Food selection as determined by availability:

The terms availability, selection and preference of a component of the habitat are used here as given in Johnson (1980). The three are interrelated factors and need to be viewed as a composite when studying animal usage of its environment.

As mentioned before, selections and preferences are dictated to an extent by the associated foraging costs. However, contrary to what the optimal foraging theory states, animals may select "sub-optimal" diets when the abundance of preferred foods are low or the foods are spatially scarce. Sub-optimal diets may also be selected if the maximum energy yielding foods are deficient in specific nutrients, or when foods in a habitat do not differ enough for the animals to discriminate among them. Obviously, feeding is more than nutrition alone. Characteristics of the environment and the behaviour of choice play a crucial role and nutritional values alone may not explain feeding patterns very accurately (Menzel 1994).

Plant species especially in taxonomically and chemically diverse rain forest differ in their abundance, their spatial distribution, their phenological cycles (Chapman 1988), their accessibilities and their nutritional qualities. Over and above this, herbivores are limited by behaviourally determined preferences which may be either rigid or variable. Selections and preferences therefore operate at three levels - at the level of the habitat, the plant species and within the plant micro-habitat.

Several studies have demonstrated that consumption of different foods corresponds directly to the availability and abundance of these foods in the forest which may or may not be related to season (Clutton-Brock 1977, Peres 1985, 1994, Chapman 1988, Strier 1991, Zhang 1994,). Apart from the availability of principal foods or preferred foods (Petrides 1975), the aggregation of alternate foods also influences diet selection (Edwards *et al.* 1994).

1.1.3.2. Food selection as determined by plant chemistry :

Although primates as a group consume a complex variety of foods, patterns of preferences have been observed for fleshy fruits and nuts - sources of readily available energy; and/or for leaves, flowers and seeds - sources of protein, minerals and most vitamins. Other, less nutrient-rich items rarely contribute more than a small percentage of the total diet (Harding 1981, Waterman 1984).

This might seem an expected phenomenon, but recent studies suggest that food selection by herbivores, both ungulates (Bryant & Kuropat 1980) and primates (Goodall 1963, Oates *et al.* 1980, Calvert 1985) are based not on maximising the positive nutritive value, but on minimising the concentration of anti-feedant chemicals produced by the plants such as digestion-inhibitors *e.g.* tannins and fibre; and/or toxins *e.g.* alkaloids, saponins, cyanogenic glycosides (Westoby 1974 and Waterman 1984). Selection therefore appears to correlate with both positive and negative factors.

1.1.3.3. Specific nutrients :

The nutritional requirements of free-living primates is not very well known and accurate measurements in the field are difficult to achieve (Waterman 1984 and Oftedal 1991). Digestibility trials are not feasible (Menzel 1994) and feeding time, the easiest method to employ in the field is a less informative measure of actual intake than weight, although records of feeding rates of different food items may offset this drawback to a degree (Chivers & Raemakers 1986, Clutton-Brock 1977).

The major nutrients in foods however, as well as their distribution within the plant parts would be expected to provide a correlation to food selection in primates. These factors are discussed below in brief:

Carbohydrates represent the most abundant nutrient source although the major part of it - the structural carbohydrates are not directly available to primates. It is the residual non-structural portion composed largely of starch and simple sugars that form the source of readily available energy. Simple sugars occur widely in plants, but rarely attain high concentrations except in the phloem and in the flesh of some types of fruits (Waterman 1984). In fruits therefore, it may be an important factor in food choice (Raemakers 1978).

Lipids constitute a second source of high-energy nutrients from plants. Its levels in most plant parts is low (Waterman 1984) and although lipid content varies widely between species, it averages the same in fruit and young leaves (Raemakers 1984). Exceptions are found in fruits of families such as Myristicaceae and Meliaceae where the aril - a fleshy structure external to the seed average high levels of lipids.

Proteins supply essential and non-essential amino acids. In rain forest plants, protein levels are highest in flowers and immature leaves, and lowest in petioles and fruit flesh (Vellayan 1981). As far as its importance in primate diets is concerned, studies have given mixed results. Significant correlations between food selection and protein concentrations have been indicated in some studies (McKey *et al.* 1981, Milton 1979 and Glander 1981, Calvert 1985) but not in others (Oates *et al.* 1980, Calvert 1985).

Minerals requirements are often cited as possible explanations for the use of items that are neither protein nor energy rich (Waterman 1984). However, distributions of major minerals in rain forest vegetation (Golley *et al.* 1980), African "miombo" woodland (Ernst 1975) and broadleaf pasture weeds (Carlisle *et al.* 1980) have been compared, and it was concluded that in general, concentrations of all nutrients except sodium are sufficient to ensure intake from a narrow diet (Waterman 1984). Foliage and bark usually have the highest concentrations of minerals. Calcium occurs in low concentration in fruit flesh (Hladik 1977, Vellayan 1981). It follows therefore that frugivores may have to look to other sources for calcium.

Water supply in the diet is thought to be a determining factor in food selection by primates (Nagy & Milton 1979). Diets low in water content such as gums and seeds can cause water-stress (Wrangham 1981). However, water content in immature leaves and fruit flesh is generally above 80% of the wet weight and in most other food classes above 50% thus ensuring enough for frugivorous or folivorous primates (Waterman 1984).

Fibre as Acid Detergent Fibre (ADF) in foliage has been found to be negatively correlated to food selection in monogastric and ruminant herbivores in studies on the black colobus (Choo *et al.*, 1981), Nilgiri langur (Oates *et al.* 1980) and the howler monkey (Milton 1979). Information on the role of fibre in frugivore food selection is sparse, but the same trend may be expected.

Tannins are plant secondary compounds that may influence food choice but do not completely deter selection of an item. (Waterman 1984). However, in monogastric primates, the negative correlation was found to be much stronger (Wrangham & Waterman 1981). The level of tannin below a certain critical value that might be specific to a certain group would possibly have no significant role in food selection. Tannins are present in leaves and are reported to be high in unripe fruits, and levels decline as the fruit ripens (Waterman 1984).

Crude protein/(Acid Detergent Fibre + Tannin): Since selection is determined by both the positive and the negative and there is a general positive correlation between the levels of a number of nutrients, a ratio of nutrients to anti-feedants/digestion inhibitors/toxins may be a better predictor for selection (McKey *et al.* 1981, Waterman 1984).

Gross energy: Animals require energy for their normal functions such as basal metabolism, activity, thermoregulation, growth, reproduction and lactation and the amount of energy obtained from foods would be an important determinant of selection. Gross energies of plant tissues are often very uniform (Robbins 1983).

1.1.3.4. Nutrition in gibbons:

Gibbons are monogastric with a relatively simple gastro-intestinal tract. They are extremely selective feeders compared to other primates. They select not only for species and food type, but also for large source size within their food species Different species of gibbons show a similar preference for fleshy, sugary fruit and figs (Chivers 1984). However the smaller gibbons seldom eat ripe fruit. They eat most vegetative parts of plants - leaves both young and mature, leaf stems, soft-stemmed climbers, buds and flowers. A small proportion of the diet is made up of animal matter which is presumed to provide a greater range of amino acids than plant matter (Chivers & Raemakers 1986, Alfred & Sati 1994).

Smaller primates like gibbons select fruit over leaves probably because they require more energy-rich food (Raemakers 1984). Within the gibbon species, it has been observed that young leaves are a major component of the diet of the larger species (10-12 kg) like the siamang, but are not eaten by the smaller Kloss gibbon (5 kg) (Chivers 1984). The hoolock gibbon weighs about 6-8 kg (Leighton 1987). Gittins & Tilson (1984) had hypothesised that the lower availability of food at the latitudes inhabited by the hoolock may cause it to have a more folivorous diet like the siamang. Alfred & Sati (1994) have reported that the hoolock gibbon is frugivorous although leaves do form a part of their diet.

Gibbons generally have a poor detoxification ability in relation to a low-fibre diet, and this has been suggested as a reason for this group being restricted to more diverse and less seasonal forests where toxic effects can be reduced by frequent change of foods (Vellayan 1981).

In a marginal habitat such as Borajan R.F with lower floristic diversity than in the undisturbed areas, factors that determine hoolock food preferences both in terms of supply and quality might be expected to show more identifiable patterns.

1.1.4. Home range

The concept of a home range is that of an area traversed by an individual in its normal activities (Burt 1943) exclusive of large scale or erratic wanderings away from the area of occupation (Jewell 1966). A territory is defined as a defended area within the home range (Noble 1939). Gibbons are strictly territorial (Leighton 1987) and show the characteristic manifestations of territoriality - defence, challenge, vocalisation, song and other signalling activities as defined by Carpenter (1958). In gibbons, overt aggression has seldom been recorded and territoriality is maintained by social boundaries and vocalisations (Whitten 1984, Kappeler 1984, Gittins 1984).

Both home ranges and territories are functions of the composition and distribution of vegetation types (Struhsaker 1967). The home range may have one or more foci of activity which is used more frequently and regularly than other parts (Carpenter 1940) and among forest living animals, fruit-bearing trees usually form focal points in the range (Jewell 1966). Within the home range, animal movements vary according to the changes in the spatial availability of food resources (Peres 1985, Zhang 1994). For frugivores like the gibbon, food resources would mean fruiting plants or those at any other edible phenophase.

Range-use in primates is suggested to be highly situation-dependent and a single fruiting tree can strongly influence the range-use pattern of a primate species. Since primates live in unpredictable environments where fruiting is asynchronous or at large time intervals, it is imperative that they sample their entire home ranges regularly by sallies into currently unused patches (Chapman 1988). This may also serve a patrolling function in territorial primates like the hoolock gibbon. As has been found for other arboreal mammals such as marmosets (Scanlon *et al.* 1989), a home range for gibbons would need to consist at the very least of a minimum number of favoured feeding trees and sleeping trees. Like for most other animals, the use of regular routes and pathways in the home range has also been reported for hoolock gibbons (Prater 1980).

1.2. OBJECTIVES

This study had the following objectives:

1. To study the structure of the vegetation and plant species richness in the areas used by gibbons.
2. Food selection
   - 2.1. To determine the number of food tree species and their densities in the study area.
   - 2.2. To determine availability and use of food tree species.
   - 2.3. To determine the relationship between selection and quality of food in terms of nutrients *viz.* dry matter, carbohydrate, protein, fat content, minerals and total calorific value and digestion-inhibitors *viz.* fibre and tannins.
3. To draw up activity budgets of the two study groups and compare the same.
4. To study the movement patterns and determine the home ranges of the study groups.

CHAPTER II

2.0. STUDY AREA

2.1. INTRODUCTION

Borajan Reserve Forest (RF) is a small patch of lowland tropical rain forest in Upper Assam. It was notified as an RF in 1916 and had been left undisturbed during the war years (1939-43) when most of the forests south of the Brahmaputra came in for heavy exploitation (Srinivasan). Even 50 years ago this pocket was connected with contiguous forest. Now however, it stands completely isolated in a matrix of tea-gardens and cultivation.

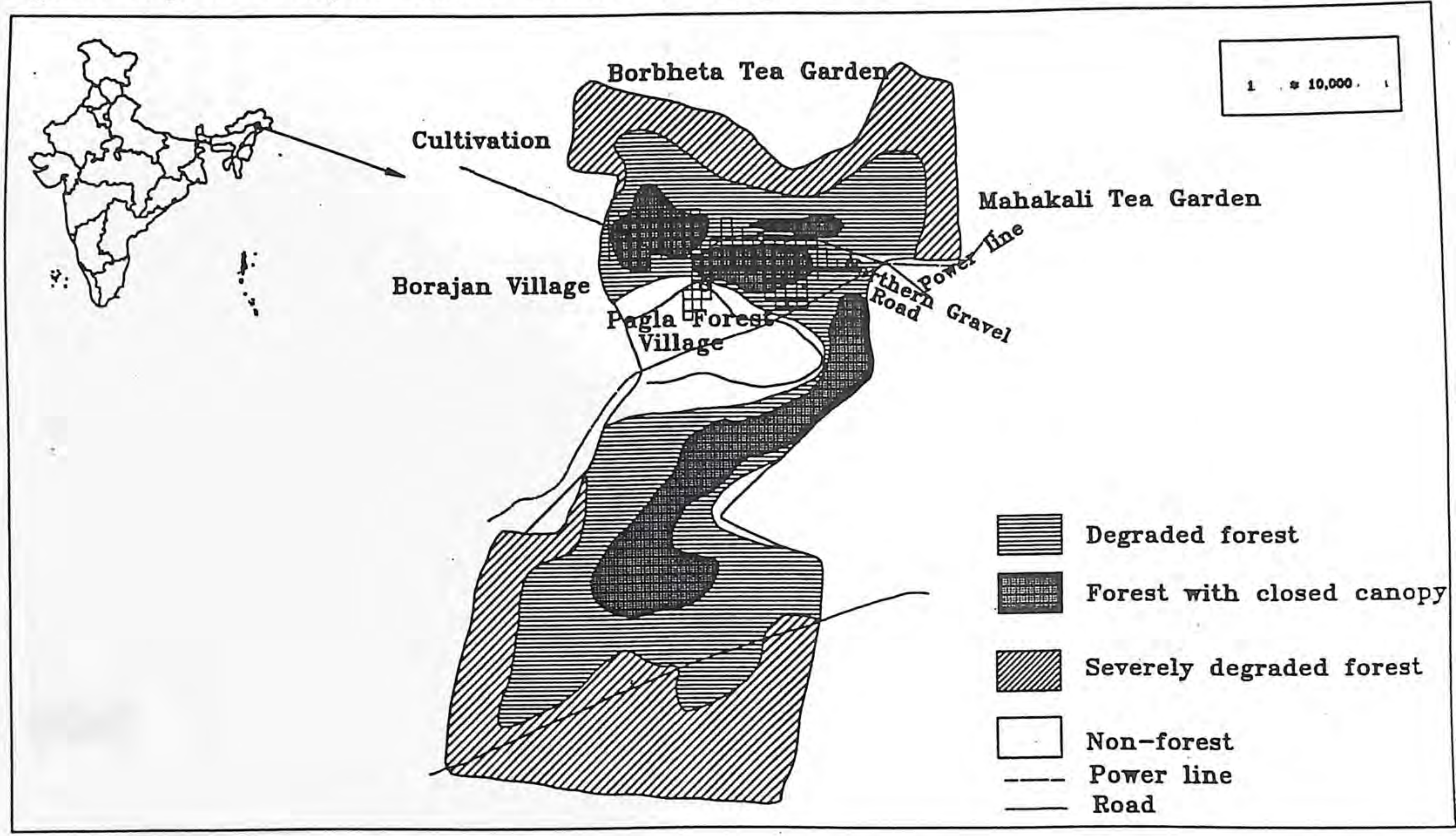
Over the years, a certain amount of degradation of the habitat in the RF has been caused by illegal felling, lopping and fuelwood-collection by the local villagers, refugee settlers from the fringes of the RF and labourers from the bordering tea estates. Within the last decade, the sudden and large-scale illegal felling by the timber mafia has reduced the forest to a severely degraded patch with a very high level of disturbance by humans and livestock. Probably less than one-fourth of the area has any canopy cover at all, with most of the remaining continuous canopy areas under the daily onslaught of felling.

Incidentally, this small patch of forest is reported to contain the highest biomass of primates anywhere on the Indian sub-continent (Choudhury 1995), although this is probably an artefact of isolation and crowding.

2.2. LOCATION, AREA AND PHYSICAL FEATURES

Borajan RF (27°25'N - 95°22'E) is located in Tinsukia District of Assam (Survey of India toposheet ref. no. 83M/7N). It covers an area of 4.93 km^2 and lies at an average elevation of 122 m asl. Located on undulating old alluvium on the south bank of the Brahmaputra river, it has a seasonal channel called the Gainala flowing across its southern part. The terrain is flat and most of the reserve area is criss-crossed by several shallow seasonal nullahs. These are generally about 1 to 2m deep and flow around disconnected earthen mounds of variable area on which the trees grow.

Fig. 1: Map of Borajan Reserve Forest showing forest cover and intensive study area



The Pagla Forest village is located inside the RF and encroachment is evident. Two locally busy roads and a high-tension power-line pass through it. Its northern, and part of its eastern boundary with the Mahakali Tea Estate is fenced off with wire (Fig.1)

2.3. CLIMATE

Borajan RF lies in the high-humidity zone. The climate is tropical monsoonal with an average rainfall of 2875mm and temperature ranging between 7°C and 32°C (Choudhury 1995). The rainfall is evenly distributed with only three months (November to January) being relatively dry. Dew and fog were common during the winter months and thunderstorms and hailstorms occurred frequently. The meteorological data collected is shown in Fig.2.

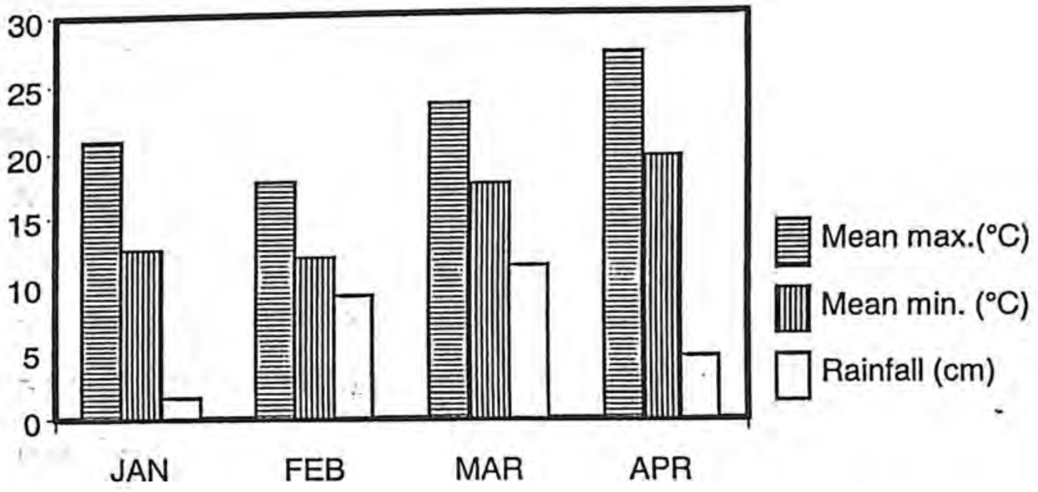


FIG.2. Mean monthly temperature and rainfall at Borajan RF (1997)

2.4. VEGETATION

The original forest type 1B/C1 - Assam Valley Tropical Wet Evergreen Forest (Champion & Seth 1968), also called the Upper Assam *Dipterocarpus-Mesua* forest, has been largely replaced by old mixed plantation with several deciduous species, although *Dipterocarpus retusus* still predominates.

Substantial tree cover in the Borajan RF remains only in two relatively large patches - in a roughly 400m broad strip along the 1.3 km long northern gravel road and in another strip running north to south-west along the eastern side of the reserve. The rest of the area falls in either of two categories -

- Degraded - with low tree density, discontinuous canopy and tangled undergrowth.
- Severely degraded - with a completely open canopy and the undergrowth overrun by weeds like *Mikania* sp. and *Azeratum* sp..

The structure of the vegetation in the areas of tree cover can be broadly divided into the following classes:

- An upper storey of *Dipterocarpus retusus* (Hollong), *Ailanthes integrifolia* (Borpat), *Artocarpus chama* (Samkothal), *Anthocephalus chinensis* (Kodom*)*, *Bombax ceiba* (Himolu), *Michelia* spp, *Terminalia myriocarpa* (Holok), *Terminalia chebula* (Hilikha) and *Syzigium* spp.(Jamuk).
- A middle storey of *Mesua ferrea* (Nahor), *Dillenia indica* (Ou-tenga), *Lagerstroemia parviflora* (Ajar), *Amoora wallichii* (Amari), *Dysoxylum binacteriferum* (Bandordīma), *Garcinia cowa* (Cau-thekera), *Talauma hodgsonii* (Barampthuri/Thou-thou), *Myristica sp., Canarium* spp. (Dhuna) and *Sapium baccatum* (Seleng).
- A lower storey of bamboos, canes and palms the common species of which are *Dendrocalamus hamiltonii* (Kako), *Pseudostacyum polymorphum* (Bojal), *Calamus erectus* (Jeng), *Calamus spp.* (Bet) and *Livistonia jenkinsiana* (Tokou).
- The undergrowth is composed of species such as *Laportea* sp. (Surat pat), *Glechenia linearis, Alpinia* sp., and *Azeratum* sp.. *Mikania* grows widespread through most of the area, especially in the degraded portions where it forms 0.5 to 2-3 m high blankets over the ground along with other weeds.

- *Piper* sp., *Thunbergia grandiflora, Dalbergia volubilis, Tiliacora cordifolia, Schefflera venulosa* and *Aeschynanthus* are some of the common climbers and the common orchids are *Vanda teres, Coelogyne cristata* and *Bulbophyllum* spp. *Asplenium nidus, Polypodium argutum* and *Pleopeltis* are the common epiphytic ferns. A few tree figs and several climber figs such as *F. pomifera, F. benjamina and F. nervosa* occur scattered in the area.

2.5. INTENSIVE STUDY AREA

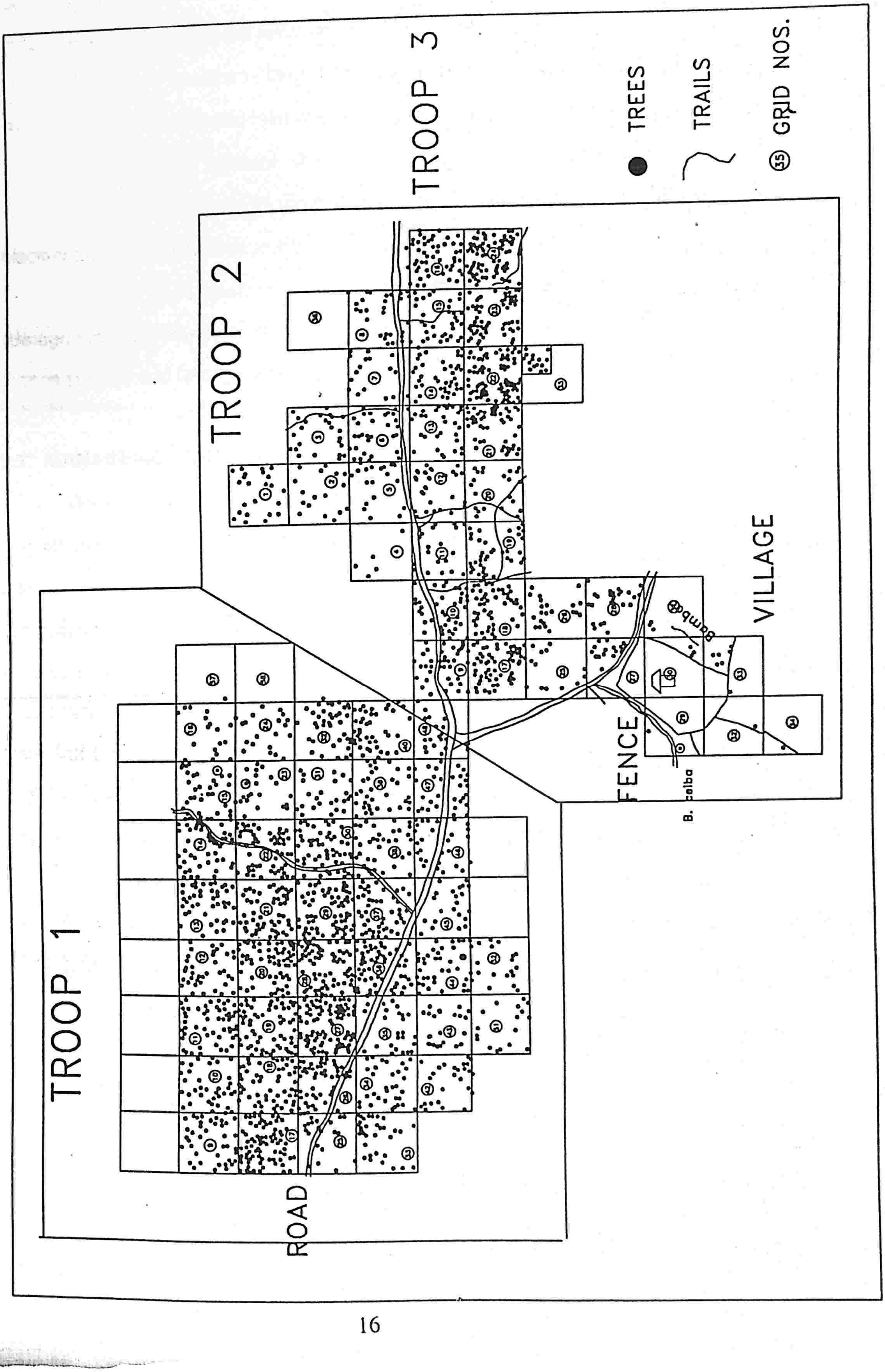
Choudhury (1995) had estimated a population of at least 30 gibbons in 7 family groups in this RF. The RF was surveyed in December 1996 for gibbon presence. Three groups of gibbons were found occupying adjacent territories in the forested strip on both sides of the northern gravel road. An area of 21.5 ha comprising the areas used by the first and second gibbon troops (18.8 ha) as well some peripheral area around this was gridded (grid size - 50 x 50 m) (Fig. 3). An additional area of approximately 5 ha that was used by the third troop was not gridded.

The intensive study area was bordered by cultivation on the west, degraded reserve area in the north, the Mahakali Tea Estate in the east and degraded area and the forest village in the south.

The power line formed the southern boundary of the third group. Each group used only one or two specific arboreal routes in order to cross the road. This road was 6.5 m wide on an average. The vegetation here was dominated by *Dipterocarpus retusus* and *Mesua ferrea* with a relatively sparse undergrowth.

2.6. FAUNA

Fourteen species of mammals were reported from Borajan RF (Choudhury 1995) and three more were added to the list during this study. Apart from the hoolock gibbon, the mammalian species seen during the study were the pig-tailed *macaque (Macaca nemestrina)*, Assamese macaque (*Macaca assamensis*), capped langur *(Semnopithecus pileatus)*, barking deer *(Muntiacus muntjac)*, particoloured flying squirrel (*Hylopetes alboniger*) and Pallas's squirrel (*Callosciurus erythraeus*). Leopard cat (*Felis bengalensis*), Large Indian civet (*Viverra zibetha*) and Small Indian mongoose (*Herpestes auropunctatus*) were the new records for the RF. Four


TROOP 3
TREES
TRAILS
35 GRID NOS.
TROOP 2
VILLAGE
Bamboo
FENCE
B. ceiba
TROOP 1
ROAD

privately owned elephants were released in the reserve in February. This apparently is a regular feature every year during the rainy season (Montu Munda pers. comm.).

Eighty two species of birds (Choudhury 1995, this study) have been recorded from the RF. This includes the Indian Pied hornbill (*Anthracoceros malabaricus*), kaleej pheasant (*Lophura leucomelana*), lesser adjutant stork (*Leptoptilos javanicus*), four species of woodpeckers (*Micropterus, Dinopium* and *Picus* species), large racket-tailed drongo (*Dicrurus paradiseus*) and black-crested baza (*Aviceda leuphotes*).

At least eight species of reptiles *e.g.* monitor lizard (*Varanus sp.*), hard-shell turtle (Bataguridae), skinks, glass snake (*Ophisaurus gracilis*) and four species of snakes including a python species and twenty species of butterflies have been recorded from the reserve so far.

2.7. MANAGEMENT AND CURRENT CONSERVATION STATUS

Borajan was notified as a Reserve Forest under the Lakhimpur Forest Division on 29th August 1916 (Das, A.C undated). It was generally categorised under 'Government Wasteland' prior to reservation. The reserve has 8 compartments (nos. 6-13) of the Makum Felling Series (Srinivasan undated). Plantations of mostly *Dipterocarpus retusus* and *Terminalia myriocarpa* were carried out between 1943-1966 and more recently in 1995-1996, but the total area planted is less than 20% of the RF. Regeneration of *Dipterocarpus* and *Mesua* were carried out between 1946 and 1968 (Assam Forest dept. records). The entire reserve was brought under the Hollong-Mekai regeneration working circle between 1974-75 to 1985-86. For administrative convenience, it was subsequently taken under the Digboi forest division (Das, B.N undated).

The forest department does not conduct logging operations. A proposal submitted by the Rhino Foundation for Nature in North-East India to declare Borajan as a wildlife sanctuary is currently under consideration by the Assam Forest Department. There is also a plan to transfer the RF to the Dibrugarh Division.

Chapter III

3.0. METHODS

3.1. GENERAL METHODS

This study was carried out between December 1996 and April 1997. The intensive study area (18.8 ha) was divided into 50 m X 50 m grids. The starting point was a known location (entry point of the RF) obtained from the Survey of India (1:50000) toposheet. Half metre wide belts marking the grid lines were cleared of vegetation to enable movement between grids. All grid lines ran in north-south and east-west directions.

There were forty one (10.25 ha) and thirty-four and a half grids (8.6 ha) in the areas used by Troop 1 and Troop 2 respectively. These are referred to as Area 1 and Area 2. The grids were used as the reference units for tracing gibbon movement routes, establishing their locations, demarcating their used areas and for the quantification and mapping of the vegetation within the study area.

3.2. QUANTIFICATION OF VEGETATION

A study of vegetation within the intensive study area was carried out to obtain information on the structure of the forest, number of tree species, their abundance, spatial distribution and phenological states. All quantification of vegetation was done towards the end of the study period. The area sampled was just over 50% of the total grid area.

- Plots of 10m radius were laid in each quarter of the grid around the centre of the grid quarter. In each of the plots, the following were recorded -

1. All tree species with GBH (girth at breast height) >20cm.
2. GBH
3. Estimates of tree height.
4. Canopy cover at four locations in the quarter using a spherical densiometer. All values for the grid were averaged to obtain a single canopy cover value per grid.
5. Canopy continuity as an attribute of the vegetation important for the movement of gibbons (Alfred & Sati 1986) was assessed by scoring the tree nearest the grid quarter center on a

categorical scale of zero to four based on canopy continuity with a neighbouring tree in one of four predetermined directions (NSEW) *e.g.* O - no canopy continuity, 1 - canopy continuous with another in one direction, etc. Canopy gaps of 5m or less which the gibbons were assumed to be able to jump across were disregarded.

6. Total vine volume on trees was estimated by assuming a cuboid. Wherever identification was possible, the palatable species, as defined by use, were recorded as a proportion of the total vine volume. All vine species that could not be identified were categorised as "others".

- The species and height of all trees (>20 cm GBH) lying outside the plot were also recorded. Densities were derived from this total count of trees in each grid. The total availability of food trees was the total number of individuals of the species within the home range of each gibbon troop. Plant species were identified at the Wildlife Institute of India herbarium.
- Mapping :- The locations of all the trees relative to the centre of the grid quarter were plotted on a map of the intensive study area to obtain a visual representation of the tree densities, canopy cover and canopy continuity within the home-ranges of the study troops. This also permitted easy identification of locations, movement routes, feeding trees and sleeping trees of the gibbons.

3.3. MONITORING CHANGES IN PLANT PHENOLOGY

Aluminium tags were used to mark two-hundred and thirty-five individual trees representing seventy species within the intensive study area at the beginning of the study. Tagged trees included gibbon food tree species reported in literature, the species commonly occurring in the study area and those that I perceived to be rare species. The phenology of the tagged trees was monitored once a month preceding the days that I followed the gibbons. The phenological state was categorised as -

1. Leaf - young or mature, and indeterminate when distinctions were difficult to make.
2. Flower
3. Fruit - ripe or unripe, indeterminate.
4. Buds

3.4. ESTIMATION OF FOOD TREE AVAILABILITY

Availability of food trees was assessed at four levels - number of trees of the species, the proportion physically accessible to the gibbons, the proportion in a usable phenophase and finally, an estimate of the biomass available within the individual tree.

3.5. ESTIMATION OF FRUIT AVAILABILITY

Fruit abundance in all food tree species fruiting at anytime during the study period was quantified by using a modified version of the unit branch method (Andrew *et al.* 1979). However, factors such as small sized fruits, cauliflory, poor visibility in high crowns or dense foliage, unequal branching and temporally staggered ripening, presented serious limitations to conducting the visual assessment. Moreover a large proportion of the fruiting figs were climbers which made the DBH method (Leighton & Leighton 1982, Peters *et al.* 1988, Chapman *et al.* 1992) invalid for comparisons. The estimates were subjective, and therefore this data were not used in the statistical analysis of availability. Qualitative terms such as "large trees", "small climbers", "super abundance of fruit" is instead used to convey relative biomass availability estimates.

3.6. STUDY OF ACTIVITY, FOOD HABITS AND HABITAT USE BY GIBBONS

3.6.1. Selection of study troops

A survey of Borajan RF for gibbons was conducted at the beginning of the study. Three troops of gibbons were found occupying territories adjacent to each other in the northern part of the RF which was easily accessible. All three troops were followed for two to three days each in December 1996 and the first troop was selected for the study.

Subsequently, apparent differences were observed in the habits and habitat of the second troop. This prompted a decision to follow this troop also for observations to enable comparisons with the first troop.

3.6.2. Habituation of the animals

Both troops were habituated during December 1996 - the first month of the study. Habituation of the troops took about two weeks. Although the area has had human presence for long the gibbons have not been disturbed. They have also been followed before (Choudhury

1995). I did not attempt to habituate the third troop. Only ad libitum (Altmann 1974) data on locations of this troop over the study period was collected and plotted on a map to obtain an idea of their home range and to look for overlap, if any, with the second troop's home range. Information on time and duration of songs of this troop were also recorded whenever they sang.

3.6.3. Group composition

Troop 1 consisted of four individuals - an adult male, an adult female, a juvenile and an infant. The infant was not included in the observations. This infant died on 1 March, 1997. Troop 2 consisted of two individuals - an adult male and an adult female. Troop 3 had four individuals - adult male, adult female and two young of different ages. The female of this troop was not seen after the third week of January 1997.

3.6.4. Sampling regime

Continuous focal animal sampling of individuals (Altmann 1974) was done from dawn-to-dusk for six (Troop 1) and four days (Troop 2) each month i.e. two days per individual per month. The total days of observation for Troop 1 in four months - January to April 1997 and on Troop 2 for three months - February to April 1997 were 24 and 12 respectively.

Simultaneously, group scans (Altmann 1974) were also done on the minute, every five minutes. This data however has not been analysed.

3.6.5. Categories of data

On each day of observation the following details were recorded:

1.Date

2.Time

3.Daily weather

   i) Temperature (Max. Min. thermometer)

   ii) Rainfall

   iii) Other notes on the weather - sunny, cloudy, foggy, windy etc.

4.Individual

5.Grid number

6.Activity

i)Plant species and part consumed if feeding

ii)Partner if socially interacting/allogrooming

7.Others - ad libitum records of feeding rates, rare behaviour such as the sequence of reactions and interactions immediately before and after the infant died, mating, reaction to human and other disturbance, interspecies interactions etc.

3.6.6. Activity classes

Activity was categorised as one of the following -

1. Feeding - foraging, inspection, handling, ingestion and chewing of food. All movement and resting phases of less than one minute duration during feeding bouts were also included in this category.
2. Moving
3. Resting - sitting inactive or sleeping, including the overnight sleeping period.
4. Vocalisation - songs, distress cries or squeals and alarm or warning sounds.
5. Grooming
    a)autogrooming - individual grooming itself
    b)allogrooming - grooming another individual
6. Other - body shaking, defecation, looking towards a disturbance source, alarm behaviour, interspecies interactions etc.

3.7. QUANTIFICATION OF FOOD QUALITY

Samples of thirty-nine of the forty-three plant species that the gibbons fed on during the study period were collected, weighed fresh in a spring balance and dried in the sun. These were later oven-dried at 60°C - 80°C. Samples were stored in paper bags until the end of the field study. For transportation, these were transferred to plastic zip-lock packets. Leaf samples from five random non-food species in young leaf were also collected for comparison. All samples were ground in a Wiley mill through a 1mm mesh-size sieve for laboratory analysis. Replicates were run for all samples and the mean values were used in the analysis. The following assays were carried out :-

1. Dry matter values of completely dry samples after 24 hours of oven-drying at 100°C. All other values were calculated on this dry matter.
2. Calorific value was determined by bomb calorimetry in a Sanyo Gallencamp Bomb calorimeter (Anon. 1994).
3. Nutrients
    a) Crude protein was calculated from total nitrogen estimated by the modified Kjeldahl method (Horwitz 1980). After acid digestion of the samples, titrations were done on a Tecator Kjeltec 1030 Autoanalyser.
    b) Fat content by Soxhlet extraction (Horwitz 1980).
    c) Total ash content (Horwitz 1980).
    d) A residual fraction of nonstructural carbohydrates presumed to be largely starch and sugar was estimated by subtracting the concentrations of crude protein, ether extract, ash and NDF from 100 (Calvert 1985).
4. Digestion inhibitors
    a) Acid detergent fibre (ADF) (VanSoest, 1963).
    b) Neutral detergent fibre(NDF) (Goering & VanSoest 1970).
5. Secondary compounds - Tannins were estimated by the modified acidified vanillin method (Burns 1971).

3.8. DETERMINATION OF MOVEMENT PATTERNS AND HOME RANGES

Locations of the two gibbon troops were taken daily by direct sighting in one of three time blocks (5AM-9AM, 9AM-12PM,12PM-5PM). Locations of the third troop were taken randomly. Route maps of the troops were drawn on a map overlaid with the reference grids on all days of continuous observation each month. All subsequent locations for the month were also plotted on this map.

3.9. STATISTICAL ANALYSIS

Vegetation :- Tree densities per hectare in Area 1 and Area 2 were compared using a t-test. Canopy cover values for the two areas are the means of the values for each grid in each area.

Food selection as a function of nutritive value was determined by developing a multiple regression model. This model used time spent on the food species as the dependent variable and various nutrient content values as the independent variables. The forward stepwise procedure of the statistical package SPPS for Windows with an alpha of 0.05 for entering variables and 0.1 for removing variables was specified. The data were tested for normality by the Kolmogorov-Smirnov test and except for tannin and ether extract, all sets were normally distributed.

In order to compare the nutritive values of twenty-five species of food trees and five species of randomly chosen non-used species, the values of the latter were bootstrapped by drawing 2000 random samples from the original data set using the statistical package SIMSTAT 3.5e (Peladeau 1995). Confidence intervals were generated on the means of both troops, for each variable. If these were found to be overlapping between the troops, it was inferred that there was no difference in that variable between the used and non-used species.

Daily activity budgets were drawn up on the basis of time spent on each activity. All data were tested for normality. An Anova was used to test for differences in mean times spent in the main activities - resting, feeding and moving <u>between</u> <u>months</u> for each troop. The means of the time spent on the main activities <u>between the two troops, over three months</u> was compared using a t-test. An Anova with two-factor replication was used to check for differences in time spent on these activities in <u>corresponding months between the two troops.</u>

Home-range estimation:- All locations were plotted on a map to obtain X-Y coordinates in the computer software AUTOCAD. Home range was then calculated using the software program CALHOME (Kie *et al.* 1994). The Minimum Convex Polygon (Mohr 1947) area was used to estimate home range size of the study troops to facilitate comparison of home range sizes. The minimum number of locations required for a stable home range was determined by plotting a cumulative graph of home range area versus number of locations.

The harmonic mean method (Dixon and Chapman 1980) was used to identify activity centres of the gibbons within their home-ranges. A minimum area curve with different isopleth percentages was used to decide on the percentage of harmonic mean isopleth to be used for determining activity centres.

Daily movement was determined by measuring distances on a map between two successive points. A one-way ANOVA was used to test for differences between mean daily movement among months. A t-test was used to look for differences in mean daily movement pooled over the months between the two troops.

CHAPTER IV

4.0. RESULTS

4.1. VEGETATION

Area 1 had a higher density of trees, more trees species and greater canopy cover than Area 2. The tree density in Area 1 (175.4±80.04/ha) was significantly higher ($p>0.05$) than in Area 2 (118.12±89.47/ha). There were a total of 133 tree species in Area 1, 101 tree species in Area 2, and 57 species common to both areas [Sorenson's similarity index (Magurran 1988)= 0.48]. The height of the canopy ranged between 25 and 30 m with few emergents over 30 m in height. A majority of the trees had some climbers or vines growing at various heights on their trunks. Whenever it occurred on a tree *Dalbergia volubilis* (a climber) tended to spread up to the canopy. *Aeschynanthus* species also tended to occur more in the canopy layer.

The canopy was relatively more closed in Area 1 (82.39±11.84%) than in Area 2 (73.23±19.91%). Except for the gap over the road and in the extreme southern grids, the canopy was largely continuous throughout the area (See Fig.3).

In Area 2 on the other hand, nearly half of the grids, mainly in the western part bordering Area 1, had open scrub patches and scattered trees. The Pagla forest village was situated south of these grids and six of the grids fell within the village. A narrow road leading to the village, with degraded patches on either side, formed an effective boundary between Areas 1 and 2 (See Fig.3).

A total of 177 species of trees and at least 30 species of vines were recorded from the intensive study area (Appendix 1). At least 10 additional tree species and some vine species remain to be identified.

4.2. ACTIVITY BUDGET

Resting, feeding and moving in that order were the most important activities in terms of time spent on each activity for both the troops over all the months. There was no difference in time spent on any of these three activities either between months for each troop or between the troops.

A very small proportion of the time was spent in vocalisations (0.23% and 1.27% by Troop 1 and Troop 2 respectively). Troop 1 sang on eleven days, while Troop 2 sang only once during the entire study period. In contrast, Troop 3 sang on twenty-seven days with two bouts of singing on three of these days. The percent time spent in different activities by the two troops over the study period is given below:

Table 1. Activity budgets of Troop 1 and Troop 2 in Borajan RF

	TIME SPENT (%)	
ACTIVITY	TROOP 1	TROOP 2
Resting	79.4	79.1
Feeding	12.2	10.9
Moving	4.1	5.9
Basking	3.3	1.9
Grooming	0.1	0.2
Vocalising	0.2	1.2
Other	0.3	0.3

FIG.4. Activity budgets of Troop 1 and Troop 2

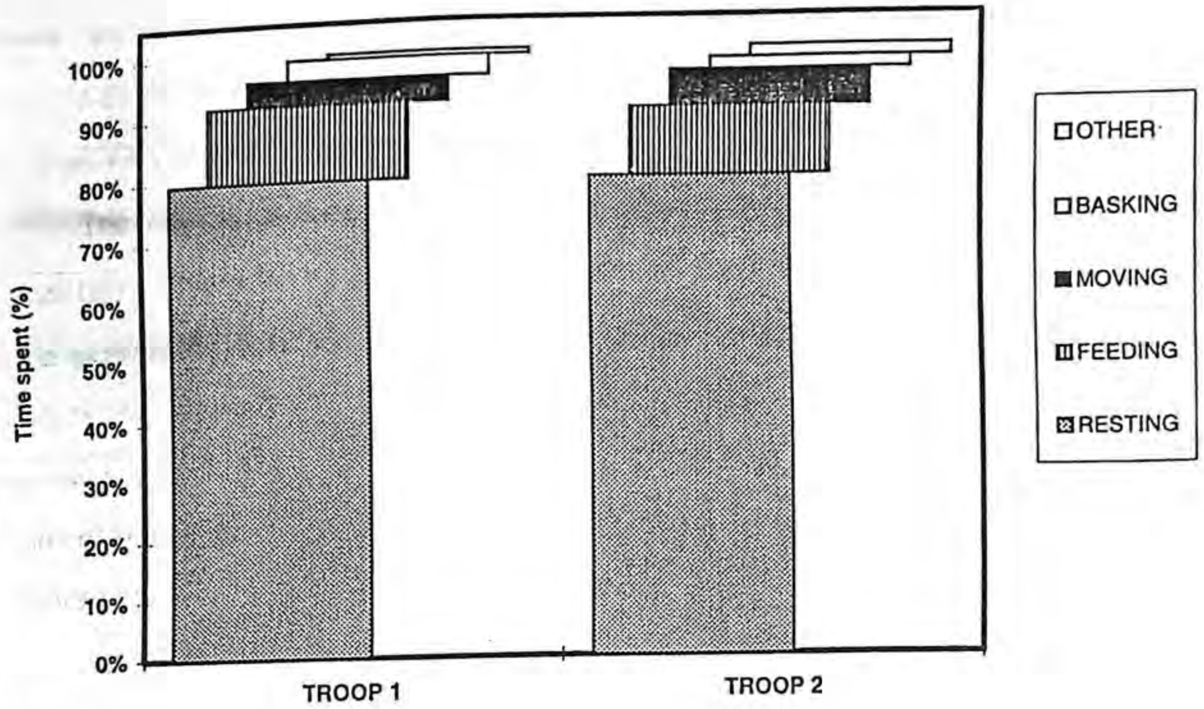


Table 2. Month wise activity budgets of Troops 1 and 2 in Borajan RF.

TIME SPENT (%)								
	January		February		March		April	
ACTIVITY	Troop 1	Troop 2	Troop 1	Troop 2	Troop 1	Troop 2	Troop 1	Troop 2
Resting	80.7	-	79.5	77.0	82.5	78.3	78.0	79.3
Feeding	10.3	-	12.7	11.9	10.7	13.1	10.2	12.7
Moving	3.7	-	2.3	7.9	3.6	4.5	6.3	5.9
Basking	4.2	-	4.8	1.9	1.5	3.2	2.4	1.1
Grooming	0.2	-	0.1	0.3	0.2	0.1	0.1	0.2
Vocalising	0.2	-	0.2	0.5	0.7	0.2	2.5	0.1
Other	0.4	-	0.2	0.2	0.4	0.3	0.3	0.4

4.3. FOOD SELECTION

4.3.1. Food species available

The gibbons used eight plant parts from forty-three species (trees -20, stranglers and climber figs - 7, vines - 13, orchids - 2, tree-fern- 1) as food out of a total of 177 species of trees and at least 30 identified species of climbers in the intensive study area. They nibbled (spent less than 1.5% of time feeding) on an additional nine species of plants.

The density of food trees in Area 1 was 11.8±9.08/ha, and that in Area 2 was 12.0±9.08/ha. The density of food trees relative to the more common species was generally low in the study area. *Ficus* species also occurred in low densities and fruiting was sporadic. For example, *Ailanthes integrifolia* and *Alcimandra cathcartii*, two important food species, numbered only three each in all of Area 1. Moreover, two of the three individuals of *Ailanthes integrifolia* could not be reached via the canopy. Similarly, of the five trees of *Magnolia hookeri*, all had buds in March but only two were accessible to the gibbons.

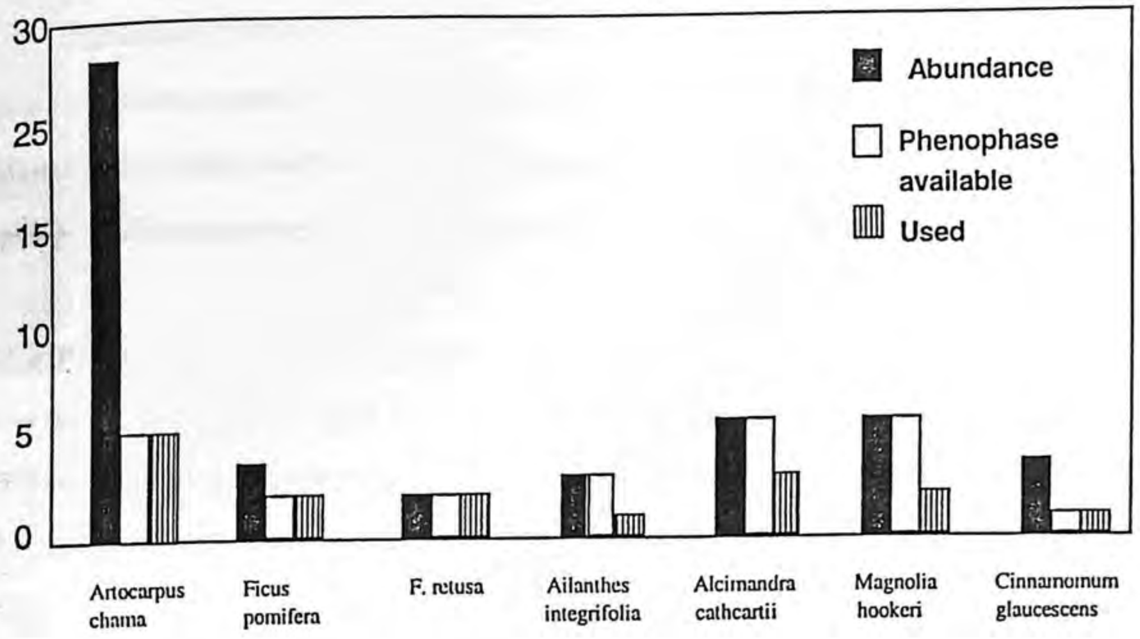
Availability of the major food species to the gibbons in terms of phenophase was mostly equal to their availability in terms of number of individuals. The only notable exception was *Artocarpus chama*, where of the twenty-seven (Area 1) and sixteen individuals (Area 2) only five and four respectively fruited during the study period. Other exceptions included *Cinnamomum glaucescens* (flowers), *Ficus pomifera* (fruits) and *Magnolia hookeri* (buds) in Area 1; and *Erythrina stricta* (flower buds/fruits) and *Michelia champaca* (buds) in Area 2. Since I could not differentiate between young and mature leaves of *Ailanthes integrifolia* and *Alcimandra cathcartii*, Icould presume them available only when they were used.

In Area 1, the variation in availability across months was marked for some species such as *Cinnamomum glaucescens* (flowers) and *Magnolia hookeri* (buds), but for others such as *Ailanthes integrifolia* and *Alcimandra cathcartii* (leaves), the availability remained largely constant. There was an instance where one individual of *F.pomifera* experienced two fruiting peaks during the study period.

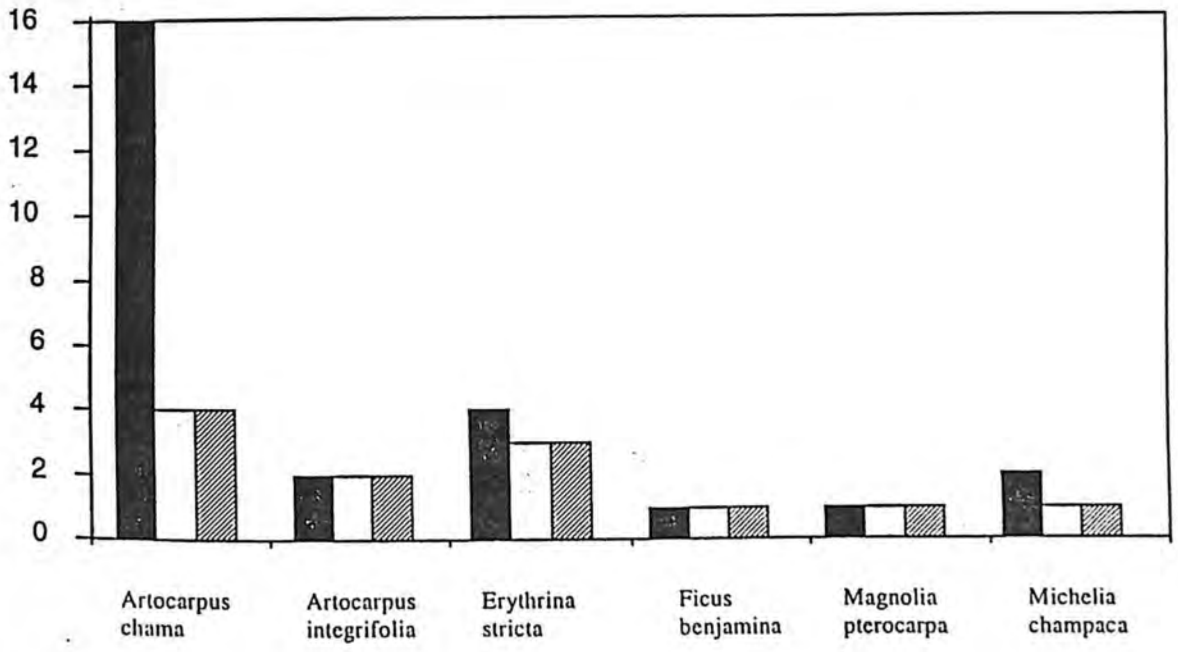
In Area 2 a single individual of *F.benjamina* with super abundant fruit was the focus of feeding activity for Troop 2 from the last week of December until the beginning of April when its

FIG. 5. Abundance of major food tree species, numbers in available phenophase and numbers used by gibbons of Troops 1and 2.

Troop 1



Troop 2



fruiting ceased. The availability of *Artocarpus integrifolia* (fruits), *Erythrina stricta* (flower buds, fruits) and *Magnolia pterocarpa* leaves remained relatively constant through the three months of observation for this troop. However, the availability of *Bombax ceiba, Ficus subulata* (fruits) and *Helixanthera parasitica* (young leaves) was sharply restricted in time.

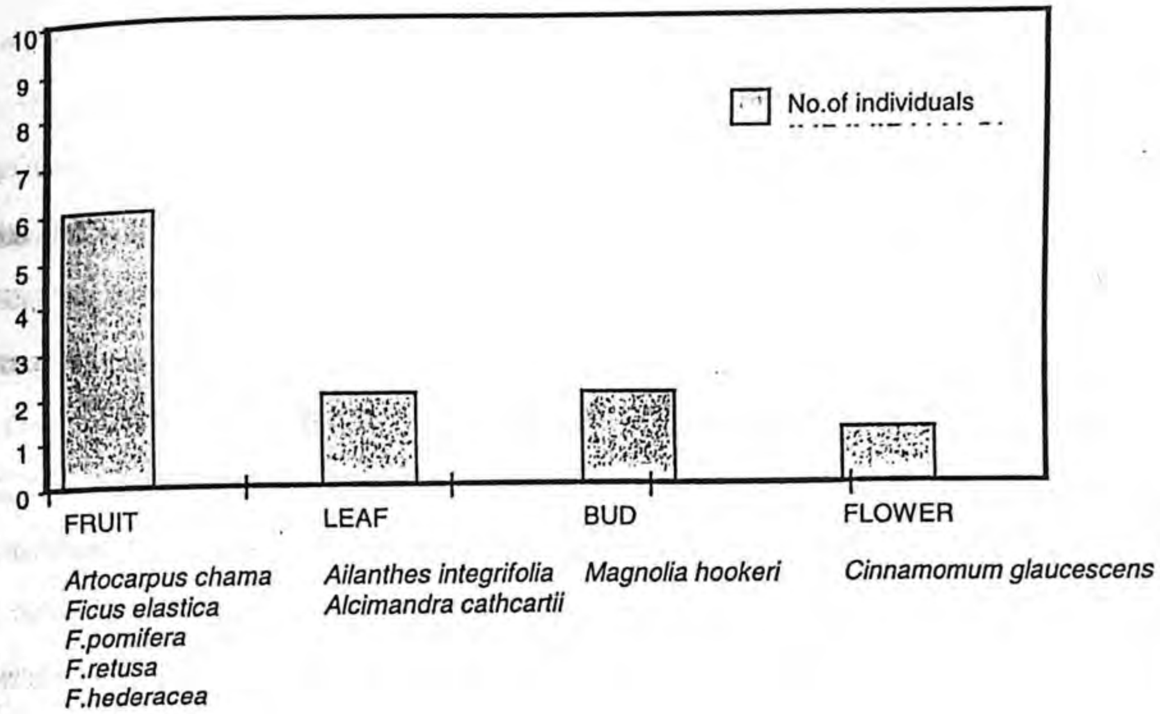
Artocarpus chama in fruit formed the most available fruit resource in both Area 1 and Area 2 in April and a shift in diet to *A.chama* in this month was observed in both the troops. (Fig. 5: Abundance of major food tree species, numbers in available phenophase and numbers used by gibbons). The availability of the vine species of interest could not be assessed.

4.3.2. Food trees available and used

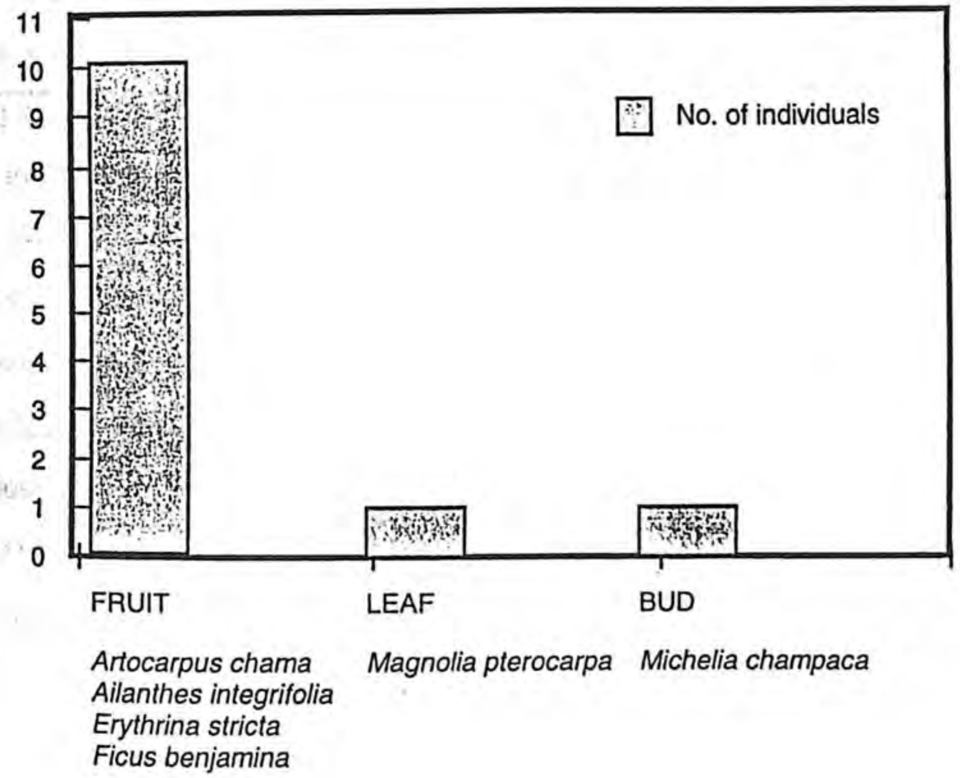
In Area 1, twenty-eight individual trees of nineteen species and in Area 2, twenty individuals belonging to thirteen species served as food sources for the gibbons during the study period. Of these, in Area 1, eleven individuals of nine species and in Area 2, twelve individuals of six species were major food sources (visited two or more times) (Fig. 6).

FIG. 6. Major food species and their total numbers in each food item class.

Troop 1



Troop 2



4.3.3. Food species used

Troop 1 fed on thirty-five species (of which five were only nibbled at) and Troop 2 fed on twenty-eight species (of which four were only nibbled at) in all. This included eight and four species respectively of *Ficus* (21.9% of all food species). There were fourteen food species common to both troops - four tree species (*Artocarpus chama, Ailanthes integrifolia, Helixanthera parasitica* and *Sterculia villosa*), four fig species (*Ficus benjamina, F.hederacea, F. elastica* and *F. geniculata*) and six species of vines and orchids (*Aeschynanthus* sps 1, *Thunbergia grandiflora, Tiliacora cordata, Gnetum scandens, Coelogyne cristata* and *Vanda teres*).

Over all the months, Troop 1 spent 72% of total feeding time on nine species alone (trees-2, figs-3 and vines-4). These included leaves of two species of a succulent vine *Aeschynanthus* sp.1 and *Aeschynanthus* sp.2 (Family - Gesneraceae) which together accounted for the most (22%) time spent feeding over the entire study period. The consumption of these two species was uniform over all the months. This was followed by feeding on leaves of *Ailanthes integrifolia* and *Alcimandra cathcartii* (22%). Fig fruits accounted for 18.5 % of the time of which *F.pomifera* and *F.retusa* contributed the most (11.25%). *Gnetum scandens* (leaves) was the other important species (8.5% of feeding time), followed by *Thunbergia grandiflora* (leaves) and *Ficus hederacea* (fruits) (8.25%).

In Troop 2, 39% of the total time spent feeding was on a single fruiting individual of *Ficus benjamina*. The second most important component of its diet were leaves of the climber *Vallaris solanacea* (Family - Apocynaceae), on which they spent 11.3% time feeding. The remaining 20% was made up of *Erythrina stricta* (flower buds, fruits), *Magnolia pterocarpa* (leaves), *Artocarpus integrifolia* and *Artocarpus chama* (fruit). Six species (trees-4, fig-1, vine-1) therefore accounted for almost 75% of time spent feeding (Table 3. Major food species of Troops 1 and 2). It is relevant to mention here that except for *A.chama*, the rest of the food sources occurred clumped in a 1 ha area located near and inside the forest village.

Table 3. Major food species of Troops 1 and 2

TROOP 1	TIME SPENT (%)
Aeschynanthus sp. 1	15.0
Alcimandra cathcartii	11.8
Allanthes integrifolia	10.3
Gnetum scandens	8.5
Aeschynanthus sp.2	7.0
Ficus pomifera	6.3
Rhaphidophora hookerii	5.3
Ficus retusa	5.0
Thunbergia grandiflora	4.8
Ficus hederacea	3.5

TROOP 2	TIME SPENT (%)
Ficus benjamina	38.7
Vallaris solanacea	11.3
Erythrina stricta	11.0
Magnolia hookeri	4.7
Artocarpus integrifolia	4.7
Artocarpus chama	4.0
Coelogyne cristata	3.7
Schefflera venulosa	3.0
Rhaphidophora hookerii	1.7
Bombax ceiba	1.7

4.3.3.1. Month-wise use of food species:

In each month, a maximum of three species accounted for close to half the time spent feeding by both troops. *Aeschynanthus* sp.1 was the most eaten species in January and March, *Alcimandra cathcartii* in February and *Ficus retusa* in April by Troop 1. *Ficus benjamina* constituted the most eaten species by Troop 2 in February and March, and *Vallaris solanacea* in April (See Table 4 for month-wise break-up of the main food species of Troops 1 and 2).

Table 4. Month-wise break up of the main food species of Troops 1 and 2 (with percent time spent on each).

TROOP 1

January	Time (%)	February	Time (%)	March	Time (%)	April	Time (%)
Aeschynanthus sp.1	21	*A.cathcartii*	27	*Aeschynanthus sp.1*	20	*F. retusa*	20
Ailanthes integrifolia	16	*Aeschynanthus sp.2*	15	*G. scandens*	18	*F. hederacea*	14
Rhaphidophora hookerii	11	*Aeschynanthus sp.1*	11	*F. pomifera*	10	*F. pomifera*	13
Alcimandra cathcartii	10	*F. nervosa*	10	*A. cathcartii*	9	*A. integrifolia*	13
Ardisia solanacea	7	*A. integrifolia*	10	*Magnolia hookeri*	9	*Aeschynanthus sp.1*	8
Aeschynanthus sp.2	7	*T. grandiflora*	6	*Aeschynanthus sp.2*	7	*G.scandens*	5
Turpinia pomifera	6	*G. scandens*	6	*F. nemoralis*	5	*Artocarpus chama*	5
Thunbergia grandiflora	6	*Tiliacora cordata*	4	*T. cordata*	4	*Dischidia benghalense*	5
Gnetum scandens	5	*Cinnamomum glaucescens*	3	*C. glaucescens*	4	*T. grandiflora*	4
Ficus elastica	3	*R.hookerii*	3	*R. hookerii*	4	*R. hookerii*	3

TROOP 2

February	Time (%)	March	Time (%)	April	Time (%)
Ficus benjamina	49	*F. benjamina*	67	*V. solanacea*	21
Vallaris solanacea	14	*Coelogyna cristata*	11	*E. stricta*	21
Erythrina stricta	13	*Schefflera venulosa*	6	*Artocarpus chama*	12
Magnolia pterocarpa	11	*Tiliacora cordata*	4	*Artocarpus integrifolia*	9
Artocarpus integrifolia	5	*Aeschynanthus sp.1*	3	*R. hookerii*	5
Glochidion	4	*Gymnema latifolium*	2	*Bombax ceiba*	5
Michelia kisopa	4	*Tiliacora racemosa*	2	*S. venulosa*	4
Sterculia villosa	1	*Michelia champaca*	2	*Magnolia hookeri*	3
		F. geniculata	1	*F. subulata*	3
		Polygonum	1	*Polygonum*	3

4.3.4. Food items used

Leaves accounted for more than 70% of the time spent feeding by Troop 1 in all the three months except April. In fact, in January, Troop 1 spent as much as 92.6% time feeding on leaves. Troop 2 on the other hand fed largely on fruits. It spent more time feeding on leaves than on fruits only in February. It spent the highest proportion of time eating fruit in March (85.8%).

The rest of the food items i.e. bud, flower, stem, root, twig and bulb taken together did not amount to more than 2-6% of time spent feeding in any of the months except for flowers of *Erythrina stricta* for Troop 2 in March (11.1%). Time spent on animal matter took up less than 1% of feeding time, and was recorded only in February (Table 5).

Table 5. Time spent (%) on different food items by Troops 1 and 2

Troop 1

	Leaf	Fruit	Bud	Other
January	92.6	5.9	-	1.3
February	82.8	11.9	3.1	1.9
March	74.4	10.6	8.9	5.8
April	40.8	54.2	4.7	0.09

Troop 2

	Leaf	Fruit	Bud	Other
February	57.3	40.8	1.7	-
March	1.5	85.8	1.5	11.1
April	40.9	54.2	2.7	2.07

For Troop 1, in January when fruit available was lowest, leaf eating of *Ailanthes integrifolia* and *Alcimandra cathcartii* was high. Conversely, in April when fruit availability was the highest among the four months, the time spent on leaves decreased. In this month, the consumption of *Aeschynanthus* which had been a consistent feature of the diet in the previous months, also hit a low point.

In Troop 2, when fruiting on the *Ficus benjamina* stopped, the gibbons fed on leaves of the climber *Vallaris solanacea* and the available fruits of *Erythrina stricta*, and then went on to exploit the new fruit crop on *Artocarpus chama*.

4.3.5. Selection on the basis of food value

Troop 1

A comparison of the important species in the diet of Troop 1 (N=6) revealed that *Aeschynanthus* sp. had the highest dry matter value (60%) and lowest tannin content (1.4%). It was also high in total ash (10.9%). Although crude protein (CP) was low and ADF high, the energy value was comparable with those for the other species.

Ailanthes integrifolia leaves had the highest protein value (22.2%) and highest CP:(ADF+Tannin) ratio (.78). It was also relatively high in ash content (9.4%). *Alcimandra cathcartii* leaves had the next highest CP:(ADF/Tannin) ratio (.34), crude protein (15.1 %) and dry matter (34%) levels. *Ficus retusa* had the highest carbohydrate (33%) and highest ether extract value (7.9%) among the top six species. *Ficus hederacea* had the highest levels of total ash (14%). Among all the food species, the aril of *Dysoxylum binectariferum* (Family Meliaceae) had the highest level of ether extract - 48.6% in comparison to all the other species whose ether extract values ranged between 1% - 8%.

Dry matter content and the crude protein:(ADF+Tannin) ratio explained 51% of the variability in time spent feeding ($r^2=0.51$, F=.002, N=27) for Troop 1.

Troop 2

Among the food species of Troop 2, *Ficus benjamina* had relatively high gross energy (5.2 Kcal/g) and ether extract (8%). Its fruits also had the lowest tannin levels and its ash content of 9.7% was among the higher ash values for the compared species.

Vallaris solanacea showed among the highest carbohydrate content (42%) of all the species. *Erythrina stricta* flowers and fruits had the highest protein levels (22.5%) and the highest CP:(ADF+Tannin) ratio (0.53). *Artocarpus integrifolia* raw fruits had high carbohydrate level (33%) and low ADF (22%), but was high in tannins. *Artocarpus chama* fruits were highest in ether extract (8.2%) and low in tannin.

No single variable significantly contributed to variability in time spent on different food items by Troop 2. Ether extract explained only a fraction ($r^2=0.20$, F=.04, N=26).

The boot strap analysis showed that gibbons chose food items that had higher nutritive content and higher digestibility (N=30). However, there was no difference in the tannin content between food items chosen and those not eaten. (Appendix 2 A and 2B: Lists of food species of Troops 1 and 2, total time spent and nutritional values).

4.4. MOVEMENT PATTERNS AND HOME RANGES

4.4.1. Home range area

A stable home range for Troop 1 was achieved after 58 locations and the home range of Troop 2 stabilised at 32 locations. The sample size used was therefore adequate to calculate home ranges for the troops.

The Minimum Convex Polygon (MCP) home range area for Troop 1 was 10.48 ha (95% HM 5.75 ha) and the 50% Harmonic Mean activity centre area was calculated as 0.3 ha (N=113).

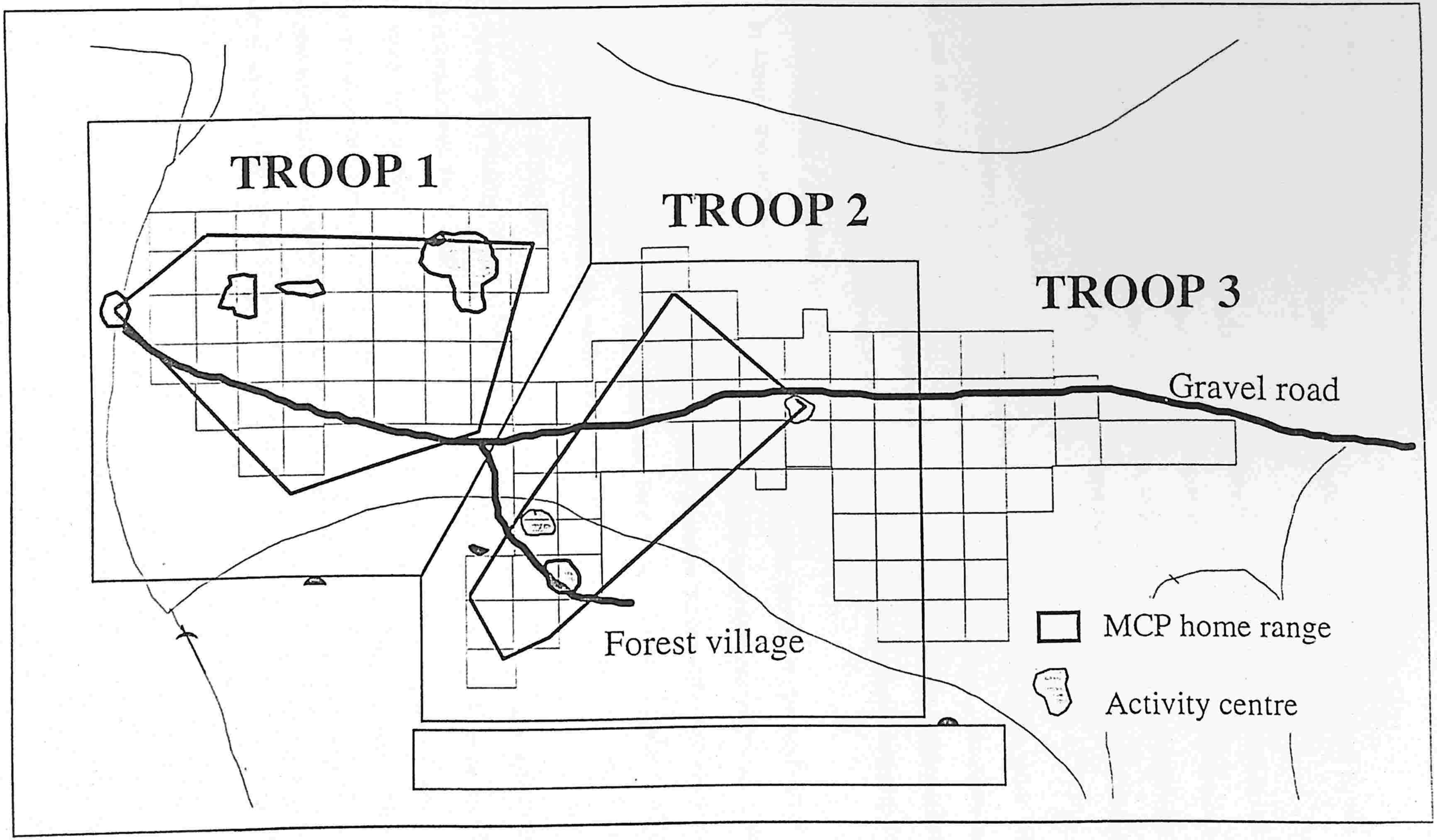
The MCP home range area for Troop 2 was 5.43 ha (95% HM 4.1 ha). Its 50% Harmonic Mean activity centre was 0.02 ha (N=41) (Fig. 7).

4.4.2. Daily movement

The mean daily movement of Troop 1 was 445.3±219.8m. The minimum distance travelled was 170 m and maximum was 1000m. The mean daily movement in April (685m) was significantly higher than that in January and February ($p<0.05$, N= 24). The least mean distance travelled was in the month of February (272.5 m).

The mean day range for Troop 2 was 316±165.9m with a minimum distance travelled of 130m and a maximum of 660m (N=12). The mean daily movement was significantly greater ($p<0.05$) in April (400m) than in February (216.2m).

g. 7: *Map of the intensive study area showing home ranges and activity centres of* Troops 1 and 2



4.4.3. Movement in relation to spatial distribution of food resources

Troop 1

The monthly movement pattern of the gibbon troops appeared to be governed by the distribution of fruiting trees (Fig. 8)

For Troop 1 in January, when fruits were in low abundance, no particular pattern of use was detectable. The troop moved from the *Ailanthes integrifolia* with a fruiting *Ficus elastica* and an *Alcimandra cathcartii* near it at one end of their range, to another *Alcimandra cathcartii* near the centre and then to two individuals of *Ficus pomifera* - one near the centre and the other at the extreme south of their range (Fig.9b).

In February however, the fruiting of a *Ficus nervosa* in the north of their range, led to the intensive use of another *A. cathcartii* near it as well as the one near the centre. The *Ailanthes* formed a second locus because of the close proximity of a flowering *Cinnamomum glaucescens*, the *A.cathcartii* and the *F. elastica* with diminishing fruit. In this month they did not venture to the south even though the *F.pomifera* was still in fruit (Fig.9c)

In March, the appearance of buds on a large *Magnolia hookeri* in the south-eastern portion of their range, shifted the focus of their feeding activity away from the *Ailanthes*. In this month with the *M.hookeri* as the focus, they used the *F.pomifera* in the south more intensively and remained near the centre where they could also feed on the central A.*cathcartii* and the *F.pomifera* near it. In this month the northern *A.cathcartii* and the *F.nervosa* with very few fruit were not visited at all (Fig 9d).

In April the fruiting of four individuals of *Artocarpus chama* in the extreme west of their range coincided with the fruiting of a *F.retusa* in the eastern and a *F.hederacea* in the southern parts. Here, they divided their time among the three portions but their activity leaned perceptibly to the central-eastern locus where apart from the *F.retusa*, there was also the central *F.pomifera*. They also went back to feeding on the *Ailanthes integrifolia* which they had largely ignored in the previous month. Use of the central *A. cathcartii* also dropped to a minimum in this month (Fig.9e).

Troop 2

Troop 2 concentrated its feeding activity to the immediate vicinity of the super-abundantly fruiting *F. benjamina* all through February and March. This patch had at least four other fruiting/flowering individuals of *Artocarpus integrifolia* and *Erythrina stricta* during this period (Fig. 9b and 9c). In April, although fruiting on the *F.benjamina* was over, one *Erythrina stricta* and the *Artocapus integrifolia* still had fruit. A *Bombax ceiba* had also started fruiting nearby. At the eastern end of their range however, two large individuals of *Artocarpus chama* bore large fruit crops in this month and the gibbons moved towards this part. An individual each of *Helixanthera parasitica* and *Capparis olacifolia* in young leaf and located close by supplemented their feeding on the *A. chama fruits* (Fig. 9e).

8 : Location of important trees within the home ranges of Troop 1 and Tro

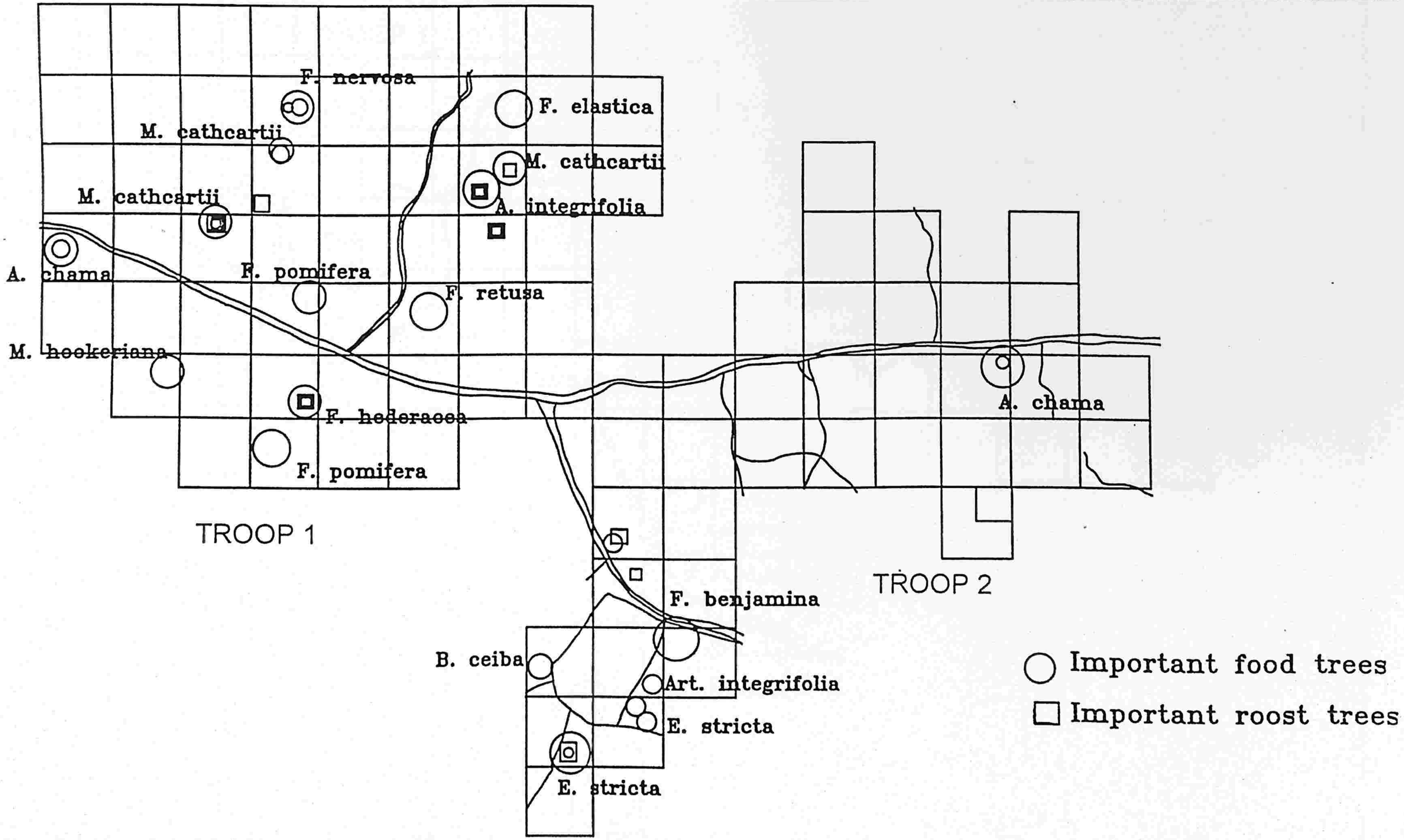


Fig. 9a: Daily routes and locations of Troop 1 and Troop 2 for the month of December

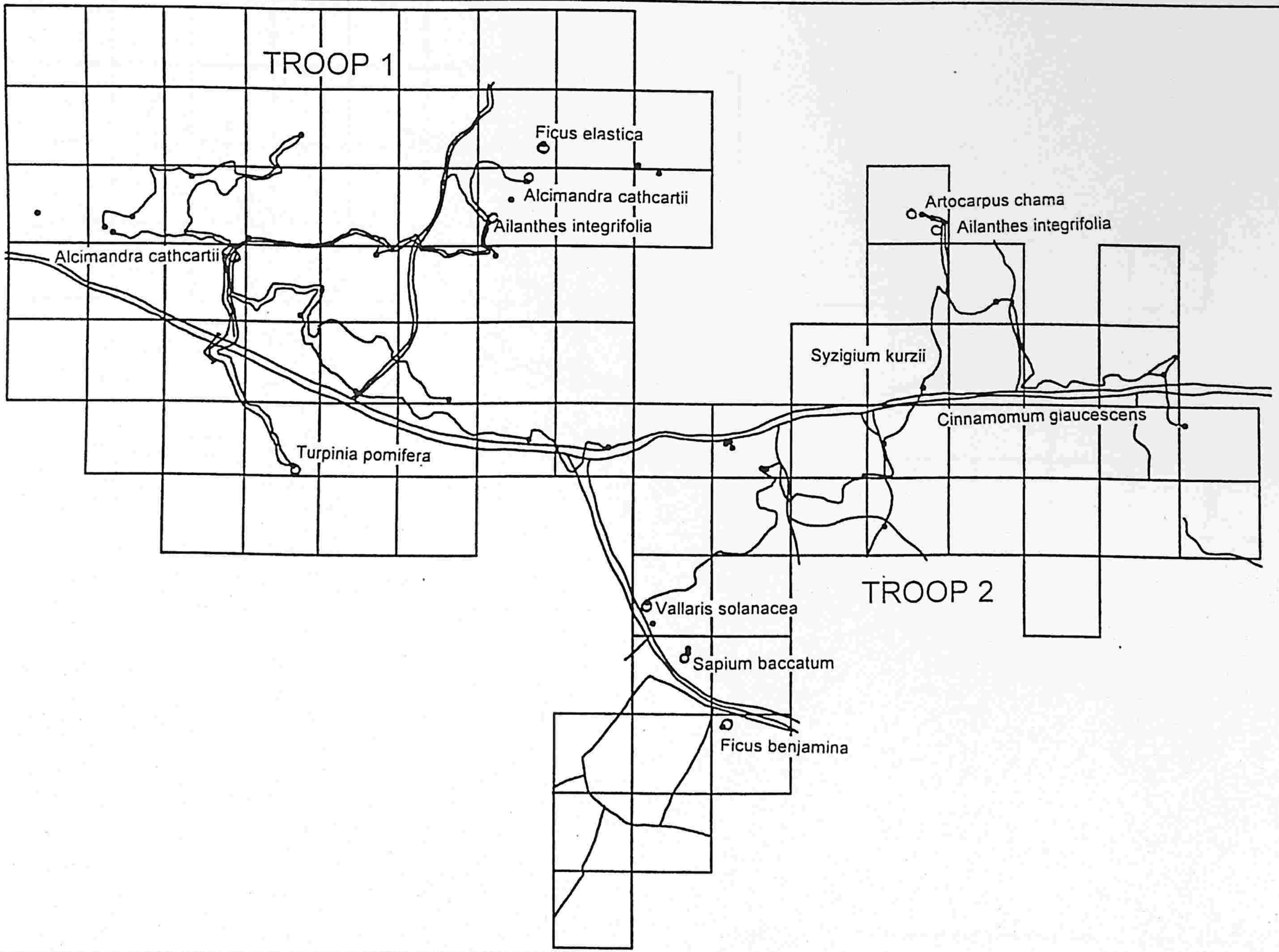


Fig. 9b: Daily routes and locations of Troop 1 for the month of January

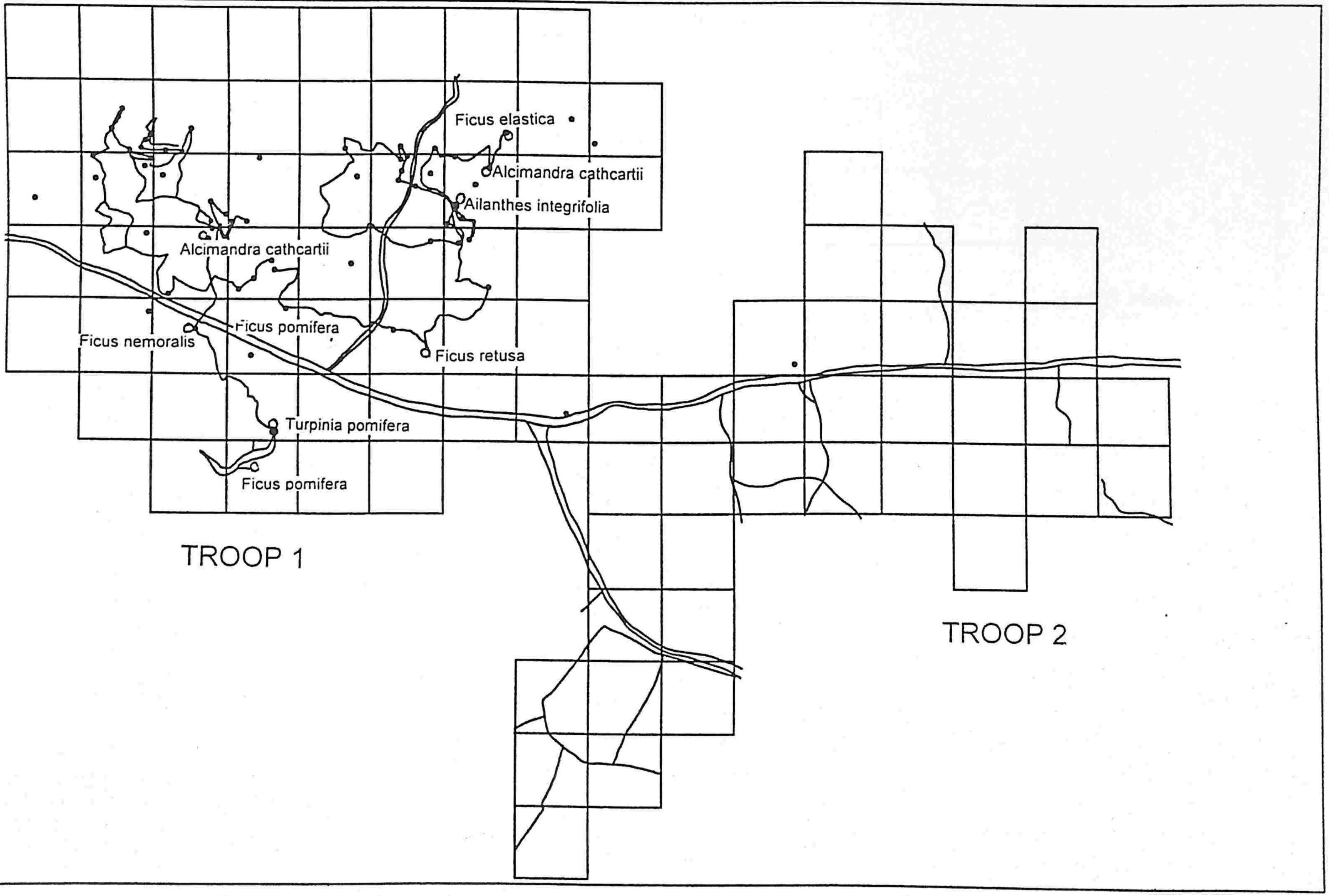


Fig. 9c: Daily routes and locations of Troop 1 and Troop 2 for the month of February

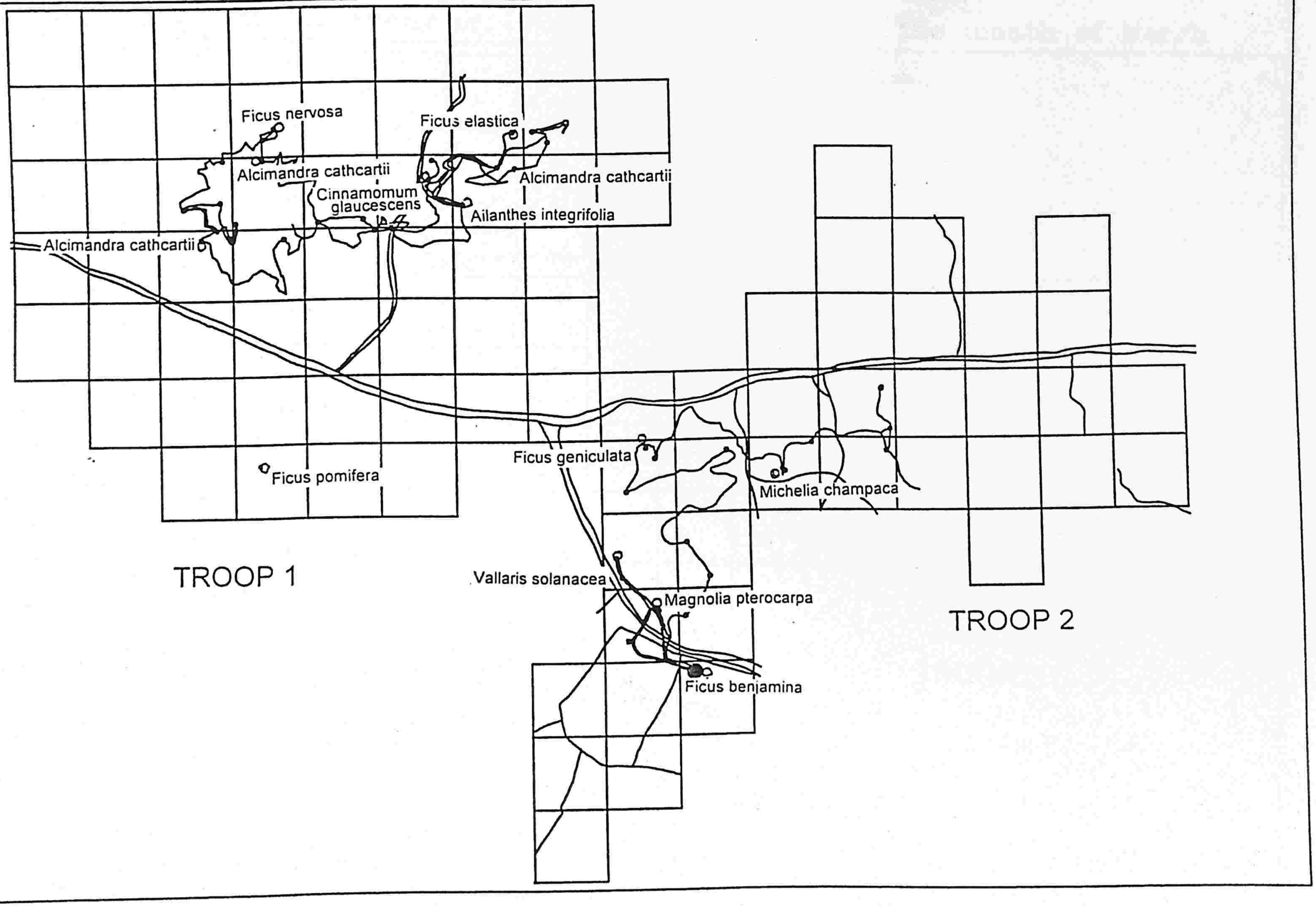


Fig. 9d: Daily routes and locations of Troop 1 and Troop 2 for the month of March

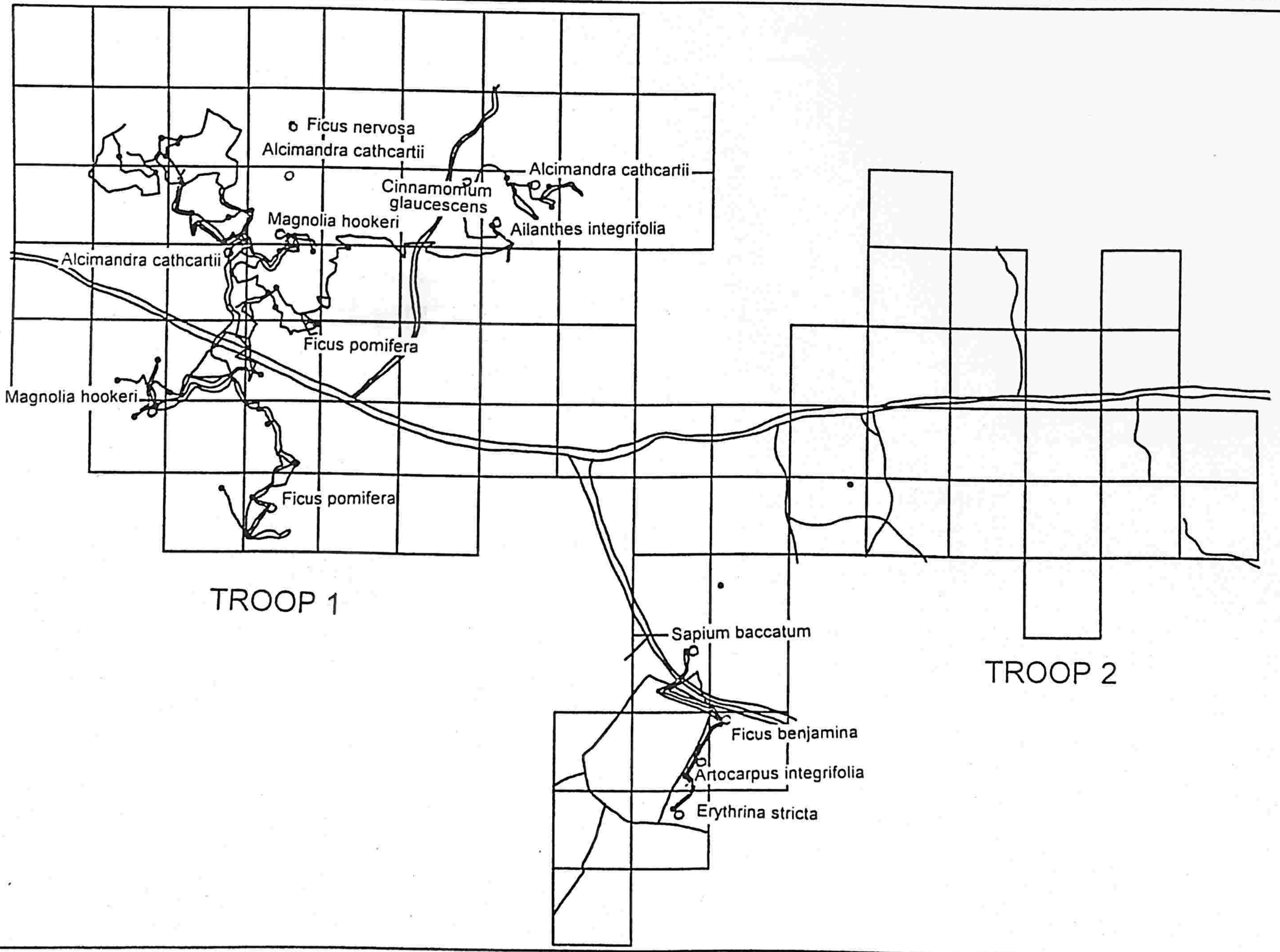
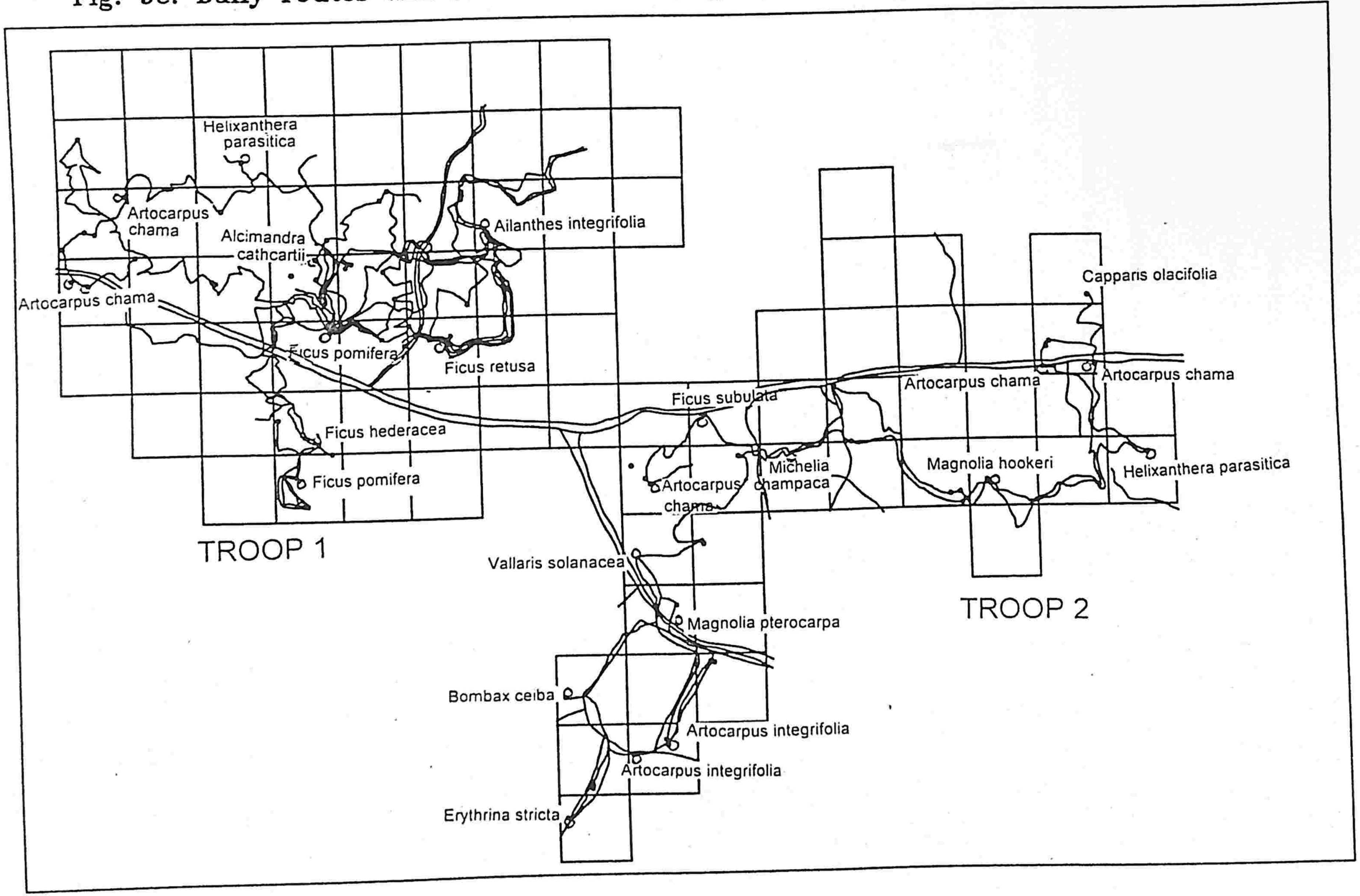


Fig. 9e: Daily routes and locations of Troop 1 and Troop 2 for the month of April



CHAPTER V

5.0. DISCUSSION

This study was originally intended to look at food selection and ranging in a troop of gibbons in order to examine what kind of limitations operate in a disturbed forest with respect to food and movement.

It was expected that gibbons would be limited by factors such as canopy discontinuity and the decrease in diversity and abundance of trees - which translates directly as a loss of pathways, shelter and food resources. It follows therefore that the effects of seasonality on the gibbons would also be more pronounced because of the fewer number of species that could serve as food resources in a lean season.

The opportunity to observe two other troops of gibbons in the same area (one intensively), allowed a level of comparison that changed the perspective of the study. All the results obtained are discussed here in this comparative perspective.

The contrasts among such immediately neighbouring groups only serve to highlight the fact that strategies for survival are adaptive, and situational differences may often render general assumptions invalid.

5.1. VEGETATION - THE IMPORTANCE OF STRUCTURE, DENSITY AND DIVERSITY

> "The dependence of gibbons on the upper layers of the forest is virtually as complete as the dependence of fishes on water"
>
> -Brockelman and Chivers(1984)

5.1.1. Structure influences behaviour

Arboreal mammals depend entirely on the closed-canopy forest for their food, shelter and movement. The structure of the forest therefore assumes central importance in determining their ecology and behaviour. In my study area, tree density, species richness and canopy continuity were relatively higher in Area 1 than in Area 2. This had a number of implications :

The area used by the first troop was double that of the second because a larger area was accessible to it via the canopy and therefore potentially available for use. The former was comparatively undivided, closed in only at the periphery by areas of progressively diminishing tree cover. Much of the second area on the other hand enclosed such open areas within the larger area (See Figs.3 and 7).

As a direct fallout of this situation, I observed that while Troop 1 descended to the ground only on one occasion (when their infant fell from the tree), Troop 2 habitually descended from the trees to move over scrub and short bamboo especially while trying to reach the isolated food trees inside the Pagla village. On one occasion they even left the relative safety of the bamboo patch and quickly walked bipedally across the village road to reach a fruiting *Bombax ceiba.* Even more astonishing was the return when they walked across nearly 50m of the village headman's kitchen garden, swung on a low beam of his half-built house, and re-entered the bamboo patch (Fig.3). In several places, such progression on or close to the ground would cover distances of 50-75 m when this was the nearest distance between neighbouring trees. I also found them sleeping at heights of 4 m or less in the bamboo clumps.

The only reports of the hoolock gibbon climbing down to the ground in the wild is when juveniles do so on failing to ford large tree gaps (Alfred and Sati 1986). However, lion-tailed macaques (*Macaca silenus*), yet another species considered to be strictly arboreal, have also been observed to descend to the ground in fragmented habitats in the Anamalai hill ranges of South India (Ajith Kumar and A.J.T. Johnsingh pers. comm.)

Thus, Troop 2 has evidently already arrived at a juncture where the overwhelming **need to obtain food outweighs its instinctive caution.** In the absence of predators, this may not have an immediate negative impact on the troop in terms of injury or mortality. The stress caused by such behaviour under the compulsion of circumstances and its long-term effect on the fitness of the individuals can only be speculated upon.

5.1.2. Canopy or tree gaps are physical barriers

The home range of an animal generally includes the minimum resources necessary for the animal in the season of most scarcity (Jewell 1966). Any reduction in either the home range area or its quality would affect the resource base of the animal to its detriment.

In an island situation such as Borajan RF, contraction of the home range area severely restricts the possibilities of a troop finding alternative food resources. At several points, most of the arboreal routes that the gibbons used were tenuous to say the least. During the study a large chunk of territory in the northern part of Troop 2's home range (which had an *Ailanthes integrifolia* and an *Artocarpus chama* visited by the troop in December) became inaccessible via the canopy with the felling of just one individual of *Syzigium kurzii*. A large *Cinnamomum glaucescens* tree that had represented the single connecting link over the road, at one of the two passages regularly used by them, was also felled in January, effectively shutting that passage (See Fig.9a). This left them with only one 'bridge' over the road at the extreme eastern part of their home range with which to access the area north of the road. The road traffic included a few motor vehicles and numerous pedestrians and cyclists travelling to and from the Mahakali Tea Estate and this only increased its effectiveness in limiting gibbon movement.

On the one hand therefore, the gibbons are limited by their strict territorial nature that prevents them from exploiting food resources even when available in any other occupied area - a feature termed by MacKinnon & MacKinnon (1984) as "spatial inflexibility". On the other hand is the loss or inaccessibility of previously used areas and the absence of new areas to seek refuge in. This represents in effect, a dead-end towards which the population in Borajan is being steadily driven.

5.1.3. Fewer trees mean fewer species mean fewer food species

Somewhat less apparent, but of considerable importance, is the fact that decreased tree densities often imply a decrease in gibbon food species diversity. In lowland Dipterocarp forests in the Malay Peninsula, a gibbon group in 25-60 ha of area would have a choice of some 500 species of trees and climbers (Chivers & Raemakers 1986). This diversity makes a higher number of species available to the gibbons at any given time so that the capricity of availability does not restrict the gibbons in terms of food to eat.

For the hoolock gibbon, mixed evergreen forest habitat in Meghalaya had high food species richness (104 species) (Alfred & Sati 1994). In other studies, the numbers of food species given were 43 in Assam (Tilson 1979), 40 in Bangladesh (Islam & Feeroz 1992) and 41 (this study) although all of these lists were constrained by short study durations.

The food species richness in disturbed areas such as Borajan RF is low compared to that in undisturbed gibbon habitats. Coupled with the low densities at which most of the food species tend to occur, this presents a very real and serious predicament for populations in areas of disturbance.

5.2. FOOD SELECTION - A MULTIPLE CAUSE-MULTIPLE EFFECT PHENOMENON IN A NON-IDEAL WORLD

"Hungry animals are less choosy than satiated animals"

- Ivlev (1961)

That the hoolock gibbon is selective at the broad level of the habitat is apparent because out of the 177 tree species and over 30 climber species available to them, they chose only forty-three (ca 20%) to feed on. There is also selection operating at the finer level of phenophase availability because not all tree species with fruits, buds or young leaves were fed upon.

Among the 20 tree and 7 fig species, use by gibbons closely tracked the phenology of the individual trees. Individuals of a species largely exhibited synchronous phenological states, a marked exception being *Artocarpus chama.* In *Cinnamomum glaucescens* too, only one of the four individuals in Area 1 flowered during the entire study period. Also of the four *Ficus pomifera*, only two bore fruit. This is to be expected however, because asynchronous fruiting in figs is a well known phenomenon (Lambert 1989, Peres 1994).

Nearly all individuals of a species in the preferred phenophase available in the home range were used by the gibbons. The exceptions occurred when the individual tree was inaccessible. For example, in Area 1 three individuals of *Magnolia hookeri* had buds in April but were not used at all. All three were isolated from the surrounding canopy and it would have been difficult for the gibbons to gain access to these trees without descending to the ground. Observations of Troop 2 would suggest that this should not have been a deterrent in reaching the food source. Moreover, during the same time, the other two *M. hookeri* trees which were used had substantial biomass of buds and were easily accessible. As Ivlev (1961) put it - "Animals are more selective when food density is high than when it is low". As a corollary, it appears therefore, that **gibbons are averse to descending to the ground even when the distances involved are not too large (less than 25m in this case) and especially when they have alternatives to fall back upon.**

5.2.1. The importance of temporal changes in food availability

The diet of Troop 1 varied from month to month according to what was available. Depending on the contribution of fruits within their narrow temporal windows of availability, the use of other resources *viz.* leaves and vines fluctuated over the months. Their use however rarely fell to zero. The prolonged fruiting and use of the *F. benjamina* in Area 2 obscured such an observation of drastic changes in food until April when cessation of fruiting in the *F. benjamina* coincided with the fruiting of *Artocarpus chama, Bombax ceiba* and an additional *Artocarpus integrifolia.* Such opportunistic feeding on seasonal foods has also been observed in other frugivores such as orangutans (*Pongo pygmaeus pygmaeus*) (Galdikas 1988) and muriquis (*Brachyteles arachnoides*) (Strier 1991).

Frugivorous mammals are constrained by such irregular patterns of both spatial and temporal availability of food resources in the forests of the tropics. Tropical frugivores therefore have to adopt lean fruiting season strategies such as feeding on fibre-rich foods like leaves, when fruit availability is low (Borges 1989, Milton 1979). However, often it is seen that at intermediate levels of availability, with alternative foods of widely different preferences, it is practically impossible to say whether a plant failed to appear in a diet because of low preference or low availability.

Strier (1991) for example, found that although fruits and flowers seemed to be the preferred foods of muriquis_they also regularly fed on leaves. Although leaf-eating may have been a lean-patch strategy for Troop 1, it is also possible that the leaves of *Alcimandra cathcartii, Ailanthes integrifolia* and the vines - *Aeschynanthus, Gnetum scandens* and for Troop 2, *Vallaris solanacea,* **may have been preferred food items on their own,** and not merely substitutes during the shortage of fruits. The importance in the diet maybe because of the protein, micronutrient or some other specific requirement they provide, which fruits alone cannot. Nutritional analysis threw some light on this possibility, but nothing can be said in categorical terms.

5.2.2. The importance of spatial dispersion of food resources

Results showed that the spatial distribution of food plants was one of the determining factors in selection of food by hoolock gibbons. The choice of food trees was influenced by the presence of other food trees in the vicinity so that at a particular visit to that part of their home range, all the available trees in that part could be used. In each month, the trend was largely determined by the location of a large fruiting tree that occurred associated with several other usable trees. A scrutiny of the gibbon route maps to look for patterns of movement, in conjunction with the phenology data revealed that when a single isolated food tree was available at a point, the **gibbons tended not to use that tree until an additional one or more trees in its vicinity also became available.**

Troop 2 spent most of its time within a small, low-cover and disturbed area which was resource-rich in terms of fruits. That groups search out areas where more than one favoured food is abundant has been recorded for other primates such as red colobus (Clutton-Brock 1975), brown capuchins (Zhang 1994), spider monkeys and sakis (Norconk & Kinzey 1994) and howlers, cebus and spider monkeys (Chapman 1988).

The net energetic benefits that accrue from clumped resource patches including reduction in foraging time and ranging distances (Krebs & Davies 1993) is probably the crucial factor operating in such choices by the gibbons.

Troop 2 was once observed to visit food trees that were distant from the resource patch, to feed on buds of *Michelia champaca*. On this trip they stopped en route to feed on *Michelia kisopa* leaves and *Ficus geniculata* fruits, both of which had very small crops at the time. That night they roosted beyond the *Michelia champaca*. In this case, the nutritional or energetic benefits or both, from the buds may have justified the travel involved in reaching this food source. The next morning however, they moved over a distance of more than 300 m directly back to the resource patch with the *F.benjamina*. This behaviour was uncharacteristic, because immediately after waking, gibbons usually move to a feeding tree very near the roost site. I cannot explain why on this day they skipped their normal early morning feeding session and instead basked for a considerable while near the roost tree before heading back to the *F.benjamina*.

5.2.3: The importance of biomass availability

Since small body size is associated with a greater reliance on highly nutritious and easily digestible food items, gibbons have a narrow range of potential food types, largely fruits. Patches of such foods generally occur in low densities. In addition, large food patches occur at even lower densities than smaller patches which provide more evenly dispersed food supplies (Leighton 1987). In this study I observed that it were the large individual patches of fruit and leaf that supplied the bulk of the diet for both troops through the study period. This has also been observed in the larger, more folivorous siamangs (Gittins & Raemakers 1980).

This is understandable in terms of the gibbons maximizing net returns from feeding on a single abundant source because small resource patches were often too small to support feeding by all individuals of a troop. The high group coherence (individuals were rarely more than a maximum of 50m apart when feeding) of hoolock gibbons would presumably not permit a fission-fusion travel pattern that serves to reduce competition as has been reported for spider monkeys and sakis (Norconk & Kinzey 1994).

Troop 1 had access to a higher number of fruiting trees (10) than Troop 2 (5) but the crop size and time of fruiting varied widely among individual trees. In terms of fruit biomass, Troop 2 had more resources than Troop 1, but Troop 1 had a wider **choice** of food. Data on availability of potential food sources in Area 2 did not show any other large resource patch that Troop 2 could have used in the hypothetical situation that the *Ficus benjamina* had failed to fruit in the study season. I present this hypothetical situation here because it is a real possibility and demonstrates the tenuous nature of this troop's existence here.

5.2.4 The importance of figs

Ficus species were the major fruit bearing trees in both areas and contributed substantially to the diet of the gibbons. Although figs are reported to be poor in nutritional quality, they play an important role in sustaining frugivores in lean seasons when alternative fruit resources are scarce. Their aseasonal fruiting, large crop sizes, intra-crown synchrony of fruit ripening and the relatively short intervals between fruiting in individual trees (Lambert 1989, Snow 1981) are traits that enable them to fulfill the role of lean season resource. Four species of figs in Area 1 and one in Area 2 bore large crops of fruit during the study period and gibbons spent

18.5% and 39% respectively of total feeding time on these. Troop 1 had no other species fruiting apart from *Dysoxylum binectariferum* (used only once) and *Artocarpus chama*. Troop 2 had other species of fruiting trees, but the fig species provided the bulk of the fruit eaten in the study period.

It has been suggested that the degree of dependence on figs may influence other aspects of a primate's ecology, including ranging behaviour and territoriality (MacKinnon & MacKinnon 1978, Chivers 1977, 1984, Raemakers 1984). Although I cannot make a strong case about fig-dependence and territoriality, the results of this study show that ranging patterns and activity are definitely influenced.

Self-standing fig trees in disturbed habitats are known to produce superabundant fruit crops (Peres 1994). This fact is important as a mitigating factor for frugivores in a disturbed habitat as is evident from observations of Troop 2 and its reliance on one fig tree for most of its food, for the better part of four months.

5.2.5. The nutritional basis for food selection

Results showed that for Troop 1, dry matter content and the CP/(ADF+Tannin) ratio together explained more than half the variability in time spent feeding. Over the study period, leaves constituted the major component of the food of Troop 1. Leaves are known protein sources and it has been established that fibre (as Acid Detergent Fibre) in foliage acts as a digestion inhibitor. Tannins are also considered important as feeding deterrents and tannin levels in most of the major foods ranged between 1% and 6% which is not very high. It is reasonable to expect that in a folivorous diet such as the one Troop 1 had, a high protein to digestion inhibitor ratio would positively correlate to selection as has been found in other studies (McKey *et al.* 1981, Oates 1981).

The positive correlation with dry matter for Troop 1, indicates the **hoolock gibbons may not have been water limited.** Presumably, the dew or rain water on their foods are adequate to fulfill their water requirements. I also observed the gibbons licking water off their hands, although they did not do this regularly.

For Troop 2, which had a predominantly frugivorous diet in all months, I expected that carbohydrates and gross energy would be the important factors in food selection. On the contrary, results indicated that only lipid content had a weak correlation with time spent feeding. Although lipid content influences energy levels, I cannot make any definite inferences from the results.

Tannins apparently played some role because the most eaten food species - *Aeschynanthus* sp.1 for Troop 1 and *Ficus benjamina* fruits for Troop 2 also had the lowest tannin levels among the major foods. Interestingly, comparison between nutrient values of used and unused species suggested that although tannin levels were comparatively higher in unused species, there was no significant difference and it probably does not play a major role in rejection of those items.

Proteins alone as a nutrient class have been found to be related to food selection in some primates such as the *Colobus polykomos* (Dasilva 1994) and western gorillas (Calvert 1985) but not in others. Oftedal (1991) suggests that primates do not need to seek out foods of particularly high nutrient density except maybe during weaning, especially when foods of balanced amino acid composition (such as leaves) are included in the diet. If this is true, it may explain the lack of correlation between time spent and the nutrient values of the food for the gibbons.

It is also a possibility that the foods did not differ sufficiently in terms of nutrient value for the gibbons to have to discriminate between them. However, the most likely explanation is that food selection by the gibbons in Borajan RF was **more a function of absolute availability than any other factor taken singly.**

5.3. DAILY ACTIVITY BUDGETS

Gibbons are unusual among tropical mammals in having a short unimodal period of activity. The exact reasons are not known, but it probably has to do with its small group size and territorial nature combined with frugivory where energy gains are rapid and there is no intra-group competition for food.

The activity budgets for Troop 1 and Troop 2 were comparable to that for gibbons in general and hoolock gibbons in particular (Chivers 1984, Tilson 1979). A folivorous diet would require more time for feeding than a frugivorous one as has been found for the siamang and the smaller Kloss and pileated gibbons (Chivers 1984). Results show that although in one month more than 90% of the diet of Troop 1 was made up of leaves, there was no difference in time spent feeding between the months, or between the troops, contrary to what I had expected.

5.3.1. Gibbon song

The **differences in the incidence of singing** in the gibbon troops were marked. Since one of the functions of singing is vocal defence of territory (McKinnon & MacKinnon 1984, DeVore 1963), I interpret these differences again as **a function of territory quality.**

Troop 2 had its food resources in an area that was well inside its territory and far from the boundary zones of both Troop 1 and Troop 3 on either side. One possibility as to why it did not sing often (N=1) could be that the rest of the area did not have resources worth defending at that period of time. Troop 1 had a relatively better territory in terms of both continuous canopy and food resources. These resources were dispersed and also occurred close to the buffer region. It called more frequently (N=11) presumably for this reason although on at least one occasion (hours after the infant fell to the ground and was abandoned) the singing was probably an instance of **information transmission** (Brockelman 1984). Another reason could be that, it did not perceive a real threat from Troop 2 because there was a physical boundary between their territories in the form of a belt of scrub and road. Troop 3 also had a relatively better territory than Troop 2 in terms of canopy cover and food trees. I cannot say with certainty if it was also better than Troop 1's territory. The high incidence of singing by this group (N=27, the highest among all the troops) was also possibly a reflection of its better territory quality. Other studies indicate that singing increases in fruiting seasons (Chivers *et al.* 1975), a situation comparable to the one in Borajan RF where the spatial locations of fruiting trees probably determined what constituted defensible resource and what did not.

5.3.2. Grooming and social interactions

The incidences of grooming and other interactive behaviour were low. This is consistent with the findings for gibbons in general (Haimoff 1984) although the available literature had no theories as to why. The male and female usually rested close together on the roost tree. In Troop 1 the juvenile was often allowed to roost with the adults.

5.4. MOVEMENT PATTERNS AND HOME RANGE USE

Movement patterns of the gibbons appeared to be **closely related to the dispersion and availability of food sources** within the home range. The highest mean day ranges of both Troop 1 and Troop 2 was in April when available food resources were also the most scattered (See Fig.9e). That range-use is situation-dependent and that even a single fruiting tree can strongly influence range-use patterns has been observed in several other primate species (Chapman 1988, Scanlon *et al.* 1989, Defler 1996, Torre *et al.* 1995, Zhang 1994).

My observations suggest that **weather conditions also strongly influence movement** in gibbons. In February, for example, the small distances travelled may not have been entirely due the localized availability of foods (See Fig.9c). Low temperatures and rainfall restricted movement between patches. Gibbons became active only after the rainfall had subsided. Fog was also a major restricting factor on activity. Their restricted diet as has been mentioned in section 4.2.2 may have been a result of this and not on food dispersion alone. The effect of weather on ranging has been observed in apes (Raemakers 1977), the siamang (Chivers 1974) and the Malabar giant squirrel (Borges 1989).

Gibbons were observed to use the same canopy pathways repeatedly. These were also usually the shortest continuous routes that could be taken between points. Familiarity with canopy pathways may have important survival value (Borges 1989). I observed that felling of trees along these routes forced them on several occasions to find alternative routes wherever possible. Mostly, those routes had been the only ones they could take. On several occasions I observed the juvenile of Troop 1 whimpering in distress when it could not follow its parents across a wide tree gap despite repeated attempts at jumping. On at least two occasions, individuals of the troop slept on separate trees when the juvenile could not reach the parents at their roost site.

Travel routes tended to be defined by the scatter of food trees and the normal interval of traversing through most of the home range and returning to the starting point was one week for Troop 1.

Both troops also showed **selective use of roost trees** in their ranges. Troop 1 regularly used at least five trees for roosting and each was used on more than five occasions. These trees were located in different parts of the home range and there was no unique feature that distinguished them from other trees in the home range apart from the presence of a sturdy horizontal branch on which the gibbons usually sat close together while sleeping and the fact that they tended to be located near a major food tree. A few trees were used only once.

Ailanthes integrifolia which was the tallest tree in Area 1 and was also a food tree was the most frequently used roost tree. Only four food trees were also used as roost sites. Troop 2's most used roost tree was a *Sapium baccatum* near the *F.benjamina*. There was rotation between the roosting sites used and corresponded to the part of the home range that the gibbons were using at a particular time. This kind of sleeping site selection and use has also been reported for spider monkeys in Costa Rica (Chapman 1989) (Fig. 8).

5.5. HOME RANGE SIZE

The home ranges of 10.4 ha and 5.4 ha for the two troops are considerably smaller than those earlier reported for hoolock gibbons (15-30 ha) (Tilson 1979, Alfred & Sati 1986). However, the smallest home range for hoolock gibbons is recorded as 3.2 ha for a troop in West Bhanugach (Gittins & Tilson 1984). Details of this area in terms of resource availability are not known.

Home range size may be determined by one or more of the following factors - group size, population density, heterospecific competitors, physical size constraints of the area, tree species diversity (Marsh 1981) or the clumped or scattered distributions of favoured foods (Clutton-Brock 1975). In Borajan, tree species diversity does not explain the difference in home range size. The most important reason for the considerable differences in home range size between the two troops is that **habitat destruction has reduced the ranging area** more drastically in Area 2. The home range seen was therefore probably a greatly compressed one.

5.5.1. Activity centres

The home range of Troop 1 had three **activity centres.** Two of these lay close together near the centre and the third was in the area around the *Ailanthes integrifolia* at one corner of their home range (Fig.7). The major canopy pathway bisected these centres. In Area 2, the single fig tree in the village formed one activity centre. while two *Dipterocarpus retusus* trees with the food climber *Vallaris solanacea* formed the other (Fig. 7). There was no correlation between grid-use (sleeping periods included) and food tree density, canopy cover, continuity or vine volume for either of the troops. Although statistical analysis showed no definite correlation because the unit of analysis was the grid, my observations show that the most used areas for both troops were defined by the presence of at least one **food tree, a roost tree, a basking tree and the intersection of a major movement route.**

5.6. CONCLUSION

In a disturbed forest, the diet, movement patterns, home range and activity of gibbons are dictated by food availability. The results of this study show that habitat destruction translates directly to a decrease in food availability before anything else. Previously thought to be strictly a primary forest dweller, the survival of gibbons in a habitat as degraded, disturbed and sub-optimal as Borajan RF attests to the fact that their ability to tolerate such poor conditions of their habitat has been sweepingly underestimated. However, before I pass judgment on the basis of a six-month study, I would like to put in perspective the probability of their continued survival in this forest on the basis of information that I collected from two smaller reserves - Bherjan and Podumoni. Both these reserves are fragmented patches like Borajan RF and located in the same district. Both had hoolock gibbon populations and were subject to similar disturbances from illegal felling of trees. Their small sizes magnified the effects of disturbance, and gibbons disappeared from Podumoni sometime in the 1960s while Bherjan boasts of a single female gibbon - a pathetic reminder of what habitat destruction ultimately means, however complacent or hopeful we may like to be about the "bigger" areas. In this light, and at the current rates of destruction, the question of whether my study animals will survive is redundant. The only question left to be asked is "How long?"

There may be hope, however, if priorities change and habitat loss is halted now. The management should concentrate on immediate and complete protection first. The plans for providing alternative options to the local villagers and refugees, tackling the "vested interests" in the small-time timber trade, moving the brick kilns to some place further away from the animals, and regulating use of the gravel roads can come in time when the exigency of the situation has been mitigated.

6.0. REFERENCES

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APPENDIX 1.

Alphabetical list of all tree species and common climbers of the intensive study area in Borajan RF

TREE SPECIES	ASSAMESE NAME	FAMILY
Acrocarpus fraxinifolius Arn.ex Wt.		CAESALPINIACEAE
Actinodaphne obovata (Nees)Bl.	Patihunda	LAURACEAE
Aglaia hiernii Visw.&Ramach. = *Amoora wallichii*		MELIACEAE
Aglaia perviridis Hiern.		"
• *Ailanthes integrifolia* Lamk. ssp. calycina Noot.= A.grandis	Borpat	SIMAROUBACEAE
Alchornea sp.		EUPHORBIACEAE
• *Alcimandra cathkartii* Dandy. = *Michelia kathcartii*	Kharika-sopa*	MAGNOLIACEAE
Aleurites sp.		EUPHORBIACEAE
Alstonia scholaris Br.		APOCYNACEAE
Anthocephalus chinensis (Lamk.)A.Rich.ex Walp	Kodom	RUBIACEAE
Antidesma acidum Retz.		EUPHORBIACEAE
Antidesma acuminatum Wall.		"
Antidesma sp.		"
Aporusa dioica (Roxb.)Muell.-Arg.		"
Ardisia humilis Vall.		MYRSINACEAE
Ardisia solanacea Roxb.		"
Areca sp.	Tamul*	ARECACEAE
• *Artocarpus chama* Buch-Ham. = *Artocarpus chaplasha*	Samkothal*	MORACEAE
• *Artocarpus integrifolia* Linn.f.	Kothal*	"
Baccaurea ramiflora Lour. = *B. sapida*	Leteku	"
Barringtonia acutangula (L.)Gaertn.	Pani-omora	BARRINGTONIACEAE
Beilshmiedia brandisii Hk.f.	Leluk	LAURACEAE
Beilshmiedia gammieana King		"
Bischofia javanica Bl.	Uriam	BISCHOFIACEAE
• *Bombax ceiba* Linn.	Himolu	BOMBASACEAE
Bridelia pubescens Kurz.		EUPHORBIACEAE
Bridelia retusa (L.)Spreng.		"
Callicarpa arborea Roxb.		VERBENACEAE
Canarium strictum Roxb. = *C. resiniferum*	Dhuna	BURSERACEAE
Canarium strictum Roxb. = *Canarium sikkimense*	Dhuna	"
• *Capparis olacifolia*	Keta-Har	CAPPARIDACEAE
Casearia graveolens		FLACOURTIACEAE
Castanopsis armata Spach.	Joba-singori*	FAGACEAE
Castanopsis indica A.DC.	Hingori	"
Castanopsis lanciaefolia Hickel & Camus.		"
Cedrela microcarpa		MELIACEAE
Chukrasia tabularis	Boga-poma	"
Cinnamomum bejolghota Sw. = C. obtusifolium	Naga-dal-chini	LAURACEAE
Cinnamomum glanduliferum (Wall.)Meissn.	Gonsoroi	"
• *Cinnamomum glaucescens* (Nees.)Hnad-Maz. = C.	Gonsoroi	"
Citrus decumana Linn.	Rabab-tenga	RUTACEAE
Croton joufra Roxb.		EUPHORBIACEAE
Croton sp.		"
Cryptocarya sp.		LAURACEAE
Dalbergia sp.		FABACEAE
Dillenia indica Linn.	Ou-tenga	DILLENIACEAE
Diospyros sp.		EBENACEAE

Dipterocarpus retusus Bl. = *D. macrocarpus*	Hollong	DIPTEROCARPACEAE
Drimycarpus racemosus (Roxb.)Hk.f.	Amsia	ANACARDIACEAE
Drypetes elliptica		EUPHORBIACEAE
Dysoxylum alliaria (Buch-Ham.)Balak. = *D. hamiltonii*	Gendhelipoma	MELIACEAE
• *Dysoxylum binectariferum* Hk.f	Bandordima	"
Dysoxylum gobara (Buch-Ham.)Merr. = *D. procerus*	Lali/Amari	"
Dysoxylum grande Hiern.	Boga-bandordima	"
Echinocarpus sp.		ELAEOCARPACEAE
Echinocarpus assamicus Benth.	Bandor-kakoi	"
Elaeocarpus acuminatus Wall.ex Mast.		"
Elaeocarpus lancifolius Roxb.		"
Elaeocarpus robustus Roxb.	Poreng	"
Elaeocarpus rugosus	Galronga	"
Elaeocarpus sp.		"
Elaeocarpus sphaericus (Gaertn.)K.Sch.= *E. ganitrus*	Rudrakhyo	"
Elaeocarpus tectorius (Laour.)Poir. = E. robustus		"
Elaeocarpus varuna Ham.ex Mast.	Nigonibual	"
Engelhardia spicata	Lewa	JUGLANDACEAE
• *Erythrina stricta* Roxb.	Modar	FABACEAE
Eurya acuminata DC.	Muymura	THEACEAE
Eurya sp.		"
• *Ficus benjamina* Linn.	Jori	MORACEAE
• *Ficus elastica*	Atha-bor	"
Ficus hispida	Dimoru	"
Ficus lepidosa		"
• *Ficus nemoralis*		"
Ficus neriifolia JE Sm. var. trilepis (King)Corner =F.nemoralis	Dimoru	"
• *Ficus nervosa*	Khari-pati-dimoru	"
• *Ficus oligodon* Miq. = *F. pomifera*		"
Flacourtia indica (Burm.f.)Merr. =*F. sepiaria*		FLACOURTIACEAE
Garcinia cowa Roxb.ex DC.	Cau-thekera	CLUSIACEAE
• *Helixanthera parasitica*		
Horsfieldia amygdalina (Wall)Warb.		MYRISTICACEAE
Knema angustifolia (Roxb.)Warb.	Tezronga	"
Knema sp.		"
Kydia calycina Roxb.	Pisola/Kukuha	MALVACEAE
Lagerstroemia speciosa (L.)Pers. = *L. flosreginae*	Ajar	LYTHRACEAE
Lindera assamica Kurz..		LAURACEAE
Lithocarpus pachyphylla (Kurz.)Rehder.		FAGACEAE
Litsaea monopetala (Roxb.)Pers. = *L. polyantha*	Muga/Hoanlu	LAURACEAE
Litsaea salicifolia	Digloti	"
Litsaea sp.		"
Maesa sp.		MYRSINACEAE
Magnolia baillonii Pierre. = *Talauma phellocarpa*		MAGNOLIACEAE
• *Magnolia hookeri* Rajan & Nair = *Manglietia hookeriana*	Phul-sopa	"
• *Magnolia pterocarpa* Roxb.	Barampthurisopa	"
Mallotus roxburghianus Muell-Arg.		EUPHORBIACEAE
Mangifera indica Linn.	Aam	ANACARDIACEAE
Mesua ferrea Linn.	Nahor	CLUSIACEAE
• *Michelia champaca* Linn.	Titasopa	MAGNOLIACEAE
• *Michelia kisopa* Ham.		"
Michelia oblonga Wall.ex Hk.f.	Phul/kothal-sopa	"
Myristica laurifolia Hk.f.&Th.		MYRISTICACEAE
Oroxylum indicum Vent.	Torwalgos*	BIGNONIACEAE

• *Ostodes paniculata* Bl.		EUPHORBIACEAE
• *Persea glaucescens*		LAURACEAE
Phoebe cooperiana U.N.Kanjilal	Mekahi	"
• *Phoebe goalparensis*	Bonsum	"
Phoebe lanceolata (Nees.)Nees.		"
Phoebe paniculata Nees.	Mekahi	"
Picrasma quassioides (D.Don.)J.J.Benn.		SIMAROUBACEAE
Polyalthia simiarum Hk.f.&Th.	Boga-khamtou	ANNONACEAE
Pseudostreblus indica Bureau.		MORACEAE
Psidium guayava		MYRTACEAE
Pterospermum lancaefolium	Bon-Nahor	STERCULIACEAE
Pyrenaria barringtoniaefolia Seem.		THEACEAE
Pyrenaria sp.		"
Quercus dealbata var *mannii* Hk.f.&Th.		FAGACEAE
Quercus glauca Thunb.		"
Quercus griffithii Hk.f.&Th.ex DC.		"
Sapium baccatum Roxb.	Seleng	EUPHORBIACEAE
Sapium eugeniaefolium Ham.ex Hk.f.		"
Saprosma ternatum Hk.f.		RUBIACEAE
Spondias pinnata Kurz.	Amora tenga	ANACARDIACEAE
• *Sterculia villosa* Roxb.	Udal	STERCULIACEAE
Stereospermum chelonoides (L.f.)DC.	Paroli	BIGNONIACEAE
Stereospermum sp.		"
Syzygium sp.		MYRTACEAE
Syzygium formosum (Wall)Mass.	Loha-jam	"
Syzygium kurzii (Duthie)Balak.	Bogi-jamuk	"
Talauma hodgsonii Hk.f.&Th.	Thou-thou*	MAGNOLIACEAE
Tectona grandis Linn.		VERBENACEAE
Terminalia alata Heyne ex Roth.		COMBRETACEAE
Terminalia bellirica Roxb.	Bhumura*	"
Terminalia chebula Retz.	Hilikha	"
Terminalia myriocarpa Heurck & Muell-Arg.	Holok	"
Toona ciliata Roem.	Poma	MELIACEAE
Toona sp.	Poma	"
• *Turpinia pomifera* (Roxb.)DC.	Gutigos*	STAPHYLIACEAE
Vernonia volkameriifolia DC.		ASTERACEAE
Vitex sp.		VERBENACEAE
Xylosma sp.	Mota-puli	FLACOURTIACEAE

VINE SPECIES		
• *Aeschynanthus* sp.1		GESNERIACEAE
• *Aeschynanthus* sp.2		"
Antidesma		EUPHORBIACEA
• *Ardisia solanacea* Roxb.		MYRSINACEAE
♣ *Species unidentified*		ASCLEPIADACEAE ?
Caryopteris sp.		VERBENACEAE
• *Cayratia japonica* (Thunb.)Gagnep.		VITACEAE
• *Coelogyne cristata* Lindl.		ORCHIDACEAE
♣ *Species unidentified*		CONVULVULACEAE ?
• *Dischidia benghalensis* Coleb.		ASCLEPIADACEAE
• *Ficus hederacea* Roxb.	Lota-dimoru	MORACEAE
• *Ficus subulata* Bl.	Daljhuri	"
• *Ficus geniculata* Kurz.	Tenga-bor	"
• *Ficus retusa* Linn.		"

♣ *Glochidion* sp.?		EUPHORBIACEAE
• *Gnetum scandens* Roxb.		GNETACEAE
• *Gymnema latifolium* Vall.		ASCLEPIADACEAE
Hiptage bengalensis (L.)Kurz.	Kerck-lota	MALPIGHIACEAE
Iodes hookeriana Baill.		ICACINACEAE
♣ *Natsiatum herpeticum* Ham.		"
• *Pleiopeltis*		-
♣ *Polygonum paniculatum* Bl.		POLYGONACEAE
• *Rhaphidophora hookeri* Schott.		ARACEAE
• *Schefflera venulosa* (W.& A.)Hams.	Jokhunilota	ARALIACEAE
Tetracera sarmentosa (Linn.) Vahl.	Ou-lota	RANUNCULACEAE
• *Thunbergia grandiflora* Roxb.		ACANTHACEAE
• *Tiliacora cordata*		MENISPERMACEAE
♣ *Tiliacora racemosa* Colebr.		"
♣ *Tinospora*		"
• *Vallaris solanacea* (Roth.)O.Ktze.	Gendheli-lota	APOCYNACEAE
• *Vanda teres* Lindl.		ORCHIDACEAE
♣ *Ventilago denticulata* Willd. = V. calyculata		RHAMNACEAE
♣ *Zehnaria amplexicaulis* (Lamk.) Gandhi.		CUCURBITACEAE

SOME OTHER PLANT SPECIES (OUTSIDE THE INTENSIVE STUDY AREA)

TREE SPECIES		
Ficus rigida Jack. = *F. globberina*		MORACEAE
Ficus auriculata Lour. = *F. roxburghii*		"
Ficus hirta Linn.		"
Gynocardia odorata R.Br.		FLACOURTIACEAE
Sapium eugeniaefolium Ham.ex Hk.f.		EUPHORBIACEAE
VINE SPECIES		
Argyreia sp.		CONVOLVULACEAE
Aspidopterys nutans (Roxb.ex DC.)Juss.		MALPIGHIACEAE
Cocculus sp.		MENISPERMACEAE
Colysis elliptica		POLYPODIACEAE
Combretum acuminatum Roxb.		COMBRETACEAE
Ficus foveolata Wall.ex Miq.		MORACEAE
Gleichenia linearis		GLEICHENIACEAE
Hodgsonia sp.		LILIACEAE
Lygodium sp.		SCHIZAEACEAE
Milletia pachycarpa Benth.		FABACEAE
Parameria pendunculosa		APOCYNACEAE
Piper sp.		PIPERACEAE
Rubus lucens Focke.		ROSACEAE
Sabia limoniacea Wall.ex Hk.f.&Th.		SABIACEAE
Styrax sp.		STYRACACEAE
Trichosanthus truncata Clarke.		CUCURBITACEAE
Wendlandia paniculata DC.		RUBIACEAE

- • Gibbon food plants.
- ♣ Food plants only nibbled at (<1.5% time spent feeding).
- • Local name (this study). All Assamese names are from Haridasan (1985)

Appendix 2a. List of food species of Troop 1, total time spent and nutritional values

Species	Sp. code	Time spent	ADF	ASH	CP	EE	G.ENERGY	MOIST	NDF	TANNIN	CARBO	CP/ADF+T
Ailanthus grandis	3	9:55:03	0.257	0.095	0.223	0.056	4.852	0.315	0.391	0.028	0.236	0.781
Artocarpus chaplasha	15	1:16:15	0.462	0.099	0.174	0.082	4.701	0.327	0.526	0.044	0.119	0.345
Cinnamomum ceciodaphne	34	1:37:13	0.493	0.041	0.116	0.024	4.668	0.121	0.634	0.277	0.184	0.151
Dysoxylum binectariferum	44	0:04:05	0.358	0.035	0.192	0.487	5.504	0.149	0.336	0.009		0.523
Ficus benjamina	61	0:37:17	0.540	0.097	0.153	0.081	5.239	0.257	0.521	0.020	0.147	0.274
Ficus elastica	62	1:00:51	0.609	0.068	0.063	0.019	4.974	0.183	0.706	0.013	0.143	0.102
Ficus pomifera	66	6:04:32	0.512	0.087	0.099	0.060	4.878	0.190	0.588	0.031	0.166	0.183
Michelia cathcartii	89	11:16:57	0.383	0.086	0.152	0.038	4.585	0.341	0.573	0.053	0.152	0.348
Persea glaucescens	95	0:10:22	0.564	0.060	0.171	0.131	6.464	0.160	0.554	0.013	0.084	0.296
Turpinia pomifera	121	1:53:29	0.442	0.085	0.094	0.050	5.392	0.286	0.318	0.126	0.453	0.166
Ficus nemoralis	180	1:45:15	0.316	0.058	0.100	0.059	5.958	0.349	0.395	0.120	0.387	0.230
Ficus hederacea	178	3:21:30	0.673	0.147	0.093	0.059	4.306		0.687	0.022	0.015	0.133
Ficus retusa	176	4:54:05	0.312	0.096	0.134	0.079	4.765	0.123	0.352	0.149	0.338	0.292
Ficus geniculata	177	0:10:23	0.757	0.079	0.112	0.009	4.908	0.163	0.753		0.047	
Coelogyne cristata	181	0:48:41	0.407	0.091	0.052	0.036	4.852	0.215	0.469	0.010	0.352	0.125
Thunbergia grandiflora	182	4:30:31	0.478	0.170	0.211	0.019	4.431	0.258	0.542	0.030	0.058	0.416
Aeschynanthus 1	183	14:26:27	0.591	0.110	0.039	0.035	4.808	0.604	0.562	0.014	0.254	0.064
Rhaphidophora hookerii	184	5:02:24	0.305	0.103	0.251	0.028	4.836	0.067	0.433	0.021	0.185	0.773
Aeschynanthus 2	185	6:49:28	0.358	0.117	0.111	0.010		0.290	0.553		0.208	
Gnetum scandens	186	8:12:50	0.460	0.069	0.180	0.036	5.032	0.225	0.522	0.021	0.193	0.374
Tiliacora cordata	187	1:59:49	0.425	0.115	0.201	0.062	4.624	0.181	0.502	0.023	0.120	0.450
Gymnema latifolium	188	0:22:10	0.445	0.078	0.206	0.066	5.143		0.543	0.041	0.107	0.423
Vanda teres	189	0:10:22	0.501	0.083	0.077	0.038	4.745	0.149	0.615	0.013	0.187	0.149
Ardisia solanacea	190	2:06:51	0.285	0.086	0.124	0.075	4.670	0.116	0.411		0.303	
Cayratia japonica	191	0:06:29	0.562	0.139	0.304	0.074	5.514	0.221	0.576	0.034		0.511
Discidia benghalense	192	1:13:31	0.505	0.059	0.150	0.032	4.426	0.204	0.621	0.119	0.138	0.241
Pleiopeltis	193	0:01:22	0.384	0.118	0.048	0.059	4.816	0.190	0.430	0.006	0.346	0.122

Appendix 2b. List of food species of Troop 2, total time spent and nutritional values

Species	Sp.code	Time spent	ADF	ASH	CP	EE	Kcal/gm	MOIST	NDF	TANNIN	CARBO	CP/ADF+T
Ailanthus grandis	3	0:02:34	0.257	0.095	0.223	0.056	4.852	0.315	0.391	0.028	0.236	0.781
Artocarpus chaplasha	15	2:54:19	0.462	0.099	0.174	0.082	4.701	0.327	0.526	0.044	0.119	0.345
Artocarpus integrifolia	16	3:19:52	0.223	0.078	0.165	0.012	4.829	0.131	0.407	0.472	0.339	0.237
Bombax ceiba	23	1:10:22	0.483	0.075	0.134	0.021	4.795	0.136	0.589	0.033	0.181	0.259
Erythrina stricta	54	7:57:31	0.382	0.096	0.225	0.044	4.119		0.548	0.041	0.087	0.534
Ficus benjamina	61	27:46:30	0.540	0.097	0.153	0.081	5.239	0.257	0.521	0.020	0.147	0.274
Ficus elastica	62	0:26:42	0.609	0.068	0.063	0.019	4.974	0.183	0.706	0.013	0.143	0.102
Manglietia hookeriana	85	3:24:57	0.486	0.080	0.157	0.014	6.817		0.417	0.045	0.332	0.297
Michelia champaca	88	0:40:18	0.610	0.038	0.115	0.002	5.244	0.193	0.721	0.021	0.124	0.182
Michelia kisopa	90	0:55:08	0.329	0.121	0.154	0.046	4.747	0.284	0.348	0.050	0.332	0.407
Sterculia villosa	175	0:15:23	0.667	0.103	0.162	0.023	4.686	0.133	0.711	0.007	0.001	0.241
Ficus hederacea	178	0:06:28	0.673	0.147	0.093	0.059	4.306		0.687	0.022	0.015	0.133
Ficus subulata	179	0:48:32	0.329	0.091	0.191	0.054	4.886	0.267	0.438	0.106	0.226	0.440
Ficus geniculata	177	0:19:26	0.757	0.079	0.112	0.009	4.908	0.163	0.753		0.047	
Coelogyne cristata	181	2:42:32	0.407	0.091	0.052	0.036	4.852	0.215	0.469	0.010	0.352	0.125
Thunbergia grandiflora	182	0:36:24	0.478	0.170	0.211	0.019	4.431	0.258	0.542	0.030	0.058	0.416
Aeschynanthus 1	183	1:06:31	0.591	0.110	0.039	0.035	4.808	0.604	0.562	0.014	0.254	0.064
Rhaphidophora hookerii	184	1:12:00	0.305	0.103	0.251	0.028	4.836	0.067	0.433	0.021	0.185	0.773
Aeschynanthus 2	185	0:08:25	0.358	0.117	0.111	0.010		0.290	0.553		0.208	
Gnetum scandens	186	0:01:27	0.460	0.069	0.180	0.036	5.032	0.225	0.522	0.021	0.193	0.374
Tiliacora cordata	187	0:51:48	0.425	0.115	0.201	0.062	4.624	0.181	0.502	0.023	0.120	0.450
Gymnema latifolium	188	0:35:37	0.445	0.078	0.206	0.066	5.143		0.543	0.041	0.107	0.423
Vanda teres	189	0:12:08	0.501	0.083	0.077	0.038	4.745	0.149	0.615	0.013	0.187	0.149
Vallaris solanacea	194	8:10:31	0.281	0.072	0.121	0.051	4.343	0.323	0.331	0.063	0.425	0.351
Schefflera verulosa	195	2:12:23	0.422	0.104	0.123	0.037	4.485	0.124	0.423	0.039	0.313	0.268
Ostodes paniculata	196	0:16:30	0.352	0.094	0.189	0.065	5.509	0.303	0.428	0.055	0.224	3.458

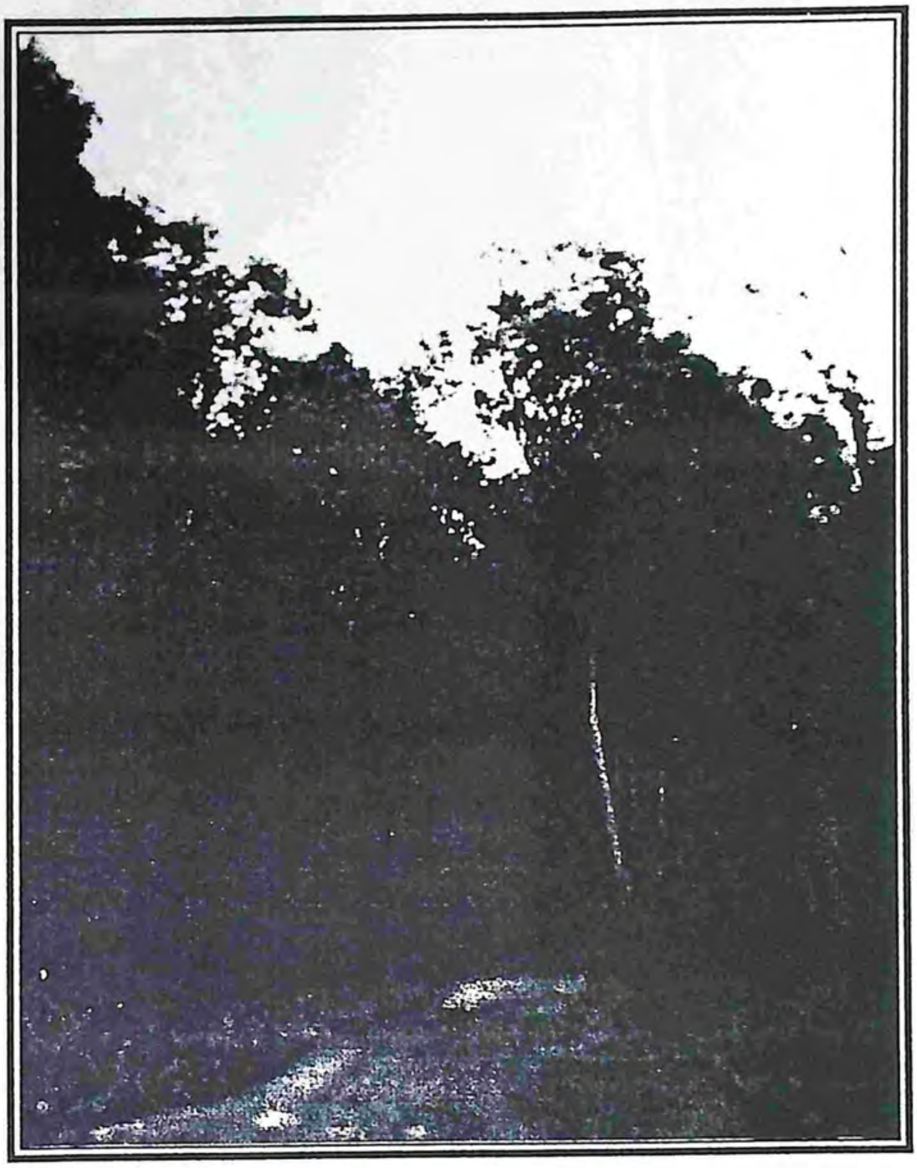

Plate 1: TREE COVER IN AREA USED BY TROOP 1

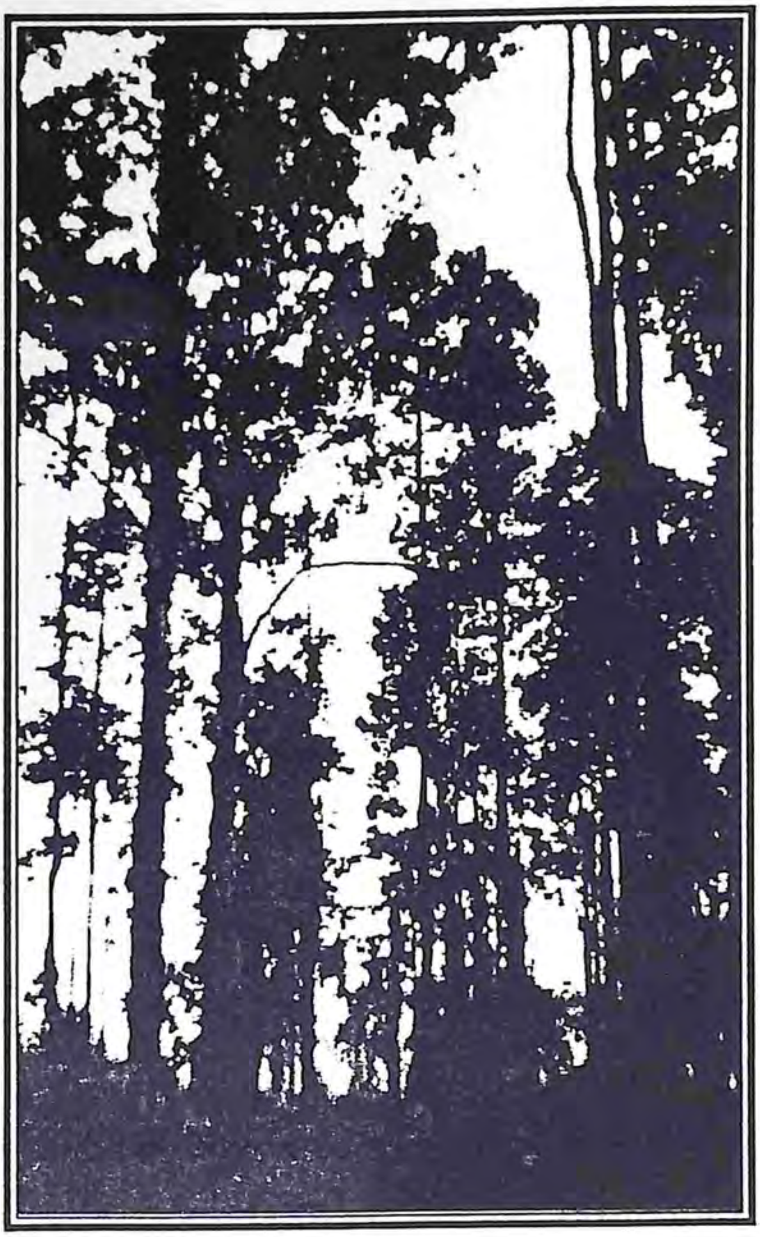

PLATE 2 TREE COVER IN AREA USED BY TROOP 2

PLATE 3 ADULT MALE GIBBON OF TROOP 1 LEAPING ACROSS A CANOPY GAP

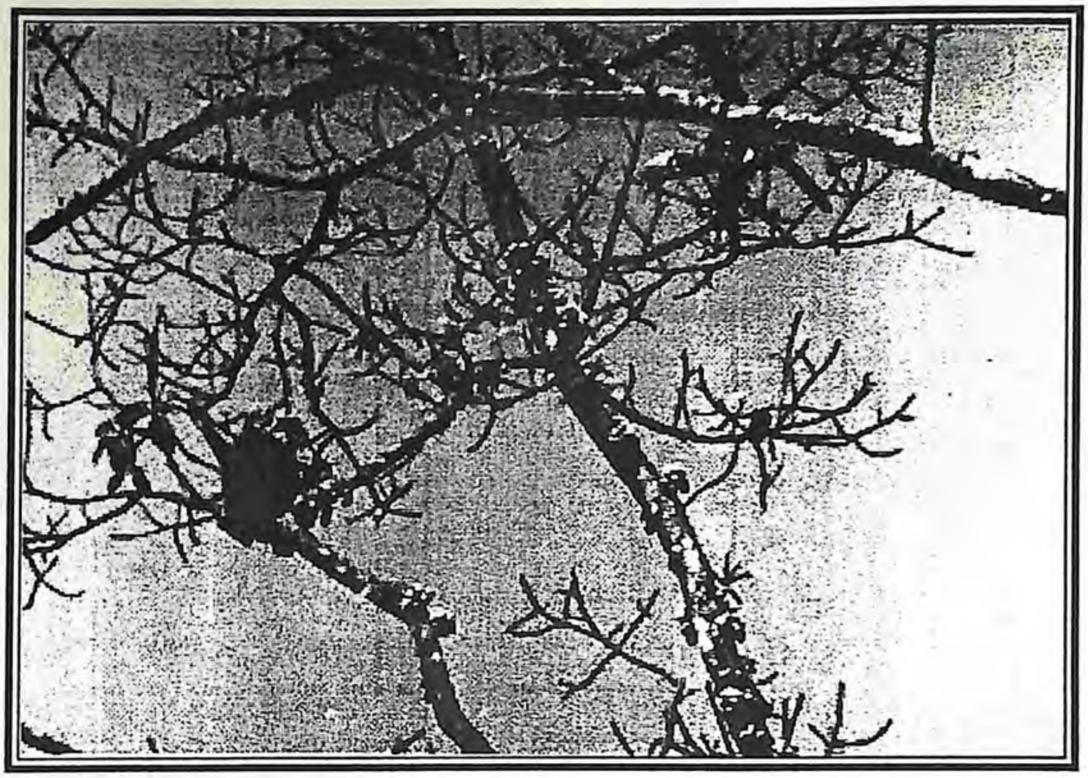

PLATE 4: JUVENILE GIBBON OF TROOP 1 AND A CURIOUS INDIAN PIED HORNBILL ON A FRUITING *FICUS POMIFERA*

PLATE 5: JUVENILE GIBBON OF TROOP 1 RESTING ON THE *FICUS POMIFERA*