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HABITAT RELATIONS OF THE SAMBAR (CERVUS UNICOLOR)

IN KHAO-YAI NATIONAL PARK, THAILAND

presented by

Choompol Ngampongsai

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Department of Fisheries and Wildlife

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Major professor

Date November 30, 1977

HABITAT RELATIONS OF THE SAMBAR (CERVUS UNICOLOR) IN KHAO-YAI NATIONAL PARK, THAILAND

By

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Fisheries and Wildlife

1977

ABSTRACT

HABITAT RELATIONS OF THE SAMBAR (CERVUS UNICOLOR) IN KHAO-YAI NATIONAL PARK, THAILAND

By

Choompol Ngampongsai

Habitat relations of sambar were studied between March 1976 and March 1977 in Khao-Yai National Park, Thailand.

Species composition of both grassland and forest vegetation was determined. Seven grassland and 21 forest plants were determined to be preferred foods of sambar. Imperata cylindrica was by far both the most available forage and the most important food in the deer's diet. As a preferred species, it was among those plants which were consumed to a greater degree than indicated by their abundance. Vegetative analysis of the grassland range indicated that 52% of the 72 species present were preferred foods, 11% were neglected forages, and 37% were avoided. No signs of range degradation were noted despite high deer density. A number of other species showed high preference rating values but their availabilities were

limited. Animals were judged to have only unimportant effects on forest production, in terms of their killing forest trees.

The average daily food consumption by a captive three-year-old female sambar was 1084.21 grams dry weight. Assuming 40% greater food intake, the daily food consumption of a wild active animal was estimated to total 1517.89 grams. Energy used for maintenance and growth over a 12-day feeding trial was 29,694 kcal or 55.84% of the energy consumed. Daily water intake averaged 1.4 liters. The captive sambar spent more time resting, ruminating, and walking than it did feeding and standing. Feeding occurred in the early morning and late evening and also at night.

Average numbers of wild deer per hectare over the period May through December were calculated to be 0.02 as determined by late-afternoon roadside counts, 0.11 from pre-midnight spotlight tallied, 3.68 from pellet-group censuses, and 3.15 on an experimentally burned food-removal study plot.

The extremely high densities indicated by pellet-counts must be tested in future studies. Regardless of precise values, however, a very high grassland density seems certain to be characteristic of sambar populations in the park. This is especially true during certain seasons and especially sambar concentrations are due to the attractions of grassland foods.

The population consisted of 44% adults, 40% sub-adults, and 16% fawns. The sex ratio among adults was 6.17 females per male and there were 2.31 adult females per fawn.

Recommendations for maintaining sambar populations in national parks are given. It is also suggested that the potential for ranching sambar for meat-production should be investigated. In view of the findings of this study, sambar may be more a productive source of meat than domestic livestock and will not require improved pasture-lands.

ACKNOWLEDGMENTS

Great appreciation is expressed to Dr. George A. Petrides, Department of Fisheries and Wildlife, committee chairman, for his direction, guidance, valuable counsel, criticisms, and for careful editing of the manuscript. I also thank my other committee members: Drs. Leslie W. Gysel, also of that department, Peter G. Murphy of the Department of Botany, and Gary Schneider of the Department of Forestry for their support and enthusiastic encouragement throughout my graduate study. The visits of both Drs. William B. Drew, Chairman emeritus of the Department of Botany, and George A. Petrides during my data collection in Thailand are deeply appreciated.

A warm expression of thanks goes to the Khao-Yai National Park staff for their cooperation and assistance which was essential to my study. My sincere appreciation and thanks also go to Dr. Tem Smitinand and Mr. Weerachai Nanakorn for plant identification, to Ph.D. candidate Thomas M. Butynski who helped me in preparing the manuscript, and to Ms. Pantipa Jantawat for her assistance in preparing drawings.

Special thanks are extended to the Kasetsart University for educational scholarships and to the Faculty of Forestry there. In particular, I wish to express gratitude to the staff of the Conservation Department at Kasetsart University and to the Royal Thai Forest Department for providing facilities and study areas. Without financial support from the New York Zoological Society for field work, I would certainly never have had the opportunity to complete this study and for this I am most grateful.

Unknown plants were identified through the kindness of the Division of Botany, Royal Thai Forest Department, Bangkok; the energy values were determined by the Department of Animal Husbandry, Kasetsart University, Bangkok, and the author wishes to express his sincere gratitude to them.

Finally, special thanks go to my wife, NIPAPUN, whose constant inspiration, encouragement, and understanding helped me to complete the study.

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INTRODUCTION

Thailand resembles other developing countries in having only recently undertaken the scientific management of its forest lands for purposes other than timber production. Attempts by the national government to establish and/or enforce regulations pertaining to forest reservations, national parks, and wildlife sanctuaries are often ineffective. This is mainly because of existing low levels of education and the low standard of living. The public is often unprepared to accept restrictions on lands that have traditionally been free of regulation. Villagers, especially those living within easy reach of the forests, national parks, and wildlife sanctuaries, often believe that trees, wildlife, scenic beauty, and other national resources are gifts of nature and belong to no one. They believe that they should have the right to occupy any lands, cut any trees, and hunt all wildlife freely (Banijbatana, 1966, 1967).

Country people have always looked to the forest as a source of food, fuel, and shelter and do not now feel the necessity of having forest areas set aside as

national parks. With rapid population growth and subsequent expansion of towns and cities, however, the need for recreational areas has increased. This is especially true to satisfy the need of people in urban areas (Banijbatana, 1966, 1967). Yet the people are apathetic to the necessity of establishing recreational areas or even for the protection of wildlife for their own enjoyment.

Successful wildlife management requires basic understandings of animal habitat requirements, such as food, cover, water, and living space. Together, these essentials determine the ability of an area to support animal life.

Due to effective fire control in Khao-Yai National Park, seedlings and saplings of woody species have become established in the grassland areas. While the present grasslands in this Park are important to wild herbivores, it is believed that secondary forests will eventually replace the meadows. No studies of wild hoofed animals and their relation to their habitats have been undertaken in all of Thailand. The objective of this study was to establish basic standards for the management of sambar (Cervus unicolor) in the park. The investigation was conducted between March 1976 and March 1977 in Khao-Yai National Park, Thailand.

Specific study objectives were:

(1) to compute food preference ratings for the sambar

(2) to apply the ratings of forages used by the sambar in predicting range condition and trend

(3) to appraise the effects of wild animals on forest regeneration and timber production

(4) to provide sound management policies so as to insure the survival of sambar and the preservation of their habitats in the park and elsewhere.

The sambar is related to the red deer or stag of Europe and Asia and to the elk of North America. It is a typical forest dweller of southeastern Asia. Sixteen subspecies of sambar (Whitehead, 1972; Grzimek, 1972) range from Ceylon through India to Burma, southern China, and Taiwan, south to Thailand, Malaysia, Sumatra, Borneo, and Celebes (Medway, 1969). Full-grown stags stand about 1.37 m at the shoulder and weigh about 227 kg. The coloration in both sexes is uniform light brown, with underparts paler. Stags are generally darker than hinds, approaching black or slaty grey in old males. The hair is long and coarse. It forms a heavy ruff around the throat of the mature stag (Thom, 1937; U Tun Yin, 1976).

The males have antlers that are shed and replaced annually (Figure 1). The first set of antlers are grown at 3 years of age and are straight spikes. The second set has two tines, and the third and subsequent sets of antlers always have three tines (Medway, 1969). For most sambar, especially at Khao-Yai National Park, the

Figure 1. Sambar stag and hind showing typical body characteristics.

antler-shedding period is from May to July. Antlers develop to the hard stage in December. During the rutting season, old stags stalk about with erect tail, outstretched muzzle, and everted face glands (Thom, 1937). At this time they are highly dangerous, especially in captivity. Each male fights for his territory and retains females which enter his area.

After the mating season, stags leave the females and stay by themselves until the next rut. Most fawns are dropped during the rainy season. At Khao-Yai National Park, mating occurs in January and February, with most young being born during September and October. The gestation period is about eight months (Thom, 1937; Kenneth et al., 1953).

The sambar is essentially an animal of the more open deciduous forests and does not favor dense tree growth. It is quite diurnal in its habits (Krishnan, 1972). When alarmed, sambar utter a loud, whistling call and raise the tail to reveal the white underside. Both sexes stamp their feet when suspicious of danger (Peacock, 1933; Bentley, 1967). Sambar in captivity have lived to a maximum of 26 years (Manville, 1957).

Description of the Study Area

Following a period of increased deforestation and land cultivation, Khao-Yai National Park was established as Thailand's first national park in September 1962 under

the recommendation of Dr. George C. Ruhle (1964). This was done to preserve at least some natural areas for the future enjoyment of Thai citizens and visitors from other parts of the world.

Geographically, the park is about 200 km northeast of Bangkok. It lies between 14° 5' and 14° 15' north latitude; and between 101° 5' and 101° 50' longitude. The park is rectangular in shape, 2168 km^2 in size and extends into four political provinces: Pak Chong district of Nakorn Ratchasima Province in the north, Nakorn Ratchasima and Prachinburi Provinces in the east, Nakorn Nayok Province in the south, and Saraburi Province in the west (Figure 2).

Topography

Except for low undulating land in the east, the park is mountainous and extends from 250 to 1400 m above sea level. The western limb of the Dongrak Range includes two vital watersheds: Lam Ta Kong in the north and Mae Nam Nakorn Nayok to the south. In general, the northern and southern boundaries are steep escarpments while the western border is made up of irregular limestone peaks and outcroppings. The eastern slopes descend gradually from upland forest to agricultural areas outside the park (Enderlein and Maxwell, 1976).

The Dongrak Range is composed of Permian and Jurassic limestones of the Ratchaburi and Kamawkala

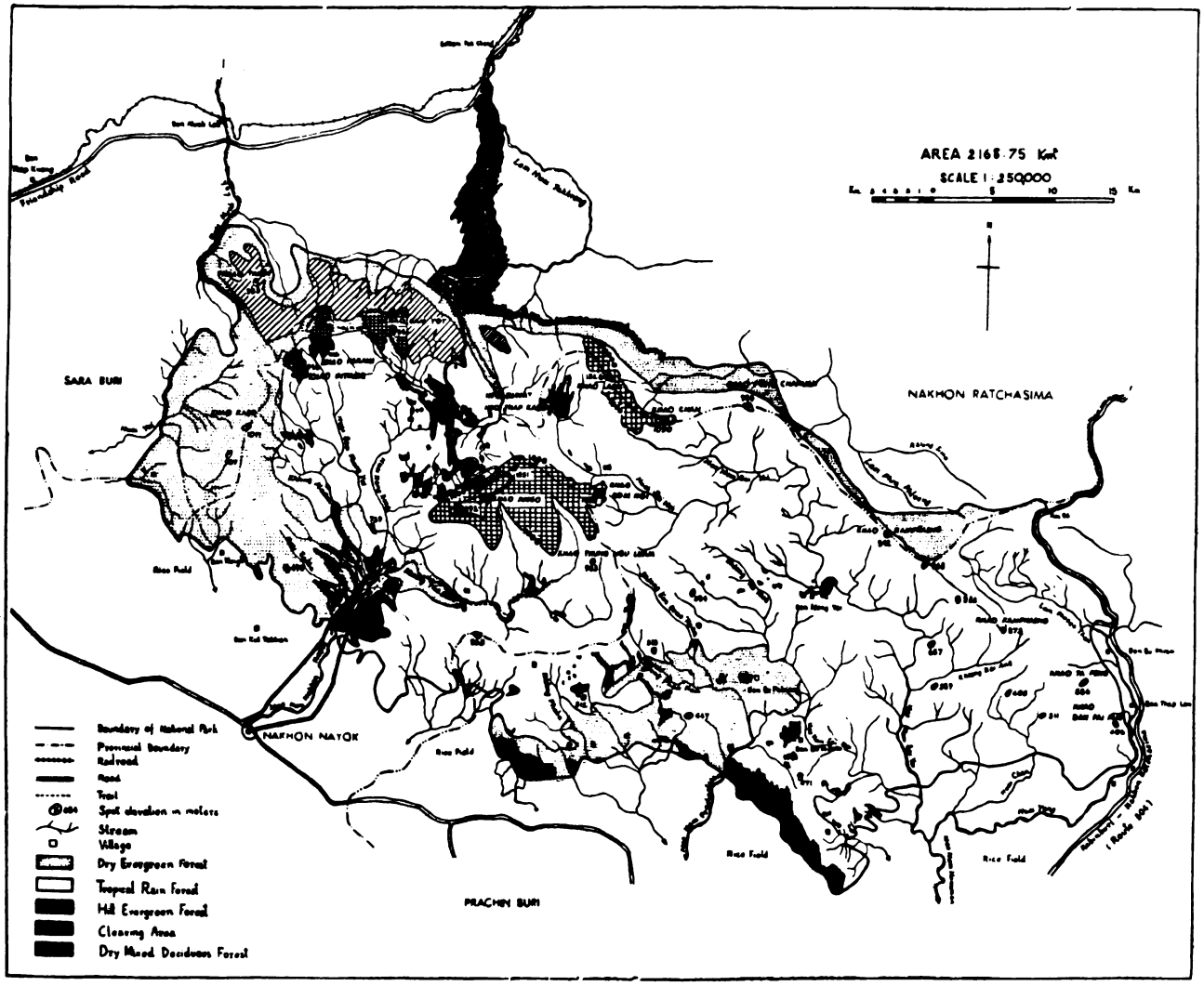

Figure 2. Map of Khao-Yai National Park and its five major vegetation types (from Smitinand, 1968).

series. These strata mostly are seen in the western part of the park in Saraburi Province. The upper bedrock series includes Jurassic sandstone of the Korat series, with shales, shists, and gneisses predominating. Conglomerate bedding is common along the Lam Ta Kong River. The southern slopes are composed of granite and conglomerates of Jurassic age. The eastern portion in Prachinburi Province has Jurassic Kamawkala limestone underlying the Jurassic Korat sandstone (Smitinand, 1968; Enderlein and Maxwell, 1976).

The soils on the study sites were reddish in color, well-drained, and mostly derived from limestone and sandstone. Rock outcrops were widely scattered.

Vegetation

There are five major vegetation types (Figure 2) in the park (Smitinand, 1968; Enderlein and Maxwell, 1967):

(1) Dry Mixed Deciduous Forest (1.5% of the area).-- Occurring at 400-600 m elevation, this type is found on the northwest boundary of the park in Saraburi Province, primarily in the limestone belt. Common trees include Garuga pinata, Afzelia zylocarpa, Xylia kerii, Terminalia bellerica, and Lagerstoemia calyculata. Unfortunately, this association in the park has been largely destroyed by clear-cutting and shifting

agriculture. Only a few isolated patches of original forest remain, mostly on the rugged peaks, and these require protection.

(2) Dry Evergreen Forest (9.2% of the area).--This forest type occurs between 100 and 200 m above sea level. It is located mostly along the northern escarpment in the western portion of the park in Saraburi and Nakorn Nayok Provinces and in the southern part in Prachinburi Province. Common trees are Dipterocarpus alatus, Shorea sericeiflora, Hopea ferrea, H. odorata, Lophopetalum wallichii, and Hydnocarpus ilicifolia. Since these trees are commercially valuable, much disturbance occurred in the past. Most of this type has been destroyed on the northern escarpment and along the park boundary in Saraburi and Nakorn Nayok Provinces. Unless protection is given, the remaining dry evergreen forest will be soon destroyed.

(3) Tropical Rain Forest (83% of the area).--The majority of the park area, from 400 to 1000 m elevation, is in this forest type. Included is most of the vegetation in the eastern half of the park. In many of the lower areas, the rainforest merges with the dry evergreen association. The rainforest, however, is comparatively more

moist, dense, and diverse in its composition. The canopy is typically 3-stories, with many epiphytes, and there is a dense ground flora. The upper story is comprised of many tall trees (Dipterocarpus alatus, D. gracilis, Schima wallichii), and a few deciduous species such as Pterocymbium javanicum, and Tetrameles nudiflora. The understory is primarily of Lithocarpus annamensis, Castanopsis acuminatissima, Knema laurina, and Eugenia siamensis. The ground flora is typically lush and shaded and, along with a rich epiphyte flora, forms a complex association of species.

(4) Hill Evergreen Forest (2.4% of the area).--Occupying the mountain tops over 1000 m above sea level, this forest is typically dense. Many of the large broadleaved species found below 1000 m are here replaced by gymnosperms. Prominent are Podocarpus nuriifolius, P. imbricatus, P. fleuyi, and Dacrydium elatum. Many species of Lithocarpus and Quecus also occur. Understory trees include: Olea maritina, Rhus succeninea, and Adina polycephala.

(5) Grassland and Secondary Growth (3.9% of the area).--Resulting from disturbance by man, these areas occur where shifting cultivation, road construction, and fires are prevalent. Grasslands

are dominated by Imperata cylindrica, Neyraudia reynaudiana, Saccharum spontanum and Themeda arundinacea. Occasional shrubs include Hibicus macrophylla and Trema orientalis. Where fire has been controlled, seedlings of various species from associated primary habitats emerge.

Fauna

According to Enderlein and Maxwell (1976), the park fauna has never been studied in detail. Due to the keen interest of members of the "Friends of Khao-Yai Association," however, a preliminary list of mammals known to exist in the park has been compiled. It includes 16 carnivores, 1 proboscidian, 7 artiodactyls, 3 insectivores, 5 primates, 1 lagomoph, 6 rodents, and at least 25 chiropterans. Preliminary observations indicated that sambar use grasslands and the tropical rainforest in the near proximity of grasslands.

Climate

The climate is of the monsoon type with year round high temperatures. The mean annual temperature is 23° C, based on 1970 to 1976 air temperature data from Khao-Yai National Park Headquarters Meteorological Station. The mean annual minimum and maximum temperatures are 17.6° C and 28.4° C, respectively. Highest temperatures occur at the end of the April-May dry season when 30° C is not

uncommon. The extreme minimum temperature recorded was 1° C in January 1975.

The average rainfall, based on 1966 to 1976 data, is 2156 mm, occurring mainly from May to September, and monthly rainfall is usually highest in June, averaging nearly 400 mm. The rainfall is low between November and March (Figure 3). Many permanent streams and creeks exist which supply fresh water for animals, even in the dry period.

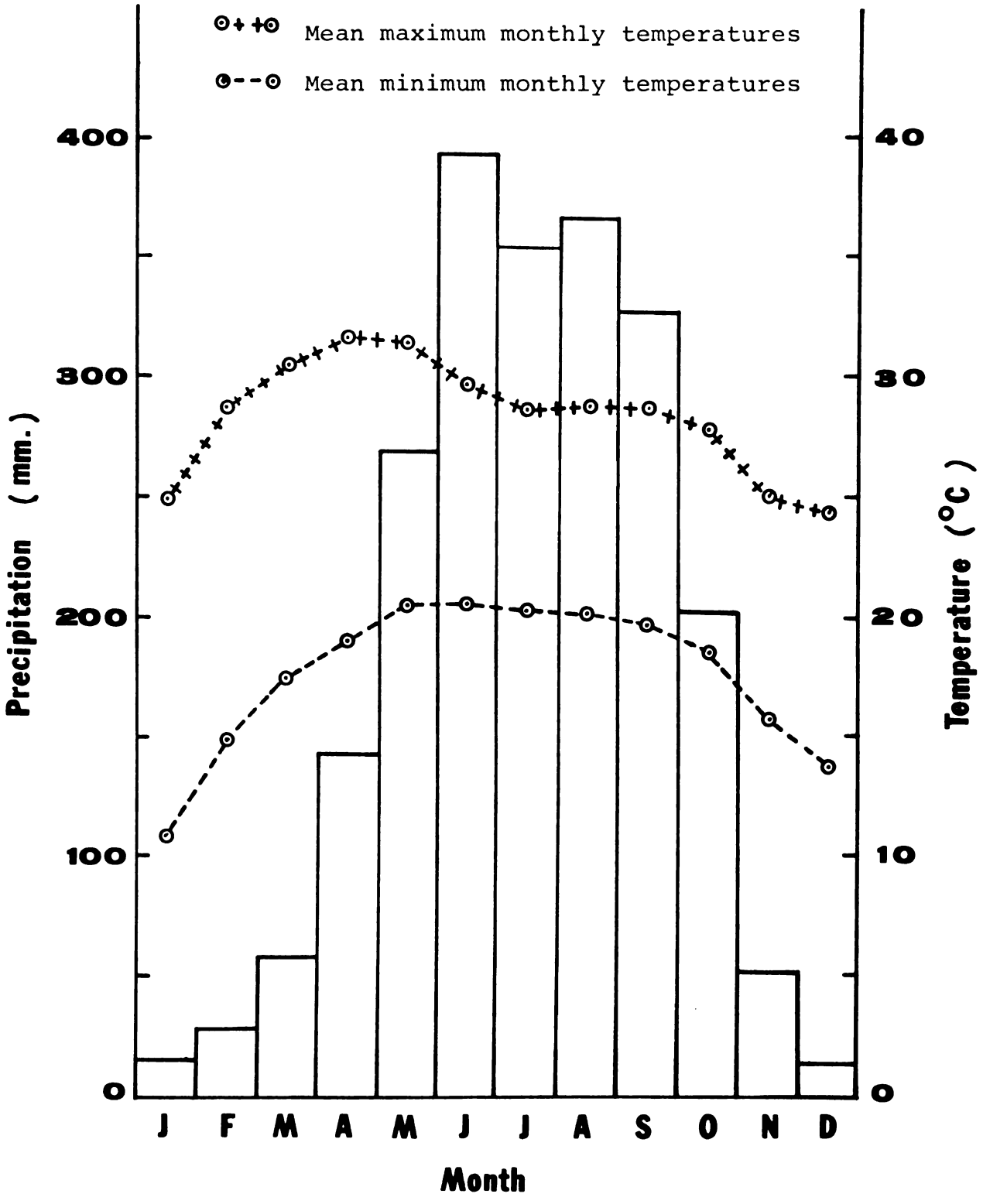

Figure 3. Distribution of precipitation and temperature at Khao-Yai National Park, based on 1966-1976 rainfall and 1970-1976 temperature data.

METHODS AND PROCEDURES

Study Sites

As time and transportation facilities were limited and provisions for security were minimal, all study sites were necessarily located within 10 km of the Park Headquarters (Figure 4). Intensive investigations were conducted on three grassland sites at Nhong-King, Moor-Singh-Toe and Nhong-Puck-Chee (Figure 4) and in the forests surrounding them. The attitude at these places was between 700-900 m above sea level.

Vegetation

Square-meter plots were used to sample the grassland community. Plots were distributed regularly throughout the three sample grassland areas. It was assumed that this distribution provided a representative sample of the grassland community. The species-area curve was used to determine the number of plots needed in order to sample the forage species adequately. Braun-Blanquet (1932) considered that the sample was adequate when the species-area curve become approximately horizontal while Cain (1938) stated that the sample size is adequate when a

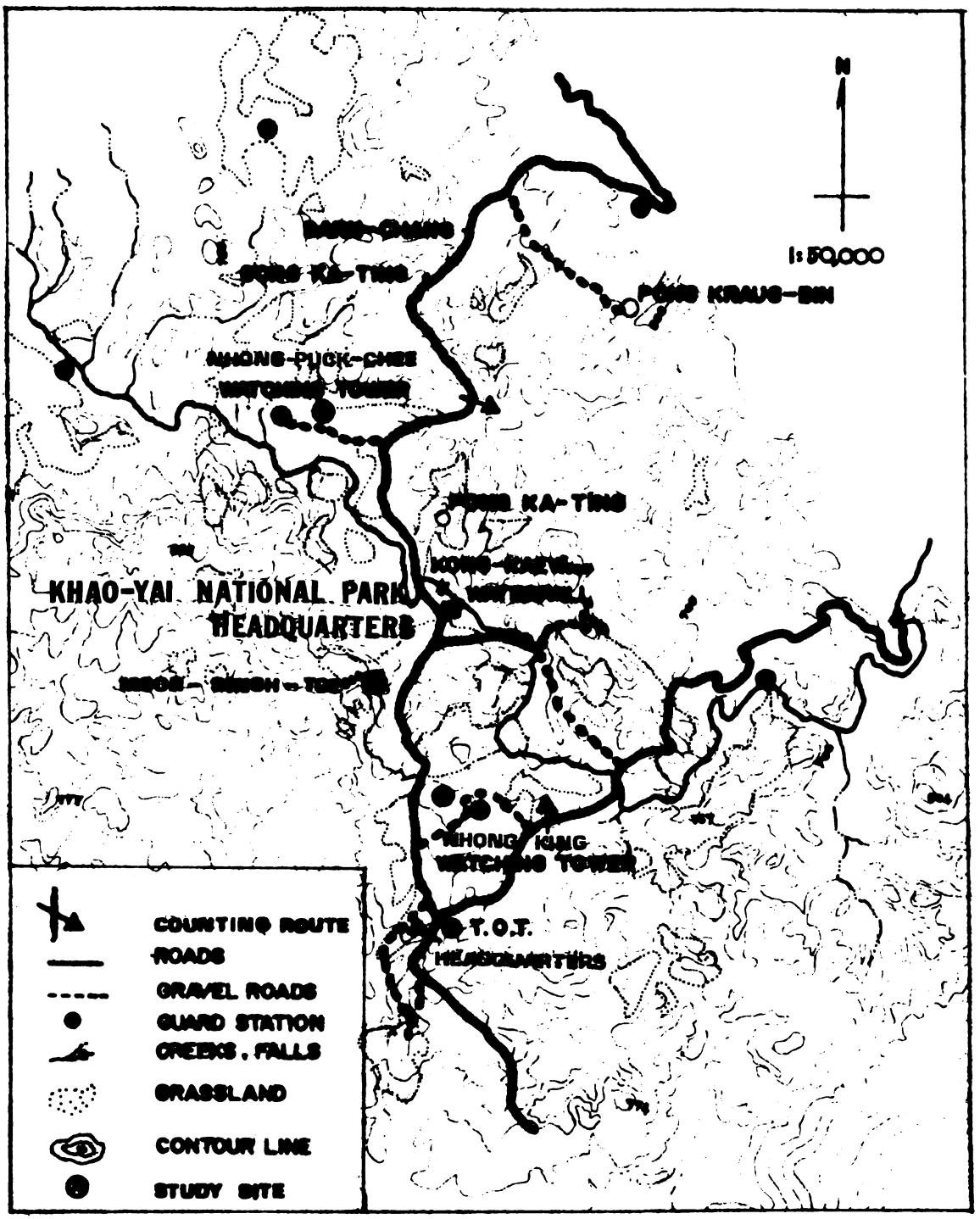

Figure 4. Topographic map of the three study sites, Khao-Yai National Park.

10% increase in the sample area results in a 10% increase in the number of species present. Braun-Blanquet's criterion was applied in this study.

At Nhong-King (Figure 5), 35-40 plots were required to meet these requirements. To insure an even sample distribution and to obtain additional information, vegetation data were gathered from 48 plots spaced at 100 m intervals along lines 100 m apart. Distance between plots were measured with a plastic rope of known length. Lines were kept equidistant using a hand compass.

The index of similarity "S" (Odum, 1971) was used to compare the vegetative composition of paired study sites. With reference to areas A and B:

$$S = 2C / (A + B)$$

where C is the number of species common to both areas, and A and B are the numbers of species found in areas A and B, respectively. S is the fraction of species on the two areas which is common to both areas. The closer the value of "S" to unity the more similar the samples. The index of dissimilarity, "D," is 1-S.

Clipping and weighing were used to estimate production and utilization (Brown, 1954; National Research Council, 1962). Herbs were clipped at the mean grazing height observed for each species and placed in a plastic bag. After weighing the fresh specimens, grasses and

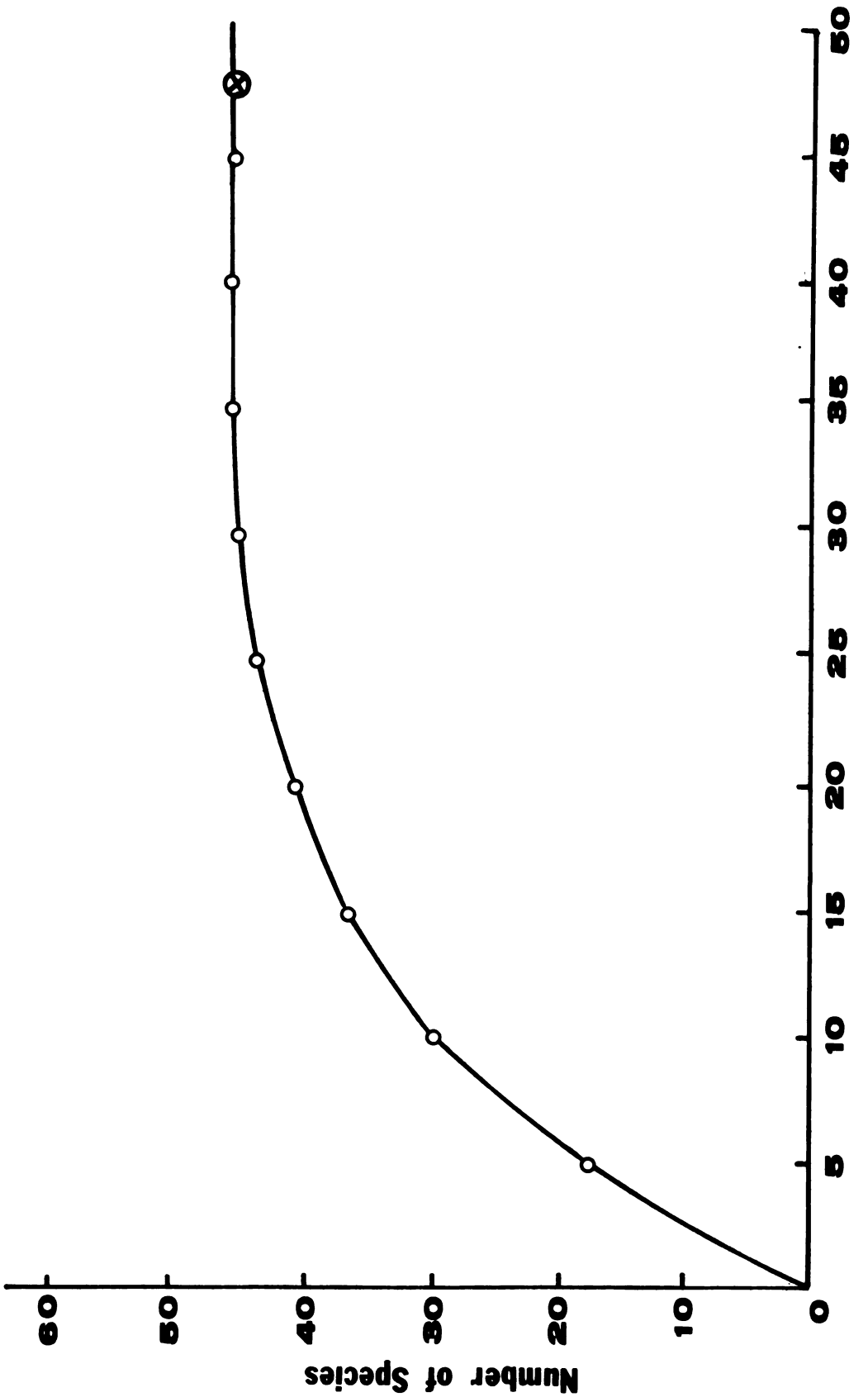

Figure 5. Species-area curve at Nhong-King grassland, Khao-Yai National Park, July 1976.

herbs were dried at 75° C for 24 hours in a vacuum oven. Leafy twigs were treated similarly but at 100° C. After cooling to room temperature, specimens were weighed to the nearest 0.001 gm and moisture percentages computed.

Production and utilization plots were established on the grassland at Nhong-King. Two 100 m^2 plots were established approximately 20 m apart, one fenced to exclude large herbivores and the other not. On September 30, 1976, before the plot markers and fencing were placed, all forage species within them were removed by burning.

Each 100 m^2 area was divided into 25 smaller plots, measuring 4 m^2 in area. These were marked by wooden pegs extending 5 cm above ground level. Every 15 days, average production and utilization rates were determined by clipping from two randomly selected 4 m^2 plots on each of the fenced and unfenced sites. Utilization was computed as the difference between forage weights on the protected and grazed plots.

On each plot, all species of grasses and sedges, forbs, shrubs, and trees present were identified. For woody plants, the number of leafy twigs up to 2 m, the maximum browsing height of sambar, were tallied by the twig-count method (Shafer, 1963).

Additionally, the line-intercept method was applied to determine the percentage of plant cover

(Canfield, 1941). The canopies of plants which intercepted the right-hand border of the wooden square-meter frame were measured as a straight-line distance and recorded by species. Similar procedures were used on 43 and 45 plots at the Moor-Singh-Toe and Nhong-Puck-Chee grasslands, respectively.

In the forest community, a system of nested plots (Daubenmire, 1968; Gysel, unpublished) was adopted for study. Three rectangular plots, 6 x 15 m, 1 x 15 m, and 1 x 3 m, were established within each other and with a common center line. All trees over 1.5 cm diameter at breast height (d.b.h.) were measured throughout the 6 x 15 m plot. Woody plants taller than 0.5 m and having a d.b.h. greater than 1.3 cm were measured in the 1 x 15 m plot. Plants less than 0.5 m in height and smaller than 1.3 cm d.b.h. were measured in two 1 x 3 m plots located at both ends of the central line of the macro-plot. The percentage of crown cover was estimated along the central line of each 6 x 15 m plot (Cain and Castro, 1959).

To assess the influence of sambar on forest trees, all plants rooted within 1 x 15 m and 1 x 3 m plots were recorded in terms of browsed and unbrowsed stems. Since sambar mainly utilize those portions of the forest in close proximity to the grasslands, 10 sets of nested plots were established in the forest in each locality. At each site, four parallel lines were extended

from the grassland at right angles to forest edge. The lines were 100 m apart and each set of plots was established on the lines no nearer than 100 m from the next one. The number of plots on each line varied between 2 and 4. A hand compass was used to keep the lines equidistant. Plastic ropes marked at the desired lengths were used to delineate plot boundaries.

The twig-count method (Shafer, 1963) was used on the ten 1 x 6 m forest plots to determine the amounts of browsed and unbrowsed twigs. The original lengths of browsed twigs were obtained by comparing their twig diameters with those of unbrowsed twig specimens (see Shafer, 1963); 30-50 specimens of unbrowsed twigs were selected randomly from different plants to determine mean dry weights.

Food Preference Study

Papageorgiou (1972) stated that there are two important observations in herbivore food habit studies: (1) the percentage of the animal's diet which a plant species contributes, and (2) the percentage of each forage which is cropped by the feeding animal. The dietary percentage indicates the principal foods consumed. The percentage cropped illustrates the degree to which that species is chosen from among those available to be eaten.

If all forage species were present and available in equal quantities, the composition of the animal's diet alone would reveal its food preferences. Such conditions, however, do not exist in nature. While forage preference may be expressed as the percentage of each species removed by the animal (Casebeer, 1948; Papageorgiou, 1972), it is usually more revealing to express forage preference ratings as the quotient which results when the species' percentage in diet is divided by its percentage availability (Petrides, 1975). The ratio of the percentage in the diet to the percentage availability yields a value which if greater than 1.00 indicates the relative degree of preference, and if under 1.00 illustrates the degree of unattractiveness. A ratio of 1.00 demonstrates that a species is eaten as it is encountered, being neither sought out nor neglected. The ratio serves as a standard of relative comparison according to the degree of preference.

The computed ratios are specific to the time that the data were collected and are restricted to the locality involved. Other food species present, the chemical composition of both soil and plant, as well as the season of the year are important factors influencing preference ratings (Ivins, 1959; Guy, 1976). The reason why certain foods are preferred over others is not disclosed by either percentage utilization determinations or by food preference values. Relative forage preference ratings, however,

may be employed to appraise range condition and trend. Reductions in highly preferred species and increases in less-eaten species may be used to indicate increases in population levels with respect to range carrying capacity (Stoddart and Smith, 1955).

The formula proposed by Petrides (1975) was used to calculate a preference rating for each food plant. These values identified preferred foods as opposed to those which were neglected or avoided. The percentages used in the ratios were calculated from species' dry weights.

Grasslands in the Khao-Yai are burned annually in late December or early January, and utilization by sambar begins in January. Food preference calculations were made from January to September in the grasslands and from January to December in the forest habitat.

Feeding Trial

Although only one captive sambar could be used, the effort was made to determine its daily food consumption and maintenance requirements. The tame 3-year-old female sambar used was held in a 10 x 10 m cage. The feeding trial was conducted for the 12 days between January 12-24, 1977, but the deer was penned for 15 days prior to the study to allow for acclimation to captive conditions. The sambar's weight was recorded before and after the trial.

Each day, pre-weighed foods were placed in a wooden feeder. Only preferred foods were offered to the animal. Since most preferred forage species were difficult to find during the time of study and a considerable amount was needed, only the relative abundant Imperata cylindrica and Neyraudia reynaudiana were utilized. Food was provided at double the animal's expected daily intake to insure that foods were available to the animal. No other foods were given to the animal during the study period.

Droppings were collected and weighed every morning. Approximately 12-15% of the droppings were placed daily in a plastic bag. These were dried for 24 hours at 100° C. The energy values both of forage plants and sambar feces were determined using a bomb calorimeter. Drinking water was available ad libitum in a 5-liter plastic container. Urine was not collected in this study.

Animal Effects on Forest Production

To determine the effects of deer on forest production, six 400 m^2 plots were located at three forest sites. Two such plots were placed about 50 m apart at each site. Their boundaries marked with red paint. Only those plants affected by animals were tallied. Three damage categories were recognized: (1) rubbed: rubbed by deer antlers and the bark damaged; (2) overbrowsed: removal of the terminal shoot or over half of stems and

branches; (3) killed: dead stems which were clearly caused by deer. Stems killed by other causes were not counted. For simplicity, the 4 m^2 plot system applied over 400 m^2 sample plot as used in the grasslands surveys was adopted. Plastic ropes were used to delineate plot boundaries of the 4 m^2 plots only when records were made. All trees were examined in each 4 m^2 unit over all parts of each 400 m^2 plot. The number of damaged trees was carefully tallied every two months between June 1976 and February 1977. Efforts were also made to count all tree seedlings browsed by animals taking care not to overlook any which might have been clipped close to the ground.

Population Study

In studies of wild herbivores, the relations between vegetation and animal population are of essential importance. Among census techniques, the fecal pellet-group count is a standard procedure. First described by Bennett et al. (1940), the method has advantages in field plot sampling and statistical analysis. Numerous refinements have made the technique a useful research and management tool (Harris, 1959; Neff, 1968).

The pellet-group count technique is the one most universally recommended by wildlife biologists throughout the northern and western deer ranges of the United States (Ryel, 1971). The method assumes that deer defecate at a constant frequency, that the pellet-groups persist long

enough to be counted, that the groups can be found and counted correctly, that the deposition period can be delineated, that the age of the groups found can be related to the deposition period.

Moen (1973) and Smith (1974) agreed that in applying this technique, knowledge concerning the defecation rate of the species under study is necessary. Neff (1968) summarized factors which are believed to cause higher defecation rates such as good range condition and relatively high feed intake (Rogers et al., 1958); high moisture content in forage (Longhurst, 1954); change in diet such as from native range to concentrates (Smith, 1964); high percentage of fawns in the population (Smith, 1964); and psychological effects of captivity (Neff, 1964). Though defecation rates do vary, the average number of pellet-groups defecated per animal per day can be used to estimate the actual or relative numbers of animals in a given area.

Pellet-group sampling involves plots and one of the most important considerations is the effect of plot size and shape on observer error. In general, the smaller the sample area and the more accurate its delineation, the smaller the error. Circular plots are easier to delineate accurately than are those of belt transects. Pellet-group sampling is more efficient in areas of moderate pellet-group density because high

density may cause overlapping groups. Preliminary surveys provide estimates of mean pellet-group density and variance as well as some idea of pellet-group distribution (Neff, 1968).

In this study, permanent line-transects were set out at each study site, using wooden stakes to mark line directions. Directions of the lines varied, depending upon site topography. Circular plots of 4.65 m^2 (50 ft^2), recommended by Smith (1968) as being the most economic and precise, were used. The number of plots needed in each sample site was obtained from pre-sample survey plots applying the formula used by Grieb (1958):

$$N = \frac{(t_{0.10})^2 \quad s^2}{(0.20 \times \bar{x})^2}$$

where:

N = number of plots needed

s^2 = variance of preliminary data

$\bar{x}$ = mean of the preliminary data

0.20 = selected risk of error (e.g., the estimate here is expected to fall within 20% of the mean 95 times out of 100)

$t_{0.10}$ = tabular value of "t" for the selected level of probability

Based on preliminary pellet-group surveys, 102, 147, and 73 sample plots were calculated to be necessary at Nhong-King, Moor-Singh-Toe, and Nhong-Puck-Chee, respectively. Due to the scarcity of pellet-groups in the forests, counts there were omitted. Sample plots were distributed over the entire study areas at each locality. The distance between plots was 20 m. Plot centers were permanently marked with wooden pegs. Before data were collected, all plots were cleared of pellet-groups. After two months, the deposited pellet-groups were counted on each plot.

Pellet-groups present on the plots were identified as belonging to sambar or to barking deer. Each plot was counted both clockwise and counter-clockwise. The investigation was first performed on May 12, 13, and 14, 1976, for Nhong-King, Moor-Singh-Toe, and Nhong-Puck-Chee, respectively. The standard value of 12 pellet-groups per deer-day was used except as described beyond. This value was obtained by the investigator during the study (Table 9) and agrees well with the 12.1 value established by Nootong (1970) for sambar in an area near Khao-Yai, and with the value of 11.88 derived for captive barking deer being studied in Virginia by Dr. Richard H. Yahner (personal letter) of The Smithsonian Institution.

Daylight counts were obtained from a truck for animals in the meadows along a permanent 10 km road route

(Figure 4) as well as from towers located at two sites. For daylight counting, a 300 m average strip width was estimated for counts made every day between 17:00 and 19:00 hours, a time when sambar come out from the shade to graze in the open. Counts were not undertaken on Saturdays and Sundays because of tourist interruptions.

The number, sex, and size of sambar seen were recorded. Sex was identified with the aid of binoculars (7 x 35), except that accuracy may have suffered during the season when males were without antlers. Size-classes tallied in this study were based on the characteristics of 4-tame sambar of known age. Experience gained by observing known-age and tame park sambar indicated that the spotted coats were replaced by unspotted pelage at 2 to 3 months of age and both males and females under 3 years of age were always accompanied by their mothers. The three age-classes recognized by size and the above characteristics were: fawns under 11 months, sub-adults under 3 years, and adults over 3 years of age.

Spotlight counts were made from the same vehicle and over the same route as the daylight tallied. A sealed-beam spotlight attached to the truck battery revealed reflected eyes. Reflected eye-shines could be seen for approximately 150 m on each side of the road. There were difficulties in identifying sex and age at a distance in the dark, and only the number of sambar seen

were recorded at night. Counts were undertaken between 20:00 and 23:00 hours.

A food-removal census was derived from the production and utilization plots as described previously. Food-removal was computed as the difference between forage weights on the protected and grazed plots. Observations made every 15 days from October 15, 1976, to January 13, 1977. The average forage-removal per square meter per day was obtained by dividing the food-removal during each period by 15 (days). Based on the known daily food consumption of the sambar from the feeding trial, the average deer present per hectare could be estimated by dividing the dry-weight food removed per day per hectare by the known daily food consumption figure.

RESULTS AND DISCUSSIONS

Grassland Community

At Nhong-King, Moor-Singh-Toe, and Nhong-Puck-Chee, 46, 46, and 42 plant species respectively were identified (Table 1, Tables 15-17 in Appendix). At the several sites, grass and sedge species varied between 10 and 13 and forbs between 22 and 25. There were from 3 to 6 kinds of shrubs and 4 to 6 tree species found on the three areas. Herbaceous plants provided most ground cover. Grasses and forbs together provided canopy-cover for 98.3%, 98.7%, and 99.98% of the respective areas (Tables 15-17 in Appendix, Figure 6).

The coarse field-invading grass, Imperata cylindrica, dominated all three sites, covering 49.49%, 41.30%, and 31.95% of the areas respectively (Tables 15-17 in Appendix) and comprised 69.77% dry weight of all vegetation (Table 2).

Following the dominant species Imperata cylindrica, Eupatorium odoratum, was most common. While this forb did not cover a large percentage of the grasslands, it was distributed widely and may be an important competitor of Imperata. Shrubs and trees were uncommon

Table 1. Total and common forage species found in the grasslands, Khao-Yai National Park (July 1976).

Forage Species	Nhong-King	Moor-Singh Toe	Nhong-Puck Chee
Grass and sedges:			
Imperata cylindrica[a]	x	x	x
Carex indica[b]	x	x	x
Carex cruciata[b]	x	x	x
Ischaemum muticum[b]	x	x	x
Coelorachis glandulosa[b]	x	x	x
Cyperus sp.[b]	x		x
Neyraudia reynaudiana[a]	x	x	x
Panicum notatum	x	x	
Chrysopogon aciculatus	x	x	
Scirpus grossus[b]	x		x
Eragrostis capensis[b]	x	x	
Cyanodon dactylon	x		
Paspalum conjucatum[c]	x		
Cyperus digitatus			x
Fimbristylis trichoides		x	x
Forbs:			
Eupatorium odoratum[b]	x	x	x
Portulaca quadrifida	x	x	x
Erechtites hieracifolia	x	x	x
Pteris sp.	x	x	x
Hedyotis sp.	x	x	x
Adiantum sp.	x	x	x
Helicteres obtusa[b]	x	x	x
Utricularia aurea	x		
Ipomoea aquatica	x	x	
Ipomoea sp.[b]			x
Hygrophila erecta	x		
Portulaca sp.	x	x	x
Portulaca oleacea			x
Dioscorea stemonoides[b]	x	x	x
Vernonia elliptica[a]	x	x	x
Scoparia dulcis[b]	x	x	x
Spilanthes ocmella[b]	x	x	x
Alpinia sp.[a]	x	x	x
Polygonum chinense	x		
Costus speciosus[b]	x		
Mosses	x	x	x
Jussiaca suffruticosa	x		x
Amaranthus gracilis	x		
Stachytarpheta indica	x		x
Euphorbia hirta	x		
Hygrophila minor	x		
Phyllanthus urinaria	x	x	
Commellina nudifolia		x	

Table 1. Continued

Forage Species	Nhong-King	Moor-Singh Toe	Nhong-Puck Chee
Forbs (continued):			
Centella asiatica		x	
Parameria bartata		x	
Arisaema sp.		x	
Crotalaria elliptica		x	
Vernonia parishii[b]		x	
Alpinia oxymytra		x	
Hedyotis coronaria		x	
Hedyotis corymbosa		x	
Eryngium foetidum[b]			x
Blumea napifolia			x
Emilia sonchifolia			x
Ageratum conyzoides			x
Merremia gemella			x
Shrubs:			
Desmodium biarticulata[b]	x	x	x
Desmodium cephalotoides	x	x	x
Prismatomeris albidifolia	x		
Melastoma malabathricum	x	x	x
Ixora sp.		x	
Pandanus sp.		x	
Trees:			
Schima wallichii	x	x	
Cratoxylon formosum[a]	x	x	
Wrightia tomentosa[a]	x		x
Bridelia sp.[b]	x	x	x
Sapium baccatum		x	
Choerospondias axillaris		x	x
Altingia excelsa		x	
Trema orientalis			x
Hibicus macrophylla			x
Oroxylum indicum			x
Total: species	46	46	42
Common: species		31	29
Grazing intensities deer/ha/day (Table 10)	4.68	4.14	2.23

[a]Preferred (p = 1.00 to 1.99)

[b]Neglected (p = < 1.00)

[c]Highly preferred (p = > 1.99)

(blank) avoided

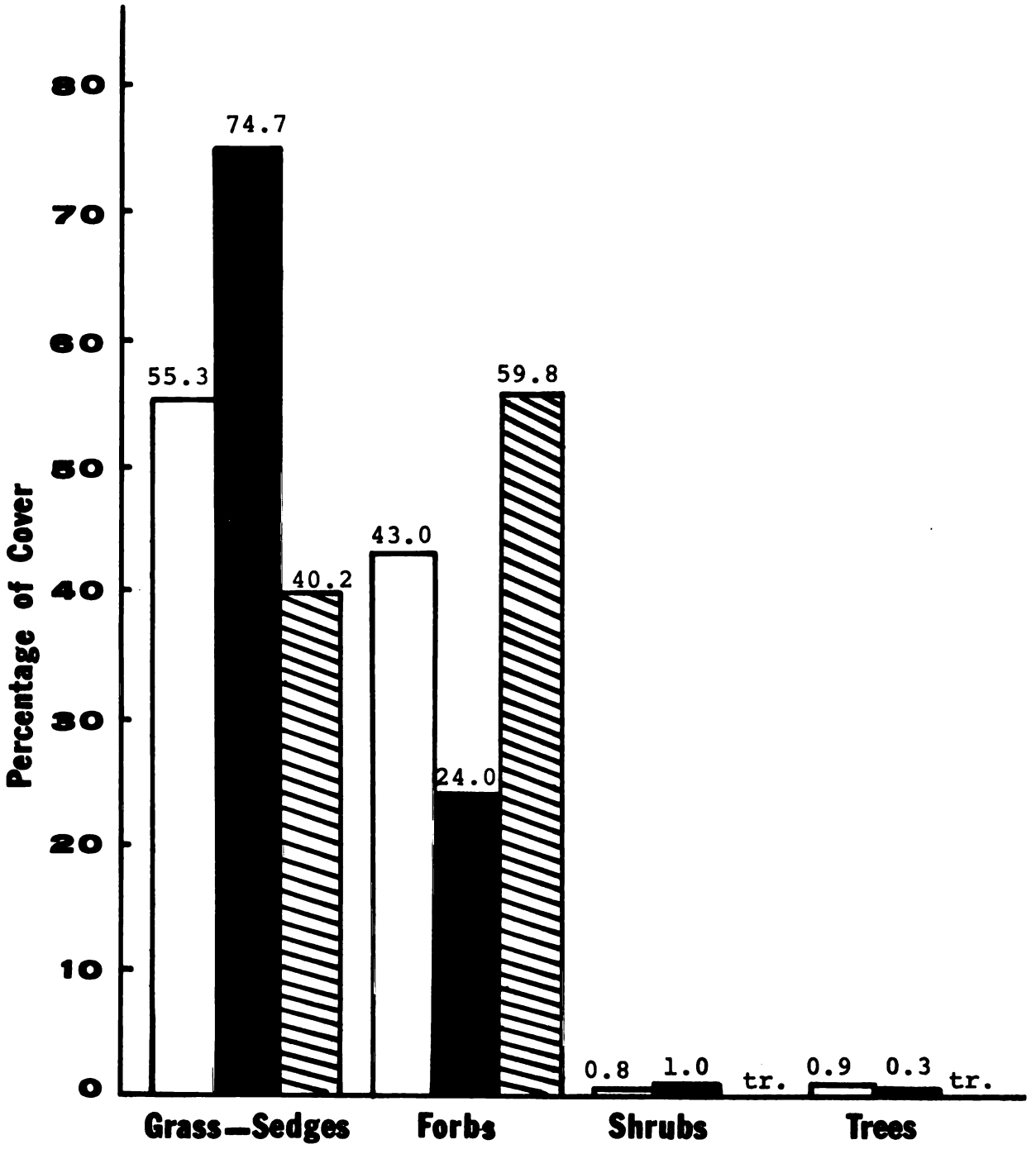

Figure 6. Vegetative canopy-cover at Nhong-King (open), Moor-Singh-Toe (solid), and Nhong-Puck-Chee (cross-hatched) grasslands, Khao-Yai National Park, July 1976.

Table 2. Sambar food preference ratings for grassland forages, Khao-Yai National Park, January to September 1976.

Forage Species	Forage Dry Weight (kg/ha)		Percentages			Preference Ratings
	Available (A)	Removal (R)	Available (a)[a]	Diet (d)[a]	Removal (r)[a]	(P)[a]
Paspalum conjugatum	0.247	0.200	0.20	0.04	80.97	2.00
Wrightia tomentosa[b]	2.666	1.556	0.21	0.34	58.36	1.62
Alpinia sp.	1.656	0.954	0.13	0.21	57.61	1.62
Neyraudia reynaudiana	26.173	14.289	2.04	3.10	54.59	1.52
Vernonia elliptica	9.400	4.700	0.47	1.02	50.00	1.38
Imperata cylindrica	895.617	409.041	69.77	88.61	45.67	1.22
Cratoxylon formosum[b]	3.432	1.471	0.28	0.32	42.86	1.14
Ischaemum muticum	17.992	5.785	1.40	1.25	32.15	0.89
Eryngium foetidum	0.008	0.002	0.0006	0.0004	25.00	0.67
Dioscorea stemonoides	0.360	0.080	0.03	0.02	22.22	0.67
Carex cruciata	48.787	9.638	3.80	2.09	19.76	0.55
Coelorachis glandulosa	2.205	0.377	0.16	0.08	18.62	0.50
Eragrostis capensis	1.546	0.274	0.12	0.06	17.72	0.50
Carex indica	9.135	1.492	0.71	0.32	16.33	0.45
Scirpus grossus	16.105	2.578	1.26	0.56	16.00	0.45
Helicteres obtusa	3.979	0.622	0.31	0.14	15.63	0.45
Cyperus sp.	0.127	0.018	0.01	0.004	14.17	0.40

Table 2. Continued

Forage Species	Forage Dry Weight (kg/ha)		Percentages			Preference Ratings
	Available (A)	Removal (R)	Available (a)[a]	Diet (d)[a]	Removal (r)[a]	(P)[a]
Bridelia sp.	0.170	0.020	0.01	0.004	11.76	0.40
Spilanthes ocmella	33.767	4.422	2.63	0.96	13.10	0.37
Costus speciosus	0.165	0.015	0.01	0.003	9.09	0.30
Scoparia dulcis	0.525	0.054	0.04	0.01	10.29	0.25
Desmodium biarticulata	38.388	2.742	2.99	0.59	7.14	0.20
Vernonia parishii	0.841	0.060	0.07	0.01	7.13	0.14
Ipomoea sp.	0.068	0.004	0.01	0.001	5.88	0.10
Eupatorium odoratum	170.027	1.255	13.25	0.27	0.74	0.02
Total = S	1283.206	461.622	100.00	100.00	-	1.00

[a] $a = \frac{A}{SA} \times 100$; $d = \frac{R}{SR} \times 100$; $r = \frac{R}{A} \times 100$; $P = \frac{d}{a}$; S = Summation.

[b] Grassland shrubs; all other species are herbaceous.

(Figure 6), probably because of burning-frequency. Only plants having special fire resistant characteristics can normally exist on annually burned areas. Both Imperata and Eupatorium sprout from the roots after the above-ground parts have been killed by fire.

Based on the formula S = 2C/(A + B), the similarity index "S" between Nhong-King and Moor-Singh-Toe, and Nhong-King and Nhong-Puck-Chee grasslands were 0.674 and 0.659 respectively, and between Moor-Singh-Toe and Nhong-Puck-Chee was 0.591. There were differences in the vegetation present on each of the three areas but they were not great. These differences did not seem clearly to be correlated with sambar grazing intensities (Table 1).

Preferred and Important Foods:
Grassland Forages

In calculating food preference ratings for grassland species, data for the three grassland sites were combined. Of the 72 plants found in the grasslands (Table 1), only 25 were eaten by sambar. By dry weight, species available in the field were 79.37% grasses and sedges, 17.12% forbs, 2.99% shrubs, and 0.50% trees. Consumption of these respective categories was 96.07%, 2.41%, 0.59%, and 0.66% (Figure 7, [a]). It is evident that the sambar is both a grazer and browser but that grasses are by far predominate in the diet.

In order of preference (Table 2), seven species were found to be eaten to a great extent than indicated

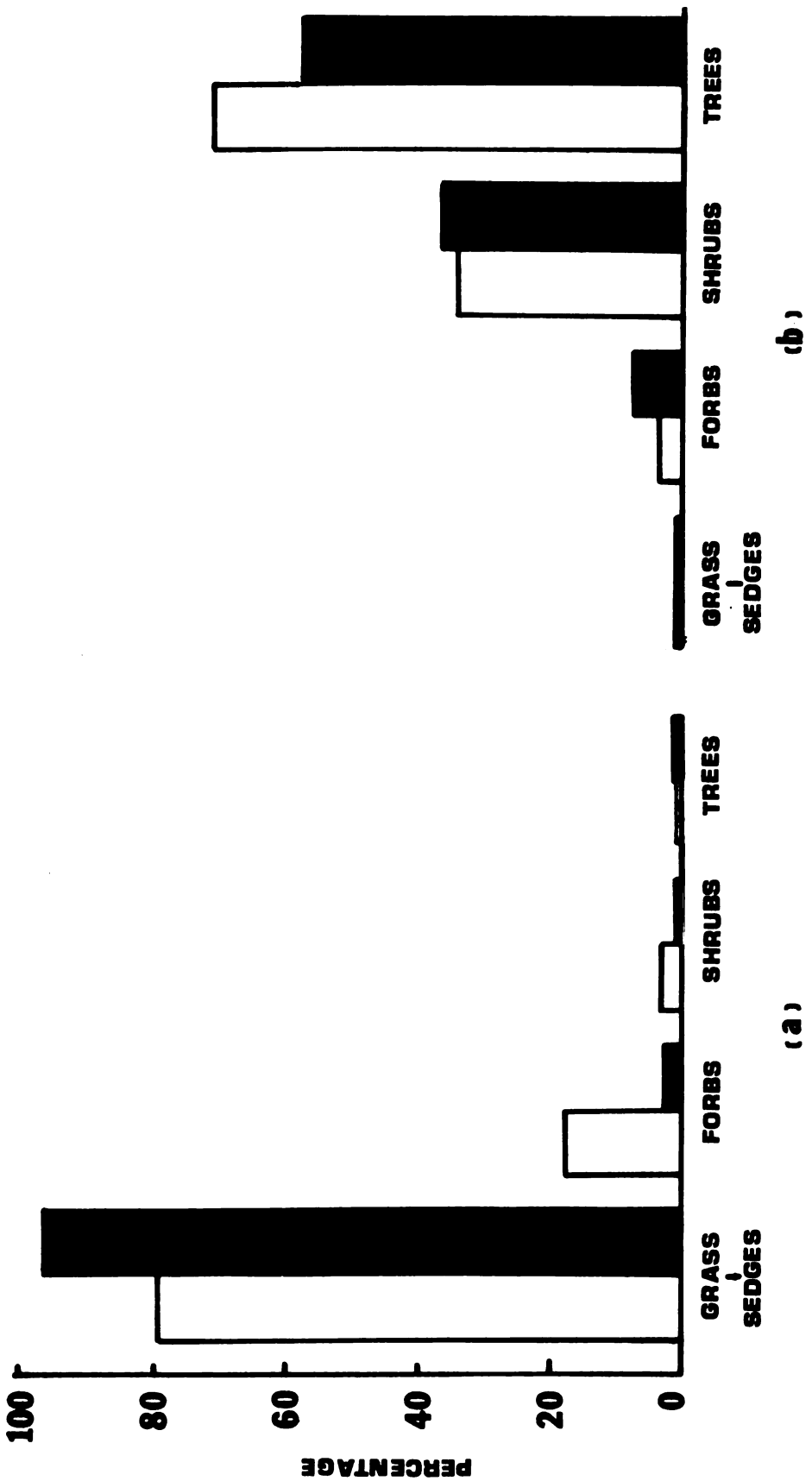

Figure 7. Percentages of forage categories available (open) and in the sambar's diet (solid) for (a) grasslands, January to September 1976, and (b) forests, January to December 1976, Khao-Yai National Park.

by their abundance. These were: Paspalum conjugatum, Wrightia tomentosa, Alpinia sp., Neyraudia reynaudiana, Vernonia elliptica, Imperata cylindrica, and Cratoxylon formosum. Up to 80.97% of Paspalum was utilized and over 50% of each of the next four species were consumed. Eighteen species (Table 2) were eaten less often than their abundance would indicate. Twenty-two other plant species (Table 1) showed no utilization by sambar.

Only a few forage species were quantitatively important in the sambar's diet (Table 2). Imperata cylindrica, Neyraudia reynaudiana, Ischaemum muticum, Carex cruciata, and Vernonia elliptica comprised 96.07% of the total consumption with Imperata alone comprising 88.81% of the sambar's diet. Known locally as ya-kar, Imperata was an abundant grass. It made up 69.77% of the available forage and was utilized heavily all year round.

Eupatorium odoratum comprised 13.25% of the available forage and was the second most abundant grassland species. Yet it constituted only 0.27% of the sambar's diet and was the most neglected of all dietary items. It appeared to compete with Imperata in some areas but whether this is an important matter in a national park depends upon the degree to which habitat management may be desirable there. In areas where sambar production is given priority (sambar ranching is thought

to warrant investigation, see beyond), increases in Eupatorium may serve as an indication of heavy grazing pressure.

Paspalum conjugatum, with a food preference rating of 2.00, had the highest preference rank of the grassland forages. While it was heavily utilized by sambar, its availability was very low (0.02%). It appears to be a species which is sought out by the sambar and any reduction in its abundance might indicate range overuse.

Wrightia tomentosa and Cratoxylon formosum were tree species having preferred ratings. They were scarce both in the grasslands and forests, however, and were relatively unimportant in the sambar's diet.

It is evident from data on the seven preferred species (Table 2) that five of these were lower both in percentages of availability and dietary contribution than either Imperata cylindrica or Neyraudia reynaudiana. It can be said with confidence that these two species are the most important foods for sambar on this rangeland. The fact they not only comprised most of the forage eaten but also were sought out by sambar as preferred items indicates their especial importance to sambar.

The close dependence of the sambar on Imperata cylindrica would seem to be a matter of particular ecological and possible economic significance. Ya-kar

is a coarse grass and an invader of open fields throughout south and southeast Asia.

Because domesticated sambar are not wild sambar, in no way could the practice of sambar-ranching be considered to be wildlife conservation (Petrides, 1977). Yet investigations should be undertaken in the interests of national and international economics to determine whether meat-production would be more efficient by ranching tamed or domesticated sambar on coarse grasslands than by raising beef cattle on improved pastures. Alternatively, sambar might be useful in some area to control ya-kar, perhaps being ranched along with cattle or other domestic stock (see also feeding trial data, beyond).

Range Condition and Trend

Species composition and the degree of forage utilization are both useful in appraising the current condition of a range area and in evaluating whether it is becoming degraded.

Forage species with the highest and lowest preference ratings can be used as indicators of animal stocking density with respect to carrying capacity, that is as indicators of range condition. When animals remove vegetation faster than it can be replaced, the most-preferred food species tend to be removed first and to the greatest extent. Other forage species are consumed more or less severely depending largely on their preference ratings

but also on animal densities and the duration of grazing. Unless grazing pressures are too severe to allow any species to reproduce or grow, the avoided species and neglected forages tend to increase under heavy grazing pressures.

Range condition, or the current status of the vegetative habitat, is a reflection of current and past stocking rates of the grazing-animal populations using the area. The degree of past range overuse and the evaluation of whether overgrazing continues can be determined by observing the performance of both the preferred and neglected food species. On areas where preferred foods are few, species which normally are neglected or avoided may be heavily cropped. Such a range is in poor condition, and lack of food may prevent herbivore population growth.

The density of any species is the number of animals occupying a defined area. A given density may be lower or higher than the carrying capacity of the range. If a high stocking density prevails, overutilization of the range may occur which ultimately leads to range degradation and habitat destruction. Malnutrition, reduction in animal production, and even starvation cannot be avoided on seriously degraded ranges unless range improvement and rehabilitation are undertaken.

The term "overstock" does not refer only to the absolute number of animals present but to animal density

with respect to the range carrying capacity for that species. The number of malnourished animals that survive on an area may still exceed that which the range can support on a long-term basis. Any stocking density which exceeds the range carrying capacity will prevent habitat recovery and lead to continuing range depletion. The current condition and trend of any rangeland can be assessed easily once food preference ratings for the area and season are determined (Petrides, 1975).

To appraise range condition and trend in this study, two indicators were used: (1) the degree of utilization of highly preferred forage species, and (2) the extent to which the more heavily utilized range species held dominance in the plant community. Plant species having preference ratings over 1.00 often are termed "decreasers" because of the effects of heavy grazing. Species rated below 1.00 are "increasers." Those plant species which are not utilized as foods can be classified as "avoided-increasers."

Forage use which removes over 50% of either the vegetative or reproductive parts of preferred food plants will normally result in harm to the range (Stoddart and Smith, 1943; Sampson, 1952; Heady, 1960; Bell, 1973). On the study areas, there were four grassland species (Table 2) and seven forest plants (Table 13) which were consumed in excess of the 50% level, and these 11 species also were scarce plants in the community.

Vegetative analysis of the grassland range in Khao-Yai revealed that preferred food species or decreasers covered 52% of the range while 11% of the plants present were increasers and 37% were avoided-increasers (Figure 8). No scarcity or overuse of preferred foods was noted. Density and frequency percentages for these categories were: 76.5% and 18.2% for decreasers; 16.4% and 49.4% for increasers, and 7.1% and 31.9% for avoided-increasers respectively (Figure 8). There were no obvious signs of excessive utilization of forage species leading to range degradation. In further support of these findings:

(1) there are only 26.9% nonpreferred food species on the range as compared with 73.1% preferred food species available;

(2) the most abundant plant on the range (Imperata cylindrica) was nevertheless a preferred food;

(3) only slight signs of soil erosion were seen;

(4) even during the dry period, few bare-soil areas occurred on the range (Figures 9 and 10).

Feeding Trial

A three-year-old tame female sambar was made available by park authorities and was penned for a feeding trial. This was done over the 12 days between 9 AM January 12 and 9 AM January 24, 1977.

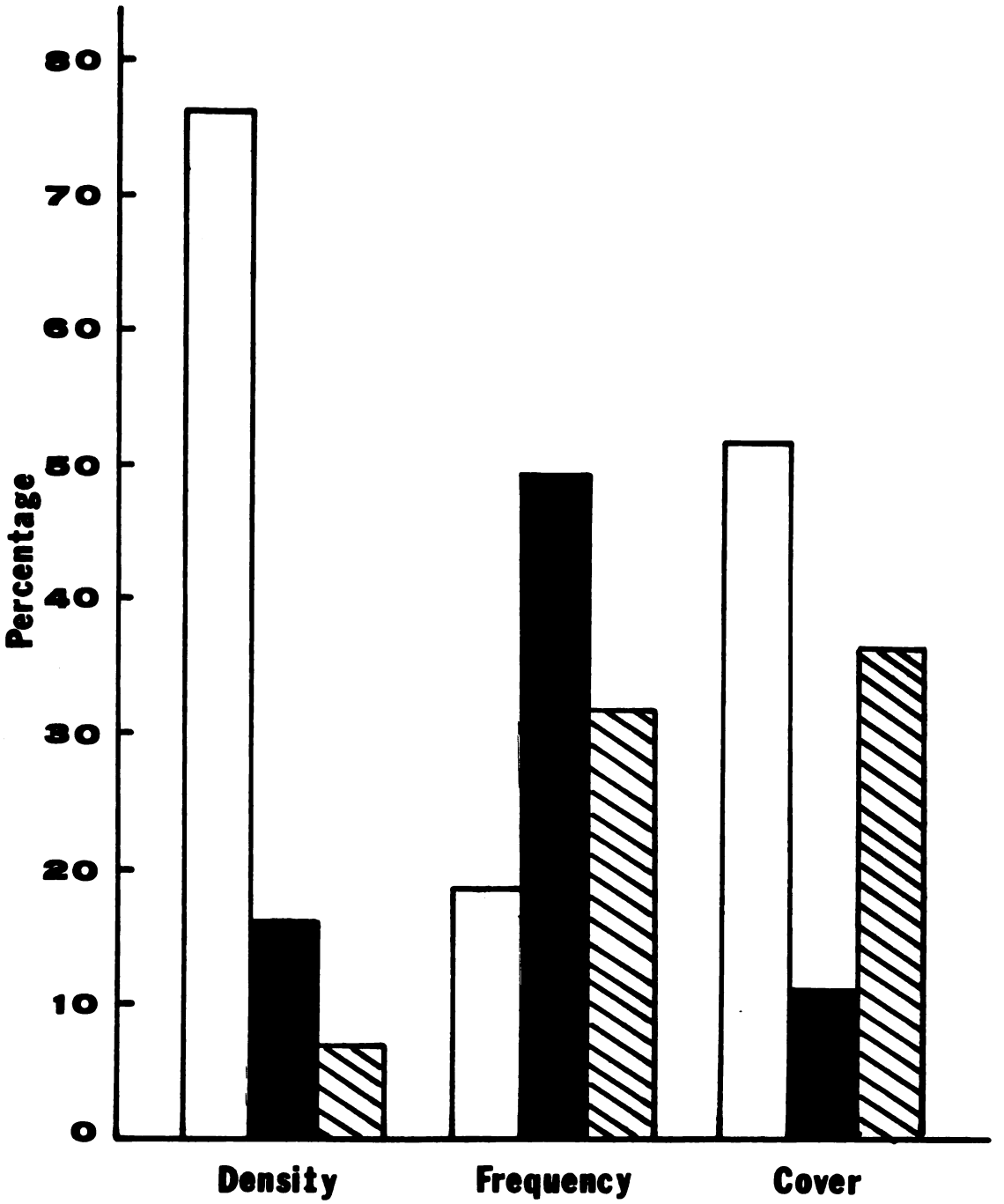

Figure 8. Density, frequency, and cover percentage of preferred (open), neglected (solid), and avoided (cross-hatched) sambar foods on grasslands in Khao-Yai National Park, July 1976.

Figure 9. Typical sambar habitat at Khao-Yai National Park, October 1976.

Figure 10. A typical sambar grazing site, Khao-Yai National Park, October 1976.

The captive sambar preferred Neyraudia reynaudiana over Imperata cylindrica (Table 3). Though comparable preference ratings cannot be calculated because other forage species were lacking, the feeding trial response supported the relative food preference values determined on the wild grasslands.

During the investigation, 6,754.79 gm dry weight of Imperata and 6,255.75 gm of Neyraudia were utilized by captive sambar over the 12-day period. Daily food consumption was 3,329 gm wet weight or 1,084.21 gm dry weight. By the end of the study the sambar had gained 0.5 kg over its original weight of 118.5 kg. Feces collected over the trial period weighed 5,588.17 grams, averaging 465.68 gm dry weight per day (Table 25 in Appendix).

The energy content of Imperata cylindrica, Neyraudia reynaudiana and droppings were 4.2043, 3.9604, and 4.2016 kcal/gm respectively (Table 24 in Appendix). Over the 12-day period, the food-energy consumed, energy defecated, and energy used in body maintenance and growth were computed to be 52,173, 23,479, and 29,694 kcal, respectively. Of the energy digested, 55.84% thus was used for maintenance and growth and 44.16% was returned to the ecosystem. Daily water consumption was about 1.4 liters.

Table 3. Dry-weight forages eaten by a 3-year-old female sambar during a 12-day feeding trial (9 AM January 12 to 9 AM January 24, 1977) at Khao-Yai National Park, Thailand.

Grass Species	Grams Offered	Grams Consumed	Percentages
Neyraudia reynaudiana	6,863.06	6,255.75	91.15
Imperata cylindrica	7,632.02	6,754.79	88.51
Totals	14,495.08	13,010.54	

Note: Feces collected over the trial period weighed 5,588.17 gm dry-weight.

For grazing sheep, Langlands et al. (1963), Lambourne and Readon (1963), Graham (1964) computed respectively that 33%, 30%, and 40% more energy is required for maintenance needs than is true for penned animals. Devendra (1967) found that free-ranging Malayan goats consumed about 44% more food than when confined. For the sambar, a 40% higher food consumption for wild deer would mean a daily food intake of 1,517.98 gm dry weight.

Forage Production and Utilization

Basic assumptions made in estimating forage production and utilization were that the forage growth rates on each plot were the same after burning and that the utilization measured was due to grazing by sambar alone. It must be emphasized that the heavy grazing on the study plot was a result of the local experimental burn which induced the growth of new grass shoots which were not available elsewhere.

Forage production (Table 4, Figure 11) continued throughout the September 30-January 13 study although the increment rate varied between study-period segments. Almost full growth was attained on the protected plot 45 days after the burn. After that, the rate of plant growth gradually decreased. Imperata cylindrica continued to grow, however, even during most of the December-January dry period (Figures 11 and 12). It

Table 4. Dry weight standing crops, production, and utilization on square-meter fenced and unfenced plots burned on September 30, 1976, plus estimated numbers of sambar present on utilized plots, Nhong-King site, Khao-Yai National Park, October 1976 to January 1977 dry period.

(A)		(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
Day After Burn	End of Period	Standing Crops		Gms. removed/m^2		Gms. removed/m^2 Since Burn		Percentages Removed Since Burn 100 F/B	Average deer/ha/day During Period $(\frac{10,000\ E}{1,517.89})$ a	Avg. deer per ha Since Burn[a]
		Fenced Plot (gm/m^2)	Unfenced Plot (gm/m^2)	Per Period	Per Day (D/15)	Total (B-C)	Per Day F/A			
15	Oct. 15	20.3256	5.8479	14.4777	0.9652	14.4777	0.9652	71.23	6.36	6.36
30	Oct. 30	35.6612	10.3060	10.8775	0.7252	25.3552	0.8452	71.10	4.78	5.57
45	Nov. 14	53.7501	13.3883	15.0066	1.0004	40.3618	0.8969	75.09	6.59	5.91
60	Nov. 29	56.8628	8.9937	7.5073	0.5004	47.8691	0.7978	84.18	3.30	5.26
75	Dec. 14	57.8133	6.7202	3.2240	0.2149	51.0931	0.6812	88.38	1.42	4.49
90	Dec. 29	58.9618	11.4523	-3.5836	-0.2389	47.5095	0.5279	80.58	-	3.48
105	Jan. 13	61.1410	11.0170	2.6145	0.1743	50.1240	0.4774	81.98	1.15	3.15

[a] $\frac{\text{Grams removed since burn/day/hectare}}{\text{Grams dry weight food eaten by wild sambar/day (see text)}} = \frac{10000\ G}{1517.89} = \frac{4774}{1517.89} = 3.15$ deer per hectare = average sambar density over the 105-day period.

Note: Unfenced plot = 100 m^2 only.

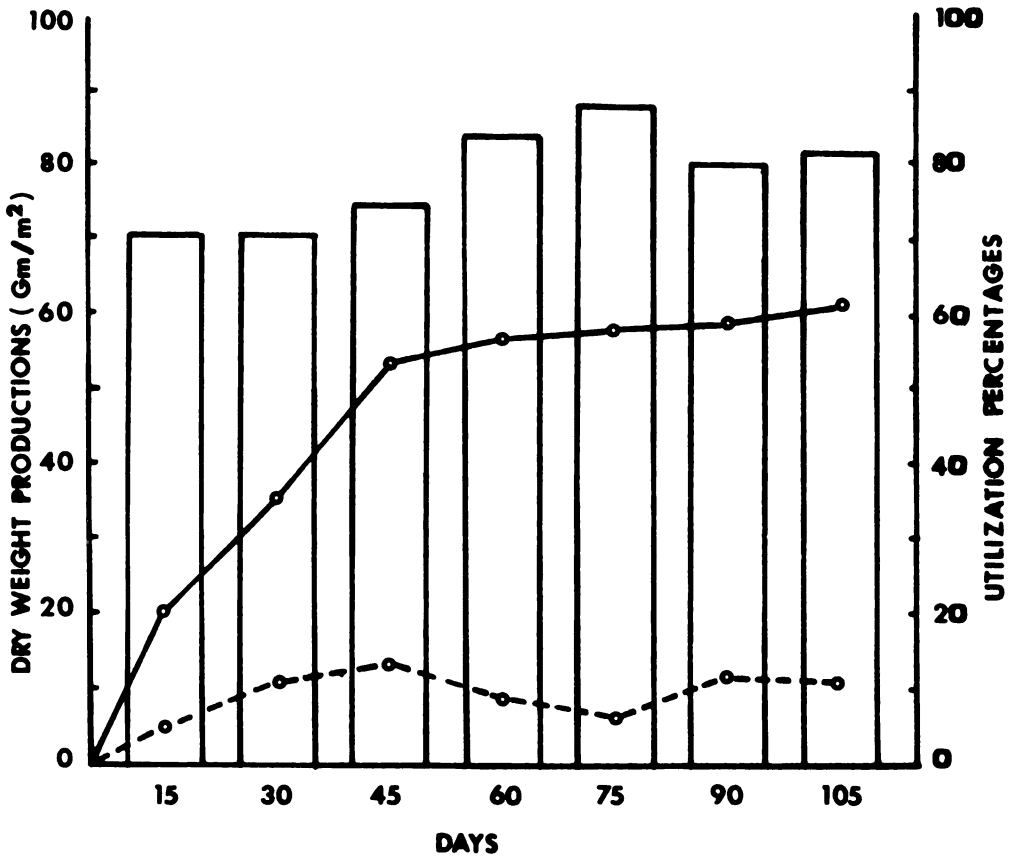

Figure 11. Total dry-weight standing-crop production on fenced plot (solid), unutilized production on grazed area (dotted), and percentage utilization (bars) where fenced and unfenced plots are compared, Khao-Yai National Park during October 1976-January 1977 dry period.

Figure 12. New Imperata dry-period sprouts on a pilot fenced plot, Khao-Yai National Park, October 1976.

Figure 13. Sambar grazing signs on an unfenced plot, Khao-Yai National Park, October 1976.

was impossible to ascertain when growth stopped completely because both plots were destroyed by fires which swept throughout the park grasslands after seven records had been collected.

In contrast to forage growth rates, the amount consumed per day on the unfenced plot decreased even though the grasses were kept short by grazing. Evidently as time went on, the plants became tough or lost nutritional value (Figure 13). Percentage utilization ranged from 71% to 88% (Table 4, Figure 11) on the unfenced plot during the study period, but it must be considered that this plot was the only burned (and therefore desirable green) spot in the entire region and attracted concentrations of deer (see beyond).

Comparisons between standing vegetation on the fenced and unfenced plots indicated the amounts of food removed for each period of the study (Table 4, Column D). The food utilized per day was highest during the first 45 days after the controlled burn of September 30. Even Imperata shoots quickly followed the fire and deer were attracted to this, the only green spot in the entire region, in large numbers as the vegetation dried out, in the November-December, deer use of the forage declined though animal densities nevertheless were high (Table 4, Column I).

Sambar Populations

Population Density

Data on sambar abundance were collected in four ways: (1) measurements of forage use, (2) daylight roadside counts, (3) spotlight roadside tallies, and (4) fecal pellet-group analyses.

Forage-Removal Studies

When computed on a per-hectare basis over a 105-day period (Table 4), an average of 4,777 grams dry weight of vegetation disappeared daily and was presumed to have been eaten by the sambar population. Since each deer consumed 1,517.89 grams dry weight per day (Table 4, p. 49), it may be calculated that the study plot was grazed with an intensity of 330.75 deer days per hectare. Sambar grazed there, that is, at an average density of 3.15 animals per hectare per day.

An average density of 315 sambar per km^2 is unbelievable over a large area. But the evidence indicates that this condition did prevail on the tiny (100 m^2) plot after it was burned on September 30. This area soon thereafter sprouted green grass from the burned stubble clumps, and this was at a time when such forage was less available elsewhere. As is commonly recognized by villagers in the region and as demonstrated by this experiment, green growth on Imperata grasslands induces high-density utilization by sambar.

That sambar occur at high densities on Khao-Yai grasslands was evident throughout the study (Tables 5, 6, 8, 9). During the same period that the food-removal study was conducted, a lower but still high average density of 135 sambar per km^2 was calculated (see beyond) over the grassland as a whole.

The fact that forest openings are few (grasslands comprise only 3.9% of the 2,168 km^2 national park) undoubtedly results in deer moving out of the forests to feed whenever new grasses become available. Seasonal levels of sambar abundance in the grasslands must be closely correlated with (and probably can serve as direct indicators of) the availability of green growth there.

Roadside Counts

Tallies made from a moving truck both before dark and prior to midnight revealed low sambar densities, at least when compared with pellet-group counts. The evening census conducted between 17:00 and 19:00 hours over the 10 km route from May to December yielded 0.02 sambar per hectare (Table 5) while during the same period and over the same route the 20:00-23:00 hours spotlight enumeration estimated an average of 0.10 per hectare (Table 6).

Though indicated even more strongly by pellet-group data (see beyond), the roadside results also

Table 5. Combined data on sambar direct daylight counts, between 17:00 and 19:00 hours, Khao-Yai National Park, from May to December 1976.

Month	No. of Sightings	No. of Counts	Avg. per Count	Deer per[a] Hectare
May	168	19	8.84	0.03
June	360	54	6.67	0.02
July	416	49	8.49	0.03
August	356	78	4.56	0.02
September	280	60	4.67	0.02
October	218	86	2.53	0.01
November	157	90	1.74	0.006
December	213	85	2.51	0.01
			Average	0.02

[a] Deer per hectare = $\frac{\text{Avg. no. deer seen}}{\text{Strip width x length}} = \frac{\text{Deer seen}}{0.3\text{km x } 10\text{km}} = \frac{\text{Deer seen}}{300 \text{ ha}}$

Table 6. Summary of spotlight counts made between 20:00 and 23:00 hours, from April 1976 to January 1977, Khao-Yai National Park.

Month	No. of Counts	No. Deer Seen	Avg. Deer per Count	Deer per[a] Hectare
April 1976	2	123	61.50	0.21
May	8	354	44.25	0.15
June	9	408	45.33	0.15
July	11	349	31.73	0.11
August	7	232	33.14	0.11
September	7	123	17.57	0.06
October	10	188	18.80	0.06
November	3	43	14.33	0.05
December	8	243	31.13	0.10
January 1977	7	267	38.14	0.13
			Average	0.11

[a] Deer per hectare = $\frac{\text{Avg. deer per count}}{\text{Strip width x length}} = \frac{\text{Deer seen}}{0.3\text{km x } 10\text{km}} = \frac{\text{Deer seen}}{300 \text{ ha}}$

disclose that deer tend to congregate most after dark. During daylight hours, the deer are much less frequently seen. They are believed then to be mostly in the forest.

Even though the sambar densities determined by these visual counts are very much lower than those derived beyond from pellet-group counts, at least the spotlight-determined average density of 10 per km^2 indicates that sambar concentrations on grasslands in late evening near the roads are not low. The effect of road traffic and tourist activities near the road, too, may have resulted in reduced deer numbers there.

The roadside counts also supplement the pellet-group censuses in revealing seasonal changes in abundance. Deer densities were highest on grasslands during the early rains when new and tender grass-shoots were most available. As the year progressed and, presumably, as the grasses became taller and more coarse and also more dry, sambar became fewer.

Pellet-Group Counts

Estimates of average deer densities on the several grassland sites over the period from May to March (Table 8) revealed that high-intensity sambar use was characteristic over wide areas, all of which were outside the boundaries of the roadside surveys. There was a close relationship between rainfall and deer density (Figure 14). Even during the driest season, however,

Table 7. Defecation rate of three-year-old captive female sambar, Khao-Yai National Park, Thailand, 1977.

Date	Pellet-groups Per Day	Date	Pellet-groups Per Day	Date	Pellet-groups Per Day
January 11	13	January 16	13	January 21	13
12	12	17	12	22	10
13	14	18	11	23	13
14	13	19	11	24	10
15	11	20	12		
				Total	168
				Average	12

Table 8. Deer densities on grassland study sites as determined from fecal pellet-group counts, Khao-Yai National Park, Thailand, 1976-1977.

Site:	Nhong-King	Moor-Singh Toe	Nhong-Puck Chee	Average
Number of plots:	102	147	73	
	Number of deer per hectare[a] (and number of days since plots cleared of pellets)			
July	9.14 (69)	9.95 (67)	2.57 (67)	
September	6.90 (54)	3.29 (57)	1.82 (54)	
November	1.82 (60)	2.21 (57)	1.81 (57)	
January	0.80 (57)	0.88 (29)	0.96 (59)	
February	4.16 (38)	1.71 (62)	4.22 (39)	
March	3.24 (13)	5.18 (20)	3.78 (13)	
Average	4.68 (291)	4.14 (272)	2.32 (289)	3.68

[a] $\text{Average/deer/hectare} = \frac{\text{Number of pellet-groups/hectare}}{\text{Number of days since plots cleared x 12 groups/day/deer}}$

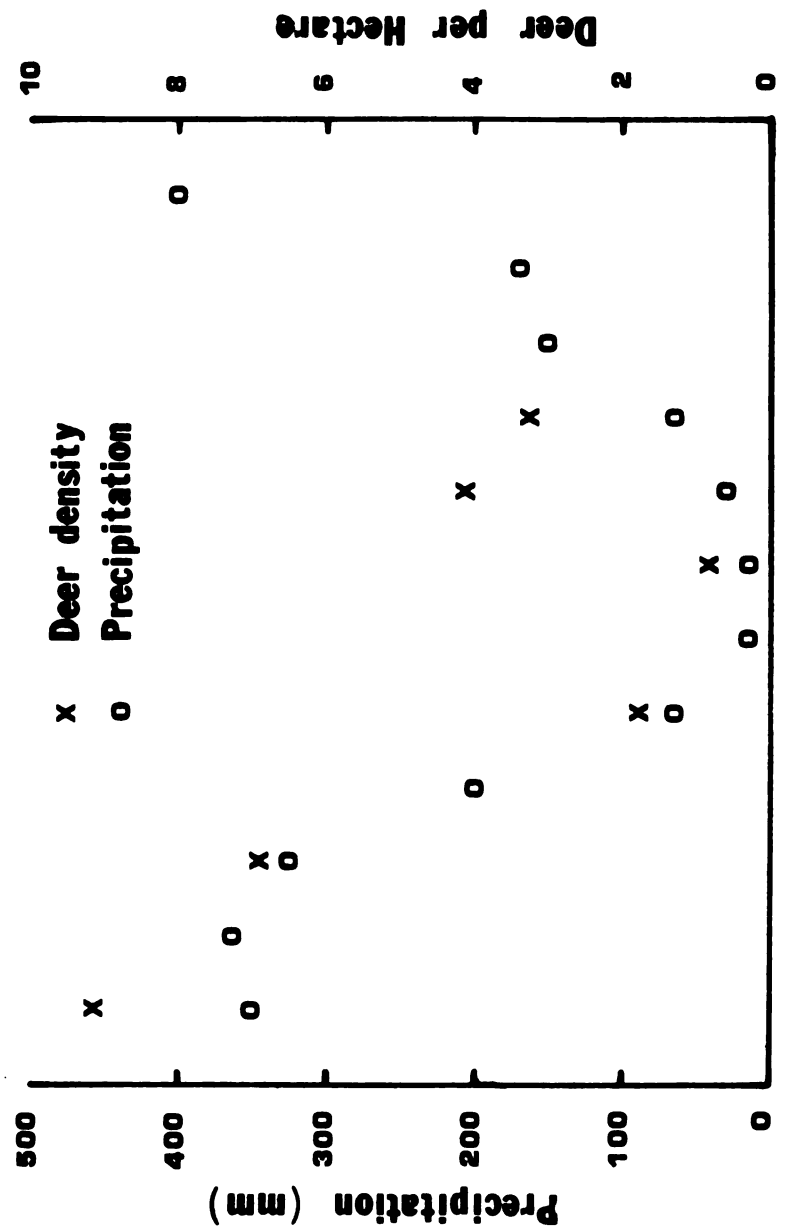

Figure 14. Seasonal changes in sambar abundance as indicated by fecal pellet-group counts (see Table 8), Nhong-King, Khao-Yai National Park, Thailand 1976-1977.

averages of 80 to 96 deer per km^2 occupied the study sites. And during the June-July time of highest sambar utilization, between 257 and 995 deer per km^2 occupied the openings.

Since these high densities were not observed during either the early or late evening counts or during more general daytime observations, concentrated sambar grazing must have occurred between midnight and dawn. (Also since all pellet-count areas were further from the road than the 150 m half-strip width as seen from the vehicle and may have received more intensive grazing pressure.)

Because sambar did not occupy the feeding areas throughout the day, many of the 12 fecal groups which they defecate daily (Table 7) must have been deposited in the forest, or at least away from the study sites. Hence, populations on the grasslands during the major late-night feeding hours must have been very great indeed.

During the 105-day period when the food-removal study indicated an average density of 3.15 sambar per hectare on the small previously burned plot (Table 4), pellet-group counts over the more widespread study sites indicated an average density of 1.35/ha (Table 9).

The very high densities of sambar found here by the pellet-count method must be confirmed in later

Table 9. Summary of calculations of average sambar densities on grasslands, Khao-Yai National Park, Thailand, 1976-77.

	Deer/ha
Roadside Counts:	
Evening tallies, May-December	0.02
Spotlight surveys, May-December	0.10
Censuses September 14-January 9:	
Pellet group counts[a]	1.35
Food removal, 100 m^2 area only	3.15
Pellet-group counts, May-March[a]	3.68

[a]Averages for all three sites and believed to be representative of the forest clearings near park headquarters.

studies. It seems certain, however, that by any standards deer utilization of the grasslands must be at a very high level.

It would be most interesting to know the size of the area from which sambar are drawn to forest openings, and also to what degree sambar require woody vegetation to be present.

Population Structure

During the 184 daylight roadside counts, attempts were made to identify the sex and age-class of each sambar seen. Though care was taken to avoid errors, it is possible that some males with shed antlers were tallied as females. Fawns, too, because of their small size and likelihood to be hidden by vegetation, may have been undercounted. That the counts showed almost identical results on the three study areas (Table 10) may either indicate that errors in identification were not serious or that they were made in a uniform manner.

Based on the data collected, males comprised only 21% of the population. Possibly, sex segregation occurred and male herds were not encountered. Mr. Weerachai Nanakorn, an educated and experienced park officer, had never observed such segregation, however, and felt that a ratio of one male to six or seven females was normal for adult sambar.

Table 10. Proportions of size categories from 184 daylight counts of sambar between May and December 1976 on grassland sites, Khao-Yai National Park.

Site[a]	Totals Seen	Males			Females		
		Fawns[b]	Sub-adults	Adults	Fawns[b]	Sub-adults	Adults
A	809	.08	.07	.06	.08	.32	.38
B	756	.08	.06	.06	.08	.32	.41
C	603	.07	.07	.06	.07	.38	.35
Totals	2168	.08	.06	.06	.08	.34	.38

[a]A-Nhong-King, B-Moor-Sing-Toe, and C-Nhong-Puck-Chee sites.

[b]Fawns were not identified by sex but are presumed to have been equally males and females.

A ratio of 339 fawns to 830 females (1 to 2.45) was determined. Khan (1968) autopsied 23 sambar hinds in Malaysia between January and December 1967, finding 9 with one embryo each (1 male, 6 females, 2 unidentified) but none of the others with either embryos or corpus luteim. Though the sample was small, his ratio of 1:2.56 was similar to that at Khao-Yai. These low percentages of fawns could be normal for sambar. There is a possibility, too, that juvenile mortality may be high. One fawn was killed in the park by a wild dog (Cuon alpinus) and three adults were killed by tigers (Panthera tigris) during the period of investigation. Fawn kills by predators, in many cases, would be rarely seen.

Daily Activity

The activity pattern of the captive sambar was observed day and night by the author and an assistant on an every-five-minutes basis for 10 days, January 12-21, 1977. Feeding occurred mainly in early morning, late evening, and at night. During the daytime, the deer mostly lay in the shade of a tree or tall grasses. A preference for shade by wild sambar also has been reported by Gilbert (1888), Thom (1937), Harris (1966), Sharatchandra and Gadgil (1975), and U Tun Yin (1976). The Khao-Yai animal spent more time resting, ruminating, and walking than eating and standing (Table 11, Figure 15).

Table 11. Number of minutes spent in various activities[a] by a 3-year-old captive female sambar (recorded day-night every 5 minutes) over a 10-day period, Khao-Yai National Park, 1977.

Date	Eating	Lying	Ruminating	Standing	Walking
January 12	200	710	545	105	365
13	225	525	425	145	450
14	130	705	585	100	375
15	135	725	565	80	270
16	210	695	750	120	380
17	150	680	590	140	395
18	120	730	585	100	300
19	130	710	560	90	310
20	200	715	570	120	360
21	140	725	580	110	315
Total minutes	1640	6920	5575	1110	3610
Average/day	164	692	558	111	361

[a]Some activities (such as ruminating and lying down) overlapped yielding total minutes in excess of 1,440 per 24-hour day.

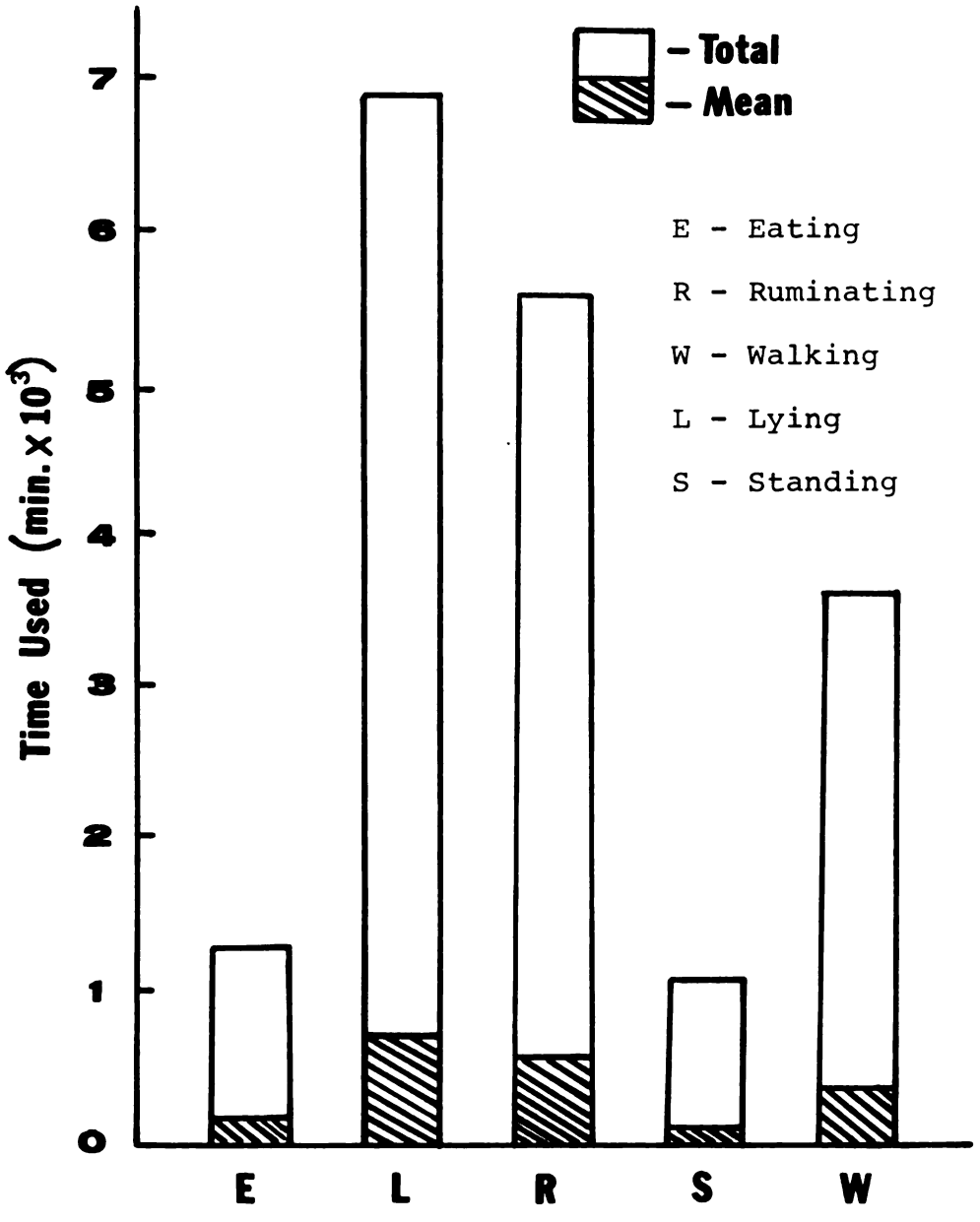

Figure 15. Total and average sambar activities (observed over a 10-day period), Khao-Yai National Park, January 12-21, 1977.

Barking Deer

The barking deer (Muntiacus munjak) was the only other cervid that occurred on the study areas. It was occasionally seen grazing with sambar but, compared with sambar, its population density was very low. Based on fecal pellet-group counts over the period May 12, 1976, to March 4, 1977, the average density was only 0.21 deer/ha (Table 12). Because only 1/18th as common as sambar, the effects of the barking deer were judged to be negligible with respect to the determination of sambar food preferences and forest damage.

Forest Community

Tropical rainforests are noted for their richness of flora and the dominance of woody plants, lianas and epiphytes (Richards, 1952; Williams, 1965; Komkris, 1965).

Diameter-class composition, density and basal area data for tree species associated on the forest sites were determined for Nhong-King, Moor-Singh-Toe, and Nhong-Puck-Chee (Tables 18-20 in Appendix). Total number of tree stems over 1.5 cm in d.b.h. were 3,596 at Nhong-King, 4,596 at Moor-Singh-Toe, and 2,965 stems/ha at Nhong-Puck-Chee while their basal areas were 31.5, 27.0, and 27.7 m^2/ha respectively (Tables 18-20 in Appendix). All sites were heavily wooded and rather similar both in plant structure and composition. Small trees were abundant but trees of large diameter were relatively scarce.

Table 12. Average barking deer densities as determined from fecal pellet-group counts between May 12, 1976, and March 4, 1977, Khao-Yai National Park (based on a defecation rate of 11.88 pellet-groups/day determined by Dr. Richard H. Yahner, personal correspondence).

Site	No. of Plots[a]	Pellet Groups	Pellet Groups per/ha	Days	Deer/ha/day
Nhong-King	102	82	1728.56	291	0.50
Moor-Singh-Toe	147	16	234.24	292	0.07
Nhong-Puck-Chee	73	7	206.22	289	0.06
Total and (Average)	322	105	2169.02	872	(0.21)

[a] 4.65 m^2 circular plots (see Smith, 1968).

No single diameter-class on any of the three sites occupied over 4.0 m^2/ha of the basal area.

It may be that the present forests do not contain the original vegetation and that they are actually secondary forest growth but this has not been determined. Aquilaria crassna, Aphanamyxis polystachya, Cinnamomum iners, Evodia gracilis, Eugenia siamensis, Gonocaryum lobbianum, and Helicia formosana were common, occurring all on sites.

Browsed and unbrowsed stems of forest species were counted (Tables 21-23 in Appendix). The percentages of browsed tree stems over 0.5 m in height and over 1.3 cm d.b.h. were 14.60% at Nhong-King, 10.71% at Moor-Singh-Toe, and 13.77% at Nhong-Puck-Chee (Tables 21-23 in Appendix). Comparatively, the percentages of browsed tree stems under 0.5 m in height and less than 1.3 cm d.b.h. were 12.81%, 5.59%, and 12.21% for Nhong-King, Moor-Singh-Toe, and Nhong-Puck-Chee sites, respectively (Tables 21-23 in Appendix).

There were no clear indications from these data of which size-classes were more damaged. Animal damage was considered to have but a very slight effect on forest composition, considering the total number of tree stems available.

Species composition for low plants was similar on all three forest sites. Carex cruciata and Carex

indica were the common sedges and Panicum notatum the common grass. Dioscorea stemonoides, D. bulbifera, Acanthus sp., Alpinia oxymytra, Chloranthus officinalis were common forbs. Tree and shrub species were as previously discussed.

A full report on botanical observations is planned for publication elsewhere.

Preferred and Important Foods:
Forest Forages

There were 47 forage species available for sambar in the forest habitat (Table 13). The percentages of plants available were 0.39% grasses and sedges, 3.32% forbs, 33.79% shrubs, and 70.54% trees while the percentages of plants consumed were 0.39%, 7.28%, 36.29%, and 56.96%, respectively (Figure 7, [b]). A preference for forbs and a neglect of woody plants were shown.

Twenty-one species were determined to be preferred foods. Among these, Carallia branchiata and Knema laurina had food preference ratings exceeding 3.00, and Lithocarpus rodgerianus, Neolitsea zeylanica, Eugenia sp., E. siamensis, and Ficus sp. each rated over 2.00. These species constituted only 5.49% of the food available to sambar and yet comprised 14.17% of their diet. The sambar's percentage removal of these species ranged from 57.46 to 81.06. Fourteen of the preferred species constituted 47.83% of the animal's diet in the forest and 29.98% of available food there.

Table 13. Sambar food preference ratings, forest forages, Khao-Yai National Park, January to December 1976.

Forage Species	Forage Dry Weight (kg/ha)		Percentages			Preference Ratings
	Available (A)	Removal (R)	Available (a)[a]	Diet (d)[a]	Removal (r)[a]	(P)[a]
Carallia brachiata	0.399	0.327	0.58	1.96	81.96	3.38
Knema laurina	0.247	0.186	0.35	1.11	75.30	3.17
Lithocarpus rodgerianus	0.110	0.074	0.16	0.44	67.27	2.75
Neolitsea zeylanica	0.068	0.045	0.10	0.27	66.18	2.70
Eugenia sp.	0.535	0.333	0.78	1.99	63.67	2.55
Eugenia siamensis	1.072	0.655	1.58	3.32	61.10	2.48
Ficus sp.	1.321	0.759	1.94	4.54	57.46	2.34
Nephelium mutabile	0.983	0.480	1.45	2.87	48.83	1.98
Uvaria rufa	0.341	0.150	0.50	0.98	43.99	1.78
Melaleuca seutellatum	2.313	1.016	3.41	6.08	43.93	1.78
Hedyotis sp.	0.752	0.316	1.11	1.98	42.02	1.70
Lasianthus cyanocarpus	8.734	3.560	12.85	21.30	40.76	1.66
Lithocarpus eucalyptifolia	0.434	0.163	0.64	0.98	37.56	1.53
Castanopsis acuminatissima	3.220	1.201	4.47	7.19	37.30	1.52
Uncaria homomalla	0.209	0.078	0.31	0.47	37.32	1.52
Eugenia sp.	0.170	0.062	0.25	0.37	36.47	1.48
Murraya paniculata	0.098	0.033	0.14	0.20	33.67	1.34
Euginia ripicola	1.857	0.521	2.73	3.12	28.06	1.42
Uvaria sp.	0.453	0.154	0.66	0.92	34.00	1.39
Styrax sp.	0.632	0.177	0.93	1.06	28.01	1.14
Podocarpus neriifolius	0.297	0.079	0.44	0.47	26.60	1.07
Uncaria sp.	0.656	0.146	0.97	0.87	22.26	0.94
Rourea stenopetala	0.332	0.609	0.49	0.41	20.78	0.84
Mangifera sylvatica	1.976	0.396	2.91	2.36	19.99	0.81
Ixora sp.	8.454	1.667	12.45	9.97	19.72	0.80

Table 13. Continued

Forage Species	Forage Dry Weight (kg/ha)		Percentages			Preference Ratings
	Available (A)	Removal (R)	Available (a)[a]	Diet (d)[a]	Removal (r)[a]	(P)[a]
Carex cruciata	0.263	0.049	0.39	0.39	18.63	0.74
Symplocos laurina	0.724	0.133	1.07	0.80	18.37	0.74
Clausena excavata	3.819	0.687	5.62	4.11	18.00	0.73
Dioscorea bulbifera	2.020	0.343	2.97	2.05	16.98	0.69
Alpinia oxymytra	4.278	0.713	6.30	4.26	16.67	0.68
Linostoma thorelii	0.282	0.046	0.42	0.28	16.31	0.67
Cinnamomum subavenum	0.928	0.147	1.37	0.88	15.84	0.64
Desmos sp.	1.097	0.157	1.62	0.94	14.31	0.58
Memecylon ovatum	3.782	0.530	5.57	3.17	14.01	0.57
Ardisia arborescens	2.030	0.245	2.99	1.52	12.51	0.51
Gonocaryum lobbianum	0.883	0.110	1.30	0.66	12.46	0.51
Alpinia sp.	0.163	0.020	0.24	0.12	12.27	0.50
Fraxinus floribunda	0.478	0.056	0.70	0.34	11.72	0.49
Litsea verticellata	1.111	0.111	0.119	1.64	10.71	0.43
Camellia oleifera	1.195	0.121	1.76	0.72	10.13	0.41
Cinnamomum iners	1.519	0.146	2.24	0.87	9.61	0.39
Evodia gracilis	2.081	0.172	3.06	1.03	8.27	0.34
Aglaia odorata	0.196	0.016	0.29	0.10	8.16	0.34
Artabotrys harmandii	1.698	0.100	2.50	0.60	5.89	0.24
Jasminum sp.	0.904	0.047	1.33	0.28	5.20	0.21
Adiantum sp.	0.610	0.027	0.90	0.16	4.43	0.18
Litsea sebifera	2.206	0.076	3.25	0.46	3.45	0.14
Total = S	67.927	16.715	100.00	100.00		

[a] $a = \frac{A}{SA} \times 100$; $d = \frac{R}{SR} \times 100$; $r = \frac{R}{A} \times 100$; $P = \frac{d}{a}$; S = summation

Lasianthus cyanocarpus, Ixora sp., Castanopsis acuminatissima, and Melaleuca seutellatum were the most important food species in the forests. They constituted 21.30%, 9.97%, 7.19%, and 6.08% to the sambar's diet, respectively. The first three of these were preferred forages. Collectively, they comprised about a third of the forest vegetation available to sambar.

Twenty-six species were rated as neglected forages. These formed 62.83% of the available food and 38.99% of the sambar's diet. Only Lasianthus, Ixora, Castanopsis, Melaleuca, Alpinia, Clausena, Memecylon, and Ardisia constituted significantly to the sambar's available food (53.66%) and diet (57.60%).

Comparing the preferred foods of grassland and forest, the forage available per hectare in the grasslands was far greater. Food preference rating values for the forest species showed that sambar preferred forest species, at least where grassland species were absent. Observations, however, indicated that sambar utilized forest species heavily and during the period when the grasslands were dry.

In Khao-Yai, the sambar's ideal habitat is a mixture of forest and grassland. Whether the sambar could survive on Imperata grasslands alone has not been tested.

Animal Effects on Forest Production

Forest damage caused by rubbing and overbrowsing were greatest at the Nhong-Puck-Chee forest site (Table 14, Figure 16). The number of tree stems killed by animals, however, were similar on all sites. Killed stems caused by rubbing and overbrowsing were high on some sites but in general, the effects of animals in causing tree deaths were slight. Animals had but little effect on forest production on the study areas. Enderlein and Maxwell (1976) also reported no serious destruction of forest trees by wild animals at Khao-Yai. Park authorities and local people living near the park boundary, too, agreed with this finding. They reported further that wild animals are seldom seen outside the park.

Table 14. Numbers of stems affected by sambar on two 400 m^2 forest sites, Khao-Yai National Park. Numbers accumulated bimonthly, June 1976-February 1977.

Site[a]	Number of Stems														
	Rubbed					Overbrowsed					Killed				
	J	A	O	D	F	J	A	O	D	F	J	A	O	D	F
A	7	10	12	15	16	1	1	3	5	8	1	2	3	3	4
B	9	11	14	16	16	2	3	4	7	10	2	3	4	4	6
C	22	26	32	35	38	8	10	15	24	28	2	4	5	6	7

[a]A - Nhong-King; B - Moor-Singh-Toe; C - Nhong-Puck-Chee; J = June; A = August; O = October; D = December; F = February.

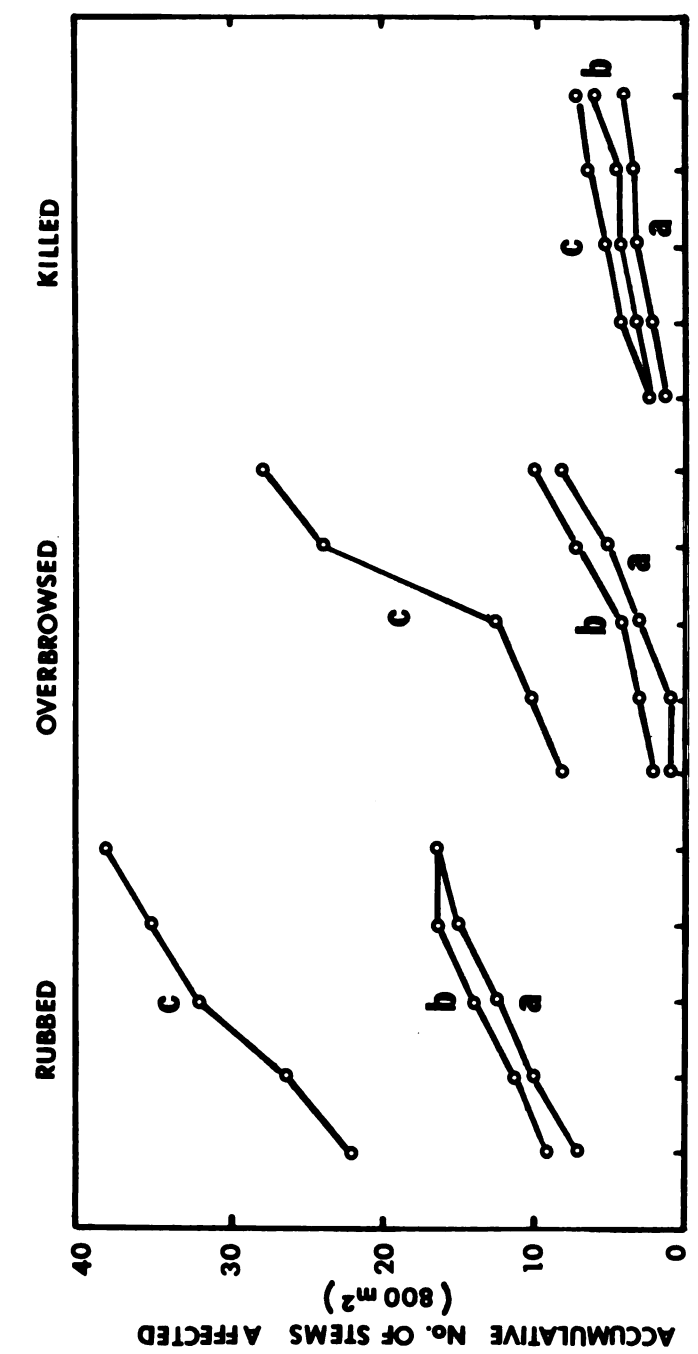

Figure 16. Animal effects on forest tree stems at Nhong-King (a), Moor-Singh-Toe (b), and Nhong-Puck-Chee (c), June 1976-February 1977.

RECOMMENDATIONS

Procedures for the management of the sambar should vary on areas devoted to different forms of land use:

National Parks. With the primary objective of maintaining natural conditions, it is suggested that:

(1) Several exclosers be built, each perhaps 0.2 to 0.5 ha in area. These would exclude all large grazing animals so that comparisons could be made between grazed and ungrazed vegetation. Such exclosures would enable early detection of range overuse. Care should be taken to measure the effects of rodents and other small herbivores that might be attracted to the protected vegetation. A portion of the area could exclude all mammals including small one, while major part could exclude the ungulate. Exclosures should be sited in hopes of avoiding damage by elephants and should be protected by firebreaks against the danger of protected vegetation being burned.

(2) Population counts of the major grazing animals should be made at least annually. Censuses should be attempted if suitable methods are available

but at least roadside counts should be made under standardized conditions to establish indices to ungulate abundance.

(3) Long-term studies of sambar population characteristics, behavior, movements, reproductive patterns, and relations to predators, diseases, and competitors are often best accomplished in national parks. The maintenance of research program in each national park is essential to receiving full benefits from it.

(4) Studies of burning practices should be designed to reveal their effects on the natural flora and fauna. Fire and fire control both have effects on nature preservation which must be evaluated.

(5) As many forest species provide fruits as foods for sambar, the importance of these species as related to the deer should be studied.

(6) Since extremely high deer density figures were derived from pellet-group counts, it is recommended that this type of census should be replicated and reviewed. The basic procedures should be tested and results confirmed. After-midnight deer densities also should be investigated by other means.

(7) The area from which sambar are attracted to grassland openings should be determined, using telemetry or other marking methods.

(8) Studies should be attempted to determine the extent to which sambar require forest cover or other woody vegetation.

Ranching Areas. Sambar were found to feed largely on Imperata grass and to prefer this to many other available species. Imperata (ya-kar) is considered to be a troublesome weed in many areas of Asia and Africa. Because of this fact, it seems reasonable to undertake further studies to test whether the sambar may be more suitable for meat-production than domestic stock, especially on unimproved rangelands.

(9) It is recommended that research be undertaken on Imperata grasslands to determine how those lands should be managed for maximum useful forage production and how sambar react to being tamed or domesticated on such sites.

(10) Since it was the new growth prevailing for 45-60 days after burning which sambar ate most during this study, the effects of mowing and controlled burning in stimulating new production should be determined. The frequency with which burning or mowing should be repeated needs to be ascertained.

SUMMARY

Sambar were studied between March 1976 and March 1977 at Khao-Yai National Park, Thailand. Three grassland and three adjacent forest sites were selected for investigation. Study objectives were: (1) to calculate food preference ratings, (2) to apply these ratings in an appraisal of range condition and trend, (3) to appraise the effects of wild animals on forest production, (4) to learn as much as possible concerning sambar population status, and (5) to develop management policies to insure survival of sambar in the park and on other areas having suitable habitats. In light of the research findings in this study, it is recommended that sambar may be more productive than domestic livestock as producers of meat on unimproved pasturelands.

There were 46, 46, and 42 plant species identified on the grasslands at Nhong-King, Moor-Singh-Toe, and Nhong-Puck-Chee respectively, yet Imperata cylindrica dominated these areas covering 50% of the ground area at Nhong-King, 41% at Moor-Singh-Toe, and 37% at Nhong-Puck-Chee. The similarity index values indicated only minor

differences between the vegetation on the three grassland areas and these differences do not seem to be correlated with sambar grazing intensities.

Among 72 plant species found on the grasslands, only 25 were eaten by sambar. Their percentage availabilities were 79% grasses and sedges, 17% forbs, 3% shrubs, and 0.5% trees. Corresponding percentages of food consumed were 96%, 2%, 0.6%, and 0.7%. Of the 25 species eaten, Paspalum, Wrightia, Alpinia, Neyraudia, Vernonia, Imperata, and Cratoxylon were preferred foods. Paspalum was utilized up to 81%. Forty-two percent to 58% of available forage was eaten in the other preferred plants; 18 species were eaten to a lesser degree than their abundance would indicate. The remaining 47 species were not eaten by sambar.

Imperata was the most abundant plant and most important food in the diet of the sambar, forming 67% of available forage and 88% of all food consumed. Imperata, Neyraudia, Ischaemum, Carex, and Vernonia were the important sambar foods on the grasslands, forming 96% of the sambar's diet.

Forage production and utilization by sambar on study plots during the dry period indicated that the production of grass forages increased up to about 45 days after burning and then gradually decreased. Forage removal from the plots ranged from 71% to 88%, though

this heavy use doubtless was because this was the only area of green grass available; sambar heavily utilized all grasslands.

The species composition, density, and basal area of trees over 1.5 cm d.b.h. in all forest sites were similar. The stem numbers ranged from 2965 to 4596 per ha and with basal areas between 27.1 to 31.5 m^2/ha. Common tree species were: Aquilaria crassna, Aphanamyxis polystachya, Cinnamomum iners, Evodia gracilis, Eugenia siamensis, and Gonocaryum lobbianum. Crown cover was 85% to 90% at all sites.

The species composition and the number of browsed and unbrowsed stems of forest ground species were similar all on sites. The percentage of browsed stems was small compared to the total stems available. Animals did not significantly affect forest production.

Among 42 plant species in the forest habitat, 21 were preferred foods. Seven were highly preferred, with Carallia and Knema being eaten 3 times as much as their abundance would indicate. Lithocarpus, Neolitsea, and Ficus had food preference ratings over 2.00. These highly preferred foods, which constituted only 5.5% of the forage available in the forest, comprised 14% of the sambar's diet, 57% to 82% of forages with preference ratings over 2.00. All 14 preferred species formed 30% of the food available and 48% of the diet. Lasianthus,

Castanopsis, Melaleuca, and Eugenia were most important in terms of bulk contribution of sambar forest foods. The 26 neglected species formed 63% of the food available and only 39% of the diet.

Daily food consumption by a captive 3-year-old female sambar (118.5 kg) was 1,084.21 gm dry-weight. Energy needed for maintenance for 12 days period was 29,694 kcal or 55.48% of the total energy consumed. Daily water intake was about 1.4 liters. The captive sambar spent more time in resting, ruminating, and walking than it did feeding and standing. Feeding occurred in the early morning, late evening, and also at night. A 40% greater food intake was assumed for the wild active animal, so that daily consumption was estimated as 1,517.89 gm.

Animal effects on forest production were heavy at Nhong-Puck-Chee forest site where considerable rubbing and overbrowsing occurred. The number of killed stems, however, was similar at all sites and animals were judged to have but unimportant total effects on forest production.

The average population density (deer/ha) was 0.02 from direct daylight counts, 0.11 from spotlight counts, 3.68 from pellet-group counts, and 3.15 from a food-removal census. Population densities of up to 995 per km^2 were calculated for certain seasons from pellet

group counts. Even the lowest densities were for 80 deer per km^2. These high concentration levels remain to be confirmed by later studies; yet by any standards, sambar densities on the grasslands must be very high.

The population consisted of 44% adults, 40% sub-adults, and 16% fawns. The fawn to adult female ratio was 1:2.31, and there were 2.31 adult females per fawn.

Recommendations are made for further studies in the national park to answer research questions still outstanding and to benefit proper park management. In particular, however, it is suggested that the potential be investigated for ranching sambar in meat-production enterprises.

The coarse Imperata cylindrica (ya-kar) grass comprises 88% of the sambar's diet and it prefers that species over other available forages. This grass is an abundant and vigorous invader of open fields. It seems likely that sambar might be tamed and raised on ya-kar at less cost and more efficiently than domestic livestock can be fed on improved pastures.

APPENDIX

Table 15. Relative density, frequency, and cover percentages plus importance index values for plant species on the Nhong-King grassland, Khao-Yai National Park, July 1976.

Species	A Relative Density %	B Relative Frequency %	C Relative Cover %	D = A+B+C Importance Index Value[a]
Grasses and sedges:				
Imperata cylindrica	75.24	12.50	49.94	137.68
Carex cruciata	8.99	11.48	3.57	24.04
Ischaemum muticum	2.67	7.00	0.38	10.05
Neyraudia reynaudiana	0.07	3.57		4.27
Carex indica	0.36	3.10	0.06	3.52
Coelorachis glandulosa	0.38	1.66		2.04
Scirpus grossus	0.25	1.56		1.81
Eragrostis capensis	0.43	1.28		1.71
Paspalum conjugatum	0.03	0.26	0.89	1.18
Cynodon dactylon	0.80	0.26		1.06
Cyperus sp.	0.12	0.67		0.79
Panicum notatum	0.01	0.26		0.27
Chrysopogon aciculatus	0.01	0.26		0.27
Total grasses and sedges			55.29	
Forbs:				
Mosses		5.61	32.49	38.10
Eupatorium odoratum	2.30	12.76	1.72	16.76
Portulaca quadrifida	3.23	8.55		11.78
Adiantum sp.	1.78	6.38		8.16
Pteris sp.	0.36	2.42	4.40	7.18
Spilanthes ocmella	0.21	1.28	3.06	4.55
Scoparia dulcis	0.09	2.42		2.51
Portulaca sp.	0.07	1.91		1.98

Table 15. Continued

Species	A Relative Density %	B Relative Frequency %	C Relative Cover %	D = A+B+C Importance Index Value[a]
Forbs: Continued				
Erechtites hieracifolia	0.29	1.66		1.95
Helicteres obtusa	0.09	1.66		1.75
Vernonia elliptica	0.08	0.77	0.64	1.41
Alpinia sp.	0.25	0.77	0.13	1.15
Ipomoea aquatica	0.02	0.51	0.51	1.04
Hygroplila erecta	0.05	0.77		0.82
Dioscorea stemonoides	0.05	0.77		0.82
Stachytarpheta indica	0.23	0.26		0.49
Euphobia hirta	0.01	0.26		0.35
Costus speciosus	0.05	0.26		0.31
Jussiaea suffruticosa	0.03	0.26		0.29
Polygonum chinense	0.03	0.26		0.29
Hedyotis sp.	0.02	0.26		0.28
Utricularia aurea	0.01	0.26		0.27
Hygrophila incana	0.01	0.26		0.27
Amaranthus gracilis	0.01	0.26		0.27
Phyllanthus urinaria	0.01	0.26		0.27
Total forbs			42.95	
Shrubs:				
Desmodium biarticulata	0.33	2.73	0.83	3.89
Melastoma malabathricum	0.14	0.51		0.65
Desmodium cephalotoides	0.01	0.26		0.27
Prismatomeris malayana	0.01	0.26		0.27
Total shrubs			0.83	

Table 15. Continued

Species	A Relative Density %	B Relative Frequency %	C Relative Cover %	D = A+B+C Importance Index Value[a]
Trees:				
Bridelia sp.	0.05	0.26	0.63	0.94
Cratoxylon formosum	0.12	0.51	0.30	0.93
Schima wallichii	0.02	0.51		0.53
Wrightia tomentosa	0.05	0.26		0.31
Total trees			0.93	
Total all plant species	100.00	100.00	100.00	

$$A = \frac{\text{Number of individuals of species X}}{\text{Total number of individual of all species}} \times 100$$

$$B = \frac{\text{Frequency species X}}{\text{Sum of frequency values of all species}} \times 100$$

$$C = \frac{\text{Cover of individuals of species X}}{\text{Total cover of individuals of all species}} \times 100$$

[a]See Cox, 1976.

Table 16. Relative density, frequency, and cover percentages plus importance index values for plant species on the Moor-Singh-Toe grassland, Khao-Yai National Park, July 1976.

Species	A Relative Density %	B Relative Frequency %	C Relative Cover %	D = A+B+C Importance Index Value[a]
Grasses and sedges:				
Imperata cylindrica	57.79	13.28	41.30	112.55
Ischaemum muticum	13.33	9.30	16.42	39.05
Carex cruciata	11.21	12.09	5.60	28.90
Carex indica	0.42	4.91	2.69	8.02
Eragrostis capensis	1.06	1.59	4.72	7.37
Neyraudia reynaudiana	2.54	3.98	0.59	7.11
Chrysopogon aciculatus	1.27	0.27	3.37	4.91
Fimbristylis aestivalis	1.02	0.27		1.29
Coelorachis glandulosa	0.23	0.93		1.16
Panicum notatum	0.42	0.27		0.69
Total grasses and sedges			74.69	
Forbs:				
Mosses		1.86	21.13	22.99
Pteris sp.	2.32	10.49		12.81
Eupatorium odoratum	0.85	11.16	0.67	12.68
Portulaca quadrifida	1.48	3.72		5.20
Vernonia elliptica	0.42	2.52	0.51	3.45
Erechtites hieracifolia	0.42	2.79	0.21	3.42
Adiantum sp.	0.09	0.66	1.31	2.06
Arisaema sp.	0.11	1.86		1.79
Dioscorea stemonoides	0.04	1.59		1.63
Spilanthes ocmella	0.42	0.93		1.35

Table 16. Continued

Species	A Relative Density %	B Relative Frequency %	C Relative Cover %	D = A+B+C Importance Index Value[a]
Forbs: Continued				
Alpinia sp.	0.30	0.66	0.21	1.17
Hedyotis corymbosa	0.12	0.66		0.78
Crotalaria albida	0.06	0.66		0.72
Portulaca sp.	0.04	0.66		0.70
Hedyotis coronaria	0.01	0.66		0.67
Phyllanthus urinaria	0.13	0.27		0.40
Vernonia parishii	0.11	0.27		0.38
Alpinia oxymytra	0.09	0.27		0.36
Scoparia dulcis	0.06	0.27		0.33
Euphobia sp.	0.04	0.27		0.31
Centella asiatica	0.02	0.27		0.29
Hedyotis sp.	0.01	0.27		0.28
Commelina nudiflora	0.01	0.27		0.28
Ipomoea aquatica	0.01	0.27		0.28
Total forbs			24.04	
Shrubs:				
Desmodium biarticulatum	1.06	5.84	0.29	7.19
Helicteres obtusa	0.04	0.93	0.67	1.64
Melastoma malabathricum	0.02	0.27		0.29
Pandanus sp.	0.01	0.27		0.28
Desmodium cephalotoides	0.01	0.27		0.28
Ixora sp.	0.01	0.27		0.28
Total shrubs			0.96	

Table 16. Continued

Species	A Relative Density %	B Relative Frequency %	C Relative Cover %	D = A+B+C Importance Index Value[a]
Trees:				
Altingia excelsa	0.17	0.60		0.77
Cratoxylon formosum	0.01	0.27	0.31	0.59
Sapium baccatum	0.01	0.27		0.28
Bridelia sp.	0.01	0.27		0.28
Schima wallichii	0.01	0.27		0.28
Choerospondias axillaris	0.01	0.27		0.28
Total trees			0.31	
Total all plant species	100.00	100.00	100.00	

$$A = \frac{\text{Number of individuals of species X}}{\text{Total number of individual of all species}} \times 100$$

$$B = \frac{\text{Frequency species X}}{\text{Sum of frequency values of all species}} \times 100$$

$$C = \frac{\text{Cover of individuals of species X}}{\text{Total cover of individuals of all species}} \times 100$$

[a]See Cox, 1976.

Table 17. Relative density, frequency, and cover percentages plus importance index values for plant species on the Nhong-Puck-Chee grassland, Khao-Yai National Park, July 1976.

Species	A Relative Density %	B Relative Frequency %	C Relative Cover %	D = A+B+C Importance Index Value[a]
Grasses and sedges:				
Imperata cylindrica	71.00	11.78	37.95	120.82
Carex cruciata	8.96	2.36	2.15	13.47
Scirpus grossus	5.15	2.85		8.00
Neyraudia reynaudiana	1.43	5.82		7.25
Ischaemum muticum	1.23	4.38		5.51
Cyperus sp.	0.20	1.90		2.10
Zoyzia sp.	0.02	0.46		0.48
Fimbristylis aestivalis	0.05	0.24		0.29
Coelorachis glandusa	0.05	0.24		0.29
Cyperus digitatus	0.05	0.24		0.29
Carex indica	1.70	7.96	0.08	9.47
Total grasses and sedges			40.18	
Forbs:				
Mosses		8.20	52.63	60.83
Spilanthes ocmella	3.58	11.05	6.60	21.23
Eupatorium odoratum	1.57	11.64	0.47	13.68
Portulaca quadrifida	2.50	7.36		9.86
Adiantum sp.	0.30	3.92		4.22
Portulaca sp.	0.20	2.85		3.05
Vernonia elliptica	0.38	1.28	0.03	1.69
Jussiaea suffruticosa	0.09	1.54		1.63
Scoparia dulcis	0.05	1.07		1.12
Blumea napifolia	0.09	0.46	0.06	0.61

Table 17. Continued

Species	A Relative Density %	B Relative Frequency %	C Relative Cover %	D = A+B+C Importance Index Value[a]
Forbs: Continued				
Ipomoea sp.	0.09	0.46		0.55
Ageratum conyzoides	0.02	0.46		0.48
Hedyotis sp.	0.01	0.46		0.47
Stachytarpheta indica	0.05	0.24		0.29
Erechtites hieracifolia	0.05	0.24		0.29
Eryingium foetidum	0.02	0.24		0.26
Alpinia sp.	0.02	0.24		0.26
Dioscorea stemonoides	0.01	0.24		0.25
Merremia gemella	0.01	0.24		0.25
Emilia sonchifolia	0.01	0.24		0.25
Helicteres obtusa	0.01	0.24		0.25
Portulaca oleacea	0.01	0.24		0.25
Total forbs			59.79	
Shrubs:				
Desmodium biarticulata	0.09	3.92		4.82
Melastoma malabathricum	0.05	0.83		0.88
Desmodium cephalotoides	0.01	0.24		0.25
Total shrubs			0.00	
Trees:				
Choerospondias axillaris	0.02	1.31	0.03	1.36
Bridelia sp.	0.02	1.07		1.09
Wrightia tomentosa	0.05	0.46		0.51

Table 17. Continued

Species	A Relative Density %	B Relative Frequency %	C Relative Cover %	D = A+B+C Importance Index Value[a]
Trees: Continued				
Trema orientalis	0.02	0.46		0.48
Oroxylum indicum	0.01	0.24		0.25
Hibicus macrophylla	0.01	0.24		0.25
Total trees			0.03	
Total all plant species	100.00	100.00	100.00	

$$A = \frac{\text{Number of individuals of species X}}{\text{Total number of individual of all species}} \times 100$$

$$B = \frac{\text{Frequency species X}}{\text{Sum of frequency values of all species}} \times 100$$

$$C = \frac{\text{Cover of individuals of species X}}{\text{Total cover of individuals of all species}} \times 100$$

[a]See Cox, 1976.

Table 18. Density and basal area of plant species, by diameter classes, Nhong-King forest site Khao-Yai National Park, June 1976.

Species	Diameter classes (cm)																			Total
	1.5- 3.5	3.6- 5.5	5.6- 7.5	7.6- 9.5	9.6-11.5	11.6-13.5	13.6-15.5	15.6-17.5	17.6-19.5	19.6-21.5	21.6-23.5	23.6-25.5	25.6-27.5	27.6-29.5	29.6-31.5	31.6-33.5	35.6-37.5	41.6-43.5	65.6-67.5	
Trees:																				
Altingia excelsa	1			2	1						2			1	1			1		10
Aphanamyxis polystachya		1		1																2
Anneslea fraglan	1																			1
Aquilaria crassna	2	3	3	4		2		1												15
Ardisia elandulosa	1																			1
Castanopsis acuminatissima	4	1	1				1	1									1			9
Cinnamomum iners	4			1	2	2		1												10
Canthium brunnescens	25	6	4	2	3	1	1	2	1	1										46
Cedrela toona												1								1
Cinnamomum siamensis	2	2				1	1													6
Carallia brachiata	1																			1
Canarium kerii										1		1								2
Calophyllum inophyllum						1														1
Baccaurea sapida												1								1
Dacrydium elatum		1																		1
Dipterocarpus gracilis	1																			1
Eurycoma longifolia	5	1																		6
Eugenia siamensis	2	3	1																	6
Eurya japonica	12	1																		13
Elaeocarpus floribunda								1												1
Ficus sp.																	1			1
Fraxinus floribunda		3																		3
Gonocaryum lobbianum	5	5	2	2	5				1											20
Grewia paniculata	1																			1
Gmelina arborea	3						1	1												5
Gironniera nervosa	2						1													3
Helicia formosana	1		3		1	1		1												7
Heliciopsis terminalis		2																		2
Hibiscus macrophylla					1															1
Lithocarpus rodgerianus	11	5	3	1	2	3		1		1			1							28
Litsea verticellata		1																		1

Table 18. Continued

Species	Diameter classes (cm)																				
	1.5- 3.5	3.6- 5.5	5.6- 7.5	7.6- 9.5	9.6-11.5	11.6-13.5	13.6-15.5	15.6-17.5	17.6-19.5	19.6-21.5	21.6-23.5	23.6-25.5	25.6-27.5	27.6-29.5	29.6-31.5	31.6-33.5	35.6-37.5	41.6-43.5	65.6-67.5	Total
Trees: Continued																				
Lophopettalum dupereanum	1	1					1													3
Lithocarpus annamensis	7	1	3		1	2		1	2	1						1				19
Lithocarpus eucalyptifolia	2	1	2				1													6
Mallotus paniculatus	1																			1
Memecylon ovatum	7	9	1																	17
Mangifera sylvatica	3	4	1																	8
Podocarpus imbricatus	1																			1
Paramichelia baillonil								1												1
Phoebe lanceolata	1																			1
Pterospermum seisagittatum			1																	1
Podocarpus nerriifolius			1																	1
Polyalthia verides		1				1														2
Schima wallichii	3		1	2		1								2						9
Ternstroemia japonica	6	4	2	1	4															17
Turpinia parvifolia	2	1	2							1										6
Tarenna hoaensis										1										1
Tetracera sp.	1																			1
Uncaria homomalla	1																			1
Shrubs:																				
Ardisia elandulosa	1																			1
Cinnamomum subavenium		2																		2
Eugenia sp.	2	2		1																5
Glycosmis subsesilis					1															1
Ixora sp.	4																			4
Evodia gracilis	3		2																	5
Melastoma normale	1																			1
Microtropis discolor	2		1																	3
No. of stems in 900 m^2	132	61	34	17	21	15	7	10	4	6	2	3	1	3	1	1	2	2	1	323
No. of stems per ha.	1467	678	378	198	233	167	78	111	44	66	22	33	11	33	11	11	22	22	11	3596
Basal area (m^2/ha)	0.719	1.102	1.273	1.085	2.036	2.065	1.296	2.387	1.189	2.188	0.878	1.561	0.609	2.115	0.806	0.915	2.307	3.127	3.820	31.478

Table 19. Density and basal area of plant species, by diameter classes, Moor-Singh-Toe forest site, Khao-Yai National Park, June 1976.

Species	Diameter classes (cm)																			
	1.5- 3.5	3.6- 5.5	5.6- 7.5	7.6- 9.5	9.6-11.5	11.6-13.5	13.6-15.5	15.6-17.5	17.6-19.5	19.6-21.5	21.6-23.5	23.6-25.5	25.6-27.5	27.6-29.5	29.6-31.5	35.6-37.5	37.6-39.5	39.6-41.5	41.6-43.5	Total
Trees:																				
Aquilaria crassna	41	35	13	4	2	1														101
Ardisia arborescens	11																			11
Aphanamyxis polyatachya	3		1				1		1											6
Altingia excelsa														1						1
Abarema clyperia	1	1			1				1											4
Aglaia odorata	2																			2
Baccaurea sapida	1		1																	2
Choerospondias axillaris												1				1			1	3
Cinnamomum iners	1	1	1																	3
Castanopsis acuminatissima							1	2									1			4
Camellia oleifera	1																			1
Dipterocarpus macrocarpus		1																		1
Dipterocarpus gracilis	1	2																		3
Eugenia siamensis	8	2	1		2	1														14
Eugenia sp.		4	1																	5
Eurycoma longifolia	3																			3
Eurya japonica	23	3		1	3	3														33
Fraxinus floribunda	1		1			1														3
Gonocaryum lobbianum	4	8	13	3		2														30
Garcinia rostrata		1																		1
Helicia formosana	14	12	1	2	2	2	1	1												35
Knema laurina							1													1
Lithocarpus eucalyptifolia	3	2	2	1		1	1	1	1	1	1									14
Lithocarpus rodgerianus	5		1		1		1	1	1							1				11
Lithocarpus annamensis	3	11	3	3		5	1	2	2	1	3	2	1		1				1	39
Lonicera microstigma	3	3																		6
Lagerstroemia calyculata	1	1		1																3
Lophopetalum duperreanum		2																		2
Litsea sebifera		1																		1
Mitrephora thorelii	7	5	3	2		1		1												19

Table 19. Continued

Species	Diameter classes (cm)																				
	1.5- 3.5	3.6- 5.5	5.6- 7.5	7.6- 9.5	9.6-11.5	11.6-13.5	13.6-15.5	15.6-17.5	17.6-19.5	19.6-21.5	21.6-23.5	23.6-25.5	25.6-27.5	27.6-29.5	29.6-31.5	35.6-37.5	37.6-39.5	39.6-41.5	41.6-43.5	Total
Trees: Continued																				
Memecylon ovatum	1	2																		3
Maesa ramentacea	2																			2
Mangifera sylvatica	4	1				1														6
Phoebe lanceolata	7	3	3	2																15
Prunus sp.	1																			1
Schima wallichii	1			1																2
Turpinia parvifolia			1																	1
Uncaria homomalla	1																			1
Wrightia tomentosa		1			1															2
Shrubs:																				
Evodia gracilis	7	1																		8
Polyalthia sp.	1																			1
Prismatomeris malayana		1	1																	2
Schefflera sp.	2	2				2	1													7
No. of stems in 900 m^2	165	105	47	21	14	21	9	8	6	2	4	3	1	1	2	1	1	1	1	412
No. of stems per ha.	1833	1167	522	233	165	233	100	89	67	22	44	33	11	11	22	11	11	11	11	4596
Basal area (m^2/ha)	0.899	1.897	1.758	1.337	1.363	2.881	1.662	1.914	1.810	0.729	1.756	1.561	0.609	0.704	0.806	1.154	1.283	1.420	1.506	27.049

Table 20. Density and basal area of plant species, by diameter classes, Nhong-Puck-Chee forest site, Khao-Yai National Park, June 1976.

Species	Diameter classes (cm)																				
	1.5- 3.5	3.6- 5.5	5.6- 7.5	7.6- 9.5	9.6-11.5	11.6-13.5	13.6-15.5	15.6-17.5	17.6-19.5	19.6-21.5	21.6-23.5	23.6-25.5	25.6-27.5	27.6-29.5	31.6-33.5	33.6-35.5	35.6-37.5	43.6-45.5	45.6-47.5	Total
Trees:																				
Aphanamyxis polystachya			1																	1
Cinnamomum iners	10	6	7		3		2													28
Cinnamomum siamensis				1																1
Cedrela toona			1				1													2
Dipterocarpus gracilis	9	7	3	2	1	3	2		3	4	3	2	1	1			1			42
Eugenia sp.	5	1	2																	8
Elaeocarpus robustus											1									1
Eugenia siamensis	3																			3
Gironniera nervosa																			1	1
Gonocaryum lobbianum	4			1																5
Helicia formosana	15	10	4	6	1	1									1					38
Hosfieldia grabbra	10	11	6	8	3	1	4	4	3			1	1	3						55
Knema laurina	6	3	1																	10
Lithocarpus annamensis	1				1			2					1							5
Microdesmis sp.	4	1		1														1		7
Mallotus paniculatus		1																		1
Macaranga denticulata						1										1				2
Memecylon ovatum	1																			1
Neolitsea zeylanica		1																		1
Symplocos laurina							2													2
Symplocos impressa		1																		1
Slonia kerii	1																			1
Schima wallichii														1						1
Uvaria sp.		1	1																	2
Wrightia tomentosa	1			1																2
Shrubs:																				
Artabotrys harmandii	10	8	2																	20
Chasalia chartacea	1																			1
Desmos dubius	3																			3
Lasianthus cyanocarpus	13	1																		14

Table 20. Continued

Species	Diameter classes (cm)																			
	1.5- 3.5	3.6- 5.5	5.6- 7.5	7.6- 9.5	9.6-11.5	11.6-13.5	13.6-15.5	15.6-17.5	17.6-19.5	19.6-21.5	21.6-23.5	23.6-25.5	25.6-27.5	27.6-29.5	31.6-33.5	33.6-35.5	35.6-37.5	43.6-45.5	45.6-47.5	Total
Shrubs: Continued																				
Lasianthus sp.	1																			1
Pinanga sp.	5																			5
Salacia prinoides	1	1																		2
No. of stems in 900 m^2	104	54	28	20	9	6	11	6	6	4	4	3	3	5	1	1	1	1	1	267
No. of stems per ha.	1155	589	311	222	100	67	122	67	67	44	44	33	33	56	11	11	11	11	11	2965
Basal area (m^2/ha)	0.567	0.957	1.047	1.274	0.874	0.828	2.027	1.441	1.810	1.459	1.765	1.561	1.826	3.583	0.915	1.031	1.154	1.714	1.871	27.704

Table 21. Browsed and unbrowsed plant stems, Nhong-King forest site, Khao-Yai National Park, June 1976.

Species	Plants Over 0.50m Height[a] (per ha)		Plants Under 0.50m Height[b] (per ha)	
	Browsed	Unbrowsed	Browsed	Unbrowsed
Grass and sedges:				
Carex indica			1333.36	1000.02
Carex cruiana			666.68	333.34
Panicum notatum			833.35	15500.31
Forbs:				
Adiantum sp.			166.67	2166.71
Alpinia oxymytra			333.34	2833.39
Arisaema sp.				1166.69
Acanthus sp.				1833.37
Alpinia sp.				1500.01
Chloranthus officinalis			1166.69	6666.80
Dioscorea bulbifera				1333.36
Dioscorea stemonoides				500.01
Linnostoma thorelii				1333.36
Oxystelma esculata				1166.69
Rourea stenopetala			666.68	1500.03
Shrubs:				
Cinnamomum subavenium		333.35		5333.44
Eurycoma longifolia		333.35	166.67	
Evodia gracilis		66.67	333.34	2000.04
Glycosmis subsesilis				166.67
Ixora sp.		200.01	833.35	2500.05
Justicia sp.	133.34			
Lasianthus cyanocarpus	333.34		666.68	166.67
Melastoma malabathricum		66.67		333.34
Pandanus sp.	66.67	266.68	166.67	333.34

Table 21. Continued

Species	Plants Over 0.50m Height[a] (per ha)		Plants Under 0.50m Height[b] (per ha)	
	Browsed	Unbrowsed	Browsed	Unbrowsed
Shrubs: Continued				
Murraya paniculata			166.67	500.01
Melastoma sp.				166.67
Symplocos laurina		800.04		1500.03
Scheffera sp.				444.45
Trees:				
Altingia excelsa	266.68	533.36		333.34
Ardisia arborescens	66.67	800.04	500.01	666.08
Anona reticulata			66.67	333.34
Aglaia odrata		200.01		500.01
Aphanamyxis polystachya		133.34	166.67	166.67
Aquilaria crassna			833.35	1333.36
Ancistrocladus tectorius	66.67			
Cinnamomum iners		2066.77		1333.36
Calamus rotang	2001.01	733.37	500.01	1000.02
Castanopsis acuminatissima		466.69	1833.37	833.35
Clausena excavata	66.67	266.68		333.34
Canthium brunnescens			9166.85	14000.28
Cinnamomum siamensis			166.67	
Cironniera nervosa				166.67
Calophyllum inophyllum				4000.08
Carallia brachiata				1000.02
Dacrydium elatum			166.67	500.01
Eugenia siamensis	66.67	933.38		166.67
Eugenia sp.	66.67	533.36	333.34	666.68
Eurya japonica		266.68	833.35	333.34

Table 21. Continued

Species	Plants Over 0.50m Height[a] (per ha)		Plants Under 0.50m Height[b] (per ha)	
	Browsed	Unbrowsed	Browsed	Unbrowsed
Trees: Continued				
Fraxinus floribunda		66.67	333.34	666.68
Gonocaryum lobbianum		600.03		166.67
Lithocarpus eucalyptifolius		266.68		
Lithocarpus annamensis		333.35		500.01
Lithocarpus rodgerianus		266.68		500.01
Litsea verticellata				1833.37
Litsea sebifera				166.67
Lophopetalum duperreanum			333.34	500.01
Melaleuca seutellatum	1266.67	4133.53		
Mangifera sylvatica		66.67		
Memecylon ovatum		66.67		833.35
Mallotus paniculata				166.67
Neolitsea zeylanica		333.35		
Podocarpus imbricatus	200.01			333.34
Schima wallichii		66.67	166.67	
Phoebe lanceolata				166.67
Ternstroemia japonica			500.01	
Terpinia parvifola				833.35
Tetracera sp.				2000.04
Tarenna hoaensis				333.34
Uncaria homomalla			666.68	
Uvaria sp.				666.68
Total stems	2633.47	15400.7	13166.48	89612.30
Percentage	14.60	85.40	12.81	87.19

[a]Specimens over 0.5 m height and stems over 1.3 cm d.b.h.

[b]Specimens under 0.5 m height and stems under 1.3 cm d.b.h.

Table 22. Browsed and unbrowsed plant stems, Moor-Singh-Toe forest site, Khao-Yai National Park, June 1976.

Species	Plants Over 0.50m Height[a] (per ha)		Plants Under 0.50m Height[b] (per ha)	
	Browsed	Unbrowsed	Browsed	Unbrowsed
Grass and sedges:				
Carex indica				333.34
Carex cruciata			166.67	
Panicum notatum			500.01	3833.41
Forbs:				
Alpinia oxymytra			166.67	7000.14
Adiantum sp.				1666.70
Chloranthus officinalis				1666.70
Dioscorea bulbifera				2500.05
Dioscorea stemonoides		133.34		333.34
Linostoma thorelii				2166.71
Rourea stenopetala			333.34	
Shrubs:				
Cinnamomum subavenium				2666.72
Desmos sp.		66.67		166.67
Evodia gracilis	66.67	333.36		1166.69
Ixora sp.			500.02	7000.14
Lasianthus sp.			166.67	
Lasianthus cyanocarpus			166.67	
Pandanus sp.			1333.36	2166.71
Trees:				
Ardisia arborescens	266.68	200.01	166.67	3666.74
Aquilaria crassna		1133.39		500.01
Artabotrys harmandii		66.67		1000.02
Aphanamyxis polyatachya				166.67
Altingia excelsa				166.67
Aglaia odorata				500.01

Table 22. Continued

Species	Plants Over 0.50m Height[a] (per ha)		Plants Under 0.50m Height[b] (per ha)	
	Browsed	Unbrowsed	Browsed	Unbrowsed
Trees: Continued				
Castanopsis acuminatissima		400.02	166.67	8000.16
Cinnamomum iners		200.01		166.67
Calamus rotang			166.67	666.68
Diterocarpus gracilis		133.34		
Eugenia siamensis	200.01	400.02	166.67	1000.02
Eugenia sp.	66.67	66.67		500.01
Eurya japonica		866.70		1000.02
Eurycoma longifola				333.34
Fraxinus floribunda				834.35
Knema laurina		166.67		
Gonocaryum lobbianum	66.67	666.70		500.01
Lithocarpus eucarlyptifolia		66.67		2000.04
Lithocarpus annamensis		66.67		1166.69
Litsea verticellata		266.68		
Lithocarpus rodgerianus		533.37		2833.39
Litsea sebifera				4833.43
Memecylon ovatum		166.67		
Mangifera sylvatica		266.68		500.01
Phoebe lanceolata		133.34	166.67	333.34
Synplocos laurina	133.34	400.02		1000.02
Scheffera sp.				666.68
Turpinia parvifolia		133.34		
Total stems	800.04	6667.00	3833.41	66001.32
Percentage	10.71	89.29	5.59	94.51

[a]Specimens over 0.5 m height and stems over 1.3 cm d.b.h.

[b]Specimens under 0.5 m height and stems under 1.3 cm d.b.h.

Table 23. Browsed and unbrowsed plant stems, Nhong-Puck-Chee forest site, Khao-Yai National Park, June 1976.

Species	Plants Over 0.50m Height[a] (per ha)		Plants Under 0.50m Height[b] (per ha)	
	Browsed	Unbrowsed	Browsed	Unbrowsed
Grass and sedges:				
Panicum notatum			333.34	1000.02
Forbs:				
Alpinia oxymytra			333.34	12666.92
Adiantum sp.			2166.71	10833.55
Acanthus sp.				666.68
Acacia commosa			1166.69	833.35
Chloranthus officinalis			166.67	
Dioscorea stemonoides				666.68
Polygonum chinensis			333.34	
Salacia prinoides			500.01	3000.06
Shrubs:				
Chasalia chartacea		66.67		1000.02
Cinnamomum subavenium			500.01	5166.59
Desmos dubius				166.67
Evodia gracilis		1933.49		166.67
Glycosmis subsesilis			166.67	500.01
Ixora sp.			500.01	1666.70
Lasianthus cyanocarpus	400.02	533.02	166.67	333.34
Lasianthus sp.		66.67	166.67	1166.69
Melastoma sp.		66.67		166.67
Trees:				
Aglaia odorata		200.01	166.67	666.68
Artabotrys harmandii	66.67	400.02		1166.69
Aphanamyxis polystachya		133.34		
Cinnamomum iners	200.01	733.39	333.34	1666.70
Calamus rotang				166.67
Dipterocarpus gracilis		266.65		500.01
Eugenia siamensis	200.01	200.01	166.67	333.34

Table 23. Continued

Species	Plants Over 0.50m Height[a] (per ha)		Plants Under 0.50m Height[b] (per ha)	
	Browsed	Unbrowsed	Browsed	Unbrowsed
Trees: Continued				
Eugenia sp.		66.67		
Gonocaryum lobbianum	266.68	200.01	333.34	
Gironniera nervosa		133.34		166.67
Glausena excavata			333.34	166.67
Horsfieldia glabbra		266.68	333.34	1666.70
Knema laurina	800.04			166.67
Lithocarpus annamensis	66.67			333.34
Litsea sebifera				1000.02
Mallotus paniculata	133.34	333.34		
Malacaranga denticulata		66.67		
Symplocos laurina	200.01	933.38		4166.75
Total stems	1533.41	9600.48	8833.51	60501.27
Percentage	13.77	82.23	12.21	87.79

[a]Specimens over 0.5 m height and stems over 1.3 cm d.b.h.

[b]Specimens under 0.5 m height and stems under 1.3 cm d.b.h.

Table 24. Length and dry weight of leafy twig, energy values of leafy vegetative species and dropping, Khao-Yai National Park, January 1976-March 1977.

Forage Species	Avg. Twig Length (cm)	Avg. Dry Wt. (gm)	Energy (kcal/gm)
Paspalum conjugatum	3.5	0.0907	4.1201
Wrightia tomentosa	5.5	0.1511	4.4622
Alpinia sp.	7.0	0.0309	3.8716
Neyraudia reynaudiana	6.5	0.3803	3.9604
Vernonia elliptica	9.5	0.1737	4.0086
Imperata cylindrica	12.0	0.0958	4.2043
Crotoxylon formosum	5.5	0.1111	4.3561
Dioscorea stemonoides	3.5	0.0272	4.0936
Ischaemum muticum	3.5	0.0692	4.1243
Carex cruciata	14.5	0.1052	3.7984
Eragrostis capensis	9.5	0.0709	4.1594
Coelorachis glandulosa	8.5	0.2137	4.1156
Helicteres obtusa	7.5	0.1691	3.9507
Carex indica	5.5	0.1301	4.0490
Scirpus grossus	10.0	0.2015	3.8329
Spilanthes ocmella	8.0	0.0781	2.4962
Scoparia dulcis	4.0	0.0366	3.9450
Desmodium biarticulata	5.5	0.1371	4.2970
Vernonia parishii	3.5	0.0354	3.0588
Ipomoea sp.	4.5	0.0513	3.1489
Eupatorium odoratum	5.0	0.2477	4.4611
Costus speciosus	4.5	0.0234	4.0644
Bridelia sp.	5.0	0.0676	4.4202
Eryngium foetidum	8.0	0.0256	3.4543
Cyperus sp.	10.5	0.0276	3.7892
Carallia brachiata	2.5	0.1958	3.4935
Knema laurina	12.5	0.3340	4.0125
Lithocarpus rodgerianus	8.5	0.1985	1.9201
Neolitsea zeylanica	3.5	0.1224	4.1278
Eugenia sp.	2.0	0.1437	4.1834
Eugenia siamensis	2.5	0.6430	3.9744
Ficus sp.	12.5	0.3566	4.0105
Nephelium mutabile	3.0	0.2468	4.6963
Melaleuca seutellatum	5.0	0.0535	4.1387
Uvaria rufa	4.0	0.1398	3.4919
Hedyotis sp.	3.5	0.1424	4.3077
Lasianthus cyanocarpus	4.5	0.6008	3.1676
Lithocarpus eucalyptifolia	10.5	0.1951	1.8114
Castanopsis acuminatissima	9.5	0.1730	1.8849
Uncaria homomalla	5.5	0.1464	4.1055
Eugenia sp.	2.5	0.0511	4.2423
Murrya paniculata	2.0	0.1848	3.2861

Table 24. Continued

Forage Species	Avg. Twig Length (cm)	Avg. Dry Wt. (cm)	Energy (kcal/gm)
Eugenia ripicola	2.5	0.1173	3.4555
Uvaria sp.	3.0	0.1473	4.2060
Podocarpus neriifolius	2.0	0.2141	4.0476
Linostoma thorelii	2.5	0.0354	3.5701
Rurea stenopetala	8.0	0.0618	3.9664
Curcuma parviflora	7.0	0.0309	3.8709
Styrax sp.	3.5	0.2731	4.1306
Dioscorea bulbifera	8.5	0.4116	4.0582
Cinnamomum subavinum	2.5	0.1222	4.6104
Litsea verticellata	2.0	0.2143	4.3154
Mangifera sylvatica	2.5	0.7115	4.0707
Ixora sp.	2.0	0.6430	3.8733
Ardisia arborescens	2.0	0.3916	4.0125
Desmos sp.	2.0	0.1547	4.2316
Gonocaryum lobbianum	5.0	0.2976	4.6425
Evodia gracilis	6.5	0.3217	4.2970
Clausena excavata	3.0	0.4634	4.0828
Symplocos laurina	4.5	0.1101	3.9280
Jasminum sp.	4.0	0.1685	3.8970
Camellia oleifera	2.5	0.1008	3.8466
Memecylon ovatum	3.0	0.1848	4.3624
Adiantum sp.	7.0	0.0983	1.9439
Uncaria sp.	6.5	0.1575	3.9857
Cinnamomum iners	3.5	0.1977	4.1420
Fraxinus floribunda	2.0	0.1013	4.3719
Aglaia odorata	3.5	0.1766	4.1311
Artabotrys harmandii	5.5	0.1543	3.8719
Litsea sebifrea	2.5	0.4108	4.1852
Alpinia oxymytra	10.5	1.5404	3.8382
Dropping (ave.)	-	-	4.2016

Table 25. Moisture percentages and weights of fresh fecal pellets, dry at 100° C for 24 hours, Khao-Yai National Park, January 12-24, 1977.

Sample	Wet Weight (gm)	Dry Weight (gm)	Weight Loss (gm)	Percentage Loss
1	160.0	60.40	99.60	62.25
2	90.0	35.66	54.34	60.38
3	210.0	73.38	136.62	65.06
4	130.0	76.33	55.67	41.29
5	130.0	61.67	68.33	52.56
6	150.0	59.78	90.22	60.15
7	230.0	78.79	151.21	65.73
8	225.0	87.38	137.62	61.14
9	290.0	118.84	171.16	59.02
10	200.0	82.49	117.51	58.76
Total	1815.0	734.72	1080.23	
Average	181.5	73.47	108.02	59.52

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